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IMPROVING BALANCE AND MOBILITY IN PEOPLE OVER 50 YEARS OF AGE WITH VISION IMPAIRMENTS: CAN THE ALEXANDER TECHNIQUE HELP?

Michael Gleeson
Bachelor of Applied Science (Physiotherapy)
Masters in Special Education (Sensory Disability)

Thesis presented for the degree of
Doctor of Philosophy
The University of Sydney
2014
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SUPERVISORS’ STATEMENT

As supervisors of Michael Gleeson’s doctoral work, we certify that we consider his thesis “Improving balance and mobility in people over 50 years of age with vision impairments: Can the Alexander Technique help?” to be suitable for examination.

Dr. Lisa Keay
The George Institute for Global Health
The University of Sydney
Date: 13 June 2014

Associate Professor Cathie Sherrington
The George Institute for Global Health
The University of Sydney
Date: 13 June 2014
CANDIDATE’S STATEMENT

This thesis is submitted to the University of Sydney in fulfillment of the requirement for the Degree of Doctor of Philosophy

I, Michael Gleeson, hereby declare that this submission is my own work and that it contains no material previously published or written by another person except where acknowledged in the text. Nor does it contain material which has been accepted for the award of another degree.

I, Michael Gleeson, understand that if I am awarded a higher degree for my thesis entitled “Improving balance and mobility in people over 50 years of age with vision impairments: Can the Alexander Technique help?” being lodged herewith for examination, the thesis will be lodged in the University library and be available immediately for use. I agree that the University Librarian (or in the case of a department, the Head of the Department) may supply a photocopy or microform of the thesis to an individual for research or study or to a library.

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Michael Gleeson
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Publications And Presentations

Parts of the work presented in this thesis have been published, accepted for publication and/or presented in the following forms:

Publications in peer reviewed journals


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Gleeson, M., Sherrington, C., Lo, S. Keay, L. Can the Alexander Technique improve balance and mobility in older adults with visual impairments? A randomised controlled trial. Accepted 2014, Clinical Rehabilitation.

Conference Presentations (presenters in bold)


Glossary

**Vision impairment / Visual impairment:** a limitation of one or more functions of the eye (or visual system).

**Legally blind / legal blindness / statutory blindness:** The level of vision that determines an individual's eligibility for pensions/benefits in their country of residence. In Australia legal blindness is defined as best corrected visual acuity of 6/60 or less in the better eye; or a visual field limitation to within 10 degrees of fixation in the better eye irrespective of corrected visual acuity; or a combination of visual defects resulting in the same degree of visual impairment as that occurring in the above points.

**Refractive error:** A refractive error occurs when the eye cannot clearly focus the images from the outside world. The result of refractive errors is blurred vision, which is sometimes so severe that it causes visual impairment.

**Edge-contrast sensitivity:** the ability of the visual system to distinguish between an object and its background.

**Depth perception:** the visual ability to perceive the world in three dimensions and to perceive the distance of object from the viewer.

**Binocular disparity information:** A depth perception cues - each eye receives a slightly different image due to the different angle from which each eye views an object. The brain uses these to form one three-dimensional object.

**Environmental preview:** the ability to visually perceive the environment that is being travelled through, which is lacking or fragmented in people with a visual impairment.

**Sensory re-weighting:** Sensory information from a number of modalities is combined according to the sensory reweighting hypothesis, i.e., more reliable information is weighted more strongly than less reliable information (visual, proprioceptive and vestibular systems in the case of balance).

**Reweight towards vision:** With age, conduction speeds in the nervous system slow, making proprioceptive input from the ankles less reliable for upright balance, so older adults begin to give more weight to visual input to maintain their balance.

**Proprioception:** The perception of movement and spatial orientation which arises from stimuli within the body itself.
**Kinaesthesia**: The sense that detects bodily position, weight, or movement of the muscles, tendons, and joints

**Postural homeostasis**: A description of posture that changes it from the idea of a fixed position to a state of change and lack of fixity. A homeostatic system returns to equilibrium after it has been disturbed.

**Dynamic modulation of muscle tone**: The regulation of muscle tone during activity

**Postural set / Central set**: An overall motor readiness to respond based on our expectations of the current situation. We anticipate the likely consequences of a given situation and prepare accordingly.

**Ethology**: The study of human behaviour and social organization from a biological perspective

**Ethological approach**: An approach to solving human problems based on the study of human behaviour

**Alexander lessons**: The Alexander Technique is taught (usually one on one but also in groups) as a series of lessons over time.

**Observer’s operational range**: The area in which an observer is able to function, usually by reweighting between sensory modalities

**Efference copy**: A central signal of the expected sensory consequences of a motor outflow
Abstract

This thesis describes a randomised controlled trial designed to determine the impact of the Alexander Technique on physical functioning in older adults with visual impairments. Successful fall prevention strategies in the general community-dwelling population of older adults that are designed to improve physical functioning have not been found to reduce falls in those with visual impairments to date, and as the population ages this is an important public health issue.

Older adults with visual impairments are a vulnerable demographic, and the current challenge is to identify interventions that are both acceptable and effective for delivery in home-based programs. The study used a novel intervention that was developed in the performing arts, and has only recently been evaluated for possible therapeutic benefits. The Alexander Technique uses verbal and tactile feedback to highlight previously unnoticed tension that interferes with coordination and balance, and provides cognitive strategies to improve performance within the context of everyday activities.

Although there were no significant between group differences in the primary outcomes of the study, improvements in some secondary outcomes and in the subgroup of multiple fallers, along with a trends for less total and injurious falls in the intervention group suggest an effect of Alexander Technique on physical functioning.

Process evaluation suggested that the intervention was acceptable but that dose may have been an issue, as the study only provided around half the recommended number of Alexander lessons. The Alexander Technique is worthy of study in a larger trial powered to detect an effect on falls with the recommended number of lessons provided.
1 INTRODUCTION

In developed countries as a whole, the number of older people is already greater than the number of children (under 15 years), and by 2050 the number of older people in developed countries will be nearly twice the number of children.\(^1\) This demographic shift highlights the need for ongoing research initiatives to deal with the biological consequences of ageing on population health.

Falls are a leading cause of morbidity and mortality and at least 30% of people aged 65 and over fall each year.\(^2\)-\(^4\) Despite an increasing focus on fall prevention in recent years the hospitalisation rates due to fall related injuries in Australia rose by 5.6% between 2007-08 and 2008-09 and this highlights the need for continued research in this area.\(^5\) Falls are the leading cause of hip fracture,\(^6\) and this can lead to a loss of confidence, admission to a nursing home or precipitate a rapid decline in health status.\(^7\)
1.1 Background

Age related changes in the visual, proprioceptive and vestibular systems are known to reduce older adults’ ability to respond as quickly to challenges to their balance\(^8\)\(^9\) and similar changes in the musculoskeletal\(^10\)\(^11\) and neurological systems\(^12\)-\(^14\) compound this difficulty. Slower nerve conduction speeds and slower central nervous system integration force older adults to rely more on vision for dynamic balance control\(^9\)\(^15\) and this puts older adults with visual impairments at greater risk. The ability to reweight towards vision also declines with age\(^16\) and individuals whose vision declines late in life are not able to develop compensation strategies as easily as younger adults.\(^17\)

1.2 Visual impairment

Visual Impairment has been defined in the International Classification of Diseases (ICD-10)\(^18\) for use in the clinical, epidemiological and health management settings. The original definition was derived from a WHO study group published in a technical report in 1973.\(^19\) Table 1.1 presents the categories defined at that time. The report suggested that categorisation could be further described based on causes and anatomical lesions.

Four levels of visual function are in general use across many settings:

- normal vision
- moderate visual impairment
- severe visual impairment
- blindness
Table 1.1 Categories of visual impairment according to the International Classification of Diseases 2003 (ICD-10: 2003)

<table>
<thead>
<tr>
<th>Category of visual impairment</th>
<th>Visual acuity with best possible correction</th>
<th>Or central visual field*</th>
<th>Classified as</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum less than</td>
<td>Minimum equal to or better than</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6/18</td>
<td>6/60</td>
<td>Low vision</td>
</tr>
<tr>
<td></td>
<td>3/10 (0.30)</td>
<td>1/10 (0.10)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20/70</td>
<td>20/200</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6/60</td>
<td>3/60</td>
<td>Low vision</td>
</tr>
<tr>
<td></td>
<td>1/10 (0.10)</td>
<td>1/20 (0.05)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20/200</td>
<td>20/400</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3/60</td>
<td>1/60 (CF at 1 metre)</td>
<td>≤ 10° but &gt; 5°</td>
</tr>
<tr>
<td></td>
<td>1/20 (0.05)</td>
<td>1/50 (0.02)</td>
<td>Blindness</td>
</tr>
<tr>
<td></td>
<td>20/400</td>
<td>5/30 (20/1200)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1/60 (CF at 1 metre)</td>
<td>Light Perception</td>
<td>≤ 5°</td>
</tr>
<tr>
<td></td>
<td>1/50 (0.02)</td>
<td></td>
<td>Blindness</td>
</tr>
<tr>
<td></td>
<td>5/30 (20/1200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>No Light Perception</td>
<td></td>
<td>Blindness</td>
</tr>
<tr>
<td>9</td>
<td>Undetermined/ unspecified</td>
<td></td>
<td>Unspecified</td>
</tr>
</tbody>
</table>

*Visual field restriction criteria applicable even if visual acuity is better than for category of visual impairment. CF = count fingers
Moderate visual impairment and severe visual impairment were grouped under the term “low vision”, and low vision taken together with blindness represented all visual impairment. Unfortunately within the literature, and within general use, ‘low vision’ and visual impairment (or vision impairment) are often used synonymously, and ‘blindness’ is then regarded separately. This is further compounded by the fact that the terms are often not defined or clarified when used. Blindness is also defined separately by various governments and agencies to determine eligibility for their services, adding to the lack of clarity for descriptive terminology within the field. Statutory (or legal) blindness has a precise definition that is required in order to determine whether a particular individual qualifies for a variety of government benefits that may be available in their country of residence.

In the USA legal blindness is defined as best corrected visual acuity of 20/200 or less in the better eye; or a visual field limitation such that the widest diameter of the visual field, in the better eye, subtends an angle no greater than 20 degrees, whereas in Australia legal blindness is defined as best corrected visual acuity of 6/60 or less in the better eye; or a visual field limitation to within 10 degrees of fixation in the better eye irrespective of corrected visual acuity; or a combination of visual defects resulting in the same degree of visual impairment as that occurring in the above points.
Despite the legal definition above, there are a number of other definitions of ‘blindness’ in common use by a variety of organisations within Australia. For example the Fred Hollows Foundation uses a visual acuity of 3/60 or corresponding field loss in the better eye with best possible correction, and the Royal Australian and New Zealand College of Ophthalmologists uses blindness to refer only to total vision loss (no light perception) and for conditions where the individual has to rely predominantly on vision substitution skills.\textsuperscript{22}

One of the problems with the ICD classification was that it referred to those in categories 1 and 2 (Table 1.2) as having ‘low vision’. This was at odds with the specific meaning of ‘low vision’ among eye care practitioners where it is defined as “\textit{one who has impairment of visual functioning even after treatment and/or standard refractive correction, and has visual acuity of less than 6/18 to light perception, or a visual field of less than 10 degree from the point of fixation, but who uses, or is potentially able to use, vision for planning and/or execution of a task}”.\textsuperscript{23} The problem with this was that there were individuals who could have benefited from low vision care who were categorised as blind and this lead to miscalculations in the estimates of those requiring low vision care.\textsuperscript{24}

Subsequent to this, revisions have been made and the current categories on the ICD-10 website are presented in Table 2.2\textsuperscript{18}
Table 1.2 Categories of visual impairment according to the International Classification of Diseases (ICD-10: 2010)

<table>
<thead>
<tr>
<th>Category of visual impairment</th>
<th>Presenting visual acuity</th>
<th>Or central visual field*</th>
<th>Classified as</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum less than</td>
<td>Minimum equal to or better than</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>6/18</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3/10 (0.30)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>20/70</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6/18</td>
<td>6/60</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>3/10 (0.30)</td>
<td>1/10 (0.10)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20/70</td>
<td>20/200</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6/60</td>
<td>3/60</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>1/10 (0.10)</td>
<td>1/20 (0.05)</td>
<td></td>
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<tr>
<td></td>
<td>20/200</td>
<td>20/400</td>
<td></td>
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<td>3</td>
<td>3/60</td>
<td>1/60 (CF at 1 metre)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 (0.05)</td>
<td>1/50 (0.02)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20/400</td>
<td>5/30 (20/1200)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1/60 (CF at 1 metre)</td>
<td>Light Perception</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/50 (0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5/300 (20/1200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>No Light Perception</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Undetermined/ unspecified</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*If the extent of the visual field is taken into account, patients with a visual field of the better eye no greater than 10° in radius around central fixation should be placed under category 3. CF = count fingers
It is beyond the scope of this thesis to standardise the terminology used in all the papers cited. When referring to a particular paper, the language of the paper will be used, and if clarification is possible it will be made. The randomised controlled trial reported in this thesis was a pragmatic study, and we were interested in the broad cross-section of the population with visual impairments that limited their ability to mobilise safely in the community.

The prevalence of visual impairment and blindness increases significantly with age across all racial and ethnic groups\textsuperscript{25} and the most recent data show that 65\% of the visually impaired population and 82\% of blind individuals are over 50 years of age.\textsuperscript{26} A prevalence study in the United States of America\textsuperscript{25} predicts a doubling of blindness from 2000 to 2020 and an Australian study\textsuperscript{27} predicts a similar increase in low vision and blindness in Australia by 2024.

The Vision 2020 initiative has reported that more than 90\% of people with a visual impairment live in developing countries, and that females have a higher risk of visual impairment than males, due to poor access to services in developing countries and longer life expectancy in more developed parts of the world.\textsuperscript{28} A significant proportion of visual impairments globally are due to cataract (34\%) and uncorrected refractive error (42\%) which are both treatable conditions.\textsuperscript{26} A prevalence study of cataract in Australia found that the number of Australians with cataract would grow by two-thirds between 2001 and 2021.\textsuperscript{29} A simulation study of blur from cataract and refractive error found significant increases in postural instability\textsuperscript{30} and those authors suggested that correction may be an important fall prevention strategy.
Surgical advances and cheaper replacement intra-ocular lenses have made cataract surgery a relatively straightforward procedure and surgery on one eye has been shown to dramatically improve vision and quality of life, and reduce fall rates.\(^{31}\) Although surgery on the second eye likewise improves vision and health status,\(^{32}\) a systematic review of expedited cataract surgery found that whilst it does significantly enhance vision there is still inconclusive evidence on the effect on fall rates.\(^{33}\) Irrespective of ocular co-morbidity, cataract surgery does results in significant improvements in subjective quality of vision for both first and second eye surgery\(^{34}\) and so ideally cataract should not contribute significantly to permanent levels of visual impairment in developed countries, although waiting times for surgery will mean some delays in treatment times.

Refractive correction by the provision of appropriate affordable eyewear is also an effective way to dramatically improve vision, however the improvements in physical functioning gained have not been maintained past one year.\(^{35}\) Multifocal lenses have been shown to increase falls risk\(^{36,37}\) but an intervention to provide single lens distance glasses to multifocal wearers was more effective for those who regularly took part in outside activities, whereas there was a significant increase in outside falls for those participants who did not regularly engage in outdoors activity.\(^{38}\) Other studies have shown either limited effects on falls rates by corrective refraction\(^{39}\) or even an increase in fall rates in this population.\(^{40}\) Those authors suggested that older adults may require some time to adjust to a new prescription or that the improved vision could lead to an increase in activities that raised their risk of falls.
Globally, the major causes of blindness in older adults after cataract are glaucoma (12%), age related macular degeneration (ARMD) (9%), diabetic retinopathy (5%), and trachoma (4%). Trachoma affects communities with poor sanitation, water supplies and health services and Australia is the only developed country where this largely preventable disease is still endemic in some indigenous communities. Although trachoma is a major cause of blindness in later life, the reservoir of the disease is in children, and it is preventable through surgery, antibiotics, facial hygiene, and provision of adequate water and sanitation facilities.

1.3 Visual impairment and falls risk

Older adults with visual impairment are 1.7 times more likely to fall than their sighted peers, 1.9 times more likely to have multiple falls, and have an increased risk of falls that result in fracture. The vulnerability to fall related injuries and the increasing numbers of older people with visual impairments makes fall prevention in this population a critical public health issue. There has been a call for research to develop and evaluate targeted interventions for high risk populations and older people with visual impairments are part of this high risk group.

The factors that predispose an individual to a fall may be intrinsic to the individual (such as their strength and balance), environmental conditions that are extrinsic to the individual (such as travel surface and illumination), or behavioural factors where the intrinsic and extrinsic factors are mediated by the individual’s response to the context of the event (such as level of attention, anxiety, propensity to rush etc.). The aetiology of falls is multi-
factorial, and is conveniently described in visual form using a model first
developed for athletic injury. A fall happens in a dynamic real-time context,
and Figure 1.1 shows how the multiple factors involved in a fall interact to
create a sequence of events that may culminate in a serious injury.

What makes visual impairment an area of particular interest with respect to
falls is that it has an effect at each point within the aetiology model. Visual
impairment is an intrinsic risk factor for falls, it magnifies the effect of extrinsic
risk factors because the individual lacks a full environmental preview, and it
impacts on the postural stability that would allow the individual to respond
optimally once an inciting event has been encountered. In the longer term,
visual impairment can also compound the effect of other risk factors, and
the impact of visual impairment on physical functioning has been shown to
be equal to or greater than the impact of other serious medical conditions.
This relationship can be seen in the framework of the WHO International
Classification of Functioning, Disability and Health in Figure 1.2.
**Figure 1.1** A dynamic multi-factorial aetiology of falls (adapted from\(^{48}\))
Figure 1.2 The impact of visual impairment using the WHO International Classification of Functioning, Disability and Health.
1.3.1 Intrinsic risk factors

Visual impairment is an independent intrinsic risk factor for falls\textsuperscript{52-56} particularly with relation to edge-contrast sensitivity and depth perception\textsuperscript{42,57}. Edge-contrast sensitivity allows an individual to distinguish changes in surface texture, and is a visual clue that the travel surface may be changing its consistency. Along with depth perception, this allows for the detection of drop-offs and other potential hazards during pedestrian travel. Other intrinsic risk factors include age\textsuperscript{58}, gender\textsuperscript{59,60}, muscle weakness\textsuperscript{61,62}, balance impairments\textsuperscript{63,64}, gait disturbances\textsuperscript{65,66}, blood pressure abnormalities\textsuperscript{67,68} and musculoskeletal pain\textsuperscript{69,70}. Additional co-morbidities add to the total intrinsic risk and conditions such as stroke\textsuperscript{71}, Parkinson’s disease\textsuperscript{72,73}, dementia\textsuperscript{74,75}, anaemia\textsuperscript{76}, incontinence\textsuperscript{77,78} and sleep disturbance\textsuperscript{79} have all been shown to increase the risk of falls.

Significant associations have been found between visual function and poor performance on physical performance tests\textsuperscript{80} and the incidence of breathing problems, diabetes, heart problems, hypertension, joint symptoms, low back pain and stroke is higher in people with visual impairments\textsuperscript{81}. Many of these co-morbid conditions are associated with difficulties in walking and climbing steps, and these are activities where falls are likely to occur\textsuperscript{82,83}.

Many co-morbidities interact with each other to further increase risk of falls. Individuals suffering from Parkinson’s disease have been shown to have a higher degree of dependence on visual information for motor control\textsuperscript{84,85} putting them at greater risk if they have a visual impairment. Visual field defects, eye movement disorders and visuospatial neglect are common
following stroke, and data from the Virtual International Stroke Trials Archive found that visual impairment was reported in 60.5% of patients at baseline and persistent visual impairment was still evident in 20.5% after 90 days.\textsuperscript{86} Visual field loss increases the risk of falls\textsuperscript{87} and if there are motor control problems following stroke these will compound falls risk. The onset of dementia in an older adult with a visual impairment will also impact on safe mobility as memory deficit reduces the ability to navigate on previously learned routes of travel.

Sleep disturbances are common in people with visual impairments\textsuperscript{88} and sleep duration has been shown to be independently associated with a higher risk of falls in women, but not in men.\textsuperscript{89} Sleep disorders secondary to comorbidities have been reported \textsuperscript{90} and sleep is disturbed by incontinence\textsuperscript{91} which also heightens the risk of falls. A recent focus on general nervous system degeneration has shown that the incidence of white matter hyperintensities\textsuperscript{92} is also an independent risk factor for falls, and the transition to frailty brings the added risk of sarcopenia.\textsuperscript{93}

With increasing numbers of comorbidities comes increased medication usage, and polypharmacy (four or more prescription medications) has been correlated with an increased risk of falls\textsuperscript{94} and hip fracture.\textsuperscript{95} Specific classes of drugs such as cardiac and analgesics\textsuperscript{94} and psychotropic medication\textsuperscript{96} have been shown to increase the risk of falls, and withdrawal of psychotropic medication has been shown to reduce falls.\textsuperscript{97} More recent studies have shown that it is the inclusion of at least one psychotropic medication that is the important factor for increasing falls risk\textsuperscript{98,99} and improved medication
control by primary care physicians has been shown to reduced falls.\textsuperscript{100}

\subsection*{1.3.2 Extrinsic risk factors}

Environmental features such as the quality of the travel surface, trip hazards and ambient illumination can increase the risk of falls in the general population and this risk is magnified for people with visual impairment. Environmental preview allows an individual with good vision to scan the environment ahead with sufficient time to recognize potential hazards. A visual impairment reduces the quality of information gathered and the amount of time between when a hazard is noticed and when an avoidance strategy can be implemented. In the case of an individual using a long cane as a mobility aid, the cane is detecting the next footfall, which gives the user little warning before a hazard is encountered. This requires that the user is both attentive and able to respond quickly if they hope to avoid injury. The situation is compounded if the obstacle to be avoided is also moving. A visually impaired pedestrian has even less time to respond if a dog, a young child, or an inattentive cyclist, skateboarder or pedestrian is moving towards them unseen.

People with visual impairments usually travel well known routes, and substitute memorized locatable landmarks for orienting themselves within the environment. With the help of mobility aids this foreknowledge can be useful in the detection and avoidance of stationary obstacles such as poles, overhanging obstacles like tree branches and drop-offs such as kerbs, steps and stairways. But public spaces are not static environments and even a relatively safe known route can be transformed quickly by spillages, changing
weather, public works (pavement repairs or garbage collection) and damage caused by accidents, carelessness or vandalism.

Ambient illumination levels can further reduce functional vision. Glare, whether from the sun or from commercial illumination, reduces visibility and is compounded by reflection from windscreens, shopfronts, and polished floors. Contrast sensitivity, which is a known risk factor for falls,\textsuperscript{42} has been shown to be reduced in the presence of glare in people with cataract.\textsuperscript{101} High levels of glare sensitivity are also reported in individuals with glaucoma, and this is often cited as a reason for cessation of night driving.\textsuperscript{102} Recovery from glare exposure is known to be slower in people with ARMD,\textsuperscript{103} so fluctuating levels of light experienced during transitions between indoors and outdoors or between sunlight and shadow can reduce functional vision recovery times, complicate hazard avoidance strategies and add to the level of travel-stress experienced.

Reduced illumination levels at night or indoors can also be a problem, particularly for people with glaucoma\textsuperscript{102} and Retinitis Pigmentosa (RP).\textsuperscript{104} Loss of peripheral vision in these conditions severely impacts traffic gap judgment even in a well-lit environment, and so raises serious concern regarding safe street crossing in built-up areas, particularly at night.\textsuperscript{105}

\subsection*{1.3.3 Behavioural risk factors}

Around one-third of adults report a fear of falling following a fall event\textsuperscript{106} and this is associated with activity avoidance and decreased quality of life.\textsuperscript{107-109} A recent cross-sectional study found that between 40-50\% of older adults with visual impairments reported limiting activity due to fear of falling
compared to 16% in a control group with normal vision.\textsuperscript{110} It is understandable that people would use such a compensation strategy when they are visually impaired, and it may limit exposure to extrinsic risks, but it also increases social isolation and reduces levels of physical activity and so can increase overall disability. Fear of falling may also preoccupy an individual with a temporary prominent hazard, which can result in other potential hazards in the environment being overlooked,\textsuperscript{111} and is associated with an increased use of the ‘hip strategy’ for balance control\textsuperscript{112} which can lead to an increased risk of falls on unstable surfaces.\textsuperscript{113}

At the other end of the spectrum, risk taking behaviour has been shown to correlate with injury, and males have generally been shown to take more risks than females.\textsuperscript{114} Although women are hospitalised more often than men following a fall, more men die from fall related injuries.\textsuperscript{115,116} Type A personality traits have been shown to correlate independently with falls in men, but not in women.\textsuperscript{117} Injurious falls in men have been shown to be associated with lower household activity but higher recreational activity,\textsuperscript{118} indicating two distinct at risk groups among men.

Some Type A personality characteristics such as impatience, over-competitiveness and over-confidence may lead individuals to engage in behaviours that could increase falls risk in old age such as climbing onto chairs to reach shelves, carrying inappropriate loads rather than waiting for assistance, or hurrying and running (e.g., to catch a bus or cross a road). Most visual impairments are developed later in life\textsuperscript{28} and so the individual has usually developed behavioural traits around risk taking and mobility that
were calculated on the basis of existing vision. Risk taking behaviours that may have been moderate or low when the individual had functional vision can become potentially dangerous behavioural strategies once visual impairment complicates safe mobility, but these behaviours may also have become habitual and so difficult to modify.

Physical health and depression are closely related in older adults\(^\text{119}^{\text{120}}\) and older adults who report depressive symptoms have been shown to be at a higher risk of physical decline.\(^\text{121}\) Older adults with visual impairments have a higher rate of depression than those with normal vision\(^\text{122}^{\text{126}}\) and the addition of reduced physical activity due to fear of falling is likely to add to the existing burden. Given that depression is often treated with psychoactive medications that are known to increase the risk of falls,\(^\text{96}\) older adults with visual impairments are exposed to increasing levels of risk as they age.

Individuals with visual impairments are required to pay more attention as they travel, as they rely more heavily on memorized aspects of the environment and are often employing some form of mobility aid. This dual tasking may have an effect on the level of attention they are then able to give to the added demands of obstacle avoidance and safe travel.

There is competition between postural and cognitive demands on attention during the performance of multiple tasks, and allocation is complex.\(^\text{127}\) Attentional requirements for postural control vary depending on the age and ability of the individual, and the difficulty of the task.\(^\text{128}\) When attention is divided, older adults have been shown to have a decreased ability to avoid obstacles in the environment compared to younger adults.\(^\text{129}\) If the person
has a visual impairment and is forced to allocate attention to route memory and mobility-aid use in addition to postural stability and hazard avoidance, this could overload attentional resources and further increase the risk of falls.

Responses to falling also differ with age. Younger adults tend to protect themselves by sharing the impact between several limbs\textsuperscript{130} or points of contact, whereas older adults do not, and it has been suggested that this helps account for higher injuries in older adults and is the results of attentional deficit giving the individual insufficient time to respond in a more protective manner.\textsuperscript{131}

Anxiety regarding personal safety may further compound safe mobility for older adults with a visual impairment when travelling in public spaces. The increased likelihood of collision in crowded public spaces or the perceived vulnerability to assault and robbery engendered by the use of a mobility aid can heighten fear and anxiety with negative consequences for safe travel. Preliminary studies on the effects of emotional states on falls have shown elevated risk following the experience of anger and emotional stress.\textsuperscript{132}

1.3.4 Modifiable risk factors

Another important aspect of risk factors for injury is the degree to which they can be modified. A study in geriatric facilities in Spain that classified falls on extrinsic (aspects of the environment such as lighting, surface quality and equipment) and intrinsic causes (balance, gait, visual impairment, cognitive decline etc.) found that sex and age had no influence on the number of falls whose cause was extrinsic, but that the frequency of falls classified as having an intrinsic cause was five times higher in women than in men.\textsuperscript{133}
Comorbidities which add to falls risk cannot always be modified in a positive direction, but appropriate medical management can sometimes stabilize or slow degeneration, and this lies within the sphere of primary care physicians.

Physical risk factors such as strength, balance and co-ordination are more amenable to modification as has been demonstrated by the success of multimodal exercise and home modification in reducing falls.\textsuperscript{134-136} It is these aspects of physical functioning that are targeted in fall prevention programs and they may require modification for the population with visual impairments if they are to be successful for this demographic.

1.4 Inciting events

Although the causes of falls are multifactorial, they ultimately result from an unexpected displacement of the body and a subsequent failure to correct it appropriately.\textsuperscript{137} As we age and as the difficulty of the task increases, the balance control mechanisms rely more heavily on visual input,\textsuperscript{9,15} particularly during single limb balance.\textsuperscript{138} Balance recovery strategies are of two general types. Either muscular effort is applied around the ankles or hips to move the centre of mass inside the base of support, or a change of support requires compensatory steps to shift the base of support back under the centre of mass. This change of support strategy is the predominant strategy among the elderly,\textsuperscript{139} who often require multiple steps compared to younger adults, with subsequent steps having a large lateral component. The characteristics of the initial steps are similar in both young and old subjects, but significant variation is seen in subsequent steps. When older adults step to a shifting target they show reduced rates of lateral force production, delayed
responses in modifying step trajectory and in modifying lateral propulsive forces under the supporting foot, and prolonged execution of movement. So while an initial compensatory step to a perturbation may be fast enough, the additional requirements of appropriate foot placement in a hazardous or poorly viewed environment may compromise balance and safety due to increased response latencies.

Up to 70% of falls occur during walking activities and this makes gait dynamics an important consideration with respect to lateral perturbations and visual impairment. Laboratory studies show that greater control needs to be exerted medio-laterally when walking and deterioration in balance control in the elderly is primarily in the medio-lateral direction. There are also age-related differences in stepping responses to lateral perturbations. Older adults take more steps, tend to use their arms more and sustain more collisions between their swing and stance foot. These collisions of the swing and stance feet compound existing trip hazards from slips and trips in the external environment, which along with loss of balance account for the majority of falls. Perturbations in the medio-lateral direction are the greatest challenge to balance and stability whilst walking and reduced visual input has been shown to have a greater impact on lateral balance control.

Another contribution to delays in appropriate response may be found within the visuo-motor system. Older adults have been shown to fix their gaze on future footfall positions sooner than younger adults in target stepping tasks, but despite this longer preview their accuracy was reduced. Adults at high risk of falls required more time to both initiate eye movements towards a
target and to look at it in order to successfully plan and carry out medio-lateral stepping adjustments.\textsuperscript{148} Adults at high risk of falls have been shown to take twice as long to initiate a shift of gaze compared to young adults, and these measures of saccadic latency have been shown to correlate with foot placement error in target stepping tasks.\textsuperscript{149}

1.5 Injury

Ageing is often accompanied by comorbidities which can reduce physical ability and increase risk of falls.\textsuperscript{3,150} As prevalence and number of comorbidities increases with age\textsuperscript{151,152} the influence of declining health with advancing age can significantly increase falls risk and injury. Table 1.3 presents the latest hospitalization data on fall-related injuries in Australia.\textsuperscript{153} Head injuries and hip fractures are the most predominant injuries and have the most serious consequences. Proportionally, injuries for men were more common on the torso or head and injuries for women were more common on the hips, shoulders and limbs. Around three in five adults over 65 years of age hospitalised for a fall related injury sustained a fracture (63\% of women and 51\% of men), and the commonest causes recorded were slips, trips and stumbles (33\%).\textsuperscript{153}

Most older adults go into residential care due to declining physical ability, so causes of falls in these two groups is likely to be different. This data is for all hospitalisations from both community-dwelling adults and those living in residential facilities. The location of the falls is presented in Table 1.4. It can be seen that around 49\% of the falls were at home and around 23\% were in residential institutions, but it is likely that some of these hospitalisations will
trigger a transition to care.

An observational study of falls in common areas of long-term care facilities in Canada using video-capture technology found that the most common cause of falls in that context was incorrect transfer of bodyweight which accounted for 41% of the falls recorded,\textsuperscript{154} followed by trips and stumbles (21%). The activities most associated with falls in the study were walking forward (24%), standing quietly (11%), sitting down or lowering the body (11%), initiation of walking (11%) and getting up or rising (9%).

An epidemiological study of causes of falls in community-dwelling older women\textsuperscript{2} found that trips accounted for 39.7% of the falls, loss of balance for 20.8%, slips for 13.2% and legs giving way for 5.5%. In contrast to the hospitalisation data, most of these falls happened outside the home. Trips and slips can relate to environmental hazards, inattention, poor vision or all three, but the individual’s level of physical ability plays a large role in whether they recover from them intact or whether they result in a fall and injury. Loss of balance is more clearly related to physical function as is legs giving way.

Collectively these causes accounted for 79.2% of the falls recorded and suggest that poor strength and balance are a significant context in which other risk factors converge and result in falls in community-dwelling older adults.
Table 1.3. Types of injuries in adults over 65 years of age hospitalised following a fall in Australia 2010 - 2011

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Head</td>
<td>7,562</td>
<td>26.1</td>
<td>11,345</td>
<td>18.0</td>
<td>18,907</td>
<td>20.5</td>
</tr>
<tr>
<td>Hip fractures</td>
<td>5,232</td>
<td>18.0</td>
<td>13,415</td>
<td>21.2</td>
<td>18,647</td>
<td>20.2</td>
</tr>
<tr>
<td>Abdomen, lower back, lumbar spine, pelvis</td>
<td>2,793</td>
<td>9.6</td>
<td>7,447</td>
<td>11.8</td>
<td>10,240</td>
<td>11.1</td>
</tr>
<tr>
<td>Shoulder and upper arm</td>
<td>2,349</td>
<td>8.1</td>
<td>6,313</td>
<td>10.0</td>
<td>8,662</td>
<td>9.4</td>
</tr>
<tr>
<td>Elbow and forearm</td>
<td>1,763</td>
<td>6.1</td>
<td>6,921</td>
<td>11.0</td>
<td>8,684</td>
<td>9.4</td>
</tr>
<tr>
<td>Knee and lower leg</td>
<td>2,356</td>
<td>8.1</td>
<td>6,263</td>
<td>9.9</td>
<td>8,619</td>
<td>9.4</td>
</tr>
<tr>
<td>Other injuries to the hip and thigh</td>
<td>1,949</td>
<td>6.7</td>
<td>4,489</td>
<td>7.1</td>
<td>6,438</td>
<td>7.0</td>
</tr>
<tr>
<td>Thorax</td>
<td>2,689</td>
<td>9.3</td>
<td>3,517</td>
<td>5.6</td>
<td>6,206</td>
<td>6.7</td>
</tr>
<tr>
<td>Other</td>
<td>2,299</td>
<td>8.0</td>
<td>3,448</td>
<td>5.4</td>
<td>5,747</td>
<td>6.3</td>
</tr>
<tr>
<td>Total</td>
<td>28,992</td>
<td>100</td>
<td>63,158</td>
<td>100</td>
<td>92,150</td>
<td>100</td>
</tr>
</tbody>
</table>

Adapted from Australian Institute of Health and Welfare figures

Table 1.4. Location of incident in adults over 65 years of age hospitalised following a fall in Australia 2010 - 2011

<table>
<thead>
<tr>
<th>Injury Location</th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Home</td>
<td>14,204</td>
<td>49.0</td>
<td>31,001</td>
<td>49.1</td>
<td>45,205</td>
<td>49.1</td>
</tr>
<tr>
<td>Residential institution</td>
<td>5,509</td>
<td>19.0</td>
<td>15,522</td>
<td>24.6</td>
<td>21,031</td>
<td>22.8</td>
</tr>
<tr>
<td>School, institution, public administrative area</td>
<td>604</td>
<td>2.1</td>
<td>1,205</td>
<td>1.9</td>
<td>1,809</td>
<td>2.0</td>
</tr>
<tr>
<td>Sports and athletics areas</td>
<td>178</td>
<td>0.6</td>
<td>234</td>
<td>0.4</td>
<td>412</td>
<td>0.4</td>
</tr>
<tr>
<td>Street and highway</td>
<td>1,350</td>
<td>4.7</td>
<td>2,368</td>
<td>3.7</td>
<td>3,718</td>
<td>4.0</td>
</tr>
<tr>
<td>Trade and service area</td>
<td>997</td>
<td>3.4</td>
<td>2,161</td>
<td>3.4</td>
<td>3,158</td>
<td>3.4</td>
</tr>
<tr>
<td>Other</td>
<td>778</td>
<td>2.6</td>
<td>1,030</td>
<td>1.6</td>
<td>1,808</td>
<td>2.0</td>
</tr>
<tr>
<td>Unspecified</td>
<td>5,372</td>
<td>18.5</td>
<td>9,637</td>
<td>15.3</td>
<td>15,009</td>
<td>16.3</td>
</tr>
<tr>
<td>Total</td>
<td>28,992</td>
<td>100</td>
<td>63,158</td>
<td>100</td>
<td>92,150</td>
<td>100</td>
</tr>
</tbody>
</table>

Adapted from Australian Institute of Health and Welfare figures
Two recent reviews have shown conclusively that well designed exercise programs reduce falls in the general population. An updated systematic review\textsuperscript{135} found that the effects on fall rates were greater in programs that included balance activities, had a higher dosage of exercise, and did not include a walking program. A Cochrane review\textsuperscript{136} found that exercise interventions reduce both the risk and the rate of falls in the general population, but the authors concluded that more research is needed to confirm the contexts in which other interventions are effective and that further research is needed to clarify the impact of strategies for people with different types of visual impairments.

1.6 Hypothesis of the study

This thesis describes a randomised controlled trial, the VISIBILITY study, run between August 2010 and September 2012 in collaboration with Guide Dogs NSW/ACT. The study was pragmatic and its aim was to establish the impact of the Alexander Technique on physical functioning in community-dwelling older adults with visual impairments that limited their functional mobility and required Orientation & Mobility training. The hypothesis of the study was that lessons in the Alexander Technique would improve physical functioning in older adults with visual impairments, and so reduce physical falls risk. We further hypothesised that if it did improve physical functioning that this may have an impact on emotional well-being and social participation.
1.7 Chapter summary

Chapter 2 is a systematic review of the literature to determine what evidence exists for intervention strategies specifically aimed at improving physical functioning and preventing falls in older adults with visual impairments. The review has been accepted for publication by the Journal of Physiotherapy. Chapter 3 discusses the physiological mechanisms underlying the maintenance of postural orientation and upright balance necessary to prevent falls and their relevance to the Alexander Technique, the intervention used in the randomised controlled trial that is the subject of this thesis. Chapter 4 is the study protocol as registered with the Australian New Zealand Clinical Trials Registry and published in Injury Prevention. Chapter 5 presents the main results of the study (the physical functioning outcomes) and has been accepted for publication by Clinical Rehabilitation. Chapter 6 presents results from the social and emotional aspects of the study based on validated questionnaires administered at the three assessment time-points, and this paper is being prepared for submission to a journal. Chapter 7 is a process evaluation of the study based on a post-intervention questionnaire administered to study participants who received the intervention and logs kept on each Alexander Technique lesson the participants received. And finally chapter 8 is a discussion of all the study findings and recommendations for the future.
1.8 References


This chapter reports a systematic review of the literature that has been accepted for publication to the *Journal of Physiotherapy*. The introduction introduces the topic to readers of the journal, and is a précis of chapter 1.

### 2.1 Introduction

Falls are a leading cause of morbidity and mortality and at least 30% of people aged 65 and over fall each year.\(^1\)\(^-\)\(^3\) Older adults with visual impairments are 1.7 times more likely to fall than their sighted peers and 1.9 times more likely to have multiple falls.\(^4\) Visual impairment has been found to be an independent risk factor for falls particularly with relation to impaired edge-contrast sensitivity and depth perception.\(^5\)\(^6\)

People with visual impairments are at a particularly high risk of falls due to impaired balance\(^7\) as well as difficulty detecting environmental hazards. With normal ageing, conduction speed and central nervous system processing slows down,\(^8\) forcing balance control mechanisms to rely more heavily on visual input to maintain stability\(^9\) particularly during single limb balance.\(^10\) This has obvious implications for older adults with visual impairments. Deterioration in balance control in older people is primarily in the medio-lateral direction\(^11\) and reduced visual input has been shown to have a greater impact on lateral balance control,\(^12\) so amplifying the deterioration in the
older population with visual impairments on mobility tasks involving single limb balance.

Effective approaches to fall prevention for the general population of older adults living in the community include exercise, home safety, medication management and interventions targeting multiple risk factors.\textsuperscript{13} This updated Cochrane Review included no new trials that provided physical training for community dwelling older adults with untreatable visual impairments. Vitamin D prescription reduces falls in residential care facilities, and interventions targeting multiple risk factors may also do so,\textsuperscript{14} but this review found no trials that provided physical training for older adults with visual impairments in care facilities and hospitals. To our knowledge this is the first systematic review to address this question.

Older adults with visual impairments are affected by age-related deterioration in balance to an even greater extent than the general population.\textsuperscript{15} Thus, exercise and physical training warrant particular investigation as fall prevention strategies for people with visual impairments living in the community as well as in residential care settings. Mobility, balance, strength and proprioception are aspects of physical functioning that have been identified as risk factors for falls. Thus we sought to investigate the impact of exercise on these factors as well as on falls themselves.

The research questions for this review were:

1. Does exercise or other physical training improve physical functioning in older adults with visual impairments?
2. Does exercise or other physical training prevent falls in older adults with visual impairments?

2.2 Method

2.2.1 Identification and selection of studies

This review focussed on exercise and training to improve physical functioning or reduce falls in older adults with untreatable visual impairments, and so excluded studies relating to cataract surgery, refractive correction, and medication. Published randomised controlled trials were included, and eligible interventions included strength and balance training and physical training such as dance, Tai Chi and other complementary therapies. Eligible trials were conducted among adults with visual impairment and primarily included people aged 60 or older. Trials which included younger participants were considered eligible if the mean age of participants minus one standard deviation was over 60 years. Comparisons in eligible studies were between the intervention group and either a usual care or control group, and studies with factorial designs comparing more than one intervention were also included. Included studies measured physical functioning with performance tests or questionnaires and/or falls with calendars or incident reports. Eligible aspects of physical functioning were mobility, balance, strength and proprioception. Language of publication was not an exclusion criterion. Inclusion criteria are summarised in Figure 2.1 and the researchers were not blinded to any aspects of the papers.

A search of the literature was conducted in February 2013 in MEDLINE, Embase, CINAHL and the Cochrane Register of Controlled Trials (Central).
The MEDLINE search strategy used is shown in Appendix 1 and this was adapted for other databases. Supplementary searches of the Physiotherapy Evidence Database (PEDro; http://www.pedro.org.au), the WHO International Clinical Trials Registry and Literatura Latino-Americana e do Caribe em Ciências da Saúde (LILACS) were also undertaken.

Figure 2.1 Inclusion criteria for papers in the review

2.2.2 Assessment of characteristics of studies
Study titles and abstracts were independently screened by two investigators (MG and LK) for inclusion in the review and any discrepancies were resolved by discussion with a third investigator (CS). The studies had already been assessed for quality by PEDro but studies were not excluded on the basis of the rating. Data were extracted by one investigator (MG) and checked by a second investigator (CS) and any discrepancies resolved by discussion. Data extracted
included the settings in which the trials were conducted, the characteristics of the participants (age, gender and visual status), the programs provided to the intervention and control groups, and outcome measures.

2.2.3 Data analysis
Random-effects meta-analyses were conducted using Comprehensive Meta-Analysis software (Version 2, Biostsat, Englewood NJ) to compare the impact on the outcomes of interest of programs designed to enhance physical functioning or prevent falls with control programs or usual care. The weighted mean difference (WMD) was calculated using the pre- and post-intervention means and standard deviations. Statistical heterogeneity was quantified with the $I^2$ and $Q$ statistics.

2.3 Results

2.3.1 Flow of studies through the review
The electronic database search identified 3,451 records after removal of duplicates. After screening by title and abstract, full articles were then obtained for ten trials and their eligibility assessed against the inclusion criteria. After more detailed investigation, three papers were excluded because they were not randomised controlled trials, one because the participants were not visually impaired, one because there was no physical intervention and one because it was another report of an included trial. Four trials were deemed to fit our inclusion criteria and results from two trials were combined in a meta-analysis. Figure 2.2 shows the flow of search results through to the selection for meta-analysis.
2.3.2 Characteristics of studies

The trials had all been independently rated for risk of bias for indexing on the Physiotherapy Evidence Database (PEDro; http://www.pedro.org.au). The PEDro scale rates the internal validity of the trial and whether the trial contains sufficient statistical information to make it interpretable. The rated scores for the included trials are provided in Table 2.1. The four studies included in the review were randomised controlled trials published in English. The trials’ design, participant characteristics, interventions and outcome measures are summarised in Table 2.2. The VIP trial by Campbell et al.\(^{16}\) was a 12-month 2 x 2 factorial community-based trial conducted among men and women over 75 years of age with visual impairment. The remaining three trials were undertaken in residential care settings. The trial by Chen et al.\(^{17}\) ran for 16 weeks and stratified the randomisation based on gender, age and level of visual impairment. Cheung et al.\(^{18}\) included women over 70 years of age in a 12 week trial, and Kovács et al.\(^{19}\) included women over 60 years of age in a six month trial. There were a total of 522 participants in the included studies, but data from only 91 participants in two studies\(^{18}^{19}\) were able to be pooled for meta-analysis.
Figure 2.2  Flow of studies through the review

- Titles and abstracts screened (n = 3451)
- Potentially-relevant papers retrieved for evaluation of full text (n = 10)
- Papers included in review (n = 4)
- Papers excluded after screening titles/abstracts (n = 3441)
- Papers excluded after evaluation of full text (n = 6)
  - Research design not RCT (n = 3)
  - Participants not visually impaired (n = 1)
  - Intervention not a physical intervention (n = 1)
  - Second paper describing the home modification results of the main trial in more detail (n = 1)
- Papers included in Meta-analysis (n=2)
Table 2.1 PEDro scores of studies included in systematic review

<table>
<thead>
<tr>
<th>Study</th>
<th>Random allocation</th>
<th>Concealed allocation</th>
<th>Groups similar at baseline</th>
<th>Participant blinding</th>
<th>Therapist blinding</th>
<th>Assessor blinding</th>
<th>Adequate follow-up</th>
<th>Intention-to-treat analysis</th>
<th>Between-group difference reported</th>
<th>Point estimate and variability reported</th>
<th>Total (0 to 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell et al (2005)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>8</td>
</tr>
<tr>
<td>Chen et al (2012)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>4</td>
</tr>
<tr>
<td>Cheung et al (2008)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>7</td>
</tr>
<tr>
<td>Kovács et al (2012)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>8</td>
</tr>
</tbody>
</table>
### Table 2.2 Summary of studies included in systematic review

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Participants</th>
<th>Intervention</th>
<th>Outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell <em>et al</em> (2005)</td>
<td>2x2 Factorial RCT</td>
<td>n = 391, Age (yr) ≥ 75, Gender = 124 M, 267 F, Community dwelling, Visual acuity ≤ 6/24</td>
<td>Exp = 2x2 factorial Otago exercise program (multimodal) and home safety 5 home visits by physiotherapist at wk 1, 2, 4, 8, and 6 months to progress and encourage independent practice of the Otago exercise program 30 min x 3/wk and walk x 2/wk if safe to do so for 12 months plus Vitamin D supplementation Con = 2 x 1 hour social visits in first 6 months</td>
<td>Falls measured with prospective calendars over 12 months, Follow up = 12 months</td>
</tr>
<tr>
<td>Chen <em>et al</em> (2012)</td>
<td>RCT</td>
<td>n = 40, Age (yr) ≥ 70, Gender = M &amp; F but data unavailable, Residential facility, Visual acuity stratified ≥ 3/60 &lt;6/18 or &lt; 3/60</td>
<td>Exp = Modified 8 form Yang style Tai Chi in small group with verbal and manual support 90 min x 3/wk x 16 weeks Con = Social music group - time and duration not stated</td>
<td>Muscle strength = %change of knee muscle strength with Cybex Norm dynamometer, Proprioception = %change of absolute angle error with Cybex Norm dynamometer, Sensory Organisation Test = %change of sensory ratios using sway referencing, Follow up = 16 weeks</td>
</tr>
<tr>
<td>Cheung <em>et al</em> (2008)</td>
<td>RCT</td>
<td>n = 50, Age (yr) ≥ 65, Gender = F only, Residential facility, Visual acuity ≤ 6/120</td>
<td>Exp = Multimodal exercise program with verbal and manual support delivered by physiotherapist 45 min x 3 /wk x 12 wk plus standard residential exercise program given to control group 45-60 min x 3 /wk x 12 wk Con = Standard residential exercise program 45-60 min x 3 /wk x 12 wk</td>
<td>Berg Balance Score, Timed up-and-go test, Chair stand test, Follow up = 12 wk</td>
</tr>
<tr>
<td>Kovács <em>et al</em> (2012)</td>
<td>RCT</td>
<td>n = 41, Age (yr) ≥ 60, Gender = F only, Residential facility for visually impaired, Excluded if totally blind</td>
<td>Exp = Otago exercise program (multimodal) with verbal and manual support in small group delivered by physiotherapists 30 min x 2/wk x 6 months plus standard osteoporosis exercise program given to the control group below x2/wk x 6 months Con = Standard osteoporosis program 30 min x 4/wk x 6 months</td>
<td>Berg balance Score, Timed up-and-go test, Barthel Activity Index, Falls, Follow up = 6 months</td>
</tr>
</tbody>
</table>

Exp = experimental group, Con = control group, RCT = randomised controlled trial, min = minutes, wk = weeks, yr = years, M = male, F = female
2.3.3 Effect of the intervention: results of individual studies and meta-analysis

Three trials\textsuperscript{17-19} measured physical functioning as the primary outcome. Chen \textit{et al}\textsuperscript{17} used Tai Chi as the intervention and the other two\textsuperscript{18 19} used group multimodal exercise, which incorporated both strength and balance training.

The Tai Chi trial of Chen \textit{et al}\textsuperscript{17} used a passive knee joint repositioning test,\textsuperscript{20} the Sensory Organisation Test\textsuperscript{21} and concentric isokinetic strength of the knee flexors and extensors of the dominant leg as outcome measures. This trial showed a significant decrease ($p = 0.032$) in the percentage change of absolute angle error of passive knee joint repositioning in the intervention group (-25.9 ± 28.8\%) compared to the control group (4.2 ± 30.7\%) measured with a Cybex Norm dynamometer. There was an overall significant difference in favour of the intervention group on the Sensory Organisation Test ($p = 0.024$), and there were also significant differences in the vestibular and visual ratios between the two groups. The intervention group achieved a greater ($p = 0.048$) percentage improvement in the vestibular ratio (32.5 ± 40.2\%) compared to controls (-17.8 ± 56.8\%) and a greater ($p = 0.006$) percentage change of visual ratio (58.1 ± 41.9\%) compared to the control group (-1.6 ± 29.4\%). There was no significant difference between the two groups in muscle strength in the dominant leg.

Kovács \textit{et al}\textsuperscript{19} and Cheung \textit{et al}\textsuperscript{18} both reported outcomes using the Timed Up and Go test\textsuperscript{22} and the Berg Balance Score\textsuperscript{23} so these data were pooled for meta-analysis. Forest plots and weighted mean differences for the Berg Balance Scale are presented in Figure 2.3 and for the Timed Up and Go test in Figure 2.4.
2.4. In both cases the pooled estimates (WMD) of effect size showed a favorable effect of the intervention. The pooled estimate indicated statistically significant differences between intervention and control groups for the Berg Balance Score (WMD, 3.85 points; 95% CI, 1.75 – 5.96; P <0.001). The pooled estimate of effect for the Timed Up and Go test indicated a between-group difference in favour of the intervention that did not reach statistical significance (WMD, 1.49 seconds; 95%CI -1.66 to 4.63; P = 0.35). The Berg Balance Scale estimates showed a low level of heterogeneity ($I^2 = 0\%$, $Q = 0.45$) as did the Timed Up and Go test estimates ($I^2 = 0\%$, $Q = 1$).

In addition to these measures Cheung et al$^{18}$ used a chair stand test and found that the intervention group showed significant improvement compared with the control group (mean time difference 2.35 seconds; 95% CI: 0.03 – 4.67; p = 0.047). Kovács et al$^{19}$ used the Barthel ADL Index$^{24}$ but found no significant difference between intervention and control groups (p = 0.622).
Figure 2.3 Weighted Mean Difference (95% CI) of effect of multimodal exercise immediately after 12 weeks to 6 months of training on the Berg Balance Score (BBS) by pooling data from 2 studies (n=91).
<table>
<thead>
<tr>
<th>Study name</th>
<th>Year</th>
<th>Outcome</th>
<th>Time point</th>
<th>Exposed N[e]/M[e]/SD[e]</th>
<th>Control N[c]/M[c]/SD[c]</th>
<th>Weight (%)</th>
<th>Association measure with 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kovacs et al</td>
<td>2012</td>
<td>TUG</td>
<td>6 months</td>
<td>21/17.93/4.96</td>
<td>20/19.30/4.16</td>
<td>80.66</td>
<td>0.700 (-1.917 to 3.317)</td>
</tr>
</tbody>
</table>

Figure 2.4 Weighted Mean Difference (95% CI) of effect of multimodal exercise immediately after 12 weeks to 6 months of training on the Timed Up and Go Test (TUG) by pooling data from 2 studies (n=91).
2.3.4 Falls outcomes: results of individual studies

Only the VIP trial of Campbell et al\(^6\) collected prospective falls data. The VIP trial was a 2 x 2 factorial design with prospective calendars and 12 months of follow up. Community-dwelling older adults were randomised into a home safety assessment and modification program, an exercise program, both the home safety and exercise programs, or social visits. The study found that home safety assessment and modification reduced falls (41% fewer falls, incidence rate ratio 0.59, 95%CI: 0.42 to 0.83), but the exercise intervention did not find a significant effect on falls although clinically relevant effects in either direction were not excluded by the study (incidence rate ratio 1.15, 95%CI: 0.82 to 1.61). The successful home safety aspect of the study is described in a separate paper.\(^{25}\)

Kovács et al\(^{19}\) used medical records and nursing documentation during the six month study period to collect falls data and reported that the risk for falls was reduced by 46% in the intervention group but the difference did not reach statistical significance (relative risk = 0.54; 95% CI: 0.294 – 1.007). This trial found a significant between group difference in the mean length of time to first fall in favour of the intervention group (\(p = 0.049\)). The mean length of time to first fall was 18.5 weeks (95% CI 15.4 – 21.7) for the intervention group and 14.8 weeks (95%CI 11.1 – 18.4) for the control group. As acknowledged by the authors these results need to be treated with caution due to the small sample size (\(n = 41\)). Cheung et al\(^{18}\) reported no falls in either group during the three month study period (\(n = 50\)) but did not state how the data were collected. The Tai Chi trial by Chen et al\(^{17}\) did not collect falls data. Due to the differences in settings and follow-up periods we did not undertake a meta-analysis for the falls outcome.
2.4 Discussion

This systematic review found few studies of mixed quality in this vulnerable population. There was only one community-based trial among older adults with visual impairments with falls as the primary outcome and it found a protective effect of home modification but not exercise (the VIP trial). Data from three small trials in residential care settings, one of which specialised in people with visual impairment, indicate that multimodal exercise programs and Tai Chi can improve balance and physical functioning and thus may reduce fall risk. This provides a rationale for future larger trials of physical interventions in this population which measure actual fall rates, given the known effect of visual impairment as an intrinsic risk factor for falls, and its subsequent negative effect on physical functioning.

It is interesting to note that in the meta-analysis, although both outcome measures were in a direction favourable to the intervention, it was only the Berg Balance Scale that reached significance. The Timed Up and Go Test is widely used, but it may not be the most appropriate measure for adults with a visual impairment. It is possible that there is a limit to how much it can be expected that walking speed will increase given the participants’ visual status, regardless of the level of physical improvement that the intervention provides. A study of age and gender matched sighted and visually impaired adults found that sighted adults responded faster than those with visual impairments on the Timed Up and Go test and concluded that adults with visual impairments have difficulty with fast paced movements. It should also be kept in mind that the data from these studies were pre- and immediately post-intervention, so there was no follow up period looking at effect duration over time.
These three trials were completed in residential care settings, one of which specialised in people with visual impairment, and this limits how much we can infer about these results for a community-dwelling population. Adherence to study protocol is easier in the controlled setting of a residential facility, and verbal guidance and manual assistance were provided,\(^{17-19}\) which may have improved the precision of the exercise performed relative to a person exercising at home without feedback. Adherence has already been shown an issue in home-based programs in this population group\(^{16}\) and group classes in the community are difficult for some people with visual impairments to access.

Improving physical ability may not always translate into a reduction in fall rates in the community as those individuals are likely to be more mobile and may be at a higher risk due to environmental hazards. Providing the level of manual assistance and verbal support available in a residential setting, or provision of transport to and from existing fall prevention programs in the community are possible options, but their cost effectiveness has yet to be established. These results suggest that residential care facilities should include visually impaired residents in fall prevention programs when it is possible to provide the additional support necessary to do so.

This review found only one trial powered to detect a reduction in falls and this was undertaken in a community setting (the VIP trial).\(^{16}\) This trial found that home safety and home modification programs reduce falls in community-dwelling older adults with visual impairments when delivered by an Occupational Therapist.\(^{16,25}\) Home safety interventions are designed to reduce the presence of extrinsic risk factors in the home environment along with general advice about
fall prevention. To date this is the only large scale trial that has implemented non-
vision-related interventions for older adults with visual impairments designed to
reduce falls.

The Otago Exercise Program which was used in this trial has been shown to be
effective in preventing falls in the general community-dwelling population and is
also a multimodal program incorporating elements of strength and balance
training.\textsuperscript{27,28} In addition to the home-based exercise program, there was a
walking program\textsuperscript{29} and participants in the exercise groups in the trial were
expected to walk at least twice a week for 30 minutes if it was safe to do so. It is
possible that the walking program may have exposed some of the participants in
the exercise group to greater risk of falling, given their visual impairment.

Falls were also recorded in two of the trials (Cheung \textit{et al}\textsuperscript{18}, Kovács \textit{et al}\textsuperscript{19}) that
delivered programs to improve physical functioning in residential settings. Data
from one small trial (n= 41) suggested a fall prevention effect of multimodal
exercise (Kovács \textit{et al}\textsuperscript{19}) but this was in a specialty residential facility for the
people with visual impairments and needs confirmation in a further study with a
larger sample size. At present no strong conclusions can be drawn regarding the
impact of improved physical functioning on fall rates within residential settings
for older adults with visual impairments.

\subsection*{2.4.1 Limitations}

There are several limitations to this review. Only four trials qualified for inclusion,
and three of these had small sample sizes. Only data from two trials could be
combined for meta-analysis, and in addition to this, the difference in setting
between the community and residential care-facilities makes it difficult to
generalise findings between them. The quality of the studies was generally high, (see PEDro ratings in Table 1) but one study\textsuperscript{17} only scored four out of ten, so those results should be interpreted with caution.

2.5 Conclusion

In conclusion, it has been shown that exercise programs that include a balance component and Tai Chi can improve physical functioning in older adults with visual impairments living in residential care, but any effect on fall rates requires a larger trial before it can be verified. Translating these results into community settings poses some problems due to the differences in residential and community populations. Home modification and safety programs have been shown to have a protective effect on falls in community dwelling older adults with visual impairments. Apart from the VIP trial\textsuperscript{16} which had an exercise intervention with falls as the primary outcome, this review found no trials designed to improve strength and balance in visually impaired older adults living in the community, and so appropriate interventions and their method of delivery have yet to be determined.
2.6 References


Appendix 2.1 Search strategy

The appended strategy was based on the SIGN filter (Scottish Intercollegiate Guidelines Network [http://www.sign.ac.uk/methodology/filters.html#systematic]). It was developed for MEDLINE and then adapted for Embase, CINAHL and the Cochrane Register of Controlled Trials (Central).

1. Randomized Controlled Trials as Topic/ 83785
2. randomized controlled trial/ 338952
3. Random Allocation/ 76138
4. Double Blind Method/ 117653
5. Single Blind Method/ 16857
6. clinical trial/ 474746
7. clinical trial, phase i.pt 12641
8. clinical trial, phase ii.pt 20202
9. clinical trial, phase iii.pt 7432
10. clinical trial, phase iv.pt 746
11. controlled clinical trial.pt 85368
12. randomized controlled trial.pt 338952
13. multicenter study.pt 151074
14. clinical trial.pt 474746
exp Clinical Trials as topic/ 262270
or/1-15 940642
(clinical adj trial$).tw 176372
((singl$ or doubl$ or treb$ or tripl$) adj (blind$3 or mask$3)).tw 115280
PLACEBOS/ 31442
placebo$.tw 139990
randomly allocated.tw 14097
(allocated adj2 random$).tw 16443
or/17-22 359862
16 or 23 1048192
case report.tw 16997
letter/ 762519
historical article/ 289034
or/25-27 1210975
24 not 28 1020172
exp Cataract/ or exp Retina/ or exp Eye Diseases/ or exp Vision, Ocular/ or exp Visual Perception/ or exp Space Perception/ or exp Vision Disorders/
exp Visual Acuity/ or exp Visually Impaired Persons/ or exp Macular Degeneration/ or exp Cataract/ or exp Blindness/
exp Vision, Low/co, cn, ep, eh, et, mo, pc, px, rh, su, th [Complications, Congenital, Epidemiology, Ethnology, Etiology, Mortality, Prevention & Control, Psychology, Rehabilitation, Surgery, Therapy]
((low$ or handicap$ or subnormal$ or partial$ or disab$) adj3 (vision or visual$ or sight$)).tw 7045
34  (Congenital$ or adventitious$) adj3 (vision or visual$ or sight$ or blind$).tw
35  Sensory adj3 (loss or impair$ or disab$).tw
36  30 or 31 or 32 or 33 or 34 or 35
37  Accidental falls/
38  Accidental falls.mp
39  (falls or faller$1 or fallen).tw
40  ((risk$ or consequence$) adj3 fall$).tw
41  Fall$ risk.tw
42  hip fracture.mp. or Hip Fractures/
43  Fall$ adj injur$.tw
44  37 or 38 or 39 or 40 or 41 or 42 or 43
45  Musculoskeletal Equilibrium/
46  posture/
47  (balance or functional reach or sway).tw.
48  (postur$ adj3 (stability or instability or orientation)).tw.
49  posturograph$.tw.
50  (cent$3 adj (pressure or mass)).tw.
51  45 or 46 or 47 or 48 or 49 or 50
52  exercise/
53  exercise$.tw.
54  train$.tw.
55  retrain$.tw.
aerobic$.tw. 48321

gym$ prog$.tw. 21

exp exercise/ 98333

physical activity.mp. 43209

exp motor activity/ 168207

(physical education and training).mp. 11444

exp physical fitness/ 20230

exp life style/ 58353

exp leisure activities/ 135054

exp exercise therapy/ 26442

(exercise$ adj aerobic$).tw. 82

(physical$ adj5 (fit$ or physical$ or activ$ or endur$)).tw. 358790

(exercis$ adj5 (train$ or physical$ or activ$)).tw. 31792

(("lifestyle" or life-style) adj5 activ$).tw. 2480

strength$.tw. 187045

complementary therapy.mp. or exp Complementary Therapies/ 164007

Tai Chi.mp. or Tai Ji/ 658

biofeedback.mp. or exp Biofeedback, Psychology/ 8044

dance therapy.mp. or exp Dance Therapy/ 203

52 or 53 or … 73 or 74 1258073

44 or 51 or 75 1437589

29 and 36 31060
78 76 an 77

79 limit 78 to (humans and ("middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)" or "aged (80 and over)")}
3 THE ALEXANDER TECHNIQUE AND POSTURAL ORIENTATION

Adequate physical functioning underpins independence and social engagement, and the International Classification of Functioning adopted by the WHO acknowledges the social aspects of disabilities and the impact of the environment on them. Adequate physical functioning is in turn underpinned by postural orientation and the ability to maintain upright balance, whether independently, using some form of mobility aid, or sitting in a wheelchair. The Alexander Technique is an untried modality to improve postural orientation in older adults with visual impairments.

3.1 The Alexander Technique

The Alexander Technique is a form of psychophysical re-education that was developed in the 1890’s and evolved in the performing arts outside mainstream medical science. It uses manual guidance and verbal feedback in everyday activities to elaborate the connection between habitual behaviours and their impact on functioning. The maintenance of balance is pivotal to fall prevention and is underpinned by postural control, which must be flexible enough to adapt to the changing tasks and environments that typify everyday movement. A feasibility study of the Alexander Technique for balance training in community-dwelling older adults in the general population suggested that it showed promise as a self-care approach in an
intensive group setting.\textsuperscript{3} The Alexander Technique is well placed as a possible candidate for improving physical functioning in older adults with visual impairments although a one-to-one approach may be more practical than a group setting for this population.

Learning the Alexander Technique can lead to greater freedom in movement and less effort. It uses tactile and verbal feedback and its application is based on practical experience in everyday movements. It was not built on theory, but established through experiment by an individual whose difficulties could not be helped by the medical advice of the day. F.M. Alexander (1869 – 1955) was an actor who developed voice trouble during performances. Through detailed self-observation he was able to discover that it was the way he was using himself in activity that was causing the problems that threatened his career, rather than an isolated malady pertaining only to his throat. Nikolaas Tinbergen, who won the Nobel Prize for Physiology and Medicine in 1973, described these experiments in his acceptance speech as an example of the usefulness of the ethological approach in medicine; “This story of perceptiveness, of intelligence, and of persistence, shown by a man without medical training is one of the true epics of medical research and practice”\textsuperscript{(p. 24)}.

\textbf{3.1.1 Alexander’s experiments}

Alexander’s voice problems resolved with rest, but returned as soon as he returned to his performances. When doctors could not help him, he determined that it must be something he was doing whilst reciting that was causing the problem. He began watching himself in a system of mirrors to
see if he could discern what this might be. In normal speech he could not see anything unusual, but “as soon as I started to recite, I tended to pull back the head, depress the larynx and suck in breath through the mouth in such a way as to produce a gasping sound” (p.26).⁵

Deciding that this may be the cause of his voice problems, Alexander experimented with ways of preventing it from happening. Initial experiments to reduce the depression of his larynx and suck in breath were unsuccessful, but he found that if he could reduce the tendency to pull his head back, this indirectly affected the degree to which he tended to do the other two things. With further experiment he discovered that the tension he had noticed in the head and neck were part of a larger pattern throughout his body associated with a tendency to lift his chest and shorten his stature.⁵

At first he “put” his head forward, but found that past a certain point this would pull it down and have a similar depressive effect on the larynx. He eventually realised that he had to prevent the pulling back of his head and allow it to go forward. His observation that he was shortening in stature related to a tendency to lift the chest, which was attained by tightening the lower back and raising the front of the head. Although this gave an impression of lengthening through the front of the torso, it was done at the expense of a shortening through the back which required the generation of undue muscle tension. He found that if he prevented the pulling back of the head and combined it with a lengthening of his stature there was an improvement in his voice problems.

A lengthening of stature in this context meant an optimal length between the
crown of his head and the soles of his feet and could only be achieved by a release of whatever tension was creating the exaggerated attitude of the chest. He went on to notice that “this condition of undue muscle tension affected particularly the use of my legs, feet and toes, my toes being contracted and bent downwards in such a way that my feet were unduly arched, my weight thrown more on to the outside of my feet than it should have been, and my balance interfered with”(p. 33).

3.1.2 Habitual behaviour and imperfect sensory appreciation

What was most interesting in these experiments was that he could see the patterns of undue tension in the mirrors, but could not feel them in himself. Movement patterns become habitual by dint of repetition, and as he was doing what ‘felt right’ it did not stand out in his field of sensory awareness. Even more interesting was that when he attempted to maintain the experimental improvements during his recitations he had great difficulty in doing so. He found that although he thought he was establishing better conditions for performance, at the critical moment when he went to speak, his old pattern of activity would override what he had decided to do and what he thought he was doing.

He coined the term ‘imperfect sensory appreciation’ to describe this phenomena, stating that he suffered from “the delusion that because we are able to do what we “will to do” in acts that are habitual and involve familiar sensory experiences, we shall be equally successful in doing what we “will to do” in acts that are contrary to our habits and therefore involve sensory experiences that are unfamiliar”(p.32). Alexander realised from these
experiences that he could not alter the patterns of misuse that were causing his voice problems just by voluntary effort and he needed to experiment further.

### 3.1.3 Direction

When we move, we send motor commands from the central nervous system to the musculature to effect changes in the tensional relationships of the muscular system. We usually do this habitually with only the goal in mind, and with only our imperfect sensory appreciation available as a comparator. Alexander realised that in order to improve the conditions necessary for a better performance, he needed to send an appropriate set of new ‘directions’ to himself regarding in particular his head, neck and back.

Instead of habitually and unconsciously tightening his neck and pulling his head back he had to consciously direct his attention and energy to allow his neck to free and let his head release forward so that his back could lengthen and widen rather than narrow and contract. Additionally he needed to give thought to his legs (and therefore his contact with the ground) so that they gave appropriate support without distorting the rest of his structure. He realised that he had been relying on an “instinctive misdirection” and that it emerged whenever he made a decision to speak.

The process of ‘directing’ in the context of the Alexander Technique, is the formulation of a positive intention based on repeated thought embedded in the functional reality of the human organism, and is different from more abstracted forms of thinking such as visualisation or ‘positive imagery’. Speaking of direction, Alexander wrote that “I wish to indicate the process
involved in projecting messages from the brain to the mechanisms and in conducting the energy necessary to the use of these mechanisms” (p.35). It is an active thought process that requires a response, but this response is not the familiar muscular response that accompanies movement. In a sense ‘direction’ precedes or sets the stage for ensuing movement by creating the optimal conditions throughout the organism that will allow the movement to be as free and effortless as possible, and is then maintained in activity to optimise performance. Directions are also the literal directions that we want the various parts of ourselves to be going in relation to each other in order to get an expanded dynamic organisation throughout the musculature (Figure 3.1).

Figure 3.1 Alexander Technique directions
3.1.4 Inhibition

Every time that Alexander went to speak, having directed his thinking to a better organisation, he invariably found that his old habit would usurp his decision at the critical moment. (Figure 3.2)

**Figure 3.2 Habitual response to a familiar stimulus**

He then experimented with a new approach, and it was here that Alexander made a breakthrough in finding a way out of his predicament. As soon as the stimulus to speak emerged, he would inhibit his immediate response and return to projecting the directions for a better use of himself. When he again came to the critical moment, he would again inhibit his response and choose whether to go ahead and speak, do something completely different like raise a hand, or do nothing at all (Figure 3.3).

**Figure 3.3 Inhibition and Direction allow for a new response**

It should be remembered that in a neurological sense inhibition is an activity, but the consequences of this neural activity is to dampen a response or withhold consent and should not be confused with the suppression of desire in a psychoanalytical sense. This process of inhibiting his initial decision, followed by continued direction of organised thought and conscious choice
led him to the point where he could maintain a new use of himself while he recited. It was this process that alleviated the problems with his voice and led to an improved functioning that ultimately led to the development of the Alexander technique as it is known today.

### 3.1.5 Primary control

Fundamentally, we have to support our body weight against gravity, and the energy to support this weight has to go in an upward direction away from the support surface. We have to generate enough tension to hold us up, but too much tension and the whole structure shortens and compresses. Alexander reasoned that releasing the tension that pulled his head back and shortened his stature was fundamental to optimal functioning in activity, and he thought that if he could avoid doing all the things he could see himself doing in the mirrors that he may be able to solve his voice problems.

As his experiments continued he realised that “the wrong way I was using myself…constituted a combined wrong use of the whole of my physical-mental mechanisms…and that my desire to recite, like any other stimulus to activity, would inevitably cause this habitual wrong use to come into play and dominate any attempt I might be making to employ a better use of myself in reciting” (p.34).² He found that if he could alter his habitual use by a new relationship of the head and neck to the rest of the body that this would prevent the specific local tensions that caused his throat trouble, and his symptoms would dissipate.

This was a major insight because it meant that his symptoms, which appeared localised, were the expression of a generalised dysfunction, and
that rather than unravelling the vast array of interactions between all the parts to remedy this, it was only necessary to re-coordinate the primary underlying organisation. Once Alexander had used this approach to solve his own voice problems, he began to teach others his discoveries. He coined the term ‘primary control’ to describe this dynamic organisation; “there is a primary control of the use of the self which governs the working of all the mechanisms and so renders the control of the complex human organism relatively simple” (p.65).\(^5\)

### 3.1.6 Use of the self

Everywhere in our language and in the way we describe experience we speak of ‘physical’ or ‘mental’ worlds as if they were quite separate and unrelated to each other. The difficulties that F. M. Alexander experienced and the experiments that he performed to solve those difficulties convinced him of an interaction of these ‘physical’ and ‘mental’ processes that are manifestations of unified human activity. This idea is not new, and was encapsulated by Sir Charles Sherrington, often called the ‘father of neurophysiology’ when he wrote “The self is a unity. The continuity of its presence in time, sometimes hardly broken by sleep, its inalienable ‘interiority’ in (sensual) space, its consistency of viewpoint, the privacy of its experience, combine to give it status as a unique existence” (p.14).\(^6\)

F. M. Alexander avoided language that separated the physical and mental spheres and stated that “Instead I prefer to call the psycho-physical organism simply “the self”, and to write of it as something “in use”, which “functions” and which “reacts” (p xxxii)”.\(^7\) He was very clear that this idea of “use” did not
refer to the use of a specific part of the body but employed it in a more comprehensive sense to the working of the whole organism. He had the support of Sir Charles Sherrington in this conception who wrote “Mr Alexander has done a service to the subject by insistently treating each act as involving the whole integrated individual, the whole psycho-physical man. To take a step is an affair, not of this or that limb solely, but of the total neuro-muscular activity of the moment – not least of the head and neck” (p 89). 8

3.2 The Alexander Technique in the literature

The first published material about what was to become the Alexander Technique was an advertorial by F.M. Alexander entitled “Elocution as an Accomplishment” that appeared in a newspaper in Hobart, Tasmania in 1894. 9 The following year another piece entitled “Speech, Culture and Natural Elocution” appeared in a New Zealand newspaper 10 and this had a greater emphasis on breathing. By 1896 Alexander was living in Melbourne and teaching what he called “Natural Elocution Cultivation”. He moved to Sydney in 1900 before leaving Australia permanently in 1904. Alexander moved to London, where he quickly established himself among theatrical circles and continued the development of his work. In 1906 he published a pamphlet in London entitled “Introduction to a New Method of Respiratory Vocal Re-Education” 11 which introduced the concept of what he described as ‘mental attitude’ to posture. In 1908 another pamphlet entitled “Re-education of the Kinaesthetic Systems” appeared, 12 and this marked a departure from the specialised area of breathing and vocal re-education to a description of
the co-ordinated use of the whole muscular system. Alexander published four books on his technique during his lifetime: Man’s Supreme Inheritance in 1910,13 Constructive Conscious Control of the Individual in 1923,14 The Use of the Self in 1932,5 and The Universal Constant in Living in 1946.7 Alexander received support from a number of doctors in London, who regularly sent him patients and wrote a letter of support which was published in the British Medical Journal in 1937.15

3.2.1 Investigations of physiological change

A number of investigators have studied the Alexander Technique with a view to demonstrating physiological changes that accompany Alexander lessons, and these will be discussed in an historical context below.

3.2.1.1 Wilfred Barlow (investigations in the 1940’s and 1950’s)

The earliest mentions of the Alexander Technique in scientific journals were by a medical doctor, Wilfred Barlow, who was a Fellow of the Royal Society, and had trained to be a teacher of the Alexander Technique following personal experience of its efficacy. Initially he wrote letters to medical journals of the day16-20 regarding the efficacy of the Alexander Technique, but later used ‘before and after photographs’ of subjects who had received Alexander lessons and attempted to place it within the context of the postural knowledge of the day.21-24 He studied students from a London voice and drama college,21 people with postural deformities23 and back pain.22 As he pointed out himself there are limitations to assessing postural homeostasis by means of single photographs, and so he added electromyography and stroboscopic photography to his studies. Despite this, there were no control
groups in these studies, and so they do not meet the standards required for clinical validation of any effects reported. Nonetheless, this early work represented the beginning of investigation into the value of the Alexander Technique as a form of postural re-education.

3.2.1.2 Frank Pierce Jones (investigations in the 1960’s)

Later on, Frank Pierce Jones began to study head balance and posture and expanded the use of stroboscopic photography in his work. This recorded a movement as time-space patterns, and then linear and angular displacement could be measured from reflective markers placed at predetermined anatomical points on the subjects. He used the methods he had developed to study changes to movement trajectories in subjects following Alexander lessons. Again these were pre and post intervention measures with no control groups, but they were the first attempt to more accurately quantify the changes to postural homeostasis and movement that were subjectively experienced by people having Alexander lessons.

In the movement from sitting to standing three indexes were found that distinguished the guided movement applied in an Alexander lesson from the individual’s habitual movement. These were head thrust (a measurement of forward thrust of the head during movement), trajectory ratio (the extent to which head trajectory departs from a straight line) and rise time (the time needed to bring the head above the starting level). He found that the guided movement given during Alexander lessons resulted in decreased head thrust, a trajectory ratio that more closely approached a straight line and a shorter rise time.
This work also included X-ray studies on 20 medical students to determine anatomical relationships in three head postures. The head postures were habitual relaxed, habitual erect (how the person would respond if asked to hold their head up) and an experimental head posture based on the Alexander Technique. Planes were constructed to analyse the differences in the x-rays. The distance between the first two vertebrae was greater in the experimental Alexander posture, and the distance between the sella turcica (corresponding roughly to the centre of gravity of the head) and the second vertebra was smaller than in the habitual erect posture \((p < 0.01)\). What this meant functionally was that the neck had lengthened, the head had rotated forward on the atlas, and the distances between the spines of the vertebrae and the vertebra and the occiput increased, leading to a slightly higher head carriage but with a slightly lower centre of gravity.\(^{28}\)

One of the hallmarks of the Alexander Technique is that most people report a sense of lightness and ease following a lesson that persists for a variable amount of time. Jones attempted to define this qualitative difference using a checklist of adjectives that were largely paired opposites. A total of 39 naïve subjects were given a 10-15 minute demonstration and then given a checklist of adjectives. The most frequent checked adjectives were lighter (72%), less familiar (62%), higher (59%) and smoother (54%).\(^{28}\) Jones hypothesised that the changes in head and neck carriage were due to altered tensional relationships of the muscles controlling the head and neck and that if there was a release of undue tension this could reduce pressure on the intervertebral discs. Electromyographic studies confirmed that the level of activity in the sternomastoid muscles was reduced in the experimental
guided head posture of the Alexander Technique.\textsuperscript{26,29} The sensation of lightness that is often reported was thought to relate to the level of effort used in the habitual movement compared to the guided movement during an Alexander lesson, and further work using a force platform\textsuperscript{30} confirmed that the subjective perception of lightness was related to a reduction of effort during movements.

3.2.1.3 Chris Stevens (investigations in the 1980’s and 1990’s)

Following on from these earlier works, Stevens et al\textsuperscript{31} recorded head movements using a 50Hz pulse emitting diode photographic technique, electromyographic recordings of specific muscles and ground reaction forces with a force plate simultaneously during the sit to stand movement. They looked first at the influence of initial leg posture and then compared the movements when done freely or with the guidance of an Alexander teacher. They found that both initial leg posture and the abolition of the habitual posture by the guidance of the Alexander teacher had a profound influence on the efficiency of the sit to stand movement. The guided sit to stand movement were smoother and the level of muscle activity was reduced (p < 0.01).\textsuperscript{31}

Another unpublished study by Stevens\textsuperscript{32} compared postural stability between six male subjects who had undergone Alexander training and 15 male and 15 female untrained subjects. The group who had undergone Alexander training were no more stable with their eyes open or when their feet were in the normal position than the non-Alexander group, but their sway was up to 26% less when standing with the eyes closed and the feet
3.2.1.4 Recent investigations (since 2000)

An fMRI study of a trained Alexander teacher attending to the directions of a second Alexander teacher who had their hands on the first teachers head, found that there was significantly greater neural activity in the brainstem of the first teacher when the second teacher was giving direction to them using their hands.\(^{33}\) This suggests that ‘hands on’ Alexander Technique has the effect of stimulating the brainstem, which may account for its hypothesized effect on altering automatic postural coordination.

Recent work on physiological mechanisms has found that dynamic postural tone can be modified by the Alexander Technique. Gurfinkel \textit{et al}\(^{34}\) developed a technique to measure axial stiffness in healthy humans and found that they dynamically modulate postural muscle tone in the body axis during anti-gravity postural maintenance. They further found that this modulation is inversely correlated with axial stiffness. Following on from this work, Cacciatore \textit{et al}\(^{35}\) examined whether teachers of the Alexander Technique, who undergo a 3-year training, have greater modulation of axial postural tone than matched control subjects (\(n = 37\)). They found that peak-to-peak torque was lower (50\%), while phase-advance and cycle-to-cycle variability were enhanced for Alexander Technique teachers compared to matched control subjects at all levels of the axis.

Another study by this group found that movement coordination in Alexander trained individuals was different from matched controls. A group of Alexander Teachers (\(n = 15\)) and matched controls (\(n = 14\)) were compared on the sit to
stand movement on measures of coordination. The study found that the Alexander Teachers had a longer weight shift ($p < 0.001$) and a shorter momentum transfer phase ($p = 0.01$) than the matched controls. In addition to this the Alexander Teachers did not unweight their feet prior to seat-off, but increased their vertical foot force monotonically, which suggested that they generate less forward momentum with the hip flexors. The prolonged weight shift also occurred over a larger range of trunk inclination, so that weight shifted continually onto the feet as the body mass came forward and there was significantly reduced spinal bending during the movement from sit to stand compared to the matched controls (cervical spine, $p < 0.001$; thoracic spins, $p < 0.001$; lumbar spine, $p < 0.05$). This group also performed a longitudinal study on the effect of short term (10-week) Alexander Technique training on the axial postural tone of individuals with low back pain as part of this study. This was chosen because short term Alexander Technique training has previously been shown to reduce low back pain. They found that the low back pain subjects decreased trunk and hip stiffness following short-term Alexander Technique training compared to a control intervention. They concluded that dynamic modulation of postural tone can be enhanced through long-term training in the Alexander Technique, and that this may constitute an important direction for therapeutic intervention.

### 3.2.2 Investigations in different populations

Most research to this point had been recording physiological changes accompanied by lessons in the Alexander Technique, but these did not
address whether the changes recorded had any impact on functioning in the long term, and hence whether the clinical benefits ascribed to the Alexander Technique could be scientifically established. A wider variety of studies of varying quality began to appear focusing on the effects of the Alexander Technique in different populations.

### 3.2.2.1 Respiratory function

There has only been one controlled clinical trial that has studied the effects of the Alexander Technique on respiratory function. A group of 10 healthy subjects were given 20 lessons in the Alexander Technique at weekly intervals and compared to 10 controls matched for age, gender, height and weight. All subjects underwent spirometric testing pre and post intervention. The intervention group showed significant increases in peak expiratory flow (9%, p < 0.05), maximal voluntary ventilation (6%, p < 0.05), maximal inspiratory mouth pressure (12%, p < 0.02), and maximal expiratory mouth pressure (9%, p < 0.005). The researchers concluded that the Alexander Technique may enhance respiratory muscular function in normal adult subjects. Since this work there have been no further trials that have investigated the use of the Alexander Technique with respect to respiratory function. A Cochrane Review of the Alexander Technique and asthma in 2000 found no trials to report on, and there have been none reported in subsequent literature.

### 3.2.2.2 Performance

The Alexander Technique developed within the performing arts and while the technique is described and discussed in performance journals there has been little research into its efficacy in this area. A prevalence study for
performance anxiety amongst musicians in 1987 found that 53% admitted to using some form of complementary therapy to reduce anxiety, and 43% of the respondents said they used the Alexander Technique.\textsuperscript{44} This suggests that it is well embedded in the performing arts and that musicians report beneficial effects.

A small randomised controlled trial (n = 21) of musicians from the Music Department of a UK University provided 15 Alexander lessons to an intervention group and no additional intervention to a control group.\textsuperscript{45} Following the study there were no significant effects of the intervention on subject height, peak respiratory flow or mean heart rate (the main hypothesis), however the intervention group showed improvements on overall technical quality of performance as judged by independent experts blinded to allocation status, improved scores on the Music Anxiety Self-Statement Scale (indicating a positive task-oriented attitude to performance) and improved scores on the ‘active and warm-hearted’ individual scales of the Nowlis mood adjective checklist compared to the control group. Taken overall the results suggested that the Alexander Technique may have beneficial effects on the mental state of the performers and on the quality of performance.

A single case time series design study used the Alexander Technique as an intervention to reduce stuttering. Two subjects were given 30 lessons over a 2–4 week period. The first case, a 23 year old female who had been stuttering since the age of three, reduced her stuttering rate from between 2.5% (during free speech) and 4.6% (on the telephone) prior to lessons down
to 0.03% (during free speech) and 0.74% (on the telephone) by the completion of the study (p <0.05). The second case, a 47 year old male, reduced his stuttering rate from between 5.24% (during free speech) and 8% (on the telephone) prior to lessons down to 0.64% (during free speech) and 2% (on the telephone) by the completion of the study (p <0.05). 46 Again the small sample size and lack of a control group demand a cautious interpretation, but it adds to the body of work suggesting that the Alexander Technique may have a role in enhancing performance related voice production.

Another small study analysed key velocity of four music students performing musical scales on an electric piano connected to a computer. The measurements were taken immediately before and after an Alexander lesson over two to five sessions and found significant improvements following the Alexander lesson for the A minor scale (p = 0.02), B major scale (p = 0.02) and the C major scale (p = 0.004).33

All of these studies are small and most have no control groups, but collectively the provide support for the notion that further research in larger randomised controlled trials is worth pursuing to establish whether performance enhancing possibilities are a likely outcome of lessons in the Alexander Technique.

3.2.2.3 Chronic pain
A study of a multidisciplinary pain management program in 1988, where all participants (n = 34) received all elements of the program, reported that the Alexander Technique sessions were consistently rated by the participants as
the most useful component of the program. The program consisted of educational lectures and/or group discussions with nurses, physiotherapists and psychologists, along with auto-hypnosis and relaxation, personal exercise training, and Alexander Technique sessions.

Another study of chronic pain in 1996 also showed improvements following a four week multidisciplinary program that included the Alexander Technique. The participants in this study (n = 67) all had chronic back pain, and all participated in a four week program that included back schooling, psychological interventions, and treatment by acupuncture, chiropractic, the Alexander Technique and a pain specialist. As with the previous study, all patients received all elements of the program, so there was no control group and no way to differentiate between the effects of the program components. The study found benefits from the program that were maintained at six months, and that outcomes were clearly related to psychosocial factors.

Although neither of these studies can clearly state anything specific about the Alexander Technique, its inclusion in the programs and the ratings of usefulness from one of the studies suggest a recognition of value within the field of pain management that has yet to be verified by randomised controlled trials. The Alexander Technique has also been recommended as a form of non-pharmacologic therapy for relief of chronic pain in autosomal dominant polycystic kidney disease, but again there have been no randomised controlled trials to verify this.

A more recent report (2012) on the usefulness of the Alexander Technique for chronic pain has been published by the University of the West of
England. The report is a service evaluation designed to explore the role, acceptability and impact of an Alexander Technique teaching service at a hospital outpatient NHS Pain Clinic. Four questionnaires were completed by service users (n = 43, mean age 52, range 23–80 years) at baseline, 6 weeks and 3 months or more after baseline. The participants received six one-to-one Alexander Technique lessons at the pain clinic with a qualified teacher of the Alexander Technique, over a period of six consecutive weeks. The study was an exploratory study so there was no control group. Outcome measures were the Brief Pain Inventory (BPI) the Measure Your Medical Outcome Profile (MYMOP), the EQ-5D (a quality of life score), and the Client Resource Use Inventory administered at baseline, six weeks and three months.

The findings of the report suggested that the Alexander Technique teaching service was feasible, acceptable, and beneficial. There were statistically significant decreases on scores for the BPI (p < 0.05) and the MYMOP (p < 0.05) at six weeks and 3 months follow-up, but there were no significant changes in quality of life as measured by the EQ-5D. The greatest changes over the period of the study were found in how service users managed their pain, and the impact of pain on their daily life. Just over half the participants (22 of the 43) stopped or reduced their medication over the three months of the study. The report concluded that the service users who had received lessons in the Alexander Technique reported that their pain reduced and that their relationship to their pain changed, and it was noted that this may lead to reductions in medication use and other NHS pain-related costs.
They also noted, however, that there was some suggestion in the data that the study population was selected on the basis of their likelihood to embrace a more educational and self-management approach to the management of their pain, and so caution is required when interpreting the results of the study.

3.2.2.4 Back pain

A number of reports have already been mentioned in preceding sections regarding the application of the Alexander Technique for people suffering from back pain.\(^47\,48\) Interest in complementary therapies is growing and with it has come the need to educate both the public and medical practitioners, and an increasing urgency to provide an evidence base to support the use of these modalities. In 2003, an article was published in the Archives of Physical Medicine and Rehabilitation with an objective to familiarise the Physiatrist with complementary techniques that have gained in popularity and to identify when they may be integrated into a comprehensive treatment approach.\(^52\) The Alexander Technique was listed as one of the movement therapies that had gained popularity in this paper.

Complementary therapies are widely used by people seeking relief from back pain, and in 2005 the evidence base for complementary therapies was reviewed to determine whether there had been any change in the weight of evidence. The review found that in 2000 no evidence had previously existed as to the efficacy of the Alexander Technique for the treatment of back pain, but that by 2005, although the weight of evidence was low, it was regarded as being in a tentatively positive direction.\(^53\) This was in part due to the multidisciplinary program for chronic back pain already discussed, and also
to a paper published about a case study that found improvements in automatic postural coordination in a person with low back pain following a course of Alexander lessons.\textsuperscript{54}

An early unpublished randomised controlled trial into the impact of the Alexander Technique on chronic mechanical low back pain randomised 91 subjects into 3 groups.\textsuperscript{51} One group received 20 one-on-one Alexander lessons over 10 weeks, a second group received a weekly group support session for 10 weeks and the third group received usual care. Outcome measures were the visual pain analogue scale (VAS), a disability score (DS) based on daily tasks limited by back pain and an inappropriate pain behaviour score (IPB). Immediately post-intervention the Alexander Technique group had significantly lower scores on the DS (p < 0.001), the VAS (p = 0.05) and the IPB (p < 0.001) compared to the other two groups. At six months the DS remained significantly lower for the Alexander Technique group compared with usual care (p = 0.005) but there were no statistically significant differences at 12 months follow up.

Since then a factorial randomised controlled trial to determine the effectiveness of the Alexander Technique, massage therapy and GP prescribed exercise with behavioural counselling for chronic or recurrent back pain has been completed. The main outcome measures were the Rolland-Morris disability score and the number of days in pain in the previous four weeks after one year. The conclusions of the study were that a series of 24 Alexander lessons taught by registered teachers had long term benefits for those with chronic back pain at one year follow-up (p < 0.001).\textsuperscript{37} Six
lessons in the Alexander Technique combined with GP prescribed aerobic exercise with behavioural counselling by a practice nurse were also helpful in the long term (p = 0.002), but massage only provided short term benefit.

3.2.2.5 Workplace ergonomic studies

One small study looked at the impact of the Alexander Technique on ergonomics in specific workplace practices. This prospective cohort study (n = 7) looked at the effect of the Alexander Technique on posture in laparoscopic surgeons, who report a high number of work-related injuries due to the constraints of minimally invasive surgery procedures.

Symptoms include surgical fatigue syndrome, repetitive stress injuries, and the deterioration of visual acuity and ocular muscle function, resulting in impaired vision. These procedures require the surgeon and their assistants to maintain awkward, non-neutral and static postures of the trunk and upper extremities for extended periods which limit the natural shifting postures usually available during activity.

Biometric data was collected and subjects were tested on four laparoscopic surgery skills using a simulator (the FLS: Fundamentals of Laparoscopic Surgery) that has been developed for teaching purposes pre and post intervention. The subjects received two group sessions and six individual lessons in the Alexander Technique. Post intervention surgeons reported a decrease in perceived effort on the four modules of the FLS with two of these reaching statistical significance (Ring transfer, p < 0.04; suturing p = 0.007). Tremor reduced in the left hand (p = 0.03) and the non-dominant hand (p = 0.02). Resting respiratory rate decreased significantly (p = 0.02), peak
inspiration chest circumference increased significantly \( (p = 0.02) \) and postural loads could be held for longer \( (p = 0.04) \).\(^{55}\) Although only a small pilot study with no control group, the study showed that the Alexander Technique improved posture and proficiency in laparoscopic surgery, and suggests the need for further research to determine whether the Alexander Technique could benefit a wider range of surgical procedures.

### 3.2.2.6 Parkinson’s disease

A preliminary study of the efficacy of the Alexander Technique to manage disability and feelings of depression in Parkinson’s Disease found that performance on the activities of daily living Scale (ADL), the body concept scale (BACS), and the Beck Depression Inventory (BDI) all showed significant improvements \( (p < 0.05) \) following 12 lessons in the Alexander Technique.\(^{56}\) The sample \( (n = 12) \) were self-selected and there was no control group however this pilot data was subsequently used to run a randomised controlled trial that included placebo and control groups.\(^{57}\) This follow-up study \( (n = 93) \) randomised participants into an intervention group who received 24 lessons in the Alexander Technique, a placebo group who received 24 light massage sessions while clothed to control for manual touch and attention, and a control group who received no additional intervention. The main outcome measure was the Self-assessment Parkinson’s Disease Disability Scale (SPDDS), and secondary measures were the Beck Inventory of Depression (BDI) and the Attitude to Self Scale.

The Alexander Technique group improved post-intervention compared to the no intervention group on SPDDS at best \( (p = 0.04, 95\%CI; -6.4 \text{ to } 0.0) \) and at
worst \((p = 0.01, 95\% \text{CI}; -11.5 \text{ to } -1.8)\) and the comparative improvement was maintained at six months follow-up \((\text{best } p = 0.04, 95\% \text{CI}; -7.7 \text{ to } 0.0; \text{worst } p = 0.01, 95\% \text{CI}; -11.8 \text{ to } -0.9)\). The Alexander Technique group was comparatively less depressed post-intervention on the BDI \((p = 0.03, 95\% \text{CI}; -3.8 \text{ to } 0.0)\) and improved on the Attitude to Self Scale at six months follow-up \((p = 0.04, 95\% \text{CI}; -13.9 \text{ to } 0.0)\). The study concluded that lessons in the Alexander Technique are likely to lead to sustained benefits for people with Parkinson’s disease.

During an Alexander lessons, the teacher uses manual guidance and verbal feedback to teach the individual cognitive strategies that will change habitual unconscious postural responses to external stimuli in order to improve physical functioning. A follow-up study of participants \((n = 28)\) who had received the 24 Alexander lessons in this study looked at skill retention at six months by questionnaire.\(^{58}\) The follow-up found that all of the participants were still using the skills they had learnt in the lessons six months after the conclusion of the program, although the scope of application varied greatly. Most were using more than one strategy to perform important daily activities, and around one third of the group mentioned beneficial psychological effects as a motivator to continue applying the Alexander Technique following the conclusion of the program.

3.2.2.7 Balance in the elderly

More relevant to the subject of this thesis have been two small studies looking at the value of the Alexander Technique for improving balance in the elderly. Functional reach is a clinical measure of balance, and represents the
maximal distance the individual can reach forward beyond arm’s length in standing without moving the base of support. An initial pilot study group (Group 1: n = 6 females, median age 85.5, range 71 - 88) was recruited from the population of a senior residence, and following this another intervention group (Group 2: n = 7 females, median age 72, range 66 – 83) and a control group (Group 3: n = 5 females, 1 male. Median age 71, range 65 -78) were recruited from the same senior educational facility. There was no record of randomisation reported in the study. The intervention groups met for one hour, twice a week for four weeks and instruction consisted of verbal and hands-on guidance in the body mechanics of standing, sitting, walking and moving from sitting to standing.

Functional reach was measured pre and post intervention. Functional reach improved in the two intervention groups compared to the control group at retest. When raw scores were transformed to compensate for bias introduced by differing lengths of body segments, Group 1 (pilot) improved by 40.8% (p < 0.05), Group 2 (intervention) improved by 32.2% (p< 0.025) and group three (control) decreased slightly.

The small sample size, the lack of demonstrable randomisation, and the lack of long term follow-up data suggest caution in interpreting the results of the study however this represents the first attempt to research the possible benefits of the Alexander Technique in older adults with a view to improving balance performance.

A more recent pilot also looked at group Alexander Technique instruction for improving balance in the community dwelling older population. The trial was
a feasibility study (n = 19) using a quasi-experimental, single group, pretest–posttest design. A convenience sample was recruited from local geriatric residences and community centres. The study used the Timed Up and Go test (TUG) and the Fullerton Advanced Balance Scale (FAB) as the primary outcomes. The intervention was a 2 week intensive daily program (Monday to Friday) with sessions lasting approximately 1.5 hours on each consecutive day. The first week was verbal instruction only, to increase awareness of body locations and relationships, understand personal maladaptive postural habits and develop coordination strategies, ease of movement during transfers and a sense of safety during ambulation.

During the second week light touch was added to movement activities to augment proprioceptive awareness of postural support. The post-test results were significant for the TUG (p = 0.006) and the FAB (p = 0.05). The study found that an intensive group delivery of the Alexander Technique resulted in select improvement in dynamic balance tasks and so showed promise as a feasible self-care approach to improving balance. This pilot data suggests a large randomized controlled trial of the Alexander Technique for improving balance in older adults would be justified.

3.2.2.8 An overview of research to date

In more recent years there has been an attempt to collate the wide variety of research into the Alexander Technique. Stevens published an overview of early investigations of the Alexander Technique and this was followed by one systematic review in 2003 and a further one in 2012. The conclusions of the most recent systematic review are that there is strong evidence for the
effectiveness the Alexander Technique for chronic back pain and moderate evidence for its effectiveness in disability associated with Parkinson’s disease. The review found preliminary evidence for improvements in balance in the elderly, general chronic pain, posture, respiratory function and stuttering, however it stated that there was currently insufficient evidence to support any recommendations in those areas.

A number of further research programs are currently in progress. A study protocol has been published for the ATLAS study which will compare the Alexander Technique, acupuncture and usual care for chronic neck pain. A pilot study is currently underway at Southampton University comparing Alexander Technique lessons with conventional physiotherapy-led exercises in people with chronic or recurrent back pain, and another pilot study by researchers from the Universities of Salford and Manchester, funded by the BUPA Foundation, is investigating the effectiveness of Alexander Technique lessons for people with knee osteoarthritis.

3.3 Anatomical considerations

What Alexander discovered through his observations of himself in activity has fundamental anatomical underpinnings which will now be described.

3.3.1 The balance of the head on the top of the spine

The average adult human head weighs between four and five kilograms and is balanced on top of the cervical spine (Figure 3.4)
The centre of gravity (G) of the head is in front of the pivot point (O), and so relies on muscular action of the posterior neck muscles (F) to stop it toppling forward. We notice this subjectively when we ‘nod off’. When we fall asleep in an upright position, the muscles relax and the action of gravity drags the head forward and down, often waking us up again. What is required is just enough tension to allow the head to delicately balance on the top of the spine. Too little tension and the head and neck drop forward under the influence of gravity, too much and the head gets pulled backwards on the neck, exaggerating the curve of the neck and compressing the associated structures.

### 3.3.2 The head-neck-back relationship

The spine is a flexible column. Muscular activity creates alternating areas of compression and tension that form the familiar curves of the spinal column to create a springy support structure (Figure 3.5).
Ideally this muscular activity should be just enough to provide a springy supportive column from which the head and upper limbs are suspended. Too much tension exaggerates the curves and begins to compress soft tissues around the spine, not enough tension causes collapse and a reduction in the supportive possibilities inherent in the structure. Optimal tension provides a supportive structure that can store and redirect energy in the same way that pulling on a bowstring stores energy that is directed into the flight of the arrow when the tension is released.

What Alexander discovered in himself, and subsequently noticed in others as he developed his teaching was that most people tended to generate excessive tension that caused compression or shortening through the spine (Figure 3.6), and that if they could learn to release the undue tension, the inherent springiness would allow it to lengthen without muscular effort in the same way that releasing the string of a bow allows the bow to lengthen.
3.4 Postural functions

Upright orientation is inherently unstable and is even subject to perturbations from the cardiac cycle\textsuperscript{70} and from respiration.\textsuperscript{71} In order to view postural orientation more globally it is necessary to look at the two main postural functions. The first is an anti-gravity function and the second serves as an interface between perception and action.\textsuperscript{72,73}

3.4.1 Antigravity control

The anti-gravity function requires the provision of joint ‘stiffness’ so that the body segments resist the pull of gravity, largely via activation of the extensor musculature running between the head and feet (Figure 3.7). In addition to this, balance has to be maintained, which means that the centre of mass of the body must remain within its base of support (Figure 3.8).
Figure 3.7 Extensor musculature running between the head and feet.\textsuperscript{74}

Figure 3.8 Keeping the centre of gravity inside the base of support.\textsuperscript{75}
This means that ‘posture’ is actually the ongoing way we organise ourselves against gravity as we move through life, and is more realistically described as poise. Of necessity this becomes habitual, and if we use ourselves poorly, soft tissue adaptations over time can make it difficult to modify patterns that may no longer suit our needs.

### 3.4.2 Interface between perception and action

Body segments are defined with respect to the trunk or head by an *egocentric reference frame*.\(^73\) The position of an object moving in external space is coded into an *allocentric reference frame* external to the body, usually the vertical gravity axis.\(^76\) The two reference frames have to be matched, and to do so the orientation of the head or trunk is estimated with respect to the gravity vertical. Information from the inner ears is used to estimate the relationship of the head to gravity\(^73\) and somatic graviceptors in the trunk provide additional estimates from visceral and vascular sources.\(^77\)\(^78\)

Other inputs come from estimates of gravity based on contact with the supporting surface through the feet in standing, or from any part of the body engaged in contact with a support surface. This means that orientation of the head and /or trunk with respect to gravity can be used to estimate the relationship of other body segments to the external world and to adjust their position as necessary. This head /trunk orientation is also used to estimate the relationship of external objects to the body for planning movement trajectories.\(^79\) This central role of head /trunk orientation was elucidated by Alexander’s ethological experiments in the 1890’s.
3.5 Models of postural orientation

Within the literature there have been three broad approaches to the study of postural organisation.\textsuperscript{72}

3.5.1 Static versus dynamic organisation of postural orientation

This model sees postural orientation as static while movement is seen as dynamic. In this view the maintenance of postural organisation requires the active orientation of one or more body segments against disturbing forces exerted from outside them (Figure 3.9). Movement, on the other hand corresponds to a change in postural organisation whereby one or more body segments move to a new position. This view looks at postural organisation from the point of view of spatial orientation.\textsuperscript{80}

![Figure 3.9 Orientation of body segments against disturbing forces.\textsuperscript{81}](image)
3.5.2 An anatomical view of postural orientation

The second model has an anatomical basis\textsuperscript{82}, and is related to support. In this view the axial or spinal muscles and the proximal muscles around the hips and shoulders support the distal segments for manipulation of the environment (Figure 3.10). In this view the activity of the axial and proximal muscles would be seen as largely postural while the distal musculature is largely engaged in movement. This represents a functional approach to the study of postural orientation.

![Deep & Core Stabilizing Muscles](image)

**Figure 3.10 Spinal and proximal muscles.\textsuperscript{83}**

3.5.3 Genetic reflex view of postural orientation

The third model uses the ‘reference posture’ of quiet standing to look at the interaction of postural reflexes in relation to gravity, and studies the central control of posture (Figure 3.11). This approach is seen in the works of early neurophysiologists such as Sherrington\textsuperscript{6}, Magnus\textsuperscript{84} and Rademaker.\textsuperscript{85}
This view emerged from work on animals and humans and asserts that posture and locomotion are basic genetically determined behaviours. Reflexes support us against gravity, stabilise the head and orient the feet for supportive functions. During movement other reflexes distribute appropriate muscular tone to body segments depending on the orientation of the head in space and it’s relation to the trunk.

3.5.4 Postural orientation in zero gravity

In the last half of the 20\textsuperscript{th} Century space travel introduced humanity to gravity free environments. Space travel has been a challenge in many ways not least in respect to physiological responses and the necessity to remain functional in a gravity free environment. In zero gravity the joints assume a mid-range position (Figure 3.11).\textsuperscript{87} This demonstrates that the human neuromuscular system does responds to gravity by extending up away from
its support surface, and this response has been termed the *positive support reaction*. This is an example of an aspect of postural organisation that is genetically predetermined as postulated by the genetic model.

Figure 3.12 Weightless neutral body position.\(^{88}\)

All of the above approaches provide some insights into the nature of postural orientation but none of them is able to adequately explain how we organise ourselves to do the things we do. This has led some workers to propose a revised goal of postural control that is “to achieve equilibrium (effective weighting of all sensory systems) to maintain a stable vertical and horizontal orientation of the body with respect to the individual’s intent, experience, instruction, and environment”\(^{(p.301)}\).\(^{89}\)
3.5.5 Central organisation and control of posture

There is now general consensus that although there are genetically predetermined reflexes that underpin postural orientation and movement, they cannot be solely responsible for our postural orientation.  

3.5.5.1 Flexibility of postural reactions

Postural reactions to external perturbations are quite flexible and reactions to the same stimulus are dependent on external constraints such as support conditions. If responses were entirely reflexive they would be more stereotyped than is seen in the myriad ways an individual can respond to a challenge to their balance.

3.5.5.2 Anticipatory postural adjustments

From repeated experience we learn to anticipate potential disturbances, and this allows for learning based on memorised models that include the external world, our body’s biomechanics and the interaction between the two.  

Anticipatory adjustments are pre-emptive and occur before the threshold needed to generate the same response reflexively. The purely genetic model cannot account for the importance that anticipation plays in achieving co-ordinated postural and movement control. Although the genetic model is valid for much basic postural control, there is a higher level of organisation that makes use of experience and learning to fine tune postural functions to the needs of ongoing movement.

These higher levels of organisation are also responsible for our habitual ways of reacting to familiar stimuli, and so they can both trap us in outmoded habits, or through re-education, free us into new ways of using ourselves.
3.6 Postural representation

3.6.1 Bottom-up

There is no one agreed upon representation of posture within the literature. One school of thought sees posture controlled as a whole entity that defines body orientation with respect to gravity. In this scheme, the body oscillates around the ankle joints like an inverted pendulum (Figure 3.13).

![Inverted pendulum model of postural sway](image)

**Figure 3.13** The inverted pendulum model of postural sway.¹¹

The goal of postural control from this perspective is to hold the body's centre of mass over the base of support.⁽²⁾ This is sometimes referred to as a ‘bottom-up’ approach.
3.6.2 Top-down

The other viewpoint sees posture as based on superimposed segments (head, trunk and legs) linked by sets of muscles under specific control which preserves their orientation with respect to space and each other. From this perspective, the head is functionally the most important segment (Figure 3.14) because the eyes and vestibular mechanisms of the inner ears provide important sensory input that stabilises the head in space and provides a reference frame for the organization of the rest of the body. This is sometimes referred to as the ‘top-down’ approach.\textsuperscript{72}

Figure 3.14 Functional importance of the head in the 'top down' model.\textsuperscript{93}
3.6.3 Where does the Alexander Technique fit?

At first glance the Alexander Technique appears to be a top-down model but closer scrutiny reveals that it is an integration of the top-down and bottom-up models. Although great emphasis is placed on releasing the head forward and lengthening up, this can only happen if there is good support from the feet or the seat, so contact with support is essential to the process. Attention is further given to the development of what Alexander referred to as ‘antagonistic pulls’ in positions of mechanical advantage. These allows the bodyweight to be “distributed within and along the structure in such a counter-balanced manner … that there’s real economy of muscular effort” (p. 53).94

3.6.4 A Global representation

Despite all these differences, it is generally agreed that a number of interrelated factors control balanced standing, which is the basis for many of our interaction with the world. Without an organised upright orientation we have limited opportunities to explore the environment and interact with others in the social context of our lives. This has an impact on the maintenance of health and our emotional wellbeing, and as they decline they further effect the postural orientation they depend on. Postural orientation and balance is best seen globally (Figure 3.15). Behaviour, environment, musculoskeletal integrity, sensory input, motor co-ordination and central postural set all interact to stabilise our balance and orient us so that we can get on with the performance of everyday activity.
3.7 Behaviour, goal or task

The task or behaviour that an individual is engaged in plays a role in postural orientation. More complex tasks require more attention and these attentional demands will influence our level of postural awareness. The goal of the task will influence how it is approached and put constraints on how we organise ourselves to accomplish it.
At a very fundamental level information from all the subsystems lead to the establishment of the *behavioural vertical*, and uprightness is maintained by reference to it. This vertical is the direction the individual judges to be “currently the best one in which to aim the limb thrusts against the ground in order to avoid falling over and hitting the head” (p. 175). The behavioural vertical is a composite of all sensory information, not just the gravity vertical measured by the vestibular apparatus, with the imperative of preserving the integrity of the major sensory receptors in the head from hitting the ground.

As discussed in section 1.3.3 behaviour also plays a role in falls risk, and preliminary studies on the effects of emotional states on falls have shown elevated risk following the experience of anger and emotional stress.

### 3.8 Environment, gravity and support

Additionally movements cannot be isolated from their environmental context. This is where lighting levels, surface quality and environmental layout make it easier or more difficult to maintain balance. Gravity is also a constant feature of the environment (except in space — see section 3.5.4), and postural orientation is our ongoing relationship to it. If we engage with gravity effectively we remain upright, and if we don’t we can lose balance and fall. We can also use gravity to minimise unnecessary effort, e.g. by releasing unnecessary tension in the back of the neck, gravity will take the head forward as it pivots on the top of the neck, (see section 3.3.1) and this creates some upward traction on the column of the neck (Figure 3.16).
3.9 Musculoskeletal integrity

Adequate joint range of motion, muscle strength and muscular activation are necessary to respond effectively to the ongoing challenges to balance. The muscles that provide movement are called skeletal muscles and the movement system is called the skeleto-motor system. The skeletal muscles are activated by alpha motor neurons in the spinal cord. The alpha motor neurons respond to commands from movement centres in the brain and this is known as voluntary movement, because it results from our immediate “will to act”. We have a will to do something and our wishes are generated as nervous impulses to which the skeletal muscles respond.
Many falls happen during motion (see section 1.4). Older adults tend to have reduced gait velocities, and these are accompanied by reduced peak hip extension and increased anterior pelvic tilt that is not seen in quiet upright standing. This dynamic reduction in hip extension in the elderly has been shown to be exaggerated in multiple fallers and may make it more difficult for them to react quickly to trip hazards and surface changes.

The production of a hasty recovery step to a trip hazard can also have the effect of further perturbing balance due to the forceful nature of the compensatory step, and older adults have greater difficulty generating the muscle torque around the ankles necessary to maintain the foot fixed on the ground during dynamic limb movements. If a person is unexpectedly pulled or pushed, ground reaction forces must be generated by the legs that will bring the centre of mass back inside the base of support. A stable ankle is an important prerequisite to these successful muscular responses in the legs if a fall is to be avoided, and relies on muscle strength, adequate sensation and timely activation.

In addition to a timely response in the legs, these forces must be steered by reactions within the upper body. The instability seen around the ankles is accompanied by a weaker coupling between movements of the centre of mass in the body and the centre of pressure in the feet in older adults, as well as a weaker coupling between the centre of mass and the swing limb, suggesting a decrease in inter-segmental coordination. The degree to which the person can react appropriately will determine how likely a fall will result in any given circumstance.
3.10 Sensory input and integration

The main inputs into postural orientation come from the somatosensory, vestibular and visual systems. Assuming musculoskeletal integrity, these systems interact to maintain upright balance and allow for functional independence. The inputs from these sensory sub-systems provide information on where body segments are relative to each other, and where the entire organism is relative to the surrounding environment.

3.10.1 Kinaesthesia

With our eyes closed, or in a dark room, we are still aware of the position of our limbs and their orientation with respect to each other, at least in a general sense. This is our sense of position. If we have not moved for a long time or when we wake up our position sense is generally well preserved. If we change the position of a joint, and therefore the relationship of body parts to each other without visual control, we perceive the direction and the velocity, and this is our sense of movement. Together these provide our sense of kinaesthesia. For a long time it was believed that the receptors for these senses would be found in the joints, but in the 1970’s it was established that the most important source of input to kinaesthesia came from within the muscles.

3.10.2 Muscle spindles

The following discussion about muscle spindles might seem somewhat tangential, but it is important to an understanding of how the Alexander Technique can influence the underlying background organisation or “use of
the self” that defines it and sets it apart from many current therapeutic approaches. The main receptors that signal these senses of position and movement are the muscle spindles, which lie in parallel with the contractile muscle fibres within the belly of the muscles of the skeleto-motor system. (Figure 3.17).

Figure 3.17  Anatomy of the muscle spindle and the Golgi tendon organ.107

Stretch applied to the muscle by an external force also stretches the muscle spindle. A mono-synaptic ‘stretch reflex’ via the spinal cord stimulates the host muscle to contract, resisting further stretch. The basic purpose of this is to maintain the muscle at a constant length and in a state of ‘neutral readiness’ for movement (Figure 3.18).
3.10.3 Golgi tendon organs

A sufficiently large stretching force could elicit a response that would tear the muscle from its tendon and so a mechanism to protect the muscle from its own responsiveness is required. The Golgi tendon organs are located in the border zone where the muscle fibres attach to the tendons and they measure the tension developing in the tendon (Figure 3.17). In contrast to the muscle spindle, the Golgi tendon organ triggers a reflex that elicits a relaxation response in the muscle being stretched. If muscle tension increases dramatically during contraction or stretching of a muscle, the Golgi tendon organs will be activated to adjust muscle tension accordingly. Apart from protecting muscles and tendons from possible damage, these responses also help to smooth out the beginning and ending of muscle contractions.
Information from the Golgi tendon organs is also used by the Central Nervous System (CNS) to accurately estimate muscle force or tension. In addition to input from these peripheral receptors it has also been shown that effort-related signals are generated centrally and so the ability to estimate the amount of effort necessary to move or maintain position, our sense of effort is generated from both the peripheral afferent input of the Golgi tendon organs and a centrally generated effort signal.

### 3.10.4 Central regulation of the stretch reflex

The stretch reflex is most important in the large extensor muscles that sustain upright posture and in the postural muscles of the trunk. Contraction of the spinal postural muscles is almost continuously regulated in this way although this does not happen in isolation from the rest of the CNS.

The muscle spindles have their own internal contractile elements, the *intra-fusal muscle fibres*, (Figure 3.17) which allows the CNS to regulate the level of activation or state of resistance to stretch in the muscles at rest. The CNS must continually modulate the activity of the spindles as the muscles contract, otherwise the spindles rate of firing would decline as the muscles shortened and they would then lose their sensitivity to stretch (Figure 3.19).

By stimulating the contractile elements in the spindles (intra-fusal muscle fibres), the CNS maintains an internal tension on the spindles during muscle contraction in order to maintain their sensitivity to stretch during changes in length. This system is known as the fusi-motor system (as distinct from the skeleto-motor system for voluntary movement) and stimulates the intra-fusal muscle fibres of the muscle spindles through gamma motor neurons (as
distinct from the alpha motor neurons of the skeleto-motor system).

Figure 3.19 Muscle spindle sensitivity during stretch and contraction.\textsuperscript{107}

3.10.4.1 Artificial stimulation of muscle spindles

Muscle spindles can be activated artificially using a specific mechanical vibration of around 100-120 Hz, and the increased discharge from the spindle is interpreted by the CNS as lengthening of the vibrated muscle. This information is referred to the joints controlled by the muscle and creates illusions of body motion. Lackner\textsuperscript{111} found that apparent motion and displacement of the body, or segments of it, could be elicited in nearly any desired configuration by vibrating the appropriate skeletal muscles. Not only is there an illusion of apparent motion, there is also a remapping of visual and auditory targets,\textsuperscript{112} suggesting that the muscle spindles play a role in the \textit{interface between perception and action} (section 3.4.2).
The body of research collected on tendon vibration experiments indicates that there is a *proprioceptive chain* running from the head to the feet that gives information about each segment with respect to the others and it is used in the organization of postural control as a whole. 72 This is interesting in relation to the concept of a primary control in the Alexander Technique (section 3.1.5), and may be a mechanism at the muscular level through which this level of control could be expressed.

### 3.10.4.2 Independent intrafusal muscle activity

It was originally believed that maintaining the sensitivity of the muscle spindle to stretch was the basic role of the fusimotor system in humans, as changes in muscle spindle sensitivity seemed to be correlated with changes in muscle activity. It has since been demonstrated that this is not always the case. 113

Activity in the fusimotor system can be triggered independently in completely relaxed subjects by cognitive, behavioural or environmental factors, suggesting that muscle spindle sensitivity may be controlled independently of voluntary skeletal muscle activity. 114 This fusimotor activity is expressed at the level of the muscle spindles as a selective changing of muscle spindle sensitivity to movement, reinforcing the idea that the fusimotor system plays a role in arousal and expectancy. 115

More recent studies have confirmed the CNS can selectively and differentially control muscle spindle sensitivity through the fusimotor system independent of any activity in the alpha motor neurones that innervate the extrafusal muscle fibres of the voluntary skeleto-motor system. 116 This means that we can have some voluntary control over the stretch reflex in
activity. Examples of this ability to modify the stretch reflex include throwing activities where we need to suppress it in order to produce large degrees of motion, and in hurdling when the leading leg is thrust forward towards the end of its range and maintained there as the hurdle is cleared. At the other end of this spectrum, activities that require maximum force will benefit from a quick stretch such as when a runner crouches before bolting into a sprint.\textsuperscript{110}

This is an aspect of voluntarily controlled movement that we are usually not consciously aware of it, although it is possible to bring it into awareness, particularly in learning situations or during training and rehabilitation activities.

3.10.4.3  \textit{Spindle activity in forward sensory models}

Muscle spindles have been known to play a role in feedback control for some time\textsuperscript{117} but more recently it has been proposed that they could play a role in forward models\textsuperscript{118} where sensory information and motor commands are thought to predict future sensory states. It has recently been shown that muscle spindle afferent discharges predict future kinematic states within the parent muscle during unrestrained wrist and finger movements in humans.\textsuperscript{119} The discharges have been shown to correlate with the velocity of length changes in the parent muscle 100-160 milliseconds in the future which allows current sensory states to be directly incorporated into predictions.

This is achieved because the spindles have access to both the current state of the parent muscle’s kinematics and the input from the fusimotor system, and this allows muscle spindle afferents to reflect the sensory consequences of movements into the future. The implications of this are that “sensorimotor
learning would imply learning to control both alpha and gamma motor neurons given that the fusimotor system is engaged in the orchestration of complex motor actions across multiple joints and muscles (p. 1776).119

3.10.4.4 The Alexander Technique and the fusimotor system
The ‘proprioceptive chain’ referred to in section 3.10.4.1 both responds to and is informed by the fusimotor system, and this sensorimotor mechanism is a possible candidate for how direction as already described in relation to the Alexander Technique may be expressed at a muscular level. The effect is not the direct activation of voluntary muscles (which must nonetheless happen if we are to go ahead and move), but an indirect conditioning of them through the fusimotor system to provide the necessary conditions for optimal functioning.

Our immediate will to act usually triggers an habitual motor response that is sent from motor centres in the brain via the alpha and gamma motor neurons to both the intrafusal fibres of the muscle spindle and the extrafusal fibres of the skeletal muscles. By inhibiting the immediate response to a stimulus to act at a cortical level we do not activate the familiar movement pattern.

By then continuing to give direction for an improved “use” we may be consciously using the fusimotor system to condition the musculature more appropriately for the task at hand. This would then allow the feed forward mechanism to operate optimally and when we did go on to activate the voluntary musculature and perform an action this action would be based on an altered background organisation that would feel unfamiliar.
3.10.5 Tactile information

Artificial stimulation of the soles of the feet and the ankle muscles have shown that the regulation of small body sway is probably regulated by tactile input and larger sway is regulated by sensory input from the ankle muscles. Specialised nerve endings in the skin called mechanoreceptors respond to changes when deformed by a mechanical force such as touch, pressure, vibration, or stretch.

3.10.5.1 The supporting reaction

An example of how this sense informs upright posture is seen in the supporting reaction (see section 3.5.4). In the first 3 to 4 months most infants will extend the lower limbs and support their weight if held vertically with their feet on the ground. In humans, gravity acting on our bodies changes the shape of our feet when we stand, and the stretch and pressure on these structures contributes to activation within the extensor, or antigravity musculature to maintain an upright organization. This reaction does not become functional until the infant can balance the weight of their trunk over their pelvis to stand independently. Nor is it obligatory, otherwise we would not be able to move out of the standing position.

3.10.5.2 Light touch

Light touch with the hand is known to have a powerful stabilizing effect on postural organization even when a surface is touched with the index finger at a level of force that is not supportive. The mean postural sway amplitude in blindfolded subjects has been shown to decrease by around 50% when allowed finger contact, and the time course for this is rapid. A finger dropped
to contact a surface will be stabilized within 100 milliseconds (ms) and there will be a decrease in mean body sway within the next 100 ms, whereas visual stabilization of posture as when turning on lights takes three to four times longer to initiate and longer again to be complete.\textsuperscript{122} Passive tactile cues from other areas of the body have also been shown to reduce postural sway where available.\textsuperscript{123} In terms of balance and postural adjustments made to maintain it, changes in pressure on the soles of the feet or any body part in contact with a supporting surface will be relayed to the CNS and this information will be processed as part of a total response to any disturbance. During quiet stance, this will provide a mapping of body orientation to the upright.

3.10.6 Vestibular information

The vestibular organs of the inner ear are situated within the bony labyrinth of the temporal bones of the skull (one on each side) and are intimately related to the organs of hearing, the cochlear (Figure 3.20).

Figure 3.20  The vestibular organs within the temporal bone of the skull.\textsuperscript{124}
Different receptors within the vestibular system called *statolith organs* and *semicircular canals* respond to different types of accelerations to detect head motion and gravitational forces.

### 3.10.6.1 Linear acceleration

The statolith organs are called *maculae* and are fixed with respect to the skull. There are two on each side with one being approximately horizontal when the body is upright and the other being vertical. The receptors within all organs are hair cells called *cilia*, and are stimulated by shearing forces. Within the maculae the cilia of the hair cells project into a gelatinous mass. Granules of high specific gravity called *otoliths* are embedded within the gelatinous mass and distort it when acted upon by gravity or other forces of *linear acceleration*.

### 3.10.6.2 Graviception

The upper drawing in Figure 3.21 shows a macula at rest.

![Diagram of a macula at rest and during tilting](image)

**Figure 3.21** Macula organ during tilting of the head in two directions.\(^{125}\)

When the head is tilted, gravity slightly displaces the otolith membrane, and
as it moves it bends the cilia. The main stimulus of the maculae is gravity, which is a special case of linear (translational) acceleration. They respond to other types of translational acceleration such as the speeding up or braking of a car, and in these situations the otolith membrane shifts like a jelly on a plate in motion. For any orientation of the skull, gravity will move the otolith membrane into specific positions and the discharges produced provide information about the position of the head in space relative to gravity.

3.10.6.3 Distinguishing between head and body movements

In humans and all higher vertebrates the head is moveable relative to the rest of the body and so information from these receptors is not sufficient to give an absolute sense of where the whole body is in space. Information regarding the position of the head relative to the rest of the body is necessary to complete the picture.

Figure 3.22 Macula organs and neck receptors in different body positions. 

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In Fig. 3.22 A, both the head and trunk are in the vertical. In 3.22B the neck has moved relative to the trunk but the head has maintained a constant relationship to the neck. Because the maculae respond to gravity they will be activated. Likewise in 3.22C the maculae respond to the stimulus of gravity but in this instance the head and neck have not moved relative to the upper trunk, rather movement in the trunk lower down has altered the position of the head relative to gravity.

Because both neck and whole body movements stimulate the maculae, it is necessary to be able to estimate the relationship of the head to the trunk, and it is sensory information from the neck that plays this vital role. Posterior neck muscles are known to have a high density of muscle spindles, and the sensory input from this rich supply of spindles, along with other afferents from the neck plays a leading role in body orientation and postural regulation. This echoes what Alexander discovered in his own observations in the 1890’s regarding the importance of the relationship of the head and neck to the rest of the body.

3.10.6.4 Rotatory acceleration

The semicircular canals consist of three rings on each side of the head (see Figure 3.20) that lie in mutually perpendicular planes. There is a canal in the horizontal plane and two canals in the vertical plane. The two vertical planes are angled at 45° to the midline, so that the plane of the anterior vertical canal on one side is parallel to the plane of the posterior vertical canal on the opposite side. The canal in the horizontal plane is angled at 30° to horizontal plane.
Receptors in the semicircular canals respond to rotation**al acceleration** rather than translational acceleration. Even at rest cilia in the maculae and semicircular canals generate a continuous stream of impulses, so that a deflection in one direction will increase the firing rate, while a deflection in the opposite direction will decrease it. By this means all possible positions and movements of the head can be accounted for when information is processed centrally.

### 3.10.7 Visual sensory input

#### 3.10.7.1 Visual structure

Although we subjectively perceive our vision as smooth and continuous, when looking at a well-structured environment we actually alternate between quick flicks called saccades and periods of fixation. Saccades shift the fixation point, and eye movements tend to follow contours, points where contours meet, or interruptions to them. When an image is examined for a period of time it is roughly reproduced as a ‘movement image’ as recorded by the scanning movements of the eyes (Figure 3.23).\(^{130}\) When looking at a face there is a preference for the eyes, mouth and the right side of the face, indicating that fixation is also controlled by cortical interpretations of the significance of the object viewed.\(^{131}\)

The visual signal is detected during the brief fixation periods between saccadic movements, but not during saccadic movements of the image over the retina. What this means is that the sense organs of vision are not just passive receivers and that active motor components play an important role in perception.\(^{131}\)
If a moving object appears in the periphery, it induces a reflex saccade. This may include a movement of the head, and these are coordinated to bring the image of the new object onto the fovea, the area of greatest acuity. These reflexive mechanisms serve to redirect attention to newly arrived phenomena such as predator or prey in earlier times or the complexity of pedestrian and vehicular traffic in the present. Individuals with peripheral field defects will thus have less time to respond to potential collisions from objects or persons coming from the side of the defect, and those with central field loss may have difficulty assessing the relative importance of new phenomena causing distraction from the immediate concerns of foot placement during forward travel.

In addition to this, eye movement control also draws on short-term memory for previously attended information in the scene being viewed, stored long-term memory about similar scenes (visual, spatial and semantic) and the current goals of the viewer. These become more important during active
tasks, as objects are identified and their relationships given meaning.\textsuperscript{133}

\section*{3.10.8 Visual anchor}

\subsection*{3.10.8.1 Illumination}

Given that most of us can remain standing with our eyes shut, and people with no vision manage to travel independently, visual input is not strictly necessary for the maintenance of balanced upright standing. However vision does have a stabilizing effect on upright posture, which can be shown subjectively and objectively by observing sway with the eyes open versus closed.

The mere perception of illumination appears to have an effect. When subjects wore opal-glass spectacles so that they could perceive only dispersed light rather than a structured view of their surroundings, they were more stable than with their eyes shut, even though in both cases visual information regarding position and body movement with respect to the environment was absent.\textsuperscript{134} Furthermore, opening of the eyes even in darkness was accompanied by an improvement in stability even though no reference point for stabilization was available in the dark.

\subsection*{3.10.8.2 Environmental structure}

Experimentally it has been found that reducing environmental structure increases postural sway, a commonly agreed indicator of stability.\textsuperscript{135} Reduced illumination levels have a similar effect, and both illumination and environmental structure affect quiet standing in an age-related way, with older participants exhibiting more postural sway than young adults.
Simoneau et al.\textsuperscript{36} tested postural sway in older and younger adults to study the effect of the sudden shift in visual anchor that occurs when elevator doors are opened. They built a simulated elevator cage, and measured postural sway in their subjects before and after the doors opened. The results of their experiment showed that opening doors similar to those found in an elevator caused displacements in postural sway as measured by the centre of foot pressure on a force plate. The effect was 2 to 3 times more destabilizing for older versus younger subjects, and significantly, none of the subjects perceived these increased displacements (Figure 3.24).

![Figure 3.24](image)

Figure 3.24 Representative displacement of centre of foot pressure for an older individual before and after the doors opening in the lift experiment.\textsuperscript{36}

The researchers concluded that opening the doors of the elevator forced the older subjects to switch rapidly from the nearby stable visual anchor of the doors to a new anchor located further away. Additionally older subjects showed a greater range of postural sway than young adults when luminosity within the elevator was lower than luminosity outside, suggesting that lower
lighting intensities inside elevators may push older adults closer to the limits of their postural stability. Simoneau et al\textsuperscript{136} also aired the possibility that the rapid switch from a nearby to a far visual anchor may have simulated optic flow, and again older individuals have been found to be more effected than younger adults.\textsuperscript{137}

### 3.10.9 Optic flow

As an individual moves through the environment there is a direct effect from the optical flow field on the visual system. Optic flow arises from changes in the geometry and dimensions of the visual patterns of the external space as the individual moves relative to the space. The optical flow radiates out from the point in the optic array that is co-incident with the direction of motion and this point is called the focus of expansion (O in Figure 3.25). The focus of expansion falls on the centre of the retina. This flow has been termed radial flow (Figure 3.25). This radial flow transforms towards the periphery to become nearly parallel to the line of motion, and this parallel flow in the peripheral visual fields has been termed lamellar flow (Figure 3.25).\textsuperscript{137}

Self-propelled movement is specified by the somatosensory input from the muscles, tendons and joints as the individual moves through the environment. Additionally, optic flow provides a visual kinesthesis that anchors movement in the context of the environment the observer moves through. Somatosensory input does not yield information about passive locomotion, as when the observer is carried by a horse, canoe, car or plane. In this situation, it is a combination of vestibular information from the inner ears and the information extracted from the optic flow field that provides us
with the detail needed to appreciate the unfolding event.

Figure 3.25 A three dimensional representation of the lines of flow of the optical flow field generated by pure translational movement.\textsuperscript{103}

3.10.9.1 \textit{Effect of optic flow on postural orientation}

Understanding of the effect of optic flow on postural orientation began in the 1970’s with work by Lee and Aronson.\textsuperscript{138} The authors constructed a moving room that had a stationary floor, but the walls and ceiling could move back and forward along tracks. Infants who were just beginning to stand independently were seen to sway and stagger when the walls moved. Further work showed that standing adults were also sensitive to the optic flow generated by the moving room but were not moved off balance in the way that the children were.\textsuperscript{139} The researchers showed that the head and
body of adult subjects could be visually driven by 3mm oscillations of the room, and that they could be made to sway abnormally if they were standing on a balance beam. The ‘moving room’ paradigm generated a huge amount of research into optic flow but the flow is now generated by video display screens rather than by mechanical means.

3.10.9.2 Effect of optic flow and locomotion

Vision plays a critical role in locomotion, providing accurate information at a distance about the environment to be traversed and local information about the observer’s movements and limb placements. In the absence of vision, somatosensory and vestibular information can substitute for vision but most would argue that the substitution is not a one-to-one correspondence. During walking trials young adult subjects tend to look 1.5 to 3 metres ahead and this anchors the gaze about two steps ahead of the walker most of the time.\textsuperscript{140} This has been called travel gaze fixation, and has led to the study of gaze behaviour in order to understand how vision is used to regulate locomotion.

3.10.10 Gaze behaviour

Gaze stabilisation is complex and requires input from all the major sensory subsystems and high level processing within the CNS in order to maintain the target image on the fovea of the retina.

3.10.10.1 Vestibulo-ocular reflex

Movements of an image off the fovea by as little as $1^\circ$ can cause substantial decreases in visual acuity.\textsuperscript{141} The combined information from the bilateral semicircular canals and maculae provides a highly accurate representation
of the head in three dimensions. This information is processed and used in vestibulo-ocular reflexes (VOR) that stabilize visual targets during movement. In Figure 3.26 a rotation of the head to the left will stimulate firing in the vestibular mechanisms that will activate the appropriate cranial nerves to provide compensatory eye movements to the right. Information regarding the movements of the head in all possible directions is translated into compensatory movements of the eyes through the combined action of all the ocular muscles (Figure 3.27).

Figure 3.26 Schematic representation of an idealised uni-dimensional angular vestibulo-ocular reflex.112
The VOR is mainly associated with holding a fixation point when the head is moved suddenly such as when watching a target while running, and at other times neural commands from other visual stabilization mechanisms are necessary to avoid observer motion leading to residual retinal image motion. There is also a need for the visual system to be able to suppress the VOR, as there are times when whole body movements would stimulate the VOR, but we may want to maintain our direction of gaze. Nonetheless, the VOR contributes to postural stability by helping to provide stable images on the retina that are then further processed by the visual system to support postural integrity.

3.10.10.2 Smooth pursuit eye movements

Smooth pursuit eye movements allow the eye to follow a moving target, and are different to the VOR which stabilises the target as we move. They usually...
require a moving target and are velocity dependant. If the target is moving at more than 30°/second then catch up saccades will be required. We are generally better at horizontal than vertical pursuit movements, and the pursuit system tries to compensate for the velocity of the moving object to avoid slipping of the image off the fovea.

### 3.10.10.3 Optokinetic nystagmus

When we look out the window of a moving vehicle there is an alternation between compensatory movements provided by the VOR and a rapid ‘catch up’ phase. Just before the eyes reach the limit of their range there will be a rapid eye movement in the direction we are travelling when the eyes fixate on a new spot. A new phase of slow compensatory movement will follow this rapid phase until the limit is reached again, when another rapid phase ensues. This phenomenon has been called *optokinetic nystagmus*.

### 3.10.10.4 The role of optic flow

It has been found that irrespective of the environmental challenges, travel gaze fixation occupies the majority of travel time. In addition to travel gaze fixation, objects to be stepped over or avoided and others relevant to the task of locomotion are fixated on, and the transition between travel gaze and object fixation is always by saccadic eye movements. The environmental information necessary for locomotion control is consistently acquired at least two steps in advance, and this gives sufficient time to implement necessary avoidance strategies. Subjects never visually scan for any longer than 300 milliseconds before beginning to walk along trial paths suggesting that visual input about the environment is acquired during locomotion. This tends to support the view that information extracted from optic flow is important in
specifying heading.

In contrast to the above view others have proposed that visual guidance is achieved by keeping the target at a fixed direction relative to the body, rather than by maintaining the focus of expansion from the optic flow on the target heading.¹⁴⁵ In visually impoverished environments individuals cannot control steering with optic flow, but when additional features are added to the environment, optic flow is used.¹⁴⁶ This suggests that humans rely on both perceived heading and on optic flow. More recent work has shown that optic flow is sufficient, but not necessary to determine heading, and suggests that the role of optic flow may have been exaggerated and the importance of binocular disparity information neglected.¹⁴⁷

Varraine et al.¹⁴⁸ studied the interaction between optic flow and leg-somatosensory feedback in locomotion control, and argued in favour of a multimodal sensory control of movements. This view supports the notion that control of locomotion is multifactorial, and not dependent on optic flow to the degree that has been thought in the years since it was first proposed.

3.10.10.5  

**Anticipatory locomotor adjustments**

Navigating through the real world environment requires adaptations to the basic gait cycle as studied in laboratory settings. We can either react to an unexpected perturbation to our balance or plan an avoidance strategy. Avoidance strategies are usually classified as predictive or anticipatory. Predictive strategies regulate locomotion at a step-by-step level by maintaining intersegmental stability within the body or stability between the body and the support surface based on an estimation of expected
perturbation generated by ongoing movement.\textsuperscript{149} Anticipatory strategies refer to the maintenance of balance over several steps and are based on visual information about the environment at a distance used to avoid the perturbation occurring in the first place.\textsuperscript{149} An anticipatory adjustment requires the selection of alternative foot placements based on a visual assessment of the terrain encountered. This is generally achieved by lengthening the stride to avoid an undesirable footfall without impeding forward movement.\textsuperscript{150} Modifications to locomotor patterns are made several steps before an obstacle is encountered in order to maintain balance, and knowledge about environmental constraints gathered from visual sources affect these anticipatory adjustments. Prior experience and knowledge about the environment being traversed will also affect anticipatory adjustments, but in environments that are constantly changing this is not always possible.

3.10.10.6 \textit{Optic flow and passive locomotion}

The primacy of optic flow may well emerge during passive locomotion, particularly after acceleration when speeds are more constant, rather than for self-propelled locomotion. Given that much of the travel in industrialised societies is based around cars, this has implications for vehicle control and accident avoidance by drivers with deteriorating vision. Studies on the use of optic flow to detect collisions have found age-related decrements in the early stages of analysing motion and in higher level tasks of collision detection.\textsuperscript{151}

3.10.10.7 \textit{Head on trunk movements}

When we move, the head moves on the trunk as it shifts back and forward and from side-to-side, and there are compensatory movements of the head on the trunk to minimise the motion of the head relative to the environment to
aid in gaze stabilisation. Tracking a target often involves both the head and eyes, and in this case the two components must be timed and scaled to each other.\textsuperscript{152} To do this the systems controlling the eyes need to know what the head is doing ahead of time. At the same time the head may also be moving due to locomotion, balance maintenance or other demands from the immediate environment. Head movements need to be predicted if compensatory eye movements are to stabilise gaze, and this highlights the need for anticipatory responses based on learning. All the principal components of the gaze stabilisation system are shown in Figure 3.28.

![Figure 3.28 Principal components of the gaze stabilization system (VOR = Vestibulo-ocular reflex).]({})

### 3.10.11 Interactions between the sensory sub-systems

#### 3.10.11.1 Optic and vestibular response dynamics

Optic flow has been shown to signal heading direction, environmental layout and postural stability in a lit environment and is a form of \textit{re-afferent} sensory
input occurring as a result of the observer's movement. As discussed earlier, vestibular input also provides information on rotation and translational movements, and these inputs are provided in darkness as well as in a lit environment. These two systems have differing response dynamics and this means that reliance on one or the other may vary. It may be that different individuals rely more on one or the other, but because one can be used to validate the other, they can be used to create a composite self-movement signal that extends the observers operational range. Given that everyday movements happen in varying light levels, the relative influence and quality of vestibular and visual signals will also vary and so influence the final response of an individual in different ways.

In environments that provide less useful optic flow patterns vestibular cues may become more important and conversely steady self-movement without directional changes may not provide sufficient vestibular input and so visual information from optic flow would be given more weighting. There is anatomical and physiological convergence between vestibular and visual signals at all levels of the neuraxis, and this supports the notion that processing could be allocated to the sensory modality most suited to the particular situation at hand.

3.10.11.2 Proprioception

The term proprioception was originally coined by Sherrington in 1907 to describe the sensation of bodily movements. At that time sensations from muscles, joints, tendons and the skin were all thought to contribute to this and he also included the vestibular system in this definition of proprioception.
Throughout the literature in more recent times, the term proprioception is more often used in a way that does not include vestibular input, and is often used synonymously with kinaesthesia. It is difficult to avoid this blurring of distinction, and given that most recent literature uses proprioception in a way that does not include vestibular input, I will use the term proprioception to refer to the sensations of bodily movement that are fused from input of somatosensory origin – the muscles, tendons, joints and skin, as this is how it is more commonly used in the current literature.

Proprioception could be seen as a higher level ability fused from all the somatosensory inputs that provide us with a sense of our ‘body-self’, the relationships of our body parts as they move relative to each other. In this sense the contribution from the skin refers to stretching at joints that signals movement rather than the total range of sensory possibilities that the skin affords us. Proprioceptive information combines with tactile information about hand or limb contact with the body and external objects to aid in the calibration of apparent dimensions of the body and its relationship to external space. These modalities have input into to what is known as the body schema.
3.11 Motor co-ordination

Motor co-ordination is based on learned motor programs that have been built up through experience from our early development right through to the present moment. Many of these are semi-automatic or habitual, in that we only need decide what it is we want to do and the movements emerge without the need for careful consideration. It is only when we are moving in unfamiliar ways or trying to learn something new e.g., a dance step, that we need to bring the process to a more conscious level.

3.11.1 Body schema

The body schema is a dynamic representation of all the body parts and their relative positions that is derived from all the sensory systems and an *efference copy* of how planned movements should feel derived from the motor system. It is thought that the knowledge of the relative positions of body parts to each other is required for the production of efficient movement. Newer models of motor control contend that sensory afference and the efferent copy of motor commands are integrated to correct for real-time motor errors and to generate more accurate estimates of body position.\(^{118}\)

3.11.2 Efference copy

The perceived position of the eye can be signalled either by proprioceptors in the extra-ocular muscles or by motor outflow signals from the CNS, also referred to as an *efference copy*, which predicts the sensory consequences of the intended movement.\(^{157}\) As the movement occurs the afferent sensory
input generated by it provides real-time information about what is actually happening and this is compared with the predicted consequences from the efference copy to adjust for discrepancies (Figure 3.29).

Although the concept of efference copy originated in debates relating to perceived eye position, it has now been established that there is a definitive role for motor outflow signals in position sense in other part of the body too.\textsuperscript{109, 110, 158, 159}

![Figure 3.29 Efference copy and movement control.\textsuperscript{160}](image)

### 3.11.3 Motor commands

Loosely, there are two parallel but integrated systems that conduct nervous impulses from the brain down the spinal cord for the control of movement. One system, the pyramidal system, (Figure 3.30A) runs directly from the motor cortex in the cerebral hemispheres to alpha motor neurons in the spinal cord that activate the skeletal muscles. The other, often called the extrapyramidal system (Figure 3.30B) is more indirect. These systems were named based on anatomical considerations in the past and do not
necessarily reflect the current thinking around how movements are actually generated in different regions of the brain.

Figure 3.30 Pyramidal and extrapyramidal motor pathways

The direct system is responsible for the final activation of the skeletal musculature to produce voluntary movement. At the same time as motor commands are sent to the voluntary muscles, the efference copy of the movement is despatched so that it can be compared with the sensations that the movements will generate, and the comparison will allow for the co-ordination of smoother movements.

The indirect extrapyramidal pathways send signals from subcortical motor centres and influence both the alpha motor neurons that control the skeletal
muscles and the gamma motor neurons that activate the intrafusal muscle fibres within the muscle spindles - the fusimotor system.

The activity in this system will help to co-ordinate movement based on the comparison of the sensory feedback and the efference copy. It is also responsible for background muscle tone and postural organisation, and exerts inhibitory control over the influence of lower centres in the CNS. This system also has input from the Autonomic Nervous System and from deeper centres in the CNS that we have less conscious awareness of, and no direct voluntary control over.\textsuperscript{107}

3.12 Central set

Central set is based on our expectations of the current situation and is a product of our conscious awareness of the immediate situation and past experience. We anticipate the likely consequences of a given situation and prepare accordingly.\textsuperscript{162} What this means is that we often prepare for movement based on past experience, and so will tend to draw on our habitual responses. Anticipation means that these preparations are not based purely on past motor experience, but are also influenced by the emotional colour of those past experiences. A good example of this is the anxiety that many older adults experience regarding concerns about falling. This anxiety will influence the CNS preparation for responses to any challenges to balance that the individual may encounter.\textsuperscript{163} We generally modulate postural control according to the perceived impending threat and the degree to which these modifications will reduce the risk of falling. It has been shown that both younger and older adults alter their gait patterns when
threats to their stability are experimentally imposed and it has been hypothesised that this reflects anxiety mediated central set modifications to postural control.\textsuperscript{163} It is possible that some of the cognitive strategies applied in the Alexander Technique modify central set at a cortical level, and this is then expressed at a muscular level through combined activity in the skeletomotor and fusimotor systems.

3.13 Integrating inputs to postural orientation

All of the inputs from the various subsystems converge within the central nervous system (Figure 3.31), and although some of it will be redundant depending on the immediate situation, it does allow for a flexible regulation of upright stance,\textsuperscript{164} and the activity that it supports.

What often appears to be redundant information in fact allows the individual to resolve perceptual ambiguities that can arise with respect to perception and motion. An obvious example is the perception of motion induced by a moving train in an observer seated in an adjacent stationary train that requires information from the vestibular system for its resolution. However, every action engenders changes in activity in the somatosensory, visual and vestibular receptors and this makes it difficult to isolate their ongoing contributions to postural orientation in everyday life.
3.14 Where does the Alexander Technique fit?

The Alexander Technique provides a cognitive construct to examine habitual responses to familiar stimuli. In order to understand how the Alexander Technique fits into the organisation of postural orientation it is necessary to understand the nature of volitional movement.

3.14.1 Volitional movement

At a personal level, we experience a continuum of sensorimotor phenomena whereby we formulate intentions and then move to produce the planned effect. Based on an identified goal, appropriate motor commands are selected and sent to the muscles, and at the same time an efference copy is sent to an internal predictive model (A in Figure 3.32).
The forward model estimates the likely effect of the motor command, and sensory feedback from the actual movement arrives later due to the delays inherent in the speed of transmission of neural impulses. Because the predictive model by-passes these delays, it allows for more rapid and fluent movement. All of these representations are bound together to provide us with a coherent experience of our self as an agency of expression (B in Figure 3.32).\footnote{165}

Our actions can be an immediate response to direct stimuli in a moment by moment sense, which are more automatic, or much longer range intentional activities that are less dependent on the immediate situation and more dependent on the context of the task and learned associations from previous experience.\footnote{166}
3.14.2 Cerebral activity and intention to act

Early work by Libet et al\textsuperscript{167} suggested that the initiation of voluntary action was preceded by unconscious neural processes. Subjects in these experiments were asked to make voluntary hand movements whenever they felt the ‘urge’ to do so, and the time between their perception of the urge to move and the onset of muscle activity was recorded. Electrical recordings showed that the related brain activity (readiness potential (RP)) preceded the awareness of the intention to move by several hundred milliseconds. This suggested that what was perceived as an intention to move did not cause the movement, as it came after the neural activity needed to generate it (Figure 3.33).

Figure 3.33 Schematic results of Libet’s findings \textsuperscript{166}

Electrical activity in the brain preparatory to movement (RP onset in Figure 3.33) began several hundred milliseconds before the subjects became aware of the urge to move (mean W judgement in Figure 3.33), which was reported on average 206 milliseconds before muscle activity related to the movement was recorded. These readiness potential preparatory to movement have also been recorded on occasions when the subject decided to veto the action and
not actually move.\textsuperscript{168} These results seemed to suggest that the impulse to act arose prior to the perception of intention and so rather that inferring a ‘free will’ to choose to act, only allowed for the possibility of veto in the window between the perception of intention (W in Figure 3.33) and the onset of muscle activity.

\subsection*{3.14.3 Voluntary or involuntary?}

Critics argued that the instruction to pay attention to the feeling of ‘wanting to move’ was artificial, and that the results were induced by the instructions within the experiment itself. This implied that feeling the ‘urge to move’ would not have been recognised unless internal processes were monitored and so normally unconscious automatic movements may have been perceived and recorded in Libet’s experiments, rather than truly voluntary movements.\textsuperscript{169}

To investigate this, readiness potentials were recorded in both the Libet paradigm and in involuntary motor acts, and the results of these experiments showed that the onset times of the readiness potentials for voluntary and involuntary movements were nearly the same.\textsuperscript{169} The investigators inferred from this that it was the instructions in the Libet experiment to “introspectively monitor internal processes which led the subjects to perceive a feeling of ‘wanting to move’. Subjects crossed the borderline between unconscious and conscious acts by focusing attention on internal events” (p.360).\textsuperscript{169}

The subjects performing the task in the Libet paradigm were anticipating a feeling of ‘wanting to move’ and so were in a state both of preparation to move and expectation to perceive a signal which triggered a “predefined well-learned motor act” (p.359).\textsuperscript{169}
3.14.4 The borderline between conscious and unconscious acts

This highlights the difficulty in measuring volition in experimental situations. Most experimental studies deliver a pre-specified stimulus, and then measure the response to it. Voluntary movements are defined by their nature as stimulus-free, and so in experimental conditions the instructions can only partly determine what the subject should do. What is interesting here is not whether Libet was right or wrong, but that introspective monitoring of the feeling of ‘wanting to move’ creates a situation where normally unconscious movement (i.e., habitual movement) is brought into conscious awareness. This is precisely what Alexander was doing in the 1890’s when he observed himself in the mirror as he went to recite.

A number of experimental paradigms have been developed including: 1) subjects perform a fixed action at the time of their choice, 2) they choose between a number of pre-specified actions at a fixed time or 3) they choose whether or not to perform an action at all. These experimental paradigms are very similar to the choices that Alexander gave himself in his experiments when he attempted to recite without creating undue tension through his head, neck and back, his habitual way of responding to the stimulus to speak (see section 3.1.4).

So underlying our conscious voluntary actions, such as reciting verse, are the largely automatic mechanisms of postural orientation that maintain our upright poise based on learned patterns from past experience. These habitual reactions are invoked preparatory to activity, but are normally not brought into conscious awareness.
We know from the above experiments that we can bring unconscious motor acts (habits) into consciousness. We also know that there is time in which to ‘veto’ and choose not to go ahead and move. This then gives us time to consider consciously what may be a more appropriate response.

3.14.5 Current views on voluntary movement

It is thought that there are two distinct systems controlling voluntary movements in the brain, the lateral premotor system (LPS) and the medial premotor system (MPS). The LPS gets its input from the sensory cortex and is mostly involved in motor acts that are responses to sensory feedback. It is also thought that spontaneous (unconscious) motor acts are mediated through this system.\textsuperscript{169} The MPS gets its input from deeper motor centres (the Basal Ganglia) and co-ordinates internally desired acts and rapid skilled movements. Although we think of voluntary movement as an endogenous mental choice, recent views suggest that volition is a set of decision making processes with different types of information determining our actions (Figure 3.34).\textsuperscript{170}

In this view there are a series of action decisions that lead to a voluntary action. When current requirements are fulfilled, and immediate stimuli are appropriately managed by routine schemas, we can describe behaviour without invoking volition. These routine schemas are thought to be managed through the LPS. If a new action is initiated, or an existing pattern is modified or vetoed, information is generated in the brain based on a hierarchy of decisions (Figure 3.34). The earliest decision is whether to respond at all, and our needs and desires have a strong influence at this point.
This is followed by decisions about ‘what’ voluntary action to perform, and there are two steps to this. Firstly we must select between the goals we want to achieve, and keep our volition focussed on the task in order to bind our intention to our action. Importantly at this point we must suppress automatic responses to current environmental stimulation. Following this we must select between the movements that will achieve the identified goal, and they are secondary to the goal.

The final decision is another ‘whether’ to go ahead with what has been planned. Once the details of the voluntary action have been specified there is a final check before we commit ourselves to the execution of the intended
movement. This is where the output of forward models is matched against
the goal description, and mismatches can be adjusted, or we can chose to
veto the response.

3.14.6 Parallels with the Alexander Technique

The process of what Alexander called ‘inhibition’ and ‘direction’ is a process
of “stopping and thinking” in activity. The process bears similarities to the
decision hierarchy just described. Alexander developed an iterative approach
whereby he would inhibit the immediate desire to speak, give ‘directions’ for
a new ‘use’ of himself, inhibit again the desire to speak, give the directions
again, and then either go on and speak, do something entirely different, such
as raise a hand, or do nothing and go back to inhibiting and directing.

The initial inhibition to the stimulus mirrors the early ‘whether’ decision. The
first ‘what decision’ is the overall goal, which in the Alexander Technique is
directing an intention to release undue tension in order to lengthen and
widen, and the second ‘what’ decision specifies the intended voluntary action
that will emerge as movement. The final ‘whether’ decision is when the
decision to move is actually carried out, or vetoed (Figure 3.35).

If we inhibit our immediate response to activity, we have a chance to ‘cross
the borderline between conscious and unconscious acts’ and “reset” our
automatic reactions to familiar stimuli. What we are resetting is the
background organisation upon which our voluntary acts are based.
Figure 3.35  The Alexander Technique in the context of the volition hierarchy

This creates ongoing monitoring in activity whereby altered sensory awareness highlights the emergence of habitual movement patterns that can be examined and replaced by more mechanically advantageous and energy efficient alternatives. These opportunities emerge during ordinary everyday movement, and we can choose whether to respond to them based on the circumstances of the moment.

If we need to respond quickly, we are unlikely to stop and think about it for too long, as the urgency of the situation calls for an immediate response. However regular application of the iterative process in everyday movements refines and updates the movement strategies that we call upon habitually and so we gradually replace our unexamined responses with updated versions that have been informed with thought in a process of ongoing refinement.
3.15 Postural movement strategies

3.15.1 The ankle strategy

Biomechanically, the centre of gravity must be maintained within the base of support in order to remain in a stable upright state. The limits of this stability are shaped like an inverted cone with the apex at, or just in front of the ankle joints (Figure 3.36).

![Figure 3.36 The limit of stability in upright standing.](image)

Figure 3.36 The limit of stability in upright standing.\(171\)

This means that “equilibrium is not a particular position but a space determined by the size of the base of support (the feet in stance) and the limitations on joint range, muscle strength and sensory information available to detect the limits (p. ii8)”.\(172\) The individual makes adjustments at the ankle and their body sway is defined as the classic inverted pendulum (Figure 3.37).
Figure 3.37  The ankle strategy is an inverted pendulum. 

3.15.2 The hip strategy

The time constant for balance using the hip strategy is shorter than for the ankle because it is based on a two-link pendulum model (Figure 3.38). The body exerts force at the hips to quickly move the centre of gravity (Figure 3.39), and this strategy is used more often when the individual is standing on a surface that does not allow adequate ankle torque, such as a narrow or a compliant surface, or if the centre of gravity needs to be moved quickly. Adults with vision impairments cannot fully compensate for the role of vision in postural stability, and have increased levels of postural sway which results in an increased use of the hip strategy, which can lead to increased falls on unstable surfaces. 

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Figure 3.38 Two-link pendulum model of the hip strategy.\textsuperscript{90}

Figure 3.39 The Hip strategy exerts force quickly at the hips.\textsuperscript{173}
3.15.3 The suspensory strategy

The suspensory strategy requires the individual to lower their centre of gravity by flexing at the hips, knees and ankles. This can be observed in young children in more static balance activities as shown in Figure. 3.40.

![Figure 3.40](image)

**Figure 3.40** Suspensory strategy in young children in more static activity.

It is interesting to note that this strategy is also the basis of much of the more sophisticated dynamic balance seen in well-coordinated sporting activities such as skiing, surfing, skateboarding, etc. (Figure 3.41). Many of these activities require the suspensory strategy to be performed effectively, and most high level performers and sportspeople display it during activity.

![Figure 3.41](image)

**Figure 3.41** The suspensory strategy in dynamic balance.
Taking this strategy to its ultimate conclusion ends in a squat (Figure 3.42), an activity that is rare in western culture, but widespread in many others. The use of chairs for sitting negates the need to squat, but also means that the ability to do so is no longer available as a functional option to many western individuals in adulthood.

Figure 3.42 Full squat. Adapted from

The need to maintain balance in activity when lowering oneself into a chair is negated because chairs provide a steady endpoint in the form of stable support. Every time an individual squats, they practice and refine the coordination necessary for the suspensory strategy to be an effective option. The lack of practice that comes with widespread use of chairs may mean that this strategy becomes less effective and therefore less utilised than it could be. Given that it underlies the dynamic balance of most skilled gross motor activity this is a loss to the potential for well-coordinated motor activity in
many individuals in old age.

This is also a strategy that is emphasised during Alexander Technique lessons (Figure 3.43). The movements between sitting and standing provide the opportunity to pay more attention to the use of the bi-articular muscles in the coordination of the hips, knees and ankles as the limbs fold and unfold going into and out of a chair.

![Figure 3.43 The suspensory strategy in an Alexander Technique lesson](image)

3.15.4 Rescue strategies

If the above strategies have not been successful, and the body does begin to fall outside the limit of stability, a common rescue strategy involves sweeping movements of the arms. In this scenario, those parts of the upper body that can be moved relative to the trunk are activated to create a backwards force against the trunk to avoid overbalancing (Figure 3.44).
The shoulders, arms and head will all pivot on the trunk about the sternoclavicular joint to provide this rescue response. If these sweeping movements of the arms fail to provide enough torque to move the upper body on the trunk in the appropriate direction, the individual will have to take a step to move their base of support under their moving centre of gravity, reach out to touch a stable object in the environment, or risk falling. The strategy that an individual uses will be selected on the basis of their intention, experience and expectations.

3.15.5 Anticipatory postural strategies

Anticipatory or feed-forward postural control is used to deal with the demands of internal biological disturbances, movement induced disturbances and externally induced disturbances. The effects of respiration are responsible for an important component of the postural sway found in quiet standing, but feed-forward adjustments can dampen this by anticipatory
action of postural muscles working 180° out of phase to the respiratory rhythm.\textsuperscript{176}

For movement induced disturbances, feed-forward activity is independent of feedback from limb movement as its activity precedes these movements. Moreover it is not just a general stiffening of muscles around the joint, rather being a task specific pre-programmed patterning of activity. These adjustments reduce disequilibrium and so minimize the energy expenditure needed to remain in balance, and optimise stability during activity.

Compensatory postural adjustments are also activated when balance is disturbed due to external forces. This response is not driven by disturbance of the postural muscles themselves, but is due to afferent input from the parts of the body that are first perturbed. Roberts\textsuperscript{90} calls these adjustments ‘anticipatory pre-emptive actions’. These are voluntary adjustments based on past experience and are made well before a reflex response of a similar nature would occur. The particular strategy selected will vary depending on the environmental context and the individual’s goals. Balance control is now considered to be a fundamental motor skill, and so like other motor skills, the use of different strategies can be improved with training and practice.

3.16 Development

3.16.1 Congenital blindness and postural development

Children and adults with congenital blindness (those born with no light perception) are relying solely on input from the somatosensory and vestibular
systems to organise their postural orientation with the world. Static balance is often underdeveloped in visually impaired children, who commonly adopt poor sitting and standing postures, which then underlie their general gross motor abilities. Figure 3.45 shows common postural deviations seen in those with congenital blindness.\textsuperscript{177}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{postural-deviations.png}
\caption{Common postural deviations in the congenitally blind.\textsuperscript{178}}
\end{figure}

Likewise, dynamic balance during movement is not fully developed in the congenitally blind who often show immature gait characteristics such as out-toeing and short stride.\textsuperscript{177} Visual impairment reduces the ability of the individual to establish optimal postural stability, which then limits physical functioning and independence levels.
3.16.2 Head control

From a developmental point of view, head control is the first skill to develop, and “this implies that head posture in space contributes importantly to the posture of the lower body segments with respect to the external world and that the ‘top down’ or descending mode of postural organization, i.e. that running from the head to the feet prevails” (p. 469). This also supports the idea that posture develops primarily as an interface with the external world and then secondarily for the antigravity organization of the whole body. This means that head posture plays the role of a reference frame for movement organization in space from very early on. Precluding visual input in balance tasks affects the predictability and motion of the heads behaviour, and this suggests a crucial role for the head in modulating postural dynamics.

3.16.3 Integration

Massion suggested that ‘bottom up’ organization emerges last with “the ability to control the whole body’s posture and the distribution of the body segment masses with respect to the supporting area” (p.469). This means that there has to be an integration of the ‘top-down’ and ‘bottom-up’ modes at some point in development, and he suggested this occurs around the age of seven when there is a reorganisation of postural control. There is also a transition phase for the use of peripheral vision in dynamic balance control around the age of seven, and there is a transition phase around seven to eight for movement control generally.
3.17 Impact of eye conditions on postural organisation

3.17.1 Visual acuity

Paulus *et al*\textsuperscript{181} found that logarithmically decreasing visual acuity increased postural instability in a linear fashion. The instability was twice as prominent for antero-posterior (AP) versus medio-lateral (ML) sway.

3.17.2 Refractive blur

Postural instability is known to increase with refractive blur, and is further increased when there is disruption to the somatosensory and/or vestibular systems. Furthermore, while refractive blur has been shown to increase AP instability more than ML instability in quiet standing,\textsuperscript{182} there are significant increases in ML instability when stepping up and down between levels, making stair negotiation more potentially dangerous in the presence of blur.\textsuperscript{183}

3.17.3 Cataract blur

Simulated cataract blur also reduces postural stability, and cataract surgery has been shown to improve it.\textsuperscript{184} Contrast sensitivity rather than resolution was shown to be responsible for these changes to postural stability caused by cataract blur.\textsuperscript{185 186} Glare sensitivity increases in all types of cataracts\textsuperscript{187} and this has implications for dynamic postural steadiness when mobilising within the community where changing levels of luminosity and reflection can impact on postural steadiness.
3.17.4 Contrast sensitivity and stereopsis

Contrast sensitivity is a measure of the ability to distinguish different levels of luminosity. Stereopsis refers to the availability of binocular vision. Both of these have implications for distinguishing changing surfaces characteristics and are significantly associated with increased postural instability on compliant surfaces.\textsuperscript{104} Accurate perception of visual stimuli and depth are important in the formulation of a visual reference frame to stabilize the body relative to the external environment.

3.17.5 Visual fields

Input from different areas of the visual field also plays a role in postural stability. Based on studies where visual input is manipulated on subjects with normal vision, Paulus et al\textsuperscript{181} concluded that the central field dominates postural control compared to the peripheral field, with the fovea having a powerful contribution particularly for ML sway.

Berencsi et al\textsuperscript{188} found that stimulation of the peripheral visual field reduced postural sway, particularly in the AP direction, more than central stimulation in quiet standing. They further found that the stabilising effect from the peripheral fields was related to the direction of observation. If the observer was looking straight ahead, the peripheral stimulus stabilised sway in the AP direction, whereas if the head was turned to the side the peripheral stimulus stabilised sway in the ML direction. They concluded that the function of peripheral vision on postural stability was likely related to head/gaze orientation rather than to the anatomical planes of the body. They suggested that the influence of peripheral vision on postural control operates in a
viewer-centred frame of reference defined by head and gaze positions.\textsuperscript{188}

\subsection*{3.17.6 Glaucoma}

It is not clear how manipulating stimuli to the visual fields in those with normal vision relates to the experience of those whose visual fields have pathological deficits. Glaucoma causes a progressive loss of the peripheral visual field and induces a deficit in the visual contribution to postural steadiness.\textsuperscript{189} Postural sway increases as binocular visual field loss increases, or retinal nerve fibre layer thickness decreases.\textsuperscript{190} Losses in the inferior visual field and contrast sensitivity have been found to be particularly associated with poor functional status in older adults with Glaucoma.\textsuperscript{191}

\subsection*{3.17.7 Retinitis Pigmentosa}

Retinitis Pigmentosa is characterised by a progressive loss of the peripheral visual field and ‘night blindness’. Disease progression is accompanied by a steady decrease in the contribution to postural stabilisation by the visual system, and eventually to a destabilisation of postural stability that is not seen in studies where visual field loss is simulated. It is thought that this destabilising effect in late stage Retinitis Pigmentosa is due to the anomalous visual processing of information from the remaining field.\textsuperscript{192}

\subsection*{3.17.8 Macular Degeneration}

Macular Degeneration affects the central visual fields, and those with central field loss show a smaller contribution of vision to postural steadiness.\textsuperscript{193} Given that most have intact peripheral fields the impact on postural stability is more marked when there is additional disruption to the somatosensory or
vestibular systems.\textsuperscript{194} There is also a significant correlation between reduced contrast sensitivity and increased postural instability in adults with age-related Macular Degeneration.\textsuperscript{194,195} Along with postural instability, impaired contrast sensitivity has also been associated with slower walking speeds, reduced stride length, and increased step width in this population.\textsuperscript{196}

3.17.9 Diabetic Retinopathy

Diabetes is a systemic disease and so those affected by diabetic retinopathy are likely to have related health issues that will also impact on their postural stability. Peripheral neuropathies are common and impair the ability to walk on irregular surfaces\textsuperscript{197} which adds to postural instability if visual input is also degraded.

3.17.10 Multifocal prescription lenses

Although multifocal glasses are not an ‘eye condition’, they are widely prescribed and when worn create a ‘visual condition’ that has been shown to impact on postural organisation. Multifocal glasses have been identified as a major risk factor predisposing older people to falls\textsuperscript{198} because viewing the environment through their lower lenses “impairs the important visual capabilities (contrast sensitivity and depth perception) for detecting environmental hazards, particularly in unfamiliar environments” (p.ii43).\textsuperscript{199} On the other hand Johnson \textit{et al}\textsuperscript{200} found that postural stability deteriorated in both multifocal and distance single-vision spectacle wearers with the head in neutral and the gaze directed down at the ground, and found that for both types of spectacles flexing the head and dropping the gaze when looking downwards was more stable.
3.18 Age-related changes to sensory input

If development has proceeded normally, young adults can resolve inter-sensory conflict and have a large safety margin to ensure postural stability. They can re-weight their relative dependence on sensory inputs as the conditions in the environment change. The functioning of this re-weighting “can be likened to a proportional representation voting system, in which every single vote has an impact on the outcome but the strength of that impact depends on the total number of votes”\(^\text{105}\).

As an individual moves through the external environment, they will need to continually re-weight their dependence on these cues according to the situation. Pathology and age-related changes in these systems can limit the ability to re-weight effectively and can push an individual to the limit of stability if the environment changes rapidly.

As nerve conduction speeds and central integration slows in the CNS\(^\text{201, 202}\), older adults rely increasingly on visual input for postural stability.\(^\text{203}\) On the other hand, some researchers found, contrary to their own hypothesis, that reduction of visual input had a greater effect on younger adults and that the older age group tended to stiffen their lower legs as a strategy to maintain their postural stability.\(^\text{204}\) Others have found that the dependence on vision is only true up to the age of 65 years, and that after this age the contribution made by vision declines.\(^\text{205}\)

Low ambient light levels have also been found to increase postural instability in the elderly, with the consequent increased risk of falls.\(^\text{206}\) Given that many
studies rely on the manipulation of sensory input it may also be that exclusion or disruption of only one sensory input does not consistently differentiate between young and older adults due to compensation by the remaining sources of sensation.

Visual impairment, particularly where contrast sensitivity and stereopsis are involved, is strongly associated with increased instability when subjects stand on a compliant surface that reduces somatosensory input from the ankles and feet.\textsuperscript{104} It has also been found that older adults have difficulty using the ankle strategy due to slower response times in the nervous system and they shift to a reliance on vision, especially for dynamic balance control.\textsuperscript{201} This has obvious implications for those older adults with vision impairments. If vision impairment compromises the usefulness of the input from the visual system, then the individual is pushed closer to the limits of their ability to maintain their postural integrity.

Individuals with visual impairments are more prone to falls and their consequences.\textsuperscript{207-209} As bodily changes occur throughout the lifespan, the CNS must adapt and recalibrate its ability to maintain postural integrity. Postural integrity is a dynamic perceptuomotor skill whereby the CNS detects the “limits of reversible action, so that movements and postures that would bring the entire body into an unstable position… are automatically eliminated” (p.13).\textsuperscript{98} Interventions such as exercise and balance training are regularly used in rehabilitation settings to improve the postural integrity in the elderly adult population, but this is not usually specifically directed to people with vision impairments. By optimising the ability to use input from the
subsystems that are functioning, individuals with visual impairments might be trained to improve their postural integrity and its relationship to the external world.

Lee and Scudds\textsuperscript{210} proposed that interventions to improve physical functioning and reduce falls were indicated in the visually impaired elderly population, and a multifactorial trial of fall prevention strategies for older adults with visual impairments was published in 2005.\textsuperscript{211} Although the study found a protective effect of the home modification and safety intervention,\textsuperscript{212} an exercise program that had been found to reduce falls in the general population did not reduce falls in this sample of older adults with visual impairments.\textsuperscript{211}

Reed\textsuperscript{98} noted that the earliest evidence for the conception of posture as an integral component of voluntary action came from the work of F.M. Alexander. The Alexander Technique was used in the randomised controlled clinical trial that forms the basis of this thesis, and the protocol for the study is discussed in the following chapter. The Alexander Technique is a novel approach to reducing falls risk by improving postural orientation grounded in the conceptual framework described above.

This involves collaborative learning as the Alexander teacher uses verbal and tactile feedback to direct the subject’s perceptual awareness to previously unnoticed habits of muscular tension during everyday activities. This is combined with the elaboration of iterative cognitive strategies that inhibit immediate responses and provide a platform for projecting a better background organisation on which functional activity can be framed. As the
person masters the Alexander Technique within the lesson context, they can pay more attention to everyday movements and apply the Alexander Technique to improve the efficiency of their functional movement.
3.19 References


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4 METHODS

The main project of this thesis was a randomised controlled trial to determine the impact of Alexander Technique on physical functioning in older adults with visual impairments with a view to reduce the risk of falls. The methods for the study were published as a protocol paper in *Injury Prevention*:


The paper has been formatted in the style of the thesis for this chapter. The author statement is Appendix 1 and the published version is Appendix 2 at the back of the thesis. Ethics approval is in Appendix 3 and the Statistical Analysis Plan is in Appendix 4.

4.1 Abstract

**Background:** Falls are an increasingly important and costly public health problem. In addition to environmental preview, vision is a key input to postural stability as we age. This puts adults with visual impairments at greater risk of falls. Physical interventions improve balance in the general population and in older adults with visual impairments in residential care. They also prevent falls in the general community but to date have not been
shown effective in community-dwelling adults with visual impairments.

Objective: This randomised controlled trial will investigate whether the Alexander Technique can improve balance and mobility in the community-dwelling population with visual impairments to reduce physical falls risk. The Alexander Technique is a form of physical re-education recently receiving attention for possible value in rehabilitation.

Method and design: One hundred and twenty people with visual impairments over 50 years of age will be recruited from Guide Dogs NSW/ACT. Participants will be independently mobile and cognitively able to engage in the program. Following baseline assessment participants will be randomly assigned to two groups. The control group will receive usual care from Guide Dogs NSW/ACT, and the intervention group will receive 12 weekly home-based lessons in the Alexander Technique in addition to usual care. The primary outcome measures will be physical measures from the Short Physical Performance Battery at three months. Secondary outcome measures will be balance, mobility, social participation and emotional well-being at three and 12 months.

Trial registration number: The protocol is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12610000634077).
4.2 Introduction

Around one third of adults over 65 years of age fall at least once per year, and in Australia hospitalisation rates due to fall related injuries rose by 5.6% between 2007-08 and 2008-09. Falls are the most common cause of injury death among Australians over 75 years of age due to the high susceptibility to trauma in this age group. The risk of injury is higher for people with visual impairment. About 12% of falls lead to serious injuries and the Auckland Hip Fracture Study found that 40% of fractures could be attributed to poor visual acuity or lack of stereopsis.

A study of prevalence in the UK found that about 618,000 adults over 75 years of age had moderate or worse visual impairment, which is just over 1% of the total population and approximately 14% of the population over 75 years of age. Another study in the UK using national data from Accident and Emergency departments found that 21% of the cost of treating unintentional falls was spent on the visually impaired population. The high burden of falls in our community and the over-representation of older people with visual impairments make proven falls prevention strategies for this group a pressing concern.

A study of balance in young adults with visual impairments found that they did not fully adapt to their vision loss with respect to maintaining postural stability. Recent work on falls in young and middle-aged adults in the general population has found that even in these age-groups, falls resulting in hospitalisation can have significant impacts on long term health and functioning. Changes in equilibrium control have been noted in the general
population after the fifth decade,\textsuperscript{14} adding to the existing impact of visual impairment on the physical functioning of this population. Lower femoral-neck bone mineral density has been reported in middle aged women with visual impairments,\textsuperscript{15} which coupled with reduced balance can compound risk of fracture. These differences in balance control in the visually impaired population as they age highlight the need for continued research into this area.

For many older adults, vision loss leads to a decrease in physical activity which then impacts on their general health and well-being. Higher rates of depression have been reported,\textsuperscript{16-18} and significant associations have also been found between vision function and poor performance on physical performance tests.\textsuperscript{19} Older adults with visual impairment more frequently experience breathing problems, diabetes, heart problems, hypertension, joint symptoms, low back pain and stroke,\textsuperscript{20} and many of these co-morbid conditions are associated with difficulties in walking, climbing steps, shopping, and socializing. Visual impairment has also been reported as contributing to frailty\textsuperscript{3,21} and increased rates of mortality.\textsuperscript{22}

Nerve conduction speed and central nervous system integration slows with age forcing older adults to rely more on vision, especially for balance control during movement.\textsuperscript{23,24} At the same time, the ability to reweight towards vision also declines with age,\textsuperscript{25} further compounding the maintenance of upright balance. This pushes older adults with visual impairments to the edge of their ability to maintain their balance under challenging conditions, and increases fall rates.\textsuperscript{26}
Interventions known to improve balance in the general population\textsuperscript{27} have also been shown to improve balance in the visually impaired population when delivered effectively. Two recent studies in residential care settings in Hong Kong were able to deliver programs to visually impaired residents in a way that maximised attendance and compliance because the classes were delivered within the residential care homes. An exercise intervention provided three times per week improved balance compared with controls,\textsuperscript{28} and a 16 week Tai Chi course significantly improved knee proprioception and balance.\textsuperscript{29}

There is evidence that exercise programs reduce falls in older adults in the general population,\textsuperscript{30,31} particularly programs which challenge balance, including group Tai Chi classes in community settings. However, programs delivered in a community group setting are difficult for people with visual impairments to access and their ability to participate effectively is also limited due to the group nature of the programs and their need for more individual attention. A trial of older people with significant visual impairments found that a home safety program successfully reduced falls but the home-based exercise intervention, which had been shown to benefit older adults in the general population, did not reduce falls in this population.\textsuperscript{32} The authors found that fall rates were highest in those with lowest adherence to the program protocol and this suggests that compliance may have been a problem with the exercise intervention. There is a need to tailor interventions to suit specific populations, and an individually delivered physical intervention that takes account of visual impairment may be better suited to reducing risk of falls in community-dwelling older adults with visual impairments.
The Alexander Technique (AT) was developed in the 1890s and although it has been widely used in the performing arts, it has developed outside the mainstream medical model and is only now being investigated for possible therapeutic benefits.\textsuperscript{33} The AT uses manual guidance and verbal feedback in everyday activities such as sitting, standing and walking to teach people how to better organise their balance and mobility by reducing largely unnoticed habitual muscular tension that may be interfering with an easier overall coordination of themselves. Although the physiological rationale behind the AT has yet to be clearly established, a case-control study of Alexander teachers and matched controls found that lessons in the AT reduce axial stiffness through the spine and enhance dynamic modulation of muscle tone.\textsuperscript{34} Because it does not require learning unfamiliar exercises or movement patterns, and uses manual guidance, it may be ideal for people with visual impairments. Randomised controlled trials of the AT have been shown to benefit people with Parkinson’s Disease\textsuperscript{35} and back pain,\textsuperscript{36} but it has not been used in studies to improve balance and mobility in the visually impaired population until now.

4.3 Objectives

The objective of this study is to determine if home-based lessons in the Alexander Technique can improve balance and mobility in community-dwelling older adults with visual impairments, as these are key risk factors for falls.
4.4 Methods

4.4.1 Design

The VISIBILITY study is a two-armed randomised controlled trial (see Fig 4.1). Ethical approval to conduct the study was granted by the Human Research Ethics Committees at the University of Sydney (Protocol no. 12985) and the University of New South Wales (HREC10277). The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12610000634077).

![Diagram of the VISIBILITY randomised controlled trial design]

Figure 4.1 The VISIBILITY randomised controlled trial design
4.4.2 Recruitment

The study is a collaboration with Guide Dogs New South Wales/Australian Capital Territory (NSW/ACT) in Sydney, Australia and all participants will be recruited from the database at Guide Dogs NSW/ACT. The organisation provides community-based services to enhance the mobility and independence of people within NSW and the ACT with visual impairments. Programs are tailored to individual client needs and can include training in the use of canes, guide dogs and electronic travel aids, along with safe strategies for pedestrian and public transport travel.

General information about the study will be included in an audio-format client newsletter called “Soundtracks” to inform clients that the study is being established. Additionally, eligible adults ≥ 50 years with visual impairments in the Sydney Region will be identified by Guide Dogs NSW/ACT from their client database. Clients from a range of socio-economic and cultural backgrounds are represented in the database. Eligible clients will be contacted by Guide Dogs NSW/ACT using their preferred mode of communication. The database identifies clients preferred communication medium and the options include: standard font size (clients may have a visual field restriction but good central acuity); large print (clients can designate the font size); e-mail (many clients have text to voice software or can resize documents electronically); audio CD or Braille.

An invitation letter will be sent to eligible clients by Guide Dogs NSW/ACT and initially clients will be asked to contact the researchers within a defined timeframe if they are interested in participating or require further information.
before making a decision. They will be informed in the invitation letter that a follow-up phone call will be made to clients who do not respond within the initial timeframe. Orientation & Mobility (O&M) Instructors employed by Guide Dogs NSW/ACT working in the community will be given a standard information sheet to answer basic questions about the study during unrelated client visits but asked to refer the client to the researchers for further information and provide the appropriate contact details. Confidentiality, impartiality and the voluntary nature of participation will be stressed by all staff at every step of the process.

4.4.3 Inclusion criteria

The inclusion criteria are as follows:

1. People over 50 years of age with visual impairments that impact on their mobility will be eligible for recruitment into the study.
2. Their visual impairment must be such that they have received mobility training from O&M Instructors at Guide Dogs NSW/ACT within the last five years to maintain their independent mobility.
3. Mobility aids may include identification canes, long white canes, support canes, walking frames and guide dogs.
4. Participants will be required to be resident in greater metropolitan Sydney.
5. They must have conversational English.

4.4.4 Exclusion criteria

The exclusion criteria are as follows:
1. Any clients who require an Interpreter will be excluded as they require conversational English to participate in the intervention arm of the study.

2. Clinically diagnosed Dementia or a Short Mental Status Questionnaire\textsuperscript{37} score of less than eight, as the intervention is a re-education process requiring cognitive engagement, and this could place unnecessary stress on those subjects.

3. Those not independently mobile with the aids already mentioned. This would exclude people confined to wheelchairs, stationary chairs or beds.

4. Those planning cataract surgery in the next 12 months are also excluded as this can significantly improve their vision and mobility.

**4.4.5 Baseline assessment**

The Baseline assessment will be conducted by trained O&M instructors from Guide Dogs NSW/ACT. The instructors have all completed a Masters of Special Education (Sensory Disability) and regularly supervise these clients in complex situations requiring attention to balance and safety when providing mobility-related services. Additionally the O&M instructors will attend a two day training course on the study assessment procedures with one of the researchers, who will accompany them on their first assessment prior to randomisation to ensure conformity to protocol.

Demographic information on participants will be collected at the initial visit prior to screening and assessment. Information on mobility status, visual impairment, residence type, living arrangement, country of birth, primary
language and level of education will be used to characterize the population. Additional co-morbidities\textsuperscript{38} and medication status will also be collected and repeated at the three and 12 month assessments to follow their health status over time.

4.4.6 Primary outcome measures

The three physical ability measures from the Short Physical Performance Battery\textsuperscript{39} (SPPB) will be used as individual primary outcome measures and investigated as a change from baseline. The study is not powered to use the three tests as a composite score. The SPPB has been validated in a large study within the general older population as a measure of lower limb function which can distinguish risk of future nursing home admission.\textsuperscript{39} It can be administered by a single investigator in the person’s home, takes about ten minutes to complete, and has been found to be both reliable and sensitive to change.\textsuperscript{40} The SPPB comprises the following:

1. Timed five times sit-to-stand test
2. Timed four metre walk
3. A standing balance test which includes side-by-side, semi-tandem, tandem and single limb balance test.

Tests will be administered prior to randomisation and following the 12 week intervention period by a trained O&M instructor from Guide Dogs NSW/ACT who is unaware of group allocation.

4.4.7 Secondary outcome measures

The secondary outcome measures are as follows:
1. The three tests from the Short Physical Performance Battery used as a primary outcome will be re-administered at 12 months as a secondary outcome and an indicator of the duration of any effect.

2. The postural sway test and maximal balance tests from the Physiological Profile Assessment\textsuperscript{41} will also be used as secondary outcome measures at the three month and 12 month time points. The extent of sway during 30 seconds of standing will be measured with four conditions: on floor with eyes open, on floor with eyes closed, on a foam mat with eyes open and on a foam mat with eyes closed. All measurements are taken on a grid paper and body sway excursions will be measured in millimetres for analysis.

3. Fall rates will be measured by falls calendars. The study will be too small to detect an effect on fall rates but will give a useful indication of the presence and size of an effect on falls, which will assist with sample size calculations for future larger trials in this study population and could be made available for future meta-analysis.

4. Fear of falling will be assessed with the Falls Efficacy Scale – International\textsuperscript{42} at baseline, three and 12 months.

5. Mood will be assessed with the Geriatric Depression Scale,\textsuperscript{43} the Positive and Negative Affect Scale,\textsuperscript{44} and the Emotional Well-Being subscale of the Impact of Vision Impairment Scale\textsuperscript{45} at baseline, three and 12 months.

6. Functional mobility will be assessed with the Perceived Visual Ability Scale\textsuperscript{46} at baseline, three and 12 months.
7. Community participation will be assessed with the Keele Assessment of Participation\textsuperscript{47} at baseline, three and 12 months.

4.4.8 Sample size

A sample size of 60 individuals in each of the two groups will give the study adequate power to detect a 15\% between group difference at a 5\% level of significance with a power of 80\% allowing for 15\% drop-out during the 12 month study. The power calculations are based on data from a study in a similar population group.\textsuperscript{48} The estimates of between-group differences used in power calculations for the three primary outcomes measures are as follows:

1. Five times Sit to Stand (Effect 3.6 seconds, Standard Deviation 9.0, correlation between baseline and final measure 0.7).
2. Timed four metre walk (Effect 0.1 m/second, Standard Deviation 0.25, correlation between baseline and final measure 0.7).
3. Standing Balance Test (Effect 3.6 seconds, Standard Deviation 9.0, correlation between baseline and final measure 0.7).

4.4.9 Sub-study

A sub-group of participants will undergo movement analysis of their walking style using a GAITrite© pressure sensitive mat in a laboratory setting prior to randomisation and following the 12 week intervention period of the study. The GAITrite© system has been shown reliable as a measure of averaged and individual step parameters used in gait analysis,\textsuperscript{49,50} and the data
collected will be used as a pilot study to determine whether gait analysis would be of value in future studies of the AT.

4.5 Discussion

Ageing populations in industrialised countries have seen an increase in the prevalence of age-related visual impairments that impact physical ability, postural stability and social functioning and increase the risk of falls. Projections for Australia show that in the over-40 population the rate of vision impairment will rise from 5.4% in 2004 to 6.5% by 2024 and the rate of blindness is projected to increase 73% from 50,000 in 2004 to 87,000 in 2024. Fall prevention programs based on well designed exercise programs have been successful in reducing falls in the general population, but to date the only intervention that has been shown effective in the community-dwelling visually impaired population was a home modification program. Many fall prevention programs are community-based group activities and this limits their suitability for older adults with visual impairments. Home based programs that take account of visual impairment may be better suited to improving balance and mobility in this population.

Falls incur in excess of one billion dollars in medical treatment, disability, lost output and mortality in Australia each year. Given that there is currently no strategy that has been proved effective in the community-dwelling population with visual impairments, there is an urgent need to identify interventions that are tailored to and suitable for the growing number of older adults whose lives are complicated by failing vision. Fall prevention programs are being
made available to the general population and these services need to be provided in a range of formats so that they are accessible to all sections of the population at risk.

Because the Alexander Technique uses manual guidance and verbal feedback, it does not require vision to learn, and so may be a useful approach for people with visual impairments. The VISIBILITY study has been designed to determine whether the Alexander Technique can improve balance and mobility in this population. If shown to be effective, a further larger study would be required to determine whether this would translate into reduced fall rates within the population with visual impairments.

4.5.1 Contributorship

MG CS and LK were responsible for the conception and design of the study. MG and EB were responsible for the study management and data acquisition. MG CS LK and EB were all involved in the drafting, revision and final approval of the paper.

4.5.2 Acknowledgements

The authors would like to acknowledge Guide Dogs NSW/ACT for the support that allowed this study to succeed.

4.5.3 Competing interests

The authors declare they have no competing interests.
4.5.4 Funding

Guide Dogs NSW/ACT provided substantial 'in-kind' support. The Australian Society of Teachers of the Alexander Technique and the FM Alexander Trust (UK) both provided small grants to support the study. Michael Gleeson received an Australian Postgraduate Award Scholarship from the Australian Federal Government.
4.6 References


5 MAIN RESULT – PHYSICAL OUTCOMES

The main results of the study have been submitted to *Clinical Rehabilitation*, and the paper has been accepted pending minor edits. The paper has been resubmitted, but is formatted here as a chapter in the style of the thesis. The Introduction and Method sections have been discussed in Chapters 1 and 4 respectively, but have been retained here. Due to equipment failure and lack of availability at critical assessment time points, we were unable to collect the necessary data for the proposed gait sub-study outlined in the VISIBILITY study protocol, and so it is not reported here.

5.1 Introduction

Visual impairment is an independent risk factor for falls.\(^1\)\(^-\)\(^3\) Well-designed exercise programs reduce falls in the general population\(^4\)\(^-\)\(^5\) but have not been successful in community-dwelling older adults with visual impairments.\(^6\) Three small studies in residential settings have shown multimodal exercise and Tai Chi improve physical functioning\(^7\)\(^-\)\(^9\) in controlled environments where physical and verbal guidance is provided, but these results cannot be generalized to community-dwelling adults who are more mobile and encounter more environmental hazards.

The Alexander Technique uses verbal feedback and manual guidance to teach awareness of previously unnoticed tension. The Alexander Technique
was developed in the 1890s and evolved within the performing arts but is also taught to people with movement problems with an aim of enhancing coordination and balance. It has only recently been investigated for therapeutic benefits.\textsuperscript{10-12} The Alexander Technique may be a suitable intervention for people with visual impairment as it does not require vision or the performance of regular exercises to learn successfully. Although the physiological rationale has not been fully evaluated, Alexander Technique lessons have been shown to reduce axial stiffness through the spine and enhance dynamic modulation of muscle tone.\textsuperscript{13}

The VISIBILITY study was designed to establish the impact of the Alexander Technique on physical functioning in community-dwelling older adults with visual impairments when compared to usual care. The outcomes were chosen due to their importance in their own right as well as their likely role in the prediction of falls. The protocol for this trial has been published elsewhere.\textsuperscript{14}

### 5.2 Methods

#### 5.2.1 Ethical approval

Ethical approval was granted by the Human Research Ethics Committees at the University of Sydney (Protocol no. 12985) and the University of New South Wales (HREC10277). The trial was registered with the Australian New Zealand Clinical Trials Registry at [http://www.ANZCTR.org.au/ACTRN12610000634077.aspx](http://www.ANZCTR.org.au/ACTRN12610000634077.aspx) (ACTRN12610000634077). The study described in this paper adhered to the tenets of the Declaration of Helsinki.
5.2.2 Participant recruitment

Participants were recruited from the client database of a community organisation providing support for people with visual impairments in Sydney, Australia (Guide Dogs). Participants were required to be 50-90 years of age, live within the Sydney metropolitan area, not need an interpreter, and have had Orientation & Mobility training within the previous five years. We included people from age 50 years as reliance on vision for postural stability in bilateral stance on compliant surfaces is evident in women in their 50’s.\textsuperscript{15} Further, the most recent data shows that 82\% of blind individuals and 65\% of those with visual impairments are over 50 years of age.\textsuperscript{16} We did not exclude people with neurological or cardio-thoracic disease in this study because incidence of breathing problems, diabetes, heart problems, hypertension and stroke is higher in people with visual impairments\textsuperscript{17} and we wanted our sample to be representative of this population.

Clients meeting these criteria were sent an invitation and follow-up phone calls were made to those who did not respond. Recruitment ran from August 2010 to August 2011, and 488 potential participants were contacted. Telephone screening by one researcher excluded clients who were not independently mobile, did not have conversational English, or were planning cataract surgery within 12 months. Participants were assessed at baseline, three and 12 months in their own homes. Participant flow through the trial is presented in Figure 5.1. The CONSORT statement \textsuperscript{18} was used to guide the content of this paper.

5.2.3 Trial design

This study used a randomized assessor-blinded controlled parallel group
design with equal numbers in the intervention and control groups.

5.2.4 Enrolment and assessment

Four Orientation & Mobility instructors from Guide Dogs attended a two-day training session on assessment procedures to ensure conformity to protocol. Written informed consent was obtained, demographic data collected and the Short Portable Mental Status Questionnaire\textsuperscript{19} administered prior to enrolment. Clients with two or less corrected errors on the Short Portable Mental Status Questionnaire were enrolled and the baseline assessment administered. Assessors informed one researcher who allocated a unique ID. They were then block-randomized (block permutation size 1, 2 and 4) using a computer generated list from http://www.randomization.com kept by a centre-based investigator who had no contact with the participants.

We were not able to include comprehensive vision assessments in baseline data collection as the assessments were performed in the participants’ homes. Instead we obtained written consent from participants to contact their eye care practitioner if a recent report was not available.

The nature of the study meant participants and the intervention provider could not be masked to group allocation. All outcome assessors remained masked to group allocation for all assessments, and participants were asked not to reveal their allocation status. The study was run in four blocks of 30 participants between September 2010 and December 2011, with the baseline assessment and randomisation occurring prior to commencement of each block.
5.2.5 Intervention

The control group received usual care from Guide Dogs and the intervention group received a weekly Alexander Technique lesson for 12 weeks in addition to usual care. Constraints on resources necessitated a reduction from a recommended 20-25 Alexander Technique lessons to 12 for this trial. This was chosen for feasibility of implementation and delivery within and beyond the study context. A factorial randomised trial for back pain found that six Alexander lessons followed by exercise prescription were nearly as effective as 25 lessons which provided some precedence for this reduction although the study populations are different and this was a novel intervention in the population with visual impairment.

Lessons are typically 30 minutes in length. They provide a cognitive construct for examining habitual responses to the familiar stimuli that precede voluntary movements and do not prescribe the strength and balance exercises common in traditional therapy programs. A lesson protocol was developed using everyday activities such as movements between sitting and standing (approximately one third of each lesson), getting to and from the floor (approximately one third of each lesson) and walking, climbing stairs and carrying everyday articles (the remainder). As subsequent lessons were based on prior progress, the lesson plan was modified as necessary. The Alexander Technique lessons were delivered by one person who is an accredited teacher of the Alexander Technique. The lesson protocol is available in Appendix 5.
5.2.6 Physical measures

The primary outcomes were the three items from the Short Physical Performance Battery\textsuperscript{20} at three months. These were five times sit-to-stand test, the four metre walk, and the standing balance test which includes side-by-side, semi-tandem, tandem and single limb balance tests. All the tests are timed, and better performance in the sit-to-stand and walking items is indicated by quicker performance and better performance in the standing balance test is indicated by holding each position longer. The study was powered using the three items from the battery individually (primary outcome), but as they are usually presented as a total score\textsuperscript{20} and more recently as a summary performance score\textsuperscript{21} we analysed the results individually and in the total and summary performance formats as well.

The 12 month measures from the Short Physical Performance Battery were secondary outcomes along with the postural sway tests from the Physiological Profile Assessment\textsuperscript{22} and the maximal balance range test\textsuperscript{23} at three and 12 months. The sway tests required participants to stand quietly for 30 seconds on firm and foam surfaces with eyes open and closed. Postural sway was traced on graph paper using a standardised instrument developed for the Physiological Profile Assessment.

Although the trial was not powered to detect an effect on fall rates, falls were collected prospectively with calendars over 12 months as this data would provide an indication of the size of any potential effect on falls. Participants recorded falls daily on calendars which were mailed to researchers on a monthly basis as recommended by the Profane Consensus.\textsuperscript{24} Electronic calendars were provided for those with accessible technology via email if
they were unable to use paper calendars. Where participants were unable to view the calendar, carers or family members agreed to manage the calendars on their behalf, and participants were contacted by telephone to record the details of any reported falls.

5.2.7 Falls efficacy
The Short Falls Efficacy Scale – International\textsuperscript{25} was also administered at baseline, three and 12 months as an additional secondary outcome related to participants concerns about falling.

5.2.8 Changes to protocol
Originally the primary outcomes were the three measures from the Short Physical Performance Battery at three and 12 months, however as there was uncertainty about effects beyond three months and for efficiency of project timelines, the 12 month outcomes were converted to secondary outcomes prior to the 12 month data collection or any data analysis (change to trial protocol made on 16 January 2012).

5.2.9 Sample size
Sample size calculations indicated that 60 individuals in each of the two groups (n = 120) would give the study 80% power to detect a 15% relative difference between the groups at a 5% level of significance allowing for 15% drop-outs during the 12 months. The sample size calculations used data from a previous study in a similar population.\textsuperscript{26} The estimates of between-group differences used in power calculations for the three primary outcomes measures were: five times Sit to Stand (effect 3.6 seconds, standard deviation 9.0, correlation between baseline and final measure 0.7), timed four metre walk (effect 0.1 meter/second, standard deviation 0.25, correlation
between baseline and final measure 0.7) and Standing Balance Test (effect
3.6 seconds, standard deviation 9.0, correlation between baseline and final
measure 0.7).

5.2.10 Statistical analysis
A statistical analysis plan was developed prior to analysis and is reproduced
as Appendix 4. Data were analysed on an intention to treat basis. Physical
assessment data at the three and 12 month visits for intervention and control
groups were compared with adjustment for baseline values using linear
regression models, and fall rates were compared using negative binomial
regression models. A per-protocol analysis based on participants who
received at least 50% of the intervention and four subgroup analyses were
specified in the statistical analysis plan. Sub-group analyses were
undertaken using interaction terms (group x sub-group variable) in the
models and sub-groups were based on a) level of cognitive impairment
(above and below the median), b) duration of visual impairment (above and
below the median), c) visual field status (presence or absence of peripheral
field in one or both eyes), and d) number of falls in the previous year (≤ 1
falls and ≥ 2 falls). A REDCap\textsuperscript{27} online database system was used to
manage all data after keyed data entry and 10% double-data entry confirmed
< 7% errors, none of these in key variables. Data were analysed with SAS
Version 9.2 and Stata Version 12.
Figure 5.1 Flow of participants through the VISIBILITY study
5.3 Results

Figure 5.1 shows participant flow through the study. Of the 488 clients identified by the database, 227 declined to participate, 65 did not meet the inclusion criteria and 72 could not be contacted. We assessed 124 potential participants in their homes and excluded four prior to randomisation for poor performance on the Short Portable Mental Status Questionnaire. We randomised 30 participants prior to the commencement of each intervention block (September 2010, January 2011, April 2011 and August 2011). Of the 120 participants who entered the study (Figure 5.1) ten did not complete all assessments.

The study population had a mean (SD) age of 75 (11) years, were predominantly female and the majority were visually impaired from age-related macular degeneration (Table 5.1). Physical measures at baseline revealed that the control group had a slightly lower level of physical functioning, (Table 5.2) however more people fell two or more times in the intervention group in the year prior to the study (Table 5.1).

5.3.1 Intention to treat analysis

Between-group differences in the three primary outcome tests from the Short Physical Performance Battery did not reach statistical significance at 3 months (Table 5.2). Between-group differences in the same measures as secondary outcomes were also not statistically significant at 12 months (Table 5.2). The total score\(^{20}\) and continuously-scored Summary Performance Score version\(^{21}\) of the Short Physical Performance Battery, and
the number of steps in the four metre walk at three and 12 months are also presented in Table 5.2. The number of steps in the four metre walk improved in the intervention group compared to the control group at three months after adjusting for baseline values (-0.90 steps, 95%CI, -1.56 to -0.23, p <0.01) suggesting increased confidence when walking.

The three and 12 month data for the balance tests are presented in Table 5.3. When adjusted for baseline, there was significantly less postural sway in the intervention group compared to the control group in the ‘Firm Surface Eyes Open’ condition at three months (-29.59mm, 95%CI -49.52 to -9.67, p <0.01). At 12 months there were no between-group differences in the physical measures although there was a trend to better performance in the maximal balance range measure (p = 0.07) in the intervention group.

There were no significant between group differences in intervention and control groups at three months (-0.69 points, 95%CI -1.77 to 0.38, p = 0.21) or 12 months (0.0008 points, 95%CI -1.26 to 1.26, p = 0.99) on the Short Falls Efficacy Scale – International.

5.3.2 Per-protocol analysis
Only four participants received less than 50% of the intervention and they withdrew before the post-intervention assessment, so the per-protocol analysis was not required.

5.3.3 Sub-group analyses
There was no indication of a differential effect of the intervention on the physical measures based on cognitive impairment or visual field status.
The subgroup analysis by duration of visual impairment produced variable results. There was an indication (interaction term p = 0.05) of a greater intervention impact on maximal balance range in those with a shorter duration of visual impairment but a greater impact on postural sway (interaction term p = 0.04) in those with a longer duration (> 14 years) of impairment at 12 months. Those with a longer duration of impairment also took longer to perform the chair stand at three months (interaction term p = 0.03). These results are presented in Table 5.4.

Analysis by subgroup based on number of falls in the previous year (multiple fallers ≥ 2 falls; non-multiple fallers ≤ 1 fall) showed larger between-group differences in multiple fallers on several tests at three months and 12 months. The intervention had a greater effect on multiple fallers compared to non-multiple fallers in three month measures of gait speed (interaction term p = 0.01; between group difference for multiple fallers after adjusting for baseline values 0.19 metres/second, 95%CI 0.03 to 0.36, p = 0.02; for non-multiple fallers -0.02 metres/second, 95%CI -0.12 to 0.08, p = 0.68) and steps taken in the 4 metre walk (interaction term p <0.01; between group difference for multiple fallers after adjusting for baseline values -2.20 steps, 95%CI -3.79 to -0.62, p <0.01; non-multiple fallers -0.32 steps, 95%CI -0.95 to 0.30, p = 0.31), and all the subgroup analyses by previous falls at three months are reported in Table 5.5.

The intervention also had a greater effect on multiple fallers compared to non-multiple fallers on the chair stand at 12 months (interaction term p < 0.01; between group difference for multiple fallers after adjusting for baseline
values, -5.40 seconds, 95%CI -8.78 to -2.03, p < 0.01; for non-multiple fallers 0.90 seconds, 95%CI -0.92 to 2.72, p =0.33) and all the significant subgroup analyses by previous falls at 12 months are reported in Table 5.6.

Subgroup analysis by cognitive impairment, duration of impairment, visual field status and previous falls did not reveal any significant sub-group differences between the intervention and control groups at three and 12 months on the Short Falls Efficacy Scale – International.

5.3.4 Falls
The mean number of calendars provided by the intervention group was 11.08 (range 0-12) and for the control group 11.03 (range 0-12). The mean number of falls was 0.93(range 0-7) in the intervention group and 1.37(range 0-17) in the control group. There were 82 falls in the control group compared to 56 falls in the intervention group. Injuries were reported in 54% of these falls, including three fractures and three head injuries, one of which lead to death (Table 5.7). Additional characteristics of the falls recorded by prospective calendars over 12 months are also provided in Table 5.7.

The unadjusted analysis (Table 5.8) showed a non-significant 33% lower rate of falls in the intervention group compared to the control group (IRR = 0.67, 95%CI 0.36 to 1.26, p = 0.22) and a 51% lower rate of injurious falls in the intervention group compared to the control group which approached statistical significance (IRR = 0.49, 95%CI 0.22 to 1.11, p = 0.09). A secondary analysis (Table 5.8) adjusted for past falls, visual field status and duration of impairment also revealed a non-significant 36% lower rate of falls in the intervention group compared to the control group (IRR = 0.64, 95%CI
0.34 to 1.15, p = 0.13) and a non-significant 39% lower rate of injurious falls in the intervention group compared to the control group (IRR = 0.61, 95%CI 0.28 to 1.30, p = 0.20).

As there were a small number of multiple fallers who fell > 10 times, there was some concern that this may have skewed the results so an additional analysis which capped falls at 10 per participant was performed. This analysis yielded similar results (Table 5.8). The incidence rate ratios for total and injurious falls adjusted for past falls are presented in Table 5.8 along with the subgroup analyses. Although increased falls risk and fall rates have been reported in individuals with neurological impairments\textsuperscript{28,29} the inclusion of these individuals was distributed across both groups in this study and did not negatively influence the outcomes (Table 5.1).
Table 5.1 Baseline demographic characteristics of VISIBILITY study participants

<table>
<thead>
<tr>
<th>Baseline demographic characteristics</th>
<th>Intervention group (N = 60)</th>
<th>Control group (N = 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years: mean (SD)</td>
<td>74.7 (10.9)</td>
<td>74.9 (11.0)</td>
</tr>
<tr>
<td>Female: n (%)</td>
<td>43 (72)</td>
<td>42 (70)</td>
</tr>
<tr>
<td>Education in years: mean (SD)</td>
<td>12.6 (3.9)</td>
<td>11.5 (3.8)</td>
</tr>
<tr>
<td>Corrected errors SPMSQ: mean (SD)</td>
<td>0.52 (0.83)</td>
<td>0.73 (0.86)</td>
</tr>
<tr>
<td>Duration impaired: years: median (IQR)</td>
<td>10.0 (18)</td>
<td>15.5 (38)</td>
</tr>
<tr>
<td>Neurological symptoms: n (%)</td>
<td>14 (23%)</td>
<td>10 (17%)</td>
</tr>
<tr>
<td>Falls in previous year: mean (SD)</td>
<td>2.5 (1.7)</td>
<td>2.9 (5.2)</td>
</tr>
<tr>
<td>≥ 2 falls in year prior to study n (%)</td>
<td>21 (35)</td>
<td>17 (28)</td>
</tr>
<tr>
<td>Number of medications: mean (SD)</td>
<td>5.5 (3.6)</td>
<td>5.3 (3.02)</td>
</tr>
<tr>
<td>Take psychotropic medication: n (%)</td>
<td>10 (17)</td>
<td>10 (17)</td>
</tr>
<tr>
<td>Legally blind: n (%)</td>
<td>46 (77)</td>
<td>49 (82)</td>
</tr>
<tr>
<td>Living alone: n (%)</td>
<td>37 (62)</td>
<td>34 (57)</td>
</tr>
<tr>
<td>Body Mass Index: Kg/m²</td>
<td>26.8 (5.0)</td>
<td>28.4 (4.9)</td>
</tr>
<tr>
<td>Comorbidities: mean (SD)</td>
<td>6.8 (3.3)</td>
<td>7.3 (3.2)</td>
</tr>
</tbody>
</table>

**Visual Acuity (vision report)**
- Better than 6/18: n (%) | 7 (12) | 7 (12)
- 6/18 to 6/60: n (%) | 6 (10) | 1 (2)
- 6/60 or worse: n (%) | 45 (75) | 49 (82)

**Field data (vision report)**
- Peripheral loss - one eye: n (%) | 4 (7) | 4 (7)
- Peripheral loss - both: n (%) | 13 (22) | 6 (10)
- Central loss - one eye: n (%) | 5 (8) | 4 (7)
- Central loss - both: n (%) | 17 (28) | 19 (32)
- Total Field involvement: n (%) | 9 (15) | 16 (27)

**Diagnosis by vision report**
- Macular disease: n (%) | 22 (37) | 25 (42)
- Glaucoma: n (%) | 9 (15) | 5 (8)
- Cerebral injury: n (%) | 4 (7) | 2 (3)
- Diabetic retinopathy: n (%) | 3 (5) | 3 (5)
- Retinitis Pigmentosa: n (%) | 9 (15) | 5 (8)
- Other: n (%) | 13 (22) | 20 (33)

**Assistance:**
- Agency assistance: n (%) | 26 (43) | 31 (52)
- Weekly or more: n (%) | 16 (27) | 18 (30)
- Family assistance: n (%) | 25 (42) | 27 (45)
- Weekly or more: n (%) | 20 (33) | 22 (37)

n = number, SD = standard deviation, IQR = Interquartile range, SPMSQ = Short Portable Mental Status Questionnaire
Table 5.2 Short Physical Performance Battery. Single items, total and summary performance scores and number of steps in 4 metre walk at 3 months and 12 months. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups with p values.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Groups</th>
<th>Difference within groups</th>
<th>Difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>3 Months</td>
<td>12 Months</td>
</tr>
<tr>
<td></td>
<td>Int (n = 60)</td>
<td>Con (n = 60)</td>
<td>Int (n = 55)</td>
</tr>
<tr>
<td>Standing Balance (seconds)</td>
<td>48.65 (9.37)</td>
<td>46.25 (8.70)</td>
<td>51.29 (7.45)</td>
</tr>
<tr>
<td>Chair Stand Test (seconds)</td>
<td>15.96 (5.27)</td>
<td>17.57 (6.12)</td>
<td>16.16 (5.19)</td>
</tr>
<tr>
<td>Gait Speed (metres per second)</td>
<td>0.98 (0.41)</td>
<td>0.89 (0.33)</td>
<td>0.96 (0.31)</td>
</tr>
<tr>
<td>Total Score (ordinal 0 -12)</td>
<td>8.58 (2.58)</td>
<td>7.85 (2.26)</td>
<td>9.06 (1.90)</td>
</tr>
<tr>
<td>Summary Performance Score (continuous 0 – 3)</td>
<td>2.25 (0.32)</td>
<td>2.13 (0.35)</td>
<td>2.30 (0.24)</td>
</tr>
<tr>
<td>Number of steps in 4 metre walk</td>
<td>8.92 (3.08)</td>
<td>8.86 (2.67)</td>
<td>8.36 (2.30)</td>
</tr>
</tbody>
</table>

Int = intervention group, Con = control group.

* Standing Balance, Chair Stand Test and Gait Speed were primary outcomes at 3 months and secondary outcomes at 12 months.
Table 5.3 Maximal Balance Range and Postural Sway tests from the Physiological Profile Assessment at 3 and 12 months (Secondary outcomes). Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups with p values

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Groups</th>
<th>Difference within groups</th>
<th>Difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline 3 Months 12 Months</td>
<td>3 Months minus Baseline</td>
<td>12 Months minus Baseline</td>
</tr>
<tr>
<td></td>
<td>Int (n = 60) Con (n = 60) Int (n = 55) Con (n = 58) Int (n = 55) Con (n = 56) Int Con Int Con Int Con</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal Balance Range (cm)</td>
<td>12.58 (4.21) 11.99 (3.46) 13.13 (4.35) 12.17 (3.52) 13.16 (3.60) 11.57 (3.60)</td>
<td>0.05 (3.60) 0.17 (3.12) 0.17 (3.64)</td>
<td>-0.62 (3.48) 0.22 (-0.96 to 1.40) 1.14 (-0.09 to 2.38)</td>
</tr>
<tr>
<td>Sway tests form the Physiological Profile Assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm Surface Eyes Open (total mm)</td>
<td>122.92 (81.33) 145.53 (180.37) 99.20 (46.63) 130.11 (89.28) 123.70 (79.44) 137.93 (78.93)</td>
<td>-22.74 (62.65) 6.09 (57.02) 3.38 (60.23)</td>
<td>14.91 (86.36) -29.59 (-49.52 to -9.67) 6.09 (-38.09 to 12.66)</td>
</tr>
<tr>
<td>Firm Surface Eyes Closed (total mm)</td>
<td>151.28 (104.11) 178.32 (117.70) 130.68 (83.61) 167.26 (117.91) 150.67 (104.85) 172.04 (113.68)</td>
<td>-14.40 (77.32) -4.88 (105.06) 1.24 (77.32)</td>
<td>4.16 (99.27) -20.60 (-52.16 to 10.95) 8.79 (-39.69 to 22.11)</td>
</tr>
<tr>
<td>Foam Surface Eyes Open (total mm)</td>
<td>353.81 (183.91) 342.39 (220.07) 351.21 (196.70) 322.07 (179.28) 299.15 (153.02) 321.17 (165.74)</td>
<td>5.54 (197.78) -10.36 (186.98) -36.13 (157.76)</td>
<td>-4.81 (193.68) 19.19 (-43.27 to 81.65) 34.45 (-88.58 to 19.67)</td>
</tr>
<tr>
<td>Foam Surface Eyes Closed (total mm)</td>
<td>465.24 (260.05) 482.83 (283.71) 491.10 (298.11) 442.82 (253.60) 471.47 (259.57) 471.72 (268.62)</td>
<td>42.70 (283.43) -37.00 (249.36) 24.96 (139.54)</td>
<td>3.64 (251.00) 60.88 (30.82 to 152.58) 11.35 (-64.72 to 87.42)</td>
</tr>
</tbody>
</table>

Int = experimental group, Con = control group, cm = centimeters, mm = millimeters
<table>
<thead>
<tr>
<th>Subgroup Analysis</th>
<th>Intervention</th>
<th>Control</th>
<th>Intervention</th>
<th>Control</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 14 years: mean (SD)</td>
<td>17.21 (5.78) n = 34</td>
<td>18.27 (6.67) n = 26</td>
<td>16.21 (5.13) n = 32</td>
<td>18.47 (6.62) n = 27</td>
<td>-1.21 (5.57) n = 31</td>
<td>-0.34 (3.40) n = 25</td>
</tr>
<tr>
<td>&gt; 14 years: mean (SD)</td>
<td>14.10 (3.80) n = 23</td>
<td>16.98 (5.67) n = 31</td>
<td>16.09 (5.38) n = 23</td>
<td>16.26 (5.58) n = 31</td>
<td>2.00 (3.54) n = 22</td>
<td>-1.38 (4.09) n = 30</td>
</tr>
</tbody>
</table>

At 12 months

<table>
<thead>
<tr>
<th>Subgroup Analysis</th>
<th>Intervention</th>
<th>Control</th>
<th>Intervention</th>
<th>Control</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 14 years: mean (SD)</td>
<td>12.82 (4.07) n = 35</td>
<td>11.54 (3.32) n = 28</td>
<td>13.77 (3.64) n = 31</td>
<td>10.57 (3.41) n = 25</td>
<td>0.4 (3.60) n = 31</td>
<td>-1.37 (3.54) n = 25</td>
</tr>
<tr>
<td>&gt; 14 years: mean (SD)</td>
<td>12.23 (4.47) n = 24</td>
<td>12.39 (3.59) n = 31</td>
<td>12.34 (4.86) n = 23</td>
<td>12.37 (3.61) n = 31</td>
<td>-0.16 (3.75) n = 22</td>
<td>-0.02 (3.37) n = 31</td>
</tr>
</tbody>
</table>

Primary outcomes: Short Physical Performance Battery Item

Chair Stand Test (seconds): Interaction terms for (duration impaired * group) p = 0.03

<table>
<thead>
<tr>
<th>≤ 14 years</th>
<th>≤ 14 years</th>
<th>&gt; 14 years</th>
<th>&gt; 14 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Baseline</td>
<td>Month 3</td>
<td>Baseline</td>
<td>Month 3</td>
</tr>
<tr>
<td>17.21 (5.78)</td>
<td>18.27 (6.67)</td>
<td>16.21 (5.13)</td>
<td>18.47 (6.62)</td>
</tr>
<tr>
<td>14.10 (3.80)</td>
<td>16.98 (5.67)</td>
<td>16.09 (5.38)</td>
<td>16.26 (5.58)</td>
</tr>
<tr>
<td>12.82 (4.07)</td>
<td>11.54 (3.32)</td>
<td>13.77 (3.64)</td>
<td>10.57 (3.41)</td>
</tr>
<tr>
<td>12.23 (4.47)</td>
<td>12.39 (3.59)</td>
<td>12.34 (4.86)</td>
<td>12.37 (3.61)</td>
</tr>
<tr>
<td>-1.21 (5.57)</td>
<td>2.00 (3.54)</td>
<td>-1.38 (4.09)</td>
<td>2.00 (3.54)</td>
</tr>
<tr>
<td>-0.34 (3.40)</td>
<td>-1.38 (4.09)</td>
<td>-0.34 (3.40)</td>
<td>-1.38 (4.09)</td>
</tr>
<tr>
<td>-1.10 (-3.25 to 1.05, p = 0.31)</td>
<td>2.44 (0.27 to 4.50, p = 0.03)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Secondary outcomes: Maximal balance range test; Sway tests from the Physiological Profile Assessment

Maximal Balance Range (cm): Interaction terms for (duration impaired * group) p = 0.05

<table>
<thead>
<tr>
<th>≤ 14 years</th>
<th>≤ 14 years</th>
<th>&gt; 14 years</th>
<th>&gt; 14 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Baseline</td>
<td>Month 12</td>
<td>Baseline</td>
<td>Month 12</td>
</tr>
<tr>
<td>111.74 (75.48)</td>
<td>167.86 (254.06)</td>
<td>136.90 (95.76)</td>
<td>127.12 (80.02)</td>
</tr>
<tr>
<td>138.56 (88.06)</td>
<td>126.00 (69.68)</td>
<td>105.91 (46.08)</td>
<td>146.65 (78.25)</td>
</tr>
<tr>
<td>11.54 (3.32)</td>
<td>23.74 (71.27)</td>
<td>127.12 (80.02)</td>
<td>127.12 (80.02)</td>
</tr>
<tr>
<td>105.91 (46.08)</td>
<td>111.74 (75.48)</td>
<td>105.91 (46.08)</td>
<td>105.91 (46.08)</td>
</tr>
<tr>
<td>0.4 (3.60)</td>
<td>19.19 (51.71)</td>
<td>19.19 (51.71)</td>
<td>19.19 (51.71)</td>
</tr>
<tr>
<td>-0.16 (3.75)</td>
<td>3.96 (102.55)</td>
<td>3.96 (102.55)</td>
<td>3.96 (102.55)</td>
</tr>
<tr>
<td>-0.02 (3.37)</td>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
</tr>
</tbody>
</table>

Firm Surface Eyes Open (mm): Interaction terms for (duration impaired * group) p = 0.04

<table>
<thead>
<tr>
<th>≤ 14 years</th>
<th>≤ 14 years</th>
<th>&gt; 14 years</th>
<th>&gt; 14 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Baseline</td>
<td>Month 12</td>
<td>Baseline</td>
<td>Month 12</td>
</tr>
<tr>
<td>111.74 (75.48)</td>
<td>167.86 (254.06)</td>
<td>136.90 (95.76)</td>
<td>127.12 (80.02)</td>
</tr>
<tr>
<td>138.56 (88.06)</td>
<td>126.00 (69.68)</td>
<td>105.91 (46.08)</td>
<td>146.65 (78.25)</td>
</tr>
<tr>
<td>111.74 (75.48)</td>
<td>167.86 (254.06)</td>
<td>136.90 (95.76)</td>
<td>127.12 (80.02)</td>
</tr>
<tr>
<td>138.56 (88.06)</td>
<td>126.00 (69.68)</td>
<td>105.91 (46.08)</td>
<td>146.65 (78.25)</td>
</tr>
<tr>
<td>-17.91 (65.33)</td>
<td>-17.91 (65.33)</td>
<td>-17.91 (65.33)</td>
<td>-17.91 (65.33)</td>
</tr>
<tr>
<td>23.74 (71.27)</td>
<td>23.74 (71.27)</td>
<td>23.74 (71.27)</td>
<td>23.74 (71.27)</td>
</tr>
<tr>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
<td>-13.15 (-25.53 to 51.82, p = 0.50)</td>
</tr>
</tbody>
</table>

cm = centimeters, mm = millimeters
### Table 5.5 Subgroup analysis by previous falls (Multiple fallers ≥2 or Non-multiple fallers ≤ 1) Significant interactions for Short Physical Performance Battery at 3 months

<table>
<thead>
<tr>
<th>Subgroup Analysis</th>
<th>Groups</th>
<th>Difference within groups</th>
<th>Difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Month 3</td>
<td>Baseline</td>
</tr>
<tr>
<td>Primary outcomes: Short Physical Performance Battery items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait Speed (metres per second): Interaction term for (previous falls*group) p = 0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers: mean (SD)</td>
<td>0.92 (0.39) n = 21</td>
<td>0.81 (0.35) n = 16</td>
<td>0.98 (0.38) n = 20</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>1.02 (0.41) n = 38</td>
<td>0.92 (0.32) n = 43</td>
<td>0.95 (0.29) n = 35</td>
</tr>
<tr>
<td>Summary Performance Score, Number of steps in 4 metre walk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summary Performance Score (continuous 0-3): Interaction term for (previous falls*group) p = 0.048</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers: mean (SD)</td>
<td>2.25 (0.27) n = 20</td>
<td>1.97 (0.44) n = 15</td>
<td>2.30 (0.26) n = 20</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>2.25 (0.35) n = 37</td>
<td>2.19 (0.29) n = 41</td>
<td>2.30 (0.24) n = 35</td>
</tr>
<tr>
<td>Number of steps in 4 metre walk: Interaction term for (previous falls*group) p = 0.008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers: mean (SD)</td>
<td>9.67 (3.40) n = 21</td>
<td>9.94 (3.28) n = 16</td>
<td>8.85 (2.78) n = 20</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>8.50 (2.72) n = 38</td>
<td>8.47 (2.33) n = 43</td>
<td>8.09 (1.96) n = 35</td>
</tr>
</tbody>
</table>
Table 5.6 Subgroup analysis by previous falls (Multiple fallers ≥ 2 or Non-multiple fallers ≤ 1) Significant interactions for Short Physical Performance Battery at 12 months

<table>
<thead>
<tr>
<th>Groups</th>
<th>Difference within groups</th>
<th>Difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 12 months</td>
<td>Baseline</td>
<td>Month 12</td>
</tr>
<tr>
<td>Secondary outcomes: Short Physical Performance Battery items, Total Score, Summary Performance Score, Number of steps in 4 metre walk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair Stand Test (seconds) Interaction term for (previous falls*group) p = 0.0004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers mean (SD)</td>
<td>15.45 (4.82) n = 20</td>
<td>19.35 (6.19) n = 16</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>16.23 (5.54) n = 37</td>
<td>16.87 (6.03) n = 41</td>
</tr>
<tr>
<td>Gait Speed (Metres per second) Interaction term for (previous falls*group) p = 0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers: mean (SD)</td>
<td>0.92 (0.39) n = 21</td>
<td>0.81 (0.35) n = 16</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>1.02 (0.41) n = 38</td>
<td>0.92 (0.32) n = 43</td>
</tr>
<tr>
<td>Total Score (Ordinal 0–12) Interaction term for (previous falls*group) p = 0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers: mean (SD)</td>
<td>8.52 (2.54) n = 21</td>
<td>6.94 (2.30) n = 17</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>8.62 (2.63) n = 39</td>
<td>8.21 (2.17) n = 43</td>
</tr>
<tr>
<td>Summary Performance Score (Continuous 0–3) Interaction term for (previous falls*group) p = 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple fallers: mean (SD)</td>
<td>2.25 (0.27) n = 20</td>
<td>1.97 (0.44) n = 15</td>
</tr>
<tr>
<td>Non-multiple fallers: mean (SD)</td>
<td>2.25 (0.35) n = 37</td>
<td>2.19 (0.29) n = 41</td>
</tr>
</tbody>
</table>
**Table 5.7 VISIBILITY falls data: Retrospective and prospective calendars for 12 months**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Prior Year (Self-report)</th>
<th>Study Year (Calendar)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>Total months recorded: n</td>
<td>665</td>
<td>662</td>
</tr>
<tr>
<td>Months per person: mean (SD)</td>
<td>11.08 (3.10)</td>
<td>11.03 (2.91)</td>
</tr>
<tr>
<td>Participants who fell: n (group %)</td>
<td>34 (57%)</td>
<td>32 (53%)</td>
</tr>
<tr>
<td>≥ 2 falls year: n (group %)</td>
<td>21 (35%)</td>
<td>17 (28%)</td>
</tr>
<tr>
<td>Falls per month: n</td>
<td>7.17</td>
<td>7.83</td>
</tr>
<tr>
<td>Falls per person year: n</td>
<td>1.43</td>
<td>1.57</td>
</tr>
<tr>
<td>Number of falls: n (total %)</td>
<td>86 (48%)</td>
<td>94 (52%)</td>
</tr>
<tr>
<td>Number of falls: mean (SD)</td>
<td>0.93 (1.55)</td>
<td>1.37 (3.08)</td>
</tr>
<tr>
<td>Inside falls: n (group %)</td>
<td>15 (27%)</td>
<td>34 (41%)</td>
</tr>
<tr>
<td>Outside falls: n (group %)</td>
<td>41 (73%)</td>
<td>47 (57%)</td>
</tr>
<tr>
<td>Total injurious falls: n (group %)</td>
<td>25 (45%)</td>
<td>50 (61%)</td>
</tr>
<tr>
<td>Head injuries: n (group %)</td>
<td>0 (0%)</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Fractures: n (group %)</td>
<td>1 (2%)</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Sprains: n (group %)</td>
<td>2 (4%)</td>
<td>10 (12%)</td>
</tr>
<tr>
<td>Cuts: n (group %)</td>
<td>15 (27%)</td>
<td>9 (11%)</td>
</tr>
<tr>
<td>Other: n (group %)</td>
<td>16 (28%)</td>
<td>33 (40%)</td>
</tr>
<tr>
<td>Cause of fall:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tripped: n (group %)</td>
<td>29 (52%)</td>
<td>48 (59%)</td>
</tr>
<tr>
<td>Slipped: n (group %)</td>
<td>11 (20%)</td>
<td>8 (10%)</td>
</tr>
<tr>
<td>Lost balance: n (group %)</td>
<td>8 (14%)</td>
<td>11 (13%)</td>
</tr>
<tr>
<td>Other: n (%)</td>
<td>8 (14%)</td>
<td>15 (18%)</td>
</tr>
<tr>
<td>Time of fall:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:00 &lt; fall ≤ 06:00</td>
<td>0 (0%)</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>06:00 &lt; fall ≤ 12:00</td>
<td>20 (36%)</td>
<td>32 (39%)</td>
</tr>
<tr>
<td>12:00 &lt; fall ≤ 18:00</td>
<td>30 (54%)</td>
<td>22 (27%)</td>
</tr>
<tr>
<td>18:00 &lt; fall ≤ 24:00</td>
<td>3 (5%)</td>
<td>11 (13%)</td>
</tr>
</tbody>
</table>

**Table 5.8 Fall rate analysis by group allocation**

<table>
<thead>
<tr>
<th>Primary unadjusted analysis:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All falls (IRR = 0.67, 95%CI 0.36 to 1.26, p = 0.216)</td>
<td></td>
</tr>
<tr>
<td>Injurious falls (IRR = 0.49, 95%CI 0.22 to 1.11, p = 0.089)</td>
<td></td>
</tr>
<tr>
<td>Adjusted for past falls:</td>
<td></td>
</tr>
<tr>
<td>All falls (IRR = 0.79, 95%CI 0.44 to 1.42, p = 0.431)</td>
<td></td>
</tr>
<tr>
<td>Injurious falls (IRR = 0.60, 95%CI 0.28 to 1.29, p = 0.193)</td>
<td></td>
</tr>
<tr>
<td>Falls (capped at 10) adjusted for past falls (capped at 10):</td>
<td></td>
</tr>
<tr>
<td>All falls (IRR = 0.81, 95%CI 0.46 to 1.42, p = 0.463)</td>
<td></td>
</tr>
<tr>
<td>Injurious falls (IRR = 0.57, 95%CI 0.26 to 1.26, p = 0.165)</td>
<td></td>
</tr>
<tr>
<td>Adjusted for past falls, duration of impairment, visual fields</td>
<td></td>
</tr>
<tr>
<td>All falls (IRR = 0.64, 95%CI 0.34 to 1.15, p = 0.13)</td>
<td></td>
</tr>
<tr>
<td>Injurious falls (IRR = 0.61, 95%CI 0.28 to 1.30, p = 0.20)</td>
<td></td>
</tr>
<tr>
<td>Subgroup Analyses: There were no significant subgroup differences</td>
<td></td>
</tr>
<tr>
<td>Previous falls: ≤ 1 fall (n= 82) or ≥ 2 falls (n= 38) in previous year;</td>
<td>p = 0.709</td>
</tr>
<tr>
<td>Duration impaired: ≤ 14 years (n = 56) &gt;14 years (n = 53);</td>
<td>p = 0.820</td>
</tr>
<tr>
<td>Visual fields: Yes (n = 52) /no (n = 59) peripheral field involvement;</td>
<td>p = 0.723</td>
</tr>
</tbody>
</table>
5.4 Discussion

Between-group differences in the primary outcomes were not significant, however the number of steps in the 4-metre walk and postural sway in quiet standing both improved significantly in the intervention group at three months, suggesting an improvement in balance. There were also greater intervention effects in the subgroup of multiple fallers who are at an increased risk of injury compared to non-multiple fallers.

Around one third of people over 65 years of age in the general population fall each year, but we found a 43% fall rate in our study. Injuries were reported in 54% of the falls in this study, which is also higher than the 31.3% rate reported in the general older population. This highlights the vulnerability of this population to fall-related injury and the need to identify interventions with the potential to reduce this level of risk. Although the study was not powered for falls the trend towards a lower rate of falls and injurious falls in the intervention group is an encouraging result given that fall reduction from a physical intervention has not been reported in community-dwelling older adults with visual impairments to date.

The Alexander Technique emphasises the need for more perceptual awareness in activity and does not use repetitive exercises or strength training. The focus is on quality of movement and economy of effort, and teaches the individual how to best use the resources they have to perform ordinary daily activities. For this reason there would not necessarily be an expectation that performance speeds would increase, although this is likely
in those whose performance is poor, and improved performance could theoretically lead to increased mobility over time.

Older adults with visual impairments have a higher risk of falls due to limited environmental preview and the impact of reduced visual input on postural control. This helps explains why home modification and safety programs reduce falls in this population. The Alexander Technique does not require the regular performance of exercises and so may be a more acceptable intervention in this vulnerable population as it may not put the participants at perceived risk of harm.

Physical performance measures are routinely used in clinical trials and so it is increasingly important to determine if identified changes are clinically meaningful. Perera et al suggested that 0.10 m/s was a substantial meaningful change in gait speed for a four metre walk. Our study was powered to detect an effect size of 0.10 m/s, and the between-group difference in the sub-group of multiple fallers was 0.19 m/s i.e., almost twice the substantial meaningful change. This needs to be interpreted with caution as it is a sub-group analysis but indicates the potential impact of the tested intervention.

The improvement in gait speed in multiple fallers in our study was not maintained at 12 months, but their performance on the chair stand test at 12 months was better than multiple fallers in the control group after adjusting for baseline (Table 5.6), indicating a maintenance effect of the intervention beyond three months. It may be that a higher and more sustained dose than we were able to provide is needed in order to maintain the effect over a
longer time period, but this would require further study.

5.4.1 Limitations
One of the limitations of this trial was the lack of a placebo group to control for the effect of touch and personal attention received by the intervention group. This was due to limited resources that did not allow for an active control with social visits or sham exercise each week, and so caution is required when interpreting the findings of this study due to this limitation. Additionally there were a high number of physical functioning tests administered, which raises the issue of multiplicity of analysis. We acknowledged this in our statistical analysis plan and cautioned on the interpretation of any results above $p = 0.025$ in the analysis. Given that most of the reported between group differences met this criteria this is unlikely to have been a major issue.

The other major limitation was limiting the Alexander Technique intervention to 12 lessons. The results of the ATEAM back pain trial\textsuperscript{10} did show that a smaller number of lessons could be of benefit, and as research into the therapeutic benefits of the Alexander Technique in different populations has only recently begun the dosage level for a therapeutic effect has yet to be established with certainty.

5.4.2 Strengths
A strength of the study was that we did not exclude people with neurological or cardio-thoracic disease, making our findings more translatable to all of the visually impaired population. It should be pointed out however that strategies to prevent falls in people with neurological impairments have yet to be clearly
ascertained, and as 20% of participants self-reported neurological symptoms in the study, this may have impacted on our findings.

5.5 Conclusion

The Alexander Technique is a novel intervention that has not been previously trialled in community-dwelling older adults with visual impairments. This study did not find a significant impact of Alexander lessons on the primary outcomes, however the improvement in balance in quiet standing, the improved gait speed in the subgroup of multiple fallers, along with indications of a possible reduction in the rate of all falls and injurious falls suggests an effect of the Alexander Technique on physical functioning and physical falls risk in older adults with visual impairments.

That the intervention was successfully delivered in the participants homes makes it a candidate program for delivery to a population that has difficulty accessing generic fall prevention programs provided in the community, and is worthy of further investigation in a trial powered to measure its impact on fall rates. Based on the estimates from this study a sample size of 350 (175/arm) will have 80% power to detect a significant 33% lower rate of falls (IRR = 0.67) for the participants receiving the Alexander Technique compared to control participants (assuming a dispersion parameter of 0.8 and a two-sided level alpha=5%).
Contributorship: MG CS and LK were responsible for the conception and design of the study. SL was responsible for statistical design and support. MG CS SL and LK were all involved in the drafting, revision and final approval of the paper.

Acknowledgements: The authors would like to acknowledge Guide Dogs NSW/ACT for the support that allowed this study to succeed. Dr. John Black supported the study, Ewa Borkowski helped co-ordinate the study, and Jessie Chen, Karen Doobov, Kelly Prentice and Kerrie Suffolk conducted all of the assessments.

Competing interests: The authors declare they have no competing interests.

Funding: Guide Dogs NSW/ACT provided substantial 'in-kind' support. The Australian Society of Teachers of the Alexander Technique and the FM Alexander Trust (UK) both provided small grants to support the study. Michael Gleeson received an Australian Postgraduate Award Scholarship from the Australian Federal Government. Catherine Sherrington’s salary is funded by the Australian National Health and Research Council. Lisa Keay’s salary is funded by the Australian Research Council.
5.6 References


6 SOCIAL AND EMOTIONAL WELLBEING

6.1 Introduction

Aging and visual impairment are associated with loss of function and reduced quality of life\(^1\) which can lead to depression.\(^2\)\(^-\)\(^4\) As the severity of depression increases, levels of disability increase, and quality of life and physical and mental functioning decline.\(^5\) Compared to older adults with normal vision, older adults with visual impairment are 2-5 times more likely to have depression,\(^2\)\(^6\) and the prevalence of depression increases as visual impairment becomes more severe.\(^7\)

In a large population-based survey in the USA, Crews et al\(^8\) found that 57.2% of older adults with visual impairments were at risk of mild or moderate depression, and 6.2% were at risk of severe depression. Both visual impairment and depression have independent impacts on physical, social and emotional functioning, however they tend to exacerbate the effects of each other to magnify disability and reduce quality of life.\(^9\)

A study of older adults who had recently contacted a vision rehabilitation agency and were screened to include recent diagnosis showed fewer depressive symptoms, greater life satisfaction and better adaptation to vision loss when people received effective assistance from family and friends,\(^10\) but these studies did not looked at the effects of long-term visual impairment. A residential blind rehabilitation program provided by the Department of Veteran Affairs in the US improved vision targeted health-related quality of
life, self-esteem and mental health and these effects were maintained at six months post rehabilitation, however this model of service delivery is not the dominant model in Australia, where services are typically community-based and client driven.

The ability to access late-life peers is dependent on mobility and the ability to socialize. Socialization has been found to be significantly lower in older adults with visual impairments with 60% of this reduced social participation explained by depressive symptoms and visual impairment. Data from the National Health Interview Survey in the USA found that adults with visual impairments and depressive symptoms were more likely to be obese, inactive, smoke, have fair-poor health and have difficulties with self-care and social participation than those with neither condition. Although this data does not indicate a causal relationship it does highlight the possible impact of visual impairment, restricted mobility and depressive symptoms on quality of life.

Mobility provides a means of independence and has been found to have a positive impact on health and wellbeing in the general population. In a review of behavioural and health factors that contribute to age decline, visual impairment rates as one of the highest risks of functional decline. Even when independent travel is not severely restricted the inability to recognize familiar faces and to read subtle non-verbal cues can add to social isolation in this population. Physical activity in old age can reduce the onset of disabilities and illness, as well as maintain independence and foster positive wellbeing. Multimodal exercise programs that have been shown to
prevent falls in the general population have not been effective in community-dwelling older adults with visual impairment to date. We hypothesized that lessons in the Alexander Technique would improve physical functioning and reduce the physical risk of falls and it was further hypothesized that if the Alexander Technique did improve physical functioning, it may have an additional effect on mobility and emotional well-being.

### 6.2 Method

The methodology for the VISIBILITY study has been described in the protocol paper in Chapter 4 and again in Chapter 5 for the main physical outcomes of the study so is not reproduced here.

#### 6.2.1 Ethical approval

Ethical approval was described in section 5.2.1.

#### 6.2.2 Participant recruitment

Participant recruitment was described in section 5.2.2. The CONSORT statement was used to guide the content of this paper.

#### 6.2.3 Intervention

The control group (n = 60) received usual care from Guide Dogs NSW/ACT and the intervention group (n = 60) received 12 lessons in the Alexander Technique in addition to usual care. Constraints on resources necessitated a reduction from 20-25 Alexander Technique lessons (recommended) to 12 for this trial and the lesson protocol is reproduced in Appendix 5. Subsequent lessons were based on prior progress, and the lesson plan was modified as necessary. The Alexander Technique lessons were delivered by one person.
who is an accredited Teacher of the Alexander Technique.

6.2.4 Physical measures
The physical measures used in the study, which included the primary outcomes have been described in Chapter 5. The social and emotional data reported here were collected as secondary outcomes to complement the physical measures and to characterise this population. Because all participants were clients of Guide Dogs NSW/ACT, and assessments were conducted in their homes we did not include vision assessments in baseline data collection but contacted their eye care practitioner if a recent report was not available.

6.2.5 Social and emotional measures
The data on social and emotional measures was collected at baseline, three and 12 month assessment points along with the physical measures used in the study by Orientation & Mobility instructors from Guide Dogs NSW/ACT who had undergone a two-day training on the assessment procedures prior to baseline assessments.

The Perceived Visual Ability Scale (PVAS)\textsuperscript{24} is a 35 item questionnaire that rates difficulty in a range of mobility situation performed without assistance from usual aids. A higher PVAS score equates to greater difficulty with mobility.

The Keele Assessment of Participation (KAP)\textsuperscript{25} is an 11 item questionnaire that captures participants perception of their actual involvement in a variety of mobility, self-care and social situations. Responses are arranged on a scale (0 – 4) with zero representing “all of the time” and 4 representing “none
of the time”. A higher score on the KAP represents less self-reported participation.

The emotional subscale from the Impact of Vision Impairment Profile (IVI)\textsuperscript{26} uses eight items to capture the degree to which the participant perceives their visual impairment causes emotional distress. Responses are on a scale (0 - 3) with zero representing “a lot of the time” and 3 representing “not at all”. A lower score on the IVI represents a higher impact of visual impairment and so a lower emotional well-being.

We administered the five item version of the Geriatric Depression Scale (GDS-5)\textsuperscript{27} to capture the extent to which participants’ subjective mobility and emotional status was manifest as symptoms of depression given the known association between visual impairment and depressive symptoms. Used as a screening tool, a score of two or more indicates possible depression in the general public. Rovner\textsuperscript{28} found that the 30-item Geriatric Depression Scale had poor discriminatory power to determine major depression in the population with visual impairment, but that it was valuable as a measure of symptomatology.

We also administered the positive scale of the Positive and Negative Affect Scale (PANAS)\textsuperscript{29} to include a measure of mood. The PANAS is a ten item questionnaire to determine the extent to which the participant feels enthusiastic, active and alert, and we used a subset of this instrument to gauge the level of positive emotional affect participants experienced. Responses are arranged on a scale (1 - 5) with 1 representing “very slightly or not at all” and 5 representing “extremely”, so a higher score represents
greater positive affect.

Socialization was measured as the frequency with which participants visited family or friends, and scored as a binary variable of weekly or more versus less than weekly interactions. Family and agency assistance were also measured in this manner.

6.2.6 Sample size
The study was powered to measure the impact of the Alexander Technique on physical function such that 60 individuals in each of the two groups \( n = 120 \) would give the study 80% power to detect a 15% between group difference at a 5% level of significance allowing for 15% drop-outs during the 12 months for the primary outcomes used in the study.\(^22\) The social and emotional well-being data were collected as secondary outcomes and were not included in the sample size calculations.

6.2.7 Statistical analysis
A REDCap\(^{30}\) online database system was used to manage all data. A statistical analysis plan was developed and is reproduced in Appendix 4. The responses to the PVAS and IVI-emotional sub-scale were scored using Rasch analysis (Winsteps Version 3.75.1) and person scores converted to a 1-100 score. Higher transformed Rasch scores relate to poorer performance on the tests.

Data were analysed on an intention to treat basis (ITT) with SAS Version 9.2. The validated questionnaires data at the three and 12 month visits were compared between the intervention and control groups with adjustment for baseline values using linear regression models.
We examined whether any useful associations could be drawn from our data that would help explain depressive symptoms at three months. Baseline data on living situation, years of education, Body Mass Index (BMI), comorbidities and anti-depressive medication were investigated as predictors of depressive symptoms at three months.

The three month data included socialisation, family and agency support, gait speed and the validated questionnaires. As two or more self-reported symptoms are indicative of possible depression in the general population, we created a binary variable for the GDS-5 scores of <2 or ≥ 2 symptoms, and used logistic regression models. If the variable had a significance of at least p = 0.20 in a univariate analysis it was included in the initial multivariate logistic regression model adjusted for age, gender and group allocation. We used a backwards stepwise method to determine the final model.

6.3 Results

Table 6.1 shows the demographic characteristics of the two groups and their performance on the validated questionnaires at baseline. There were no significant differences in scores at 3 and 12 months after adjusting for baseline (Table 6.2), although the emotional subscale of the IVI approached significance in favour of improved impact of visual impairment on emotional well-being in the intervention group at 3 months (difference 4.54 points, 95%CI: -0.14 to 9.21, p = 0.06). As only four participants received less than 50% of the intervention, and they withdrew before the intervention was completed, we had no data for them and the per-protocol analysis was not required.
Table 6.1 Baseline demographic characteristics of VISIBILITY study participants

<table>
<thead>
<tr>
<th>Baseline Demographic Characteristics</th>
<th>Intervention Group (N = 60)</th>
<th>Control Group (N = 60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years: Mean (SD)</td>
<td>74.72 (10.87)</td>
<td>74.88 (11.04)</td>
</tr>
<tr>
<td>Female: n (%)</td>
<td>43 (72)</td>
<td>42 (70)</td>
</tr>
<tr>
<td>Education in years: Mean (SD)</td>
<td>12.62 (3.89)</td>
<td>11.53 (3.83)</td>
</tr>
<tr>
<td>Corrected errors SPMSQ: Mean (SD)</td>
<td>0.52 (0.83)</td>
<td>0.73 (0.86)</td>
</tr>
<tr>
<td>Duration impaired: years: median (IQR)</td>
<td>10.0 (18)</td>
<td>15.5 (38)</td>
</tr>
<tr>
<td>Neurological symptoms: n (%)</td>
<td>14 (23)</td>
<td>10 (17)</td>
</tr>
<tr>
<td>Legally blind</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no: n (%)</td>
<td>14 (23)</td>
<td>11 (18)</td>
</tr>
<tr>
<td>yes: n (%)</td>
<td>46 (77)</td>
<td>49 (82)</td>
</tr>
<tr>
<td>Diagnosis by vision report:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macular disease: n (%)</td>
<td>22 (37)</td>
<td>25 (42)</td>
</tr>
<tr>
<td>Peripheral disease: n (%)</td>
<td>18 (30)</td>
<td>10 (16)</td>
</tr>
<tr>
<td>Other: n (%)</td>
<td>20 (33)</td>
<td>25 (42)</td>
</tr>
<tr>
<td>Falls in previous year: Mean (SD)</td>
<td>2.53 (1.67)</td>
<td>2.94 (5.19)</td>
</tr>
<tr>
<td>Prescription medication: Mean (SD)</td>
<td>5.48 (3.56)</td>
<td>5.27 (3.02)</td>
</tr>
<tr>
<td>Takes psychotropic medication: n (%)</td>
<td>10 (17)</td>
<td>10 (17)</td>
</tr>
<tr>
<td>Living Alone: n (%)</td>
<td>37 (62)</td>
<td>34 (57)</td>
</tr>
<tr>
<td>Bmi: Kg/m²</td>
<td>26.77 (4.96)</td>
<td>28.37 (4.92)</td>
</tr>
<tr>
<td>Comorbidities: Mean (SD)</td>
<td>6.80 (3.33)</td>
<td>7.30 (3.19)</td>
</tr>
<tr>
<td>Agency assistance:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly or more: n (%)</td>
<td>16 (27)</td>
<td>18 (30)</td>
</tr>
<tr>
<td>Less than weekly: n (%)</td>
<td>10 (17)</td>
<td>13 (22)</td>
</tr>
<tr>
<td>Family assistance:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly or more: n (%)</td>
<td>20 (33)</td>
<td>22 (37)</td>
</tr>
<tr>
<td>Less than weekly: n (%)</td>
<td>5 (8)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>Socialisation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly or more: n (%)</td>
<td>29 (48)</td>
<td>34 (57)</td>
</tr>
<tr>
<td>Less than weekly: n (%)</td>
<td>31 (52)</td>
<td>26 (43)</td>
</tr>
<tr>
<td>Gait speed: metres/second</td>
<td>0.98 (0.41)</td>
<td>0.89 (0.33)</td>
</tr>
<tr>
<td>Validated questionnaires</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Visual Ability Scale (1-100)</td>
<td>48.6 (7.9)</td>
<td>48.6 (9.4)</td>
</tr>
<tr>
<td>Short Falls Efficacy Scale (1-28)</td>
<td>12.5 (4.2)</td>
<td>12.4 (4.9)</td>
</tr>
<tr>
<td>Keele Assessment of Participation (0-44)</td>
<td>4.1 (4.7)</td>
<td>2.7 (3.8)</td>
</tr>
<tr>
<td>Impact of Vision Impairment Profile (1-100)</td>
<td>43.8 (16.1)</td>
<td>46.8 (18.3)</td>
</tr>
<tr>
<td>Positive and Negative Affect Scale (1-50)</td>
<td>33.1 (8.4)</td>
<td>33.4 (7.3)</td>
</tr>
<tr>
<td>5-Item Geriatric Depression Scale (1-5)</td>
<td>1.3 (1.4)</td>
<td>1.4 (1.3)</td>
</tr>
<tr>
<td>≥ 2 depressive symptoms at baseline</td>
<td>22 (37)</td>
<td>23 (38)</td>
</tr>
</tbody>
</table>

SPMSQ = Short Portable Mental Status Questionnaire
Table 6.2 Secondary outcomes: Validated questionnaires at 3 and 12 months
Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups with p values

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Groups</th>
<th>Difference within groups</th>
<th>Difference between groups</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline (Exp = n = 60, Con = n = 60)</td>
<td>3 Months (Exp = n = 55, Con = n = 59)</td>
<td>12 Months (Exp = n = 55, Con = n = 56)</td>
<td>3 Months minus Baseline</td>
</tr>
<tr>
<td>GDS-5 [0 – 5]</td>
<td>mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.32 (1.41)</td>
<td>1.38 (1.28)</td>
<td>1.29 (1.36)</td>
<td>1.34 (1.47)</td>
</tr>
<tr>
<td>PANAS [0 - 50]</td>
<td>mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33.13 (8.38)</td>
<td>33.35 (6.69)</td>
<td>34.57 (7.56)</td>
<td>35.04 (8.55)</td>
</tr>
<tr>
<td>IVI [0 – 100]</td>
<td>mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>43.80 (16.11)</td>
<td>48.89 (20.06)</td>
<td>46.01 (17.06)</td>
<td>49.77 (18.91)</td>
</tr>
<tr>
<td>PVAS [0 - 100]</td>
<td>mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>48.62 (7.94)</td>
<td>48.59 (9.38)</td>
<td>49.01 (7.84)</td>
<td>47.04 (8.51)</td>
</tr>
<tr>
<td>SFES-I [0 – 28]</td>
<td>mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12.45 (4.19)</td>
<td>12.37 (4.42)</td>
<td>12.08 (4.25)</td>
<td>12.47 (5.65)</td>
</tr>
<tr>
<td>KAP [0 - 44]</td>
<td>mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.12 (4.68)</td>
<td>2.68 (3.79)</td>
<td>3.95 (4.31)</td>
<td>4.24 (4.76)</td>
</tr>
<tr>
<td>KAP subgroup</td>
<td>Full peripheral field mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.93 (3.58)</td>
<td>2.00 (3.65)</td>
<td>4.21 (3.53)</td>
<td>4.88 (5.41)</td>
</tr>
<tr>
<td>KAP subgroup</td>
<td>Peripheral field loss mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.83 (5.29)</td>
<td>3.14 (4.12)</td>
<td>3.29 (4.67)</td>
<td>4.07 (4.62)</td>
</tr>
</tbody>
</table>

Exp = experimental group, Con = control group, PAVS = Perceived Visual Ability Scale, SFES-I = Short Falls Efficacy Scale International, KAP = Keele Assessment of Participation, IVI = Impact of Vision Impairment Profile, PANAS = Positive and Negative Affect Scale, GDS-5 = 5 Item Geriatric Depression Scale , Grey shading = Subgroup analysis by visual field status for KAP
Table 6.3 Predictors of ≥ 2 self-reported depressive symptoms at 3 months: odds ratios from univariate and multivariate logistic regression analyses model the likelihood of having 2 or more depressive symptoms (N = 112)

<table>
<thead>
<tr>
<th>Variable</th>
<th>&lt; 2 Depressive symptoms</th>
<th>≥ 2 Depressive symptoms</th>
<th>Odds Ratio in Univariate analysis</th>
<th>Odds ratio in Multivariate analysis Variables remaining in model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender male: n (%)</td>
<td>22 (28)</td>
<td>13 (33)</td>
<td>1.27 (0.56 to 2.89)</td>
<td></td>
</tr>
<tr>
<td>Age: years mean (SD)</td>
<td>74.81 (10.76)</td>
<td>74.78 (11.34)</td>
<td>1.00 (0.97 to 1.04)</td>
<td></td>
</tr>
<tr>
<td>Group – intervention: n (%)</td>
<td>41 (51)</td>
<td>19 (46)</td>
<td>1.16 (0.54 to 2.48)</td>
<td></td>
</tr>
<tr>
<td>Education: years mean (SD)</td>
<td>12.53 (3.78)</td>
<td>11.18 (3.99)</td>
<td>0.91 (0.82 to 1.01)</td>
<td></td>
</tr>
<tr>
<td>Living alone: n (%)</td>
<td>50 (63)</td>
<td>21 (53)</td>
<td>0.66 (0.31 to 1.43)</td>
<td></td>
</tr>
<tr>
<td>Legally blind: n (%)</td>
<td>61 (76)</td>
<td>34 (85)</td>
<td>1.76 (0.64 to 4.84)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities: n mean (SD)</td>
<td>6.66 (2.97)</td>
<td>7.83 (3.69)</td>
<td>1.12 (0.99 to 1.26)</td>
<td></td>
</tr>
<tr>
<td>BMI: Kg/m^2: mean (SD)</td>
<td>27.72 (4.69)</td>
<td>27.27 (5.58)</td>
<td>0.98 (0.91 to 1.06)</td>
<td></td>
</tr>
<tr>
<td>Anti-depressive medication: n (%)</td>
<td>15 (19)</td>
<td>5 (13)</td>
<td>0.62 (0.21 to 1.85)</td>
<td></td>
</tr>
<tr>
<td>Gait speed: metres/second: mean (SD)</td>
<td>0.96 (0.30)</td>
<td>0.82 (0.32)</td>
<td>1.16 (1.01 to 1.32) *</td>
<td>1.27 (1.06 to 1.54) * p = 0.01</td>
</tr>
<tr>
<td>PVAS: 1 – 100: mean (SD)</td>
<td>47.25 (8.20)</td>
<td>49.43 (8.13)</td>
<td>1.03 (0.99 to 1.09)</td>
<td></td>
</tr>
<tr>
<td>Socialisation: weekly or more: n (%)</td>
<td>41 (56)</td>
<td>16 (40)</td>
<td>0.52 (0.24 to 1.14)</td>
<td></td>
</tr>
<tr>
<td>Family assistance: weekly or more: n (%)</td>
<td>34 (47)</td>
<td>17 (43)</td>
<td>0.83 (0.38 to 1.80)</td>
<td></td>
</tr>
<tr>
<td>Agency assistance: weekly or more: n (%)</td>
<td>18 (25)</td>
<td>13 (33)</td>
<td>1.47 (0.63 to 3.44)</td>
<td></td>
</tr>
<tr>
<td>KAP (0 – 44)</td>
<td>2.45 (3.71)</td>
<td>5.55 (4.53)</td>
<td>1.19 (1.08 to 1.32)</td>
<td></td>
</tr>
<tr>
<td>IVI (0 - 100)</td>
<td>54.89 (14.04)</td>
<td>33.76 (17.13)</td>
<td>1.10 (1.06 to 1.15) *</td>
<td>1.12 (1.07 to 1.17) * p&lt; 0.0001</td>
</tr>
<tr>
<td>SFES-I (0 – 28)</td>
<td>11.57 (4.15)</td>
<td>14.41 (6.05)</td>
<td>1.12 (1.03 to 1.21)</td>
<td></td>
</tr>
<tr>
<td>Previous Falls: ≥ 2 falls in previous year</td>
<td>22 (28)</td>
<td>16 (40)</td>
<td>1.76 (0.79 to 3.91)</td>
<td></td>
</tr>
<tr>
<td>Duration of impairment: &gt; 14 years n (%)</td>
<td>36 (45)</td>
<td>21 (53)</td>
<td>1.35 (0.63 to 2.89)</td>
<td></td>
</tr>
</tbody>
</table>

*per 0.1ms * decrease in gait speed
* per unit decrease in IVI score
At baseline, 45 of 120 participants (38%) reported two or more symptoms of depression on the GDS-5. As expected there was a strong negative correlation between scores on the GDS-5 and positive emotions reported on the PANAS ($R = -0.445$, $p < 0.0001$) and this was not considered in models predicting depressive symptoms.

A correlation analysis investigated the strength and direction of the association between remaining variables of interest and a score of $\geq 2$ on the GDS-5 at three months. There was a highly significant negative correlation between scores on the emotional sub-scale of the IVI and GDS-5 score ($r = -0.557$, $n = 113$, $p < 0.0001$). Those who scored $\geq 2$ on the GDS-5 had a higher impact of visual impairment on emotional well-being. There was a highly significant positive correlation between KAP scores and GDS-5 scores ($r = 0.349$, $n = 113$, $p = 0.0002$). Those who scored $\geq 2$ on the GDS-5 had a higher level of dependence on others and less participation, and finally there was a significant negative correlation between gait speed and GDS-5 scores ($r = -0.208$, $n = 112$, $p = 0.028$). Those who scored $\geq 2$ on the GDS-5 had slower gait speeds. Socialisation was positively correlated to gait speed ($r = 0.223$, $n = 112$, $p = 0.018$) suggesting that those with slower gait speeds socialised less.

The variables that qualified for inclusion in the multivariate model were years of education, number of comorbidities, gait speed, socialisation, the Perceived Visual Ability Scale, the Keele Assessment of Participation and the emotional sub-scale of the Impact of Vision Impairment Profile (Table
6.3. As expected, after adjusting for age, gender and group allocation, vision-related emotional distress (IVI score) was associated with likely depression in this population (OR 1.12, 95%CI: 1.07 to 1.17, p < 0.001). The only other variable that remained significant in the model was gait speed (OR 1.27, 95%CI: 1.06 to 1.54, p = 0.01).

6.4 Discussion

The Alexander Technique intervention did not have an impact on measures of social and emotional wellbeing at three or 12 months in this trial. This is not surprising as the main hypothesis of the study was that Alexander Technique lessons would improve physical functioning related to falls risk and any such benefits were secondary to this main aim. There was a trend for less visual impairment-related emotional distress in the intervention group and this may have been due to the intervention improving mobility which indirectly impacted emotional wellbeing. This needs to be confirmed in a larger trial as it did not persist at 12 months, indicating a short term effect.

There was a high level of self-reported depressive symptoms across the total sample in the study, and this confirms findings from other studies in the population with visual impairments. A recent cluster randomised study of 383 General Practices in Australia reported a 1.8% prevalence of major depressive episodes in Australians over 60 years of age with 8% experiencing clinically significant depressive symptoms. Significant factors linked to depressive symptoms and aging in the general population are level of mobility, assistance, socialization and emotional wellbeing.
therefore not surprising that the degree of visual impairment-related emotional distress is highly correlated to general depressive symptoms.

Gait speed is an objective measure of mobility and faster gait speeds were associated with less depressive symptoms. Mobility is a key factor in maintaining positive wellbeing into old age, providing a means of freedom, independence and quality of life. The Alameda County Study found a protective effect of greater physical activity for both prevalent and incident depression after adjusting for age, sex, ethnicity, financial strain, chronic conditions, disability, BMI, alcohol consumption, smoking, and social relations over 5 years. An 8-year prospective longitudinal study on the impact of physical and leisure activity on mental well-being in the elderly found that a higher level of leisure activity, better levels of mobility and a low level of chronic health conditions predicted mental well-being in later life.

What was surprising was that other factors that are seen to be protective in the general population, such as socialisation and level of assistance from agencies and family, did not appear to influence depressive symptoms in our study. Restricted mobility can make activities of daily living more demanding and exhausting, and increase the time needed to perform these daily functions. This can lead to the need for assistance from others to perform activities that were previously performed independently. Although this may provoke feelings of dependence which may be perceived negatively, levels of assistance may also be a protective factor against depression. We did not find an association between levels of support and depressive symptomatology in our study.
However, the participants in the study were all clients of Guide Dogs NSW/ACT, and had all sought agency assistance for problems relating to their mobility, so comparison with findings in the general population with visual impairments, which is more heterogeneous, may be misleading. Low levels of socialization can contribute to depression, and increased levels of social participation have been shown to reduce levels of depressive symptoms.\textsuperscript{45} Restricted mobility and limited assistance affect the ability to socialise, which further impacts emotional wellbeing. Although emotional expression becomes more predictable and stable with age, social networks become less accessible, physical functioning requires more effort and sensory losses add strain to social interactions. Collectively these changes can lead to negative emotional wellbeing due to embarrassment, frustration, loneliness and feeling like a burden, all of which are correlated with depression.\textsuperscript{26}

In our sample 79% of participants were legally blind, and 59% lived alone with 28% reporting weekly or more agency assistance and 35% reporting weekly or more family assistance. There was a significant negative correlation between family and agency assistance suggesting that there was good access to agency support where family support was unavailable. Although support from family and friends has been shown to reduce self-reported depressive symptoms in older adults who have been recently diagnosed with visual impairments\textsuperscript{10} follow-up work has shown that friendship support is more important than family support for long-term adaptation.\textsuperscript{46} The mean (SD) duration of visual impairment in our sample was 22.4 (21.8) years. Only one participant had been visually impaired for
less than two years, and 76% of the sample had been visually impaired for >
5 years, so long-term adaptation may be more relevant in this study.

6.4.1 Study limitations
A key limitation to the VISIBILITY study as a whole was the lack of an active
control group to allow for the effect of touch and personal attention received
by the intervention group for the 12 weeks of the intervention. Given there
was no impact of the intervention on social and emotional measures at three
and 12 months this does not appear to impact heavily on the findings relating
to depression presented here.

All the participants in the study were clients of Guide Dogs NSW/ACT in
Sydney, Australia and this means that their visual impairment was severe
enough to require professional assistance from Orientation & Mobility
specialist for mobility training. This may constitute a degree of selection bias,
given that all participants were proactive enough to seek support, and that
those who agreed to participate in the research may have less inter-personal
problems than those who did not. If this was the case, it would tend to
underestimate the prevalence of depressive symptomatology that may exist
in the wider community in older adults with visual impairments.

Another limitation of the study was that we did not differentiate between
friend and family support which may have been relevant given the duration of
visual impairment in our sample. Finally, we were unable to definitively
diagnose depression or differentiate between early and late onset
depression.
6.5 Conclusion

A greater recognition of the vulnerability of this population to depression will help families, primary health care providers and support networks to engage in a way that encourages maximal independence and a realistic but positive disposition. The value of maintaining friendships has been highlighted in other work\textsuperscript{46} and should be encouraged by care providers. Orientation and Mobility instructors provide training to visually impaired individuals to enhance their mobility and independence. Programs are tailored to individual client needs and can include training in the use of canes, guide dogs and electronic travel aids, along with safe strategies for pedestrian and public transport travel. Referral for mobility training by eye care practitioners may be another way to minimize the impact of visual impairment on the development of depressive symptoms by maintaining mobility and the access to social networks that provide protection against depressive symptoms.

In conclusion, while lessons in the Alexander Technique improved some physical functioning, particularly in the subgroup of multiple fallers, and may reduce falls risk (see Chapter 5) the impact on emotional well-being, participation and depressive symptoms was not evident. This population had a high prevalence of depressive symptoms and our data suggest that better mobility and a lesser emotional distress associated with vision loss was protective against likely depression. It is important that eye care practitioners are aware of the psychosocial impact of visual impairment, particularly on older clients, so that treatments and rehabilitation outcomes are optimized.\textsuperscript{47}
6.6 References


44. Moak ZB, Agrawal A. The association between perceived interpersonal social support and physical and mental health: results from the national epidemiological survey on alcohol and related conditions. *J. Public Health* 2010;32(2):191-201.


7 PROCESS EVALUATION

The VISIBILITY study was an assessor-blind randomised controlled trial to evaluate the impact of the Alexander Technique on physical functioning in older adults with visual impairments. Because the primary outcomes in the main intention to treat analysis were not significant but there were some encouraging findings in the secondary analyses and in the subgroup analyses based on previous falls, we undertook further analyses to determine whether there were any factors that may help explain these results.

It is particularly important to monitor fidelity when evaluating new interventions. If the program implementation is not monitored there is no way of knowing if findings are due to the tested intervention’s effectiveness or to unknown factors that were added or omitted from the intervention. Conversely if there was a null finding and there was no monitoring of fidelity you cannot be sure whether this was the result of an ineffective intervention or due to poor implementation of the intervention.\textsuperscript{1,2} This is particularly so in complex interventions, where the intervention is not as easily standardised, as for example the delivery of a drug may be. The social context in which an intervention is delivered\textsuperscript{3} and the need to respond to the challenges of the moment, particularly in community-based deliveries can alter the way material is presented across sites or individuals.

The framework proposed by Saunders \textit{et al}\textsuperscript{4} was used to evaluate the
comprehensiveness of recruitment for lessons in the Alexander Technique amongst older adults with visual impairments, the reach of the program, the context of delivery, program fidelity, participant satisfaction and the exposure or dose of the program. Recommendations were sought about implementation and any dose effects explaining the effectiveness of the Alexander Technique as a falls prevention intervention strategy in older people with visual impairments.

7.1 Methods

The VISIBILITY study used an assessor-blinded controlled parallel group design with equal numbers in both the intervention and control groups (n=120). Here we report on the process evaluation of the study using data from the intervention group (n=60). The methods for the VISIBILITY study have been documented extensively in Chapter 4 (the study protocol) and more briefly in the results chapters (Chapters 5 and 6) and so will not be repeated here.

The lesson plan developed for the Alexander Technique intervention of the VISIBILITY study outlined a consistent program for all participants (Appendix 5). All the Alexander lessons were delivered by the teacher who developed the lesson plan (the PhD candidate), who is a qualified Teacher of the Alexander Technique with over 20 years of teaching experience.

7.1.1 Physical measures

The primary outcomes for the study were the three items from the Short Physical Performance Battery (SPPB)\(^5\) at three months. These have been
described in Section 4.4.6 in chapter 4. The individual items were continuous variables, but the SPPB also has an ordinal scale to assign a total summary score for the entire test.\(^6\) Although our study was only powered to use the items separately, we also converted the individual scores to the total summary score on the ordinal scale (0-12) and to the continuous version of the summary score\(^7\) (0-1 per item, total 3) as these scores are commonly reported in the literature and would allow for some comparison if they approached significance. The physical measures that were secondary outcomes are described in Section 4.4.7 in Chapter 4.

### 7.1.2 Social and Emotional measures

A number of validated questionnaires were administered along with the physical outcome measures as we had hypothesised that if the intervention improved mobility there may have been an additional benefit to social and emotional well-being. These social and emotional measures have likewise been described in Section 4.4.7 in Chapter 4, and more extensively in Chapter 6 where those results are discussed (Section 6.2.5). Following the approach of Saunders et al\(^4\) we evaluated the comprehensiveness of recruitment, the reach of the program, the context of delivery, program fidelity, participant satisfaction and program exposure or dose.

### 7.1.3 Recruitment, reach and context of delivery

Participants were recruited through Guide Dogs NSW/ACT. The study was first announced as an item on a regular client audio newsletter called “Soundtracks”. This was followed by a database search that sought all clients between 50 and 90 years of age who had received a mobility program in the
previous five years. At the time of the study inception, all older adults requiring Orientation & Mobility training in the Eastern Sydney Region were referred to Guide Dogs NSW/ACT, which provided almost all of the mobility services in this area. Clients from a range of socio-economic and cultural backgrounds are represented in the database. We excluded those who required an interpreter, as the study required that participants have conversational English.

Eligible clients were contacted by Guide Dogs NSW/ACT using their preferred format. This included standard font size, large print (clients can designate the font size), e-mail, audio CD or Braille. This allowed for a comprehensive recruitment strategy that did not bias against clients based on information accessibility.

The program was delivered in the participants’ homes, giving all eligible clients equal access to the study, as they were not required to travel to a central location. We chose to deliver the program in participants’ homes for a number of reasons. Travel to unfamiliar locations, often on public transport, is difficult for many older adults with visual impairments and can increase exposure to the possibility of injury and provoke anxiety. A home based program delivery meant that all participants were seen in a familiar environment where contextually relevant discussion of everyday movement, the basis of the program, could be appropriately provided.

7.1.4 Program fidelity

Fidelity was assessed in terms of successful delivery of the essential components of the intervention in this population. Participants were offered
one Alexander lesson per week in their homes for 12 consecutive weeks. All
the lessons for the study were provided by the same teacher which provided
a continuity and consistency of program delivery.

The critical elements of the program were defined in the lesson plan
(Appendix 5) and used as a structure to assess fidelity. This described the
conceptual themes and related activities for a sequence of 12 lessons. The
underpinnings of the Alexander Technique are a number of inter-related
concepts that relate to how we think as we engage in habitual activities, and
how we respond to the stimulus to move and the sensory feedback that it
produces. An understanding of these concepts was built up over the 12
lesson series.

The nature of the Alexander Technique delivery meant that if a particular
individual needed more than one lesson on an identified theme, they did not
move onto the next concept until they had grasped the previous one, and not
all participants completed all the activities that were described. The teacher
made written notes of progress through the lesson plan and deviations from
the plan were recorded for each participant.

7.1.5 Participant satisfaction

A post-intervention follow-up questionnaire was conducted over the
telephone by research staff with no prior contact with the participants at least
one month after completion of the intervention (Appendix 6). The
questionnaire was designed to measure the acceptability of the program. A
5-point Likert scale (strongly disagree, disagree, neutral, agree, strongly
agree) assessed responses to nine statements about the Alexander
Technique and a further six open-ended questions were asked to allow pupils to elaborate on any aspects of the lessons that were not covered by this formal structure.

7.1.6 Dose

All participants were given equal access to a standardised program, and absorbed as much of the offered material as they were capable of in the number of lessons they received. Dose in the context of an educational program has been defined as the amount of program content that the participants received. It has been suggested that self-reports by teachers using logs and checklists may overestimate dose. Additional material that can provide a better estimate include attendance data for each participant and appraisal of sample lessons to assess the proportion of the curriculum that was covered.

Dose was quantified based on three parameters: program delivery, program receipt and enactment. Program delivery is based simply on the number of lessons received. The concept of program receipt involves quantifying the participants’ understanding and demonstrable knowledge of a program and their ability to use the skills learned in the program, and was assessed by teacher evaluation. The third concept is that of enactment, which measures the participants’ ability to implement what they have learned in their real-life, and this was measured by participant report.

7.1.6.1 Program delivery (number of lessons)

In the statistical analysis plan for the main study we proposed a per protocol analysis based on those participants who had at least 50% of the
intervention, but as only four participants had < 50% of the lessons, and they all withdrew prior to the post-intervention assessment at three months, the per protocol analysis was not required (see Chapter 5). The number of lessons received was analysed as a continuous variable (0-12) to determine whether the dosage level may have had an effect on study outcome measures.

7.1.6.2 Program receipt (teacher evaluation)

Notes were kept on each Alexander lesson in the participant’s lesson logs and these were used to estimate their level of participation. Participants were scored on three domains for each of the 12 possible lessons. If the lesson was cancelled by the participant, or they did not attend they scored 0 for that lesson. Table 7.1 shows how participants were scored for each domain.

<table>
<thead>
<tr>
<th>Domain</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>Cancelled</td>
<td>Disengaged</td>
<td>Neutral</td>
<td>Interested</td>
</tr>
<tr>
<td>Awareness</td>
<td>Cancelled</td>
<td>Low</td>
<td>Prompted</td>
<td>Independent</td>
</tr>
<tr>
<td>Ability</td>
<td>Cancelled</td>
<td>Unresponsive</td>
<td>Facilitated</td>
<td>Independent</td>
</tr>
</tbody>
</table>

The first domain was ‘engagement’, and referred to the participant’s degree of personal involvement in each Alexander lesson. The second domain was ‘awareness’. This referred to body awareness, the degree to which participants could perceive changes in their neuromuscular state during the lesson. The final domain was ‘ability’ and this referred to the participant’s ability to respond to improved body awareness by releasing previously unnoticed tension or improving their overall co-ordination in activity. Figure 7.1 shows some examples of individual participant’s scores over the
intervention period based on teacher evaluated progress to illustrate how they were scored. The scores from the teacher evaluated progress were used in an analysis of the study outcomes as a continuous variable (0-108).

7.1.6.3 Enactment (participant report)

Based on responses to the post-intervention questionnaire, the participants who received the intervention were placed into one of two groups by a researcher not involved with the delivery of the intervention. The groups were based on whether a participant perceived they had benefitted or not from the Alexander lessons.

7.1.7 Statistical analysis

Simple descriptive statistics were produced from the post-intervention questionnaire to assess participant satisfaction and the acceptability of the Alexander Technique as an intervention in the population with visual impairments. Physical, social and emotional outcome data at the three and 12 month visits were modelled, with adjustment for baseline values, using linear regression models and the three measures of dose (program delivery, program receipt and enactment) as independent variables. The strength and direction of association between these three measures was assessed in a correlation analysis. Univariate cut-off entry into the multivariate models was set at $p \leq 0.25$. Backwards stepwise elimination was used until only those variables with $p < 0.05$ remained. Data were analysed with SAS Version 9.
<table>
<thead>
<tr>
<th>Example ID</th>
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<th>Ability</th>
<th>Total Lessons</th>
</tr>
</thead>
<tbody>
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<td>21</td>
</tr>
<tr>
<td></td>
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<td>low</td>
<td>neutral</td>
<td></td>
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<td></td>
<td>neutral</td>
<td>low</td>
<td>hospital</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutral</td>
<td>hospital</td>
<td>hospital</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutral</td>
<td>hospital</td>
<td>hospital</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutral</td>
<td>hospital</td>
<td>hospital</td>
<td></td>
</tr>
<tr>
<td>Example 2</td>
<td>neutral</td>
<td>low</td>
<td>neutral</td>
<td>11</td>
</tr>
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<td></td>
<td>neutral</td>
<td>low</td>
<td>neutral</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>cancelled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>disengaged</td>
<td>low</td>
<td>cancelled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>disengaged</td>
<td>low</td>
<td>cancelled</td>
<td></td>
</tr>
<tr>
<td>Example 3</td>
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<td>low</td>
<td>neutral</td>
<td>7</td>
</tr>
<tr>
<td></td>
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<td>low</td>
<td>cancelled</td>
<td></td>
</tr>
<tr>
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<td>disengaged</td>
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</tr>
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<td></td>
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<td>low</td>
<td>interested</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutral</td>
<td>low</td>
<td>interested</td>
<td></td>
</tr>
<tr>
<td>Example 5</td>
<td>neutral</td>
<td>low</td>
<td>cancelled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutral</td>
<td>low</td>
<td>cancelled</td>
<td></td>
</tr>
<tr>
<td>Example 6</td>
<td>neutral</td>
<td>low</td>
<td>interested</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutral</td>
<td>low</td>
<td>interested</td>
<td></td>
</tr>
<tr>
<td>Example 7</td>
<td>interested</td>
<td>independent</td>
<td>cancelled</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.1 Examples of individual participant's score for 'Program Receipt' based on teacher evaluation.
7.2 Results

7.2.1 Recruitment, reach and context of delivery

Of the 488 clients identified by the database search, 76 (16%) could not be contacted and 227 (47%) declined to participate. This left 185 potential recruits of whom 65 were excluded as not meeting all the inclusion criteria, a response rate of 38%. Home based delivery enabled good program reach. The baseline demographic characteristics of the intervention group are presented in Table 7.2.

7.2.2 Program fidelity

The lesson plan developed for the VISIBILITY study had to cater to a heterogeneous sample of visually impaired adults, and so required both fundamental material that was applicable to all, and a range of activities that would suit a variety of abilities, levels of visual impairments and settings. Some activities were not appropriate for all participants and were modified as necessary.

One lesson used stairs as an activity, but access to stairs was not available for 16 of the participants and so we could only use a modified activity for that lesson. Another aspect of the program was a self–awareness thought activity lying in semi-supine (on the back with the knees bent and the feet on the floor). Most participants could manage this (40 of 60), although some found it difficult.
Table 7.2 Baseline demographic characteristics of intervention group (n = 60)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years: Mean (SD)</td>
<td>74.72 (10.87)</td>
</tr>
<tr>
<td>Female: n (%)</td>
<td>43 (72)</td>
</tr>
<tr>
<td>Education in years: Mean (SD)</td>
<td>12.62 (3.89)</td>
</tr>
<tr>
<td>Corrected errors SPMSQ: mean (SD)</td>
<td>0.52 (0.83)</td>
</tr>
<tr>
<td>Duration impaired: years: median (IQR)</td>
<td>10.0 (18)</td>
</tr>
<tr>
<td>Neurological symptoms: n (%)</td>
<td>14 (23)</td>
</tr>
<tr>
<td>Falls in previous year: Mean (SD)</td>
<td>2.53 (1.67)</td>
</tr>
<tr>
<td>Prescription medication: Mean (SD)</td>
<td>5.48 (3.56)</td>
</tr>
<tr>
<td>Takes psychotropic medication: n (%)</td>
<td>10 (17)</td>
</tr>
<tr>
<td>Legally Blind: n (%)</td>
<td>46 (77)</td>
</tr>
<tr>
<td>Living Alone: n (%)</td>
<td>37 (62)</td>
</tr>
<tr>
<td>BMI: Kg/m²</td>
<td>26.77 (4.96)</td>
</tr>
<tr>
<td>Comorbidities: Mean (SD)</td>
<td>6.80 (3.33)</td>
</tr>
</tbody>
</table>

**Visual Acuity (vision report)**

<table>
<thead>
<tr>
<th>Visual Acuity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better than 6/18: n (%)</td>
<td>7 (12)</td>
</tr>
<tr>
<td>6/18 to 6/60: n (%)</td>
<td>6 (10)</td>
</tr>
<tr>
<td>6/60 or worse: n (%)</td>
<td>45 (75)</td>
</tr>
</tbody>
</table>

**Field Data (vision report)**

<table>
<thead>
<tr>
<th>Field Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral loss -one eye: n (%)</td>
<td>4 (7)</td>
</tr>
<tr>
<td>Peripheral loss -both: n (%)</td>
<td>13 (22)</td>
</tr>
<tr>
<td>Central loss -one eye: n (%)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>Central loss –both: n (%)</td>
<td>19 (32)</td>
</tr>
<tr>
<td>Total Field involvement: n (%)</td>
<td>9 (15)</td>
</tr>
</tbody>
</table>

**Diagnosis by vision report**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macular disease: n (%)</td>
<td>22 (37)</td>
</tr>
<tr>
<td>Glaucoma: n (%)</td>
<td>9 (15)</td>
</tr>
<tr>
<td>Cerebral injury: n (%)</td>
<td>4 (7)</td>
</tr>
<tr>
<td>Diabetic retinopathy: n (%)</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Retinitis Pigmentosa: n (%)</td>
<td>9 (15)</td>
</tr>
<tr>
<td>Other: n (%)</td>
<td>13 (22)</td>
</tr>
</tbody>
</table>

**Agency assistance: n (%)**

<table>
<thead>
<tr>
<th>Assistance</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency assistance: n (%)</td>
<td>26 (43)</td>
</tr>
<tr>
<td>Weekly or more: n (%)</td>
<td>16 (27)</td>
</tr>
<tr>
<td>Family assistance: n (%)</td>
<td>25 (42)</td>
</tr>
<tr>
<td>Weekly or more: n (%)</td>
<td>20 (33)</td>
</tr>
</tbody>
</table>

Legally blind = best corrected visual acuity of 6/60 or less in the better eye; or a visual field limitation to within 10 degrees of fixation in the better eye irrespective of corrected visual acuity; or a combination of visual defects resulting in the same degree of visual impairment as that occurring in the above points.

Getting to and from the floor is a useful skill to maintain for someone at risk of falling as the ability to get up again (if not seriously injured) can be the difference between a reasonable recovery or a long period of discomfort waiting for help to arrive. Where feasible, the activity was broken down into constituent parts and used as an instructional activity for those likely to
benefit from it. One third of the participants were not able to get to and from the floor so were not able to engage in this activity.

7.2.3 Participant satisfaction

Of the 60 participants in the intervention group, four withdrew from the study, one could not be contacted following the intervention and one was deaf and could not be interviewed by telephone. Responses from the remaining 54 participants are reported. Figure 7.2 shows participant responses to nine statements about the Alexander Technique measured by a Likert scale. Most participants enjoyed learning the Alexander Technique (87%) and found it easy to apply (82%). Many felt it helped their mobility (58%), although a substantial proportion (29% neutral, 3% disagree) did not. Generally people felt it improved their body awareness (70%), which lead them to attend more to the performance of everyday activities (75%). Most indicated they had gained a better understanding of how their bodies moved (75%), were confident they could continue to practice the Alexander Technique in their daily lives (75%), and would recommend it to others (82%).

A further six open ended questions were asked, allowing participants to elaborate on aspects of their experience that were not covered by the categorical responses and a summary of the responses to those questions is presented in Table 7.3.
Figure 7.2 Likert scale responses to statements about the Alexander Technique from the post-intervention questionnaire
### Table 7.3 Post-intervention questionnaire: main themes from open-ended questions

<table>
<thead>
<tr>
<th>Response</th>
<th>N (%)</th>
<th>Key words or themes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Did you feel comfortable having lessons in the Alexander technique?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>51 (85)</td>
<td>Comfortable: comfort, very happy, terrific, surprise, relaxing</td>
</tr>
<tr>
<td>No</td>
<td>3 (5)</td>
<td>Initial concern: trust, uncertainty, got used to it</td>
</tr>
<tr>
<td>Missing</td>
<td>6 (10)</td>
<td></td>
</tr>
<tr>
<td><strong>How did you feel about the level of touch involved?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>51 (85)</td>
<td>Acceptable: fine, comfortable, normal, appropriate</td>
</tr>
<tr>
<td></td>
<td>9 (15)</td>
<td>No feeling of intrusion or invasion: “explained and pre-empted what he was doing”</td>
</tr>
<tr>
<td>Negative</td>
<td>3 (5)</td>
<td>Initial concern: embarrassed - generation gap, clothing</td>
</tr>
<tr>
<td>Missing</td>
<td>6 (10)</td>
<td></td>
</tr>
<tr>
<td><strong>How do you feel your mobility has changed as a result of having the lessons?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>23 (38)</td>
<td>Improved: better posture, balance and control of movement, more confident, decreased falls</td>
</tr>
<tr>
<td>Not sure</td>
<td>14 (23)</td>
<td>Maybe: not sure, possibly, generally good already</td>
</tr>
<tr>
<td>No</td>
<td>17 (29)</td>
<td>Very little difference: other health issues, not enough – only once a week (dosage)</td>
</tr>
<tr>
<td>Missing</td>
<td>6 (10)</td>
<td></td>
</tr>
<tr>
<td><strong>Were there any unexpected outcomes from having the lessons?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>22 (37)</td>
<td>Improvement in self, increased confidence, balance, awareness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surprised: better on stairs, in and out of chair, to and from floor, walking without a stick, bending over</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No pins and needles (1), less back and neck pain (1), chronic vertigo gone (1)</td>
</tr>
<tr>
<td>No</td>
<td>32 (53)</td>
<td>No unexpected outcomes</td>
</tr>
<tr>
<td>Missing</td>
<td>6 (10)</td>
<td></td>
</tr>
<tr>
<td><strong>What is the main thing you learned from the lessons?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnt</td>
<td>52 (87)</td>
<td>Understanding self, performance and reactions, confidence, awareness, posture, balance</td>
</tr>
<tr>
<td></td>
<td>21 (35)</td>
<td>The importance of managing balance, to stretch regularly, to move slowly, take care with obstacles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discipline and the positive idea of regular practice was of benefit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alexander lessons affect health: relaxation, pain management, confidence</td>
</tr>
<tr>
<td>Nothing</td>
<td>2 (3)</td>
<td>Didn’t feel I learnt much</td>
</tr>
<tr>
<td>Missing</td>
<td>6 (10)</td>
<td></td>
</tr>
<tr>
<td><strong>How has this impacted on your everyday activities?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>44 (73)</td>
<td>Increased confidence, better balance, able to participate, awareness</td>
</tr>
<tr>
<td></td>
<td>17 (28)</td>
<td>In and outside of house and in unfamiliar areas. Better able to participate in hobbies; gardening, knitting, singing, sitting at computer. Could breathe better in choir. More aware of neck and shoulder position led to decreased head, neck and shoulder discomfort.</td>
</tr>
<tr>
<td>Not sure</td>
<td>4 (7)</td>
<td>Overriding health issues were of more concern</td>
</tr>
<tr>
<td>Nothing</td>
<td>6 (10)</td>
<td>No impact</td>
</tr>
<tr>
<td>Missing</td>
<td>6 (10)</td>
<td></td>
</tr>
</tbody>
</table>
7.2.4 Dose

The average number of lessons attended across the whole intervention group was 10 (range 1-12). As four participants in the intervention group withdrew the mean number of lessons on which we had three month data available for comparison was 11 (range 7–12).

The scores on program receipt (teacher evaluated) were an average of 67.33 (range 4-104) across the whole intervention group and 71.41 (range 35–104) for those with three month data, and 35 of 58 participants (60%) were rated as benefitting from the program (enactment). There was a very strong positive correlation between program delivery and program receipt ($r^2 = 0.8055$, $p < 0.0001$), with program delivery (number of lessons) explaining around 80% of program receipt (teacher evaluation). This is to be expected given that teacher evaluated program receipt was scored on each lesson individually.

Interestingly although there was also a strong positive correlation ($r^2 = 0.3149$, $p = 0.016$) between program delivery (number of lessons) and enactment (participant evaluation), program delivery only explained around 31% of enactment. Likewise, although there was a very strong positive correlation ($r^2 = 0.3777$, $p = 0.004$) between program receipt (teacher evaluation) and enactment (participant evaluation), program receipt only explained 38% of the enactment. This shows that even though the correlations were strong and positive, the participants evaluated the effect of the intervention differently to the teacher, and this justifies the inclusion of these variables in the regression models.
The impact of the measures of dose on the outcome measures are presented in Table 7.4 at three months and Table 7.5 at 12 months. In all instances, only one variable remained predictive of intervention effect in multivariate models.

### 7.2.5 Program delivery (number of lessons)

Performance on the chair stand test, a primary outcome at three months improved as the number of lessons increased (-0.98 seconds, 95%CI: -1.83 to -0.14, p = 0.02) however this was not maintained at 12 months. Paradoxically, performance on the standing balance test at three months was slightly reduced, although this was not statistically significant and not present at 12 months (-1.19 seconds, 95%CI: -2.41 to 0.02, p = 0.054). While this seems like a contrary trend, older adults with reduced visual input have been shown to stiffen their legs as a strategy to maintain their postural integrity\textsuperscript{12} so the Alexander lessons may have reduced this preparatory to teaching a better overall coordination, resulting in poorer performance on the timed test.
Table 7.4 Relationship between outcome measures for intervention group and Program Delivery, Receipt and Enactment at 3 months. All analyses adjusted for baseline and estimates represent the beta coefficients in linear regression models. Significant results are bolded.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Delivery</th>
<th>Receipt</th>
<th>Enactment</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate (P)</td>
<td>Estimate (P)</td>
<td>Estimate (P)</td>
<td>Estimate (95% confidence interval) p value</td>
</tr>
<tr>
<td>Standing balance (sec)</td>
<td>-1.194 (0.05)</td>
<td>-0.072 (0.12)</td>
<td>-0.513 (0.78)</td>
<td>Delivery: -1.19 (-2.41 to 0.02) p = 0.054</td>
</tr>
<tr>
<td>Chair stand test (sec)</td>
<td>-0.983 (0.02)</td>
<td>-0.099 (&lt;0.01)</td>
<td>-1.896 (0.13)</td>
<td>Receipt: -0.10 (-0.16 to -0.40) p = 0.002</td>
</tr>
<tr>
<td>Gait speed (sec)</td>
<td>0.013 (0.63)</td>
<td>0.002 (0.26)</td>
<td>0.075 (0.30)</td>
<td></td>
</tr>
</tbody>
</table>

Secondary outcomes: from Short Physical Performance Battery

| Number of steps in 4 metre walk | -0.003 (0.99) | -0.007 (0.54) | 0.212 (0.61) |
| Total score - ordinal (0 -12)   | -0.066 (0.65) | 0.010 (0.37)  | 0.556 (0.17) |
| Total score – continuous (0 -1) | 0.001 (0.97)  | 0.003 (0.08)  | 0.030 (0.61) |

Maximal range test

| Maximal range (cm) | -0.221 (0.55) | -0.003 (0.92) | 2.200 (0.02) |

Maximal range test

Physiological Profile Assessment – sway tests

| Firm - eyes open: area (mm²) | 69.665 (0.12) | 0.856 (0.79) | 42.239 (0.73) |
| Firm - eyes open: total (mm) | 7.154 (0.10)  | -0.021 (0.95) | -0.314 (0.98) |
| Firm - eyes closed: area (mm²) | 69.276 (0.38) | 1.727 (0.77) | 153.780 (0.48) |
| Firm - eyes closed: total (mm) | 6.848 (0.34)  | 0.376 (0.47)  | 12.075 (0.54) |
| Foam - eyes open: area (mm²) | -5.307 (0.72) | -20.837 (0.11) | -884.634 (0.06) |
| Foam - eyes open: total (mm) | 12.147 (0.54) | -0.808 (0.58) | -39.870 (0.45) |
| Foam - eyes closed: area (mm²) | -5.851 (0.86) | -21.823 (0.36) | -970.541 (0.29) |
| Foam - eyes closed: total (mm) | 25.994 (0.38) | 0.115 (0.96) | -48.080 (0.56) |

Validated Questionnaires

| SFES-I (0 - 28) | -0.340 (0.26) | -0.052 (0.02) | -0.413 (0.61) |
| KAP (0 - 44) | 0.255 (0.56) | -0.014 (0.66) | 2.614 (0.02) |
| PVAS (0 -100) | -0.202 (0.72) | -0.051 (0.22) | 0.189 (0.90) |
| IRI (0 -100) | 0.631 (0.55) | 0.113 (0.15) | 3.217 (0.27) |
| PANAS (0 - 50) | 0.175 (0.73) | 0.001 (0.98) | -1.700 (0.23) |
| GDS-5 (0 – 5) | 0.044 (0.70) | -0.004 (0.63) | 0.627 (0.03) |

Delivery = number of lessons, Receipt = Teacher evaluation, Enactment = Participant report, sec = seconds, cm = centimetres, mm² = millimetres squared, mm= millimetres, SFES-I = Short Falls Efficacy Scale – International, KAP = Keele Assessment of Participation, PVAS = Perceived Visual Ability Scale, IRI = Impact of Vision Impairment Profile – emotional subscale, PANAS = Positive and Negative Affect Scale, GDS-5 = Geriatric Depression Scale -5 item version.
Table 7.5 Relationship between outcome measures for intervention group and Program Delivery, Receipt and Enactment at 12 months. All analyses adjusted for baseline and estimates represent the beta coefficients in linear regression models. Significant results are bolded.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Delivery</th>
<th></th>
<th>Receipt</th>
<th></th>
<th></th>
<th>Enactment</th>
<th></th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Outcomes: Short Physical Performance Battery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing balance (sec)</td>
<td>-0.913</td>
<td>0.22</td>
<td>0.054</td>
<td>0.32</td>
<td>3.953</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair stand test (sec)</td>
<td>-0.345</td>
<td>0.48</td>
<td>-0.041</td>
<td>0.26</td>
<td>-2.240</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait speed (sec)</td>
<td>0.045</td>
<td>0.14</td>
<td>0.004</td>
<td>0.09</td>
<td>-0.003</td>
<td>0.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of steps in 4 metre walk</td>
<td>-0.305</td>
<td>0.12</td>
<td>-0.020</td>
<td>0.17</td>
<td>0.489</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score – ordinal (0 -12)</td>
<td>-0.082</td>
<td>0.61</td>
<td>0.017</td>
<td>0.16</td>
<td>0.806</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score – continuous (0 -3)</td>
<td>-0.004</td>
<td>0.85</td>
<td><strong>0.003</strong></td>
<td><strong>0.04</strong></td>
<td>0.130</td>
<td><strong>0.03</strong></td>
<td>Enactment: 0.13 (0.01 to 0.25) p = 0.03</td>
<td></td>
</tr>
<tr>
<td>Maximal balance range test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal range (cm)</td>
<td>-0.686</td>
<td>0.06</td>
<td>-0.036</td>
<td>0.17</td>
<td>0.138</td>
<td>0.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiological Profile Assessment – sway tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm - eyes open: area (mm²)</td>
<td>81.990</td>
<td>0.05</td>
<td>3.783</td>
<td>0.22</td>
<td>-93.635</td>
<td>0.41</td>
<td>Delivery: 81.99 (-0.38 to 164.36) p = 0.051</td>
<td></td>
</tr>
<tr>
<td>Firm - eyes open: total (mm)</td>
<td>7.225</td>
<td>0.26</td>
<td>0.799</td>
<td>0.08</td>
<td>-9.110</td>
<td>0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm - eyes closed: area (mm²)</td>
<td>119.550</td>
<td>0.21</td>
<td>6.265</td>
<td>0.37</td>
<td>118.818</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm - eyes closed: total (mm)</td>
<td>8.650</td>
<td>0.26</td>
<td>1.011</td>
<td>0.07</td>
<td>14.426</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foam - eyes open: area (mm²)</td>
<td>-46.680</td>
<td>0.71</td>
<td>-1.345</td>
<td>0.88</td>
<td>-825.163</td>
<td><strong>0.01</strong></td>
<td>Enactment: -825.16 (-1450.17 to -200.16) p = 0.01</td>
<td></td>
</tr>
<tr>
<td>Foam - eyes open: total (mm)</td>
<td>-17.122</td>
<td>0.22</td>
<td>-0.716</td>
<td>0.49</td>
<td>-77.828</td>
<td><strong>0.04</strong></td>
<td>Learnt: -77.83 (-151.43 to -4.23) p = 0.004</td>
<td></td>
</tr>
<tr>
<td>Foam - eyes closed: area (mm²)</td>
<td>-330.065</td>
<td>0.14</td>
<td><strong>-42.395</strong></td>
<td><strong>0.01</strong></td>
<td>-299.605</td>
<td>0.65</td>
<td>Receipt: -42.40 (-74.03 to -10.76) p =0.01</td>
<td></td>
</tr>
<tr>
<td>Foam - eyes closed: total (mm)</td>
<td>-28.551</td>
<td>0.06</td>
<td><strong>-2.206</strong></td>
<td><strong>0.05</strong></td>
<td>-44.018</td>
<td>0.30</td>
<td>Receipt: -2.21 (-4.40 to -0.01) p=0.05</td>
<td></td>
</tr>
<tr>
<td>Validated Questionnaires</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SFES-I (0 - 28)</td>
<td>0.051</td>
<td>0.89</td>
<td>-0.024</td>
<td>0.38</td>
<td>0.3057</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KAP (0 - 44)</td>
<td>0.694</td>
<td>0.14</td>
<td>-0.008</td>
<td>0.81</td>
<td>-0.9893</td>
<td>0.45</td>
<td></td>
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</tr>
<tr>
<td>PVAS (0 -100)</td>
<td>0.097</td>
<td>0.90</td>
<td>-0.029</td>
<td>0.62</td>
<td>0.0746</td>
<td>0.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IVI (0 -100)</td>
<td>0.324</td>
<td>0.81</td>
<td>0.068</td>
<td>0.50</td>
<td>-1.6614</td>
<td>0.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANAS (0 - 50)</td>
<td>-0.290</td>
<td>0.68</td>
<td>0.003</td>
<td>0.95</td>
<td>-1.2459</td>
<td>0.54</td>
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</tr>
<tr>
<td>GDS-5 (0 - 5)</td>
<td>0.0334</td>
<td>0.73</td>
<td>-0.003</td>
<td>0.70</td>
<td>0.1472</td>
<td>0.58</td>
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</tr>
</tbody>
</table>

Delivery = number of lessons, Receipt = Teacher evaluated progress, Enactment = Participant perceived progress, sec = seconds, cm = centimetres, mm² = millimetres squared, mm= millimetres, SFES-I = Short Falls Efficacy Scale – International, KAP = Keele Assessment of Participation, PVAS = Perceived Visual Ability Scale, IVI = Impact of Vision Impairment Profile –emotional subscale, PANAS = Positive and Negative Affect Scale, GDS-5 = Geriatric Depression Scale -5 item version
7.2.6 Program receipt (Teacher evaluation)

Physical performance also improved based on program receipt (continuous variable 0-108). At three months, performance on the chair stand test from the SPPB improved as program receipt scores increased (-0.10 seconds, 95%CI: -0.16 to -0.04, p = 0.002). When the program delivery and program receipt variables were entered into a multivariate analysis for the chair stand test at three months, only program receipt remained significant (Table 4). There was also a reduction in scores on the SFES-I at three months based on program receipt indicating a reduction in concern about falling as program receipt scores increased (-0.05 points, 95%CI: -0.09 to -0.01, p = 0.02).

Reflex standing balance improved as program receipt scores increased at the 12 month follow-up. Both area of sway (-42.40 mm$^2$, 95%CI: -74.03 to -10.76, p = 0.01) and total length of sway (-2.21 mm, 95%CI: -4.40 to -0.01, p < 0.05) reduced on the ‘foam surface eyes closed’ condition of the sway tests from the PPA. The ‘foam surface eyes closed’ condition is the most difficult of the sway tests. It reduces proprioceptive input from the ankles and precludes input from vision, and so indirectly measures vestibular functioning.

7.2.7 Enactment (Participant report)

Voluntary standing balance improved with participant-reported enactment. At three months, participants who felt they had benefitted from the program improved on the maximal balance range test$^{13}$ compared to those who had not benefitted (2.2 cm, 95%CI: 0.31 to 4.09, p = 0.02). In contrast, based on the Keele Assessment of Participation, these participants also felt they were
participating slightly less (2.6 points, 95%CI: 0.37 to 4.86, p = 0.02) and also scored slightly higher on the five item Geriatric Depression Scale (0.6 points, 95%CI: 0.43 to 0.83), suggesting slightly more depressive symptoms, but these effects were not evident at 12 months.

At 12 months participants who felt they had benefitted from the program had a better level of general physical functioning, scoring higher on the continuously scored version of the summary performance score for the SPPB (0.13, 95%CI: 0.013 to 0.246, p = 0.03) which is a composite score for performance across the three items of the SPPB. Reflex balance performance on the ‘foam surface eyes open’ condition of the sway test also improved for those who felt they had benefitted from the program compared to those who felt they had not for both area of sway (-825.16mm², 95%CI: -1450 to -200.16, p = 0.01) and total length of sway (-77.83mm, 95%CI: -151.43 to -4.23, p = 0.04).

7.3 Discussion

The VISIBILITY study did not find significant between group differences in the primary outcomes of the SPPB in the main intention to treat analysis (Chapter 5) but did find improvements in some of the secondary outcomes and improvements in physical functioning in the subgroup of multiple fallers, along with a trend for less total falls and injurious falls. This provided an impetus to evaluate the program for any overall differential benefits and explanation of the program effect.
7.3.1 Dose

There was a differential effect of the intervention by dose on some measures at three months, less so at 12 months. The primary outcomes for the study were the three items from the SPPB; a balance test, a chair stand test and a 4-metre walk. At three months improvements on the chair stand were related to program dose, and this was a primary outcome measure for the study. Specifically, program receipt (teacher evaluated progress) explained improvements in the chair stand test, but this was highly correlated to program delivery (number of lessons).

The chair stand test has been used to gain a representative measure of lower limb strength in older people, and as part of the SPPB is a predictor of disability, mortality and nursing home admission. Performance on the chair stand test has also been shown to predict falls. In addition to lower limb strength, performance on chair stand tests has been shown to depend on a range of sensorimotor, balance and psychological processes and should be seen as a transfer skill and not just a test of lower limb strength. A transfer skill is an activity performed when transferring from one stable position or posture to another. It is worth mentioning at this point that as program receipt improved, and performance on the chair stand test improved, scores on the Short Falls Efficacy Scale – International reduced, indicating a reduction in concerns about falling at the three month assessment (Table 7.4).

The Alexander Technique does not use repetitive exercises, and there was no attempt in the program to specifically strengthen lower limb musculature.
Participants were taught a better co-ordination of the hips, knees and ankles during sit-to-stand activities which may account for the improved performance associated with program receipt (teacher evaluation) on the chair stand test at three months. This impact on the chair stand test was not present at the 12 month follow-up, however there was some evidence for a relationship between program enactment (participant report) and overall SPPB score, perhaps indicating those who felt they benefited from the program may have had a longer lasting effect. Poorer scores on the continuously scored summary performance score are significantly associated with the onset of both progressive and catastrophic mobility disability.\(^7\)

Further analysis based on enactment (participant report) indicated that participants who reported gaining from the program improved their performance on the maximal balance range test, a dynamic stability test that measures the voluntary control of posture.\(^{13}\) Those participants improved their maximal balance range by 2.20 centimetres (0.30 to 4.09, \(p = 0.02\)) at 3 months, but this was not maintained at 12 months. Although direct comparisons cannot be made, this was a similar improvement to the subjects in the study by Lord et al\(^{13}\) who developed the protocol for this test. In that study the participants attended a twice-weekly exercise class for one hour in four blocks of 10-12 week duration over 12 months. The exercise group showed an improvement on the maximal balance range test from 18.5 centimetres (± 3.5) at baseline to 20.1 centimetres (± 4.0) at 22 weeks and 20.2 centimetres (± 3.2) at 12 months. Lord et al\(^{13}\) found that a composite score of lower limb strength and reaction time were the best predictors of performance in the maximal balance range test in their study.
In addition to the improvements to voluntary control of posture discussed above, reflex postural responses also improved in participants who felt they had gained from the program compared to those who did not. Based on enactment (participant report) those who felt they had improved performed significantly better on the ‘foam surface eyes open’ sway test at 12 months. What is interesting here is that Lord et al.\textsuperscript{13} found a significant correlation between performance on the maximal balance range test and the ‘foam surface eyes open’ sway test in their study described above too, which suggests that these were not isolated findings in our study. Moreover, performance on the ‘foam surface eyes open’ sway test has been found to discriminate between multiple fallers (≥ 2 falls per year) and non-multiple fallers (≤ 1 fall per year).\textsuperscript{18}

Another point of interest is that program receipt (teacher evaluation) predicted better performance on the most difficult condition of the sway tests, ‘foam surface eyes closed’ at 12 months follow-up. The foam surface eyes closed condition reduces proprioceptive input from the ankles and precludes any input from vision, and so provides a proxy measure of vestibular functioning. Although this may seem unrelated, the vestibular apparatus are housed in the temporal bones of the skull and are quite close to the atlanto-occipital joint where the skull balances on the top of the cervical spine (see section 3.2.1). A primary aim of the Alexander Technique is to release undue tension in the neck to facilitate a better balance of the head on the neck, and this may indirectly help to optimise inputs from the vestibular mechanisms on balance control. It should be remarked however, that unlike the other measures, although this was statistically significant, the absolute measures were very
small and may not be clinically significant (Table 7.5).

A final remark regarding these exploratory analyses is that for the dosage variable \textit{enactment} (participant report), although there were improvements in physical functioning at three and 12 months, these participants scored slightly higher on the Keele Assessment of Participation and the 5-item Geriatric Depression Scales at three months, suggesting less participation and higher depressive symptoms, although this effect on social measures was not maintained at 12 months. This at first seems at odds with their improvement on the tests of physical functioning, but it may be that their improved physical function amplified the impact that visual impairment had on their ability to engage socially and prompted a reappraisal of their predicament.

We have conducted a detailed process evaluation which suggested that measures of balance and mobility improved as dosage increased. Although some effects were still present at 12 months most were not evident, suggesting that 12 lessons was not sufficient to deliver sustained clinical change in this population. Most teachers of the Alexander Technique recommend 20-25 lessons for the average pupil to be able to gain sustainable benefit however limitation on resources meant that we could only offer 12 lessons. This is illustrated in Figure 7.1 where a number of case studies are shown which illustrate that more lessons would have enabled delivery of all aspects of the lesson plan.

\textbf{7.3.2 Participant satisfaction}

Participant responses to the post-intervention questionnaire were generally positive and suggest that Alexander Technique lessons are unlikely to cause
distress to participants with similar characteristics to this population. The development of improved body awareness by most respondents was a stimulus to attend more closely to the performance quality of everyday movement, although a minority did not find this so. This demographic have poorer health and greater activity limitations than the general population, decreased postural stability, and difficulty with fast-paced movements, so any improvements in movement quality are likely to be beneficial to overall physical functioning.

Given the average number of lessons that participants received was 11, and the recommended number of lessons is 20-25 for most people, it is not surprising that some did not find it helpful to maintain or improve their everyday mobility. Responses suggest that many were benefitting from the lessons, but because of the limited number of lessons that were offered they may not all have reached a critical point where heightened awareness led to the changes in behaviour needed to improve their everyday mobility, where improvement was possible.

Many of the responses to the open-ended questions (Table 7.3) echoed the responses to the statements on the Likert scale. The Alexander Technique uses a ‘hands-on’ teaching mode that provides tactile guidance during movement along with specific verbal instructions. In addition to this, a less formal dialogue develops between the teacher and the pupil regarding the pupil’s current neuromuscular state, the way they are using themselves to move during the lesson and how they think about the use of themselves in daily activity. Lessons typically last 30 minutes, and although the pupil remains
fully clothed, the sustained physical contact engenders an intimacy that some may find uncomfortable. It is important that people feel comfortable in an educational context, as anxiety about physical contact is likely to hinder progress. Only a small percentage had initial concerns about the level of touch, which were dispelled as the program unfolded, so our results suggest that the level of touch was acceptable for this population.

Because the Alexander Technique does not require the performance of repetitive exercises, participants were not required to set aside a specific time in their day for regular practice. The approach of the Alexander Technique is to heighten awareness of habitual tension during everyday activities, and this allows for an ongoing monitoring of performance as the person moves about their daily routine. Regular movement provides sensory feedback, and the heightened awareness acts as a prompt for the individual to rethink the way they perform the activity of the moment. Most found it easy to include the Alexander Technique into their daily routine. Taken in total, the responses suggest that most participants found the program enjoyable and useful, and would recommend it to others.

The Alexander lessons were provided to participants in their own homes for their convenience. Balanced against this was the degree of anxiety that having a stranger in their homes may have provoked. This was particularly so given the demographics of the respondents (Table 7.2). Most participants were older (mean (SD); 74.7 (10.9) years), female (72%) and living alone (62%) and may have had legitimate concerns about their vulnerability with the addition of a visual impairment. The majority of the intervention group (85%) found lessons
comfortable and the level of touch acceptable. This study was conducted under the auspices of the George Institute for Global Health and the University of Sydney, and was a collaboration with Guide Dogs NSW/ACT who provided the participants with mobility services, and this perhaps added to its perceived legitimacy. While our results suggest that the home-based Alexander Technique program was an acceptable intervention for this demographic, it is not certain how acceptable the program would be outside of this context and with different teachers.

Personal coping strategies also play a role in both adjusting to visual impairment\(^{22}\) and in the acceptability of an intervention, and timing of delivery may be important in this regard. Adjustment to visual impairment does require time, and can be an ongoing process if vision continues to deteriorate. Success is more likely if participants have had time to adjust to their impairment and are emotionally ready to engage in programs that require self-direction. This raises the question of when would be an appropriate time to provide an intervention for maximum benefit.

### 7.3.3 Limitations

A limitation of the VISIBILITY study with respect to the social and emotional well-being data is that we did not gather information on health locus of control.\(^{23}\) Health locus of control is a measure of the extent to which an individual believes they have a degree of control over their own well-being or the degree to which they believe it is influenced by factors beyond their control. This may have been a useful measure, as if there was an interaction between health locus of control and our performance measures, it would have
indicated that the intervention may be more suitable for individuals with particular belief systems. It would also have been of interest to measure whether health locus of control could be modified by the intervention.

A further limitation was that some of the activities outlined in the lesson plan could not be used due to some participants functional status (inability to get to and from floor) or to environmental constraints (access to stairs). However these variations from the planned lesson structure did not stop participants from learning the Alexander Technique, as it teaches perceptual awareness and cognitive strategies\(^{24}\) that can be applied in any activity.

### 7.4 Conclusion

This process evaluation found some indication of differential improvement between participants in the intervention group based on dose although most were not statistically significant when compared with the control group and so should be treated with caution. There were scattered but consistent results related to *program delivery* (number of lessons), *program receipt* (teacher evaluation) and *program enactment* (participant report), suggesting that increased dosage led to improvements in many of the outcome measures of the study.

Participant responses suggest the Alexander Technique is an acceptable intervention for the study population. A program that delivered the recommended number (20-25) of lessons may have provided more definitive results with more enduring effects, but a larger study would be required to clarify this point. Information on health locus of control may be useful
additional information to target individuals more likely to respond to this type of intervention, and the timing of delivery to coincide with a stable adjustment to their disability may further engender successful implementation in older adults with visual impairment.
7.5 References


8 DISCUSSION

8.1 Context for the findings of the VISIBILITY study

Older adults with visual impairments are at increased risk of falls and fall related injuries, and although multimodal exercise and Tai Chi have been found to improve physical functioning in residential settings where verbal and manual support is provided, physical interventions in community-dwelling populations have met with limited success. Residential settings are generally modified to provide adequate illumination and reduce trip hazards. Fittings such as rails, ramps, anti-slip surfaces, and appropriate furniture also reduce environmental risks.

The environment in residential settings is also more controlled, and so avoids many of the spontaneous events encountered in the public domain. Although community-dwelling older adults with visual impairments have a generally higher level of physical functioning, they also have to deal with numerous environmental travel hazards, fluctuating weather conditions and unpredictable pedestrian behavior, which increases the likelihood of challenges to their postural stability. For these reasons, research findings cannot be easily generalized from one setting to another.

The factorial VIP trial of Campbell et al found that a home-modification and safety program reduced falls but the multimodal exercise program used in the study did not. An analysis of adherence to the exercise program showed that
falls rates were lower in those who exercised at least three times a week compared to those who exercised less than once a week. The authors posited compliance to the exercise protocol as a possible issue. Participants were expected to exercise for 30 minutes, three times per week for the year of the study, and the program included strength and balance training. To date this is the only large scale trial that has implemented interventions for community-dwelling older adults with visual impairments designed to reduce falls.

With respect to compliance, apart from those who do not like to exercise, it may be that some older adults with visual impairments are reticent to practice exercises that challenge balance unsupervised, and this is an understandable concern, particularly if they already have poor physical function and live alone.

8.2 The VISIBILITY study

Although the VISIBILITY study was not powered to detect a difference in fall rates, it was designed with some of the issues raised by the VIP study in mind. Like the VIP study, a home based intervention was deemed more suitable for this population due to the difficulties posed by travel to a central location. We chose a novel intervention, the Alexander Technique for a number of reasons. Firstly, the absence of vision impairment forces a greater reliance on other sensory sub-systems, and application of the Alexander Technique leads to improvements in body awareness. Secondly, it does not use repetitive exercises, and so may be more acceptable to those who are not fond of them, and thirdly because it uses a hands-on teaching modality it does not require vision to learn effectively.
8.2.1 Results

8.2.1.1 Physical outcomes: main analysis

The three items from the SPPB as primary outcomes were not significant at three months. However there were improvements in some of the secondary physical measures. Postural sway on a firm surface with the eyes open is a measure of reflex balance in quiet standing and the intervention group reduced their postural sway on this test compared to controls, indicating an improved performance. The number of steps taken in the 4-metre walk also reduced in the intervention group compared to controls. This means their step length increased, suggesting increased confidence when walking.

8.2.1.2 Physical outcomes: multiple fallers (≥2 falls in previous year)

The improved gait speed and step length in multiple fallers in the intervention group is particularly encouraging as multiple fallers are at higher risk of future injury. A recent systematic review of longitudinal studies in autonomous community-dwelling older adults\(^1\) found that gait speed was consistently reported as a risk factor for cognitive impairment, disability, falls, institutionalisation and mortality. The multiple fallers in the intervention group improved their gait speed by almost twice the clinically meaningful change\(^2\) compared to the multiple fallers in the control group at three months although this did not persist at the 12 month follow-up. The chair stand test from the SPPB at 12 months showed that multiple fallers in the intervention group performed better than multiple fallers in the control group. The chair stand test requires lower limb strength and a range of sensorimotor, balance and psychological processes for adequate performance. The performance of multiple fallers in the intervention group on the chair stand test at 12 months
indicates that there was a persistence of the effect of the intervention on physical functioning in this subgroup on some of the outcome measures.

8.2.1.3 Social and emotional measures
Consistent with other studies reported in the literature, there was a high level of self-reported depressive symptoms in our study sample. A secondary study hypothesis was that if the intervention improved mobility it may also have an impact on social and emotional well-being. There were no significant between group differences in social and emotional measures after adjusting for baseline at 3 or 12 months, however there was a trend for less visual impairment-related emotional distress in the intervention group and this may have been due to the intervention improving some aspects of mobility which indirectly impacted emotional wellbeing. This did not persist at 12 months, indicating a short term effect.

8.2.1.4 Falls
The VISIBILITY study was not powered to detect a difference in fall rates, however we collected falls prospectively with calendars over 12 months as this would provide a useful indication of the presence and size of any effect on falls, and assist with sample size calculations for future larger trials in this study population.

There was a 33% lower rate of total falls and a 51% lower rate of injurious falls in the intervention group compared to the control group but these results were not statistically significant. A secondary analysis adjusted for past falls, visual field status and duration of impairment also revealed a 36% lower rate of falls in the intervention group (non-significant) compared to controls.
The number of multiple fallers reduced in the intervention group from 35% in the year prior to the study to 22% in the year of the study, whereas the number in the control group barely changed (from 28% to 27%). Although it is acknowledged that there may be some level of reporting bias with respect to retrospective falls, and these results should be treated with caution, participants provided information on retrospective falls prior to randomisation, and it would be expected that the level of bias across the two groups would be similar. Taken together these data show a trend towards less total falls and injurious falls across the intervention group and a shift in status from multiple faller to non-multiple faller for around 13% of the intervention group.

8.2.2 Process evaluation

The process evaluation of the VISIBILITY study showed that the Alexander Technique was an acceptable intervention for the majority of those in the study. The lesson protocol and the use of a single teacher ensured that program delivery was as equitable as is possible in the dynamic context of a community-based complex intervention. Exploratory analysis of the intervention group using three criterion of dosage (program delivery, program receipt and program enactment) confirmed that there were differential effects on the outcome measures of the study, and the issue of dose was flagged at the study’s inception.

8.2.3 Suitability of outcome measures

Our baseline data showed that over 55% of participants performed poorly on postural sway tests on a foam surface where proprioception at the ankles is reduced. Individuals with visual impairments lose much of the visual anchor
provided by illumination, a structured environment\(^3\) and the input from optic flow\(^4\) and so the reduction in proprioceptive inputs when standing on foam impacts significantly on balance performance. Their performance is further challenged by the impact of visual impairment on the vestibulo-ocular reflex, which helps maintain effectiveness of vestibular balance.\(^5\)

Ray et al\(^6\) compared age and sex matched sighted and visually impaired individuals using the Sensory Organisation Test which uses sway-referencing to more clearly delineate contributions from the sensory sub-systems and concluded that individuals with profound vision loss have decreased postural stability and cannot fully compensate for the absence of visual input. A similar study in the general population of adults > 75 years of age found that although reduced proprioception had a four times greater effect on balance than reducing visual input alone, the relative risk of loss of balance was five to seven times greater when visual input is additionally reduced.\(^7\) A large representative population-based study in Finland confirmed that poor functional vision is related to worse performance on balance and mobility tests in community-dwelling older adults.\(^8\)

The SPPB was chosen as the primary outcome in this study as it is used widely to assess gait, balance and lower limb function, and was validated in the general population of adults > 70 years of age as a predictor of mortality and nursing home admission. It is used as an assessment of lower limb function in studies designed to reduce falls\(^9\) and poor performance on the SPPB is associated with an increased risk of falls.\(^10\) The four metre walk and the chair stand test from SPPB are both timed, and improvement is based on
a faster re-test. Given that adults with visual impairments have difficulty with fast-paced movements there may be a limit to how much they can improve on timed physical function tests, and as 78% of participants in this trial were legally blind this necessitated some caution on their part when performing the timed tests in the battery.

Specifically this precluded optimal visual input to postural stability and this may mean that adults with visual impairments cannot improve to the extent that sighted individuals in the general population can on items in the battery. There was a significant between group difference in the number of steps in the four metre walk that favoured the intervention group (p < 0.01) and may reflect increased confidence and co-ordination of muscle actions. Less steps equates to an increased step length which is positively correlated to muscle strength. The Alexander Technique does not specifically implement strengthening exercises, but it may be that improved co-ordinated activity allowed the individual to make better use of their existing strength by reducing interference from habitual counterproductive muscle tension during activity.

Improved gait speed over a one year period has been shown to predict survival through the subsequent eight years. Although not maintained at 12 months, gait speed improved in multiple fallers in the intervention group at three months and there was a differential effect at the slow and fast end of the spectrum. Some of the ‘faster multiple fallers’ may have been at risk by ‘rushing’ and the intervention taught them to perform the activity more carefully. If performance is measured on speed alone, the ‘faster multiple
fallers’ would be considered to have deteriorated, but in the context of visual impairment this may correlate with a more safety-conscious performance resulting in less risk of falls despite a lower score on a quantitative assessment tool.

Although the standing balance test from the SPPB (a primary outcome at three months) was not significant as a continuous variable in the main intention to treat analysis, it approached significance as an ordinal variable (p = 0.06) when calculated for the total summary performance score. In the subgroup analysis by duration of impairment, those who had been visually impaired for ≤ 14 years in the intervention group improved their performance on the balance test in the SPPB compared to those who had been visually impaired for ≤ 14 years in the control group at 12 months (p = 0.005). In the subgroup analysis by previous falls, the difference between multiple fallers in the intervention and control groups approached significance for the standing balance test in favour of the intervention group at three months (p = 0.06). Likewise in the process evaluation for program delivery (number of lessons) standing balance approached significance (p = 0.054) at 3 months, and for program enactment (participant report) standing balance approached significance (p = 0.06) at 12 months. This suggests the presence of a likely effect of the intervention on standing balance which may have been enhanced with greater dose. The SPPB has not been validated in the population with visual impairments, and in a sense they are required to perform physical function tests validated for the general population without the benefit of vision, or with potentially conflicting or distractive visual input.
This suggests that although timed performance measures are good indicators of physical function in the general population they may not always be appropriate, or may need to be re-validated for the population with visual impairments, and the SPPB may not have been the most appropriate choice as a primary outcome measure.

Given that gait speed improved in the subgroup of multiple fallers and step length on the 4 metre walk improved in the intervention group generally, it may be that gait parameters would have been a more suitable primary outcome measure in this population. Unfortunately, equipment failure and availability issues at critical time points meant that we were unable to collect enough gait data for the planned sub-study, so we are unable to verify this.

8.2.4 Limitations

A limitation of the VISIBILITY study was the reduction from 20-25 Alexander lessons (recommended) to 12 lessons for the intervention group. This was due to limited resources and the necessity to complete the project within the timelines of the PhD program. Another limitation was the lack of a placebo group to control for the effect of touch and personal attention received by the intervention group. This was also due to limited resources that did not allow for an active control with social visits or sham exercise each week.

The collection of data on Health Locus of Control would have also provided additional information on whether the Alexander Technique may be more suited to some individuals rather than others. A measure of emotional adjustment to disability would also have been useful as a covariate for
determining optimal timing for participant engagement.

The program required conversational English, and so we excluded all clients of Guide Dogs NSW/ACT who required an interpreter. Although this did affect the reach of the program to newly arrived immigrants, it was necessary as the Alexander is a re-education modality that requires cognitive engagement and the teaching of conceptual material needed a reasonable command of the language of instruction.

We also excluded clients based on cognitive impairment for the same reason. The Alexander Technique requires cognitive engagement, and it was felt that this would have placed unnecessary stress on those in cognitive decline, along with the difficulty of gaining informed consent.

8.2.5 Strengths

A strength of this study was that the exclusion criteria were not as prohibitive as in many studies where physical interventions are used. Because the Alexander Technique does not use aerobic exercises or strength training, we did not exclude potential recruits due to cardiovascular problems or neurological disorders. Given that it has been established that the population with visual impairments has a higher rate of co-morbidities, our sample was more representative of that population than it would have been if the stricter exclusion factors often seen in such studies were applied.

8.2.6 Conclusion

The VISIBILITY study delivered a novel intervention in a population where physical interventions have had limited success to date. Although the study
did not find a significant impact of Alexander lessons on the primary outcomes, the improvement in balance in quiet standing and step length in the intervention group, the improved gait speed and step length in the subgroup of multiple fallers, and the indication of a possible reduction in the rate of all falls and injurious falls suggests an effect of the Alexander Technique on physical functioning and physical falls risk in older adults with visual impairments. The process evaluation showed a differential effect of Alexander lessons based on dosage which suggests that the Alexander Technique is worthy of further investigation. A future trial in this study population would benefit from an increase in the number of lessons delivered from the 12 that were provided in the VISIBILITY study to the recommended number (20-25 lessons), a robust sub-study of gait parameters and a larger sample size powered to measure the impact of the Alexander Technique on fall rates. In addition to this it would be advantageous to include greater specificity in the range and types of chronic visual impairments in the study population.
8.3 References


Appendix 1

Author’s statement

Protocol paper
25th November, 2013

Student Services
Edward Ford Building (A27)
Fisher Road
The University of Sydney
Australia

To Whom It May Concern


Michael Gleeson, during his PhD candidature, was the primary author responsible for writing the manuscript, responding to reviewers’ reports and coordinating submission and publication of this original research paper.

Dr Lisa Keay, and Associate Professor Catherine Sherrington contributed to the conception and design of the study, to revision of the article for critically important content and to supervision of candidature. Ms Ewa Borkowski was involved in data acquisition, administrative support of the study and revision of the paper for critically important content.

Yours sincerely

Lisa Keay

Catherine Sherrington

Ewa Borkowski

Affiliated with

THE UNIVERSITY OF SYDNEY

Australia | China | India | UK
Appendix 2

Protocol paper

VISIBILITY study

Improving balance and mobility in people over 50 years of age with vision impairments: can the Alexander Technique help? A study protocol for the VISIBILITY randomised controlled trial.

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Improving balance and mobility in people over 50 years of age with vision impairments: can the Alexander Technique help? A study protocol for the VISIBILITY randomised controlled trial

Michael Gleeson,1 Catherine Sherrington,2 Ewa Borkowski,3 Lisa Keay1

ABSTRACT
Background Falls are an increasingly important and costly public health problem. Vision is key to postural stability as we age and this puts adults with visual impairments at greater risk of falls. Physical interventions improve balance in the general population and in older adults with visual impairments in residential care. They also prevent falls in the general community but to date have not been shown effective in community-dwelling adults with visual impairments.

Objective To investigate, with a randomised controlled trial, whether the Alexander Technique (AT) can improve balance and mobility in the community-dwelling population with visual impairments and thus reduce the risk of falls. The AT is a form of physical re-education that has recently received attention for its possible value in rehabilitation.

Method and design One hundred and twenty people with visual impairments over 50 years of age will be recruited from Guide Dogs New South Wales/Australian Capital Territory (NSW/ACT). Participants will be independently mobile and cognitively able to take part in the programme. After baseline assessment participants will be randomly assigned to two groups. The control group will receive usual care from Guide Dogs NSW/ACT, and the intervention group will receive 12 weekly home-based lessons in the AT in addition to usual care. The primary outcome measures will be physical measures from the short physical performance battery at 3 months. Secondary outcome measures will be balance, mobility, social participation and emotional well-being at 3 and 12 months.

Trial registration number: The protocol is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12610000634077).

INTRODUCTION

Around one-third of adults over 65 years of age fall at least once a year,1–4 and in Australia hospitalisation rates due to fall-related injuries rose by 5.6% between 2007–8 and 2008–9.5 Falls are the most common cause of injury death among Australians over 75 years of age owing to the high susceptibility to trauma in this age group.5 The risk of injury is higher for people with visual impairment.6–8 About 12% of falls lead to serious injuries4 and the Auckland Hip Fracture Study6 found that 40% of fractures could be attributed to poor visual acuity or lack of stereopsis.

A study in the UK found that about 618 000 adults over 75 years of age had moderate or worse visual impairment, which is just over 1% of the total population and about 14% of the population over 75 years of age.9 Another study in the UK using national data from accident and emergency departments found that 21% of the cost of treating falls was spent on the visually impaired population.10 The high burden of falls in our community and the over-representation of older people with visual impairments make verified strategies for prevention of falls for this group a pressing concern.

A study of balance in young adults with visual impairments found that they did not fully adapt to their vision loss with respect to maintaining postural stability.12 Recent work on falls in young and middle-aged adults in the general population has found that even in these age groups, falls resulting in admission to hospital can have a significant effect on long-term health and functioning.13 Changes in equilibrium control have been noted in the general population after the fifth decade,14 adding to the existing impact of visual impairment on the physical functioning of this population. Lower femoral-neck bone mineral density has been reported in middle-aged women with visual impairments,15 which coupled with reduced balance can compound the risk of fracture. These differences in balance control in the visually impaired population as they age, highlight the need for continued research into this area.

For many older adults, vision loss leads to a decrease in physical activity, which then affects their general health and well-being. Higher rates of depression have been reported,16–18 and significant associations have also been found between vision function and poor performance on physical tests.19 Older adults with visual impairment more often have breathing problems, diabetes, heart problems, hypertension, joint symptoms, low back pain and stroke,20 and many of these comorbid conditions are associated with difficulties in walking, climbing steps, shopping and socialising. Visual impairment has also been reported to contribute to frailty21 and increased rates of mortality.22

Nerve conduction speed and central nervous system integration slow with age, forcing older adults to rely more on vision, especially for balance control during movement.23–24 At the same time, the ability to rely on vision also declines with age,24 further compounding the difficulty of maintaining upright balance. This pushes older adults with visual impairments to use compensatory strategies to help maintain balance, such as leaning on objects, 

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impairments to the edge of their ability to maintain balance under challenging conditions, and increases fall rates.26

Interventions known to improve balance in the general population27–29 have also been shown to improve balance in the visually impaired population when delivered effectively. Two recent studies of visually impaired people in residential care in Hong Kong showed that programmes could be delivered in a way that maximised attendance and compliance because the classes took place in the residential care homes. An exercise programme provided three times a week improved balance compared with controls,28 and a 16-week Tai Chi course significantly improved knee proprioception and balance.29

There is evidence that exercise programmes reduce falls in older adults in the general population,30–31 particularly programmes which challenge balance, including group Tai Chi classes in community settings. However, programmes delivered in a community group setting are difficult to access for people with visual impairments and their ability to participate effectively is also limited owing to their need for more individual attention. A trial of older people with significant visual impairments found that a home safety programme reduced falls but the home-based exercise intervention, which had been shown to benefit older adults in the general population, did not reduce falls in this population.32 The authors found that fall rates were highest in those with lowest adherence to the programme protocol and this suggests that compliance might have been a problem with the exercise intervention. There is a need to tailor interventions to suit specific populations, and an individually delivered physical intervention that takes account of visual impairment might be better suited to reducing risk of falls in community-dwelling older adults with visual impairments.

The Alexander Technique (AT) was developed in the 1890s and although it has been widely used in the performing arts, it has developed outside the mainstream medical model and is only now being investigated for its possible therapeutic benefits.33 The AT uses manual guidance and verbal feedback in everyday activities such as sitting, standing and walking to teach people how to better organise their balance and mobility by reducing largely unnoticed habitual muscular tension that may be interfering with an easier overall coordination. Although the physiological rationale behind the AT has yet to be clearly established, a case-control study of Alexander teachers and matched controls found that lessons in the AT reduce axial stiffness through the spine and enhance dynamic modulation of muscle tone.34 Because it does not require learning of unfamiliar exercises or movement patterns, and uses manual guidance, it may be ideal for people with visual impairments. Randomised controlled trials of the AT have been shown to benefit people with Parkinson’s disease35 and back pain,36 but it has not been used in studies to improve balance and mobility in the visually impaired population until now.

OBJECTIVE
The objective of this study is to determine if home-based lessons in the AT can improve balance and mobility in community-dwelling older adults with visual impairments, as these are key risk factors for falls.

METHODS
Design
The VISIBILITY study is a two-armed randomised controlled trial (see figure 1). Ethical approval for the study was granted by the human research ethics committees at the University of Sydney (Protocol No 12985) and the University of New South Wales (HREC10277). The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12610000634077).

Recruitment and randomisation
The study is a collaboration with Guide Dogs New South Wales/Australian Capital Territory (NSW/ACT) in Sydney, Australia, and all participants will be recruited from the database at Guide Dogs NSW/ACT. The organisation provides community-based services to enhance the mobility and independence of people within NSW and the ACT with visual impairments. Programmes are tailored to individual needs and can include training in the use of canes, guide dogs and electronic travel aids, together with safe strategies for pedestrian and public transport travel.

General information about the study will be included in an audio-format client newsletter called ‘Soundtracks’ to inform clients that the study is being established. Additionally, eligible adults aged ≥50 years with visual impairments in the Sydney region will be identified by Guide Dogs NSW/ACT from their client database. People from a range of socioeconomic and cultural backgrounds are represented in the database. Eligible subjects will be contacted by Guide Dogs NSW/ACT using their preferred mode of communication. The database identifies people’s preferred communication medium and the options include: standard font size (clients may have a visual field restriction but good central acuity); large print (clients can designate the font size); email (many clients have text to voice software or can resize documents electronically); audio CD or Braille.

An invitation letter will be sent by Guide Dogs NSW/ACT to eligible people who, initially, will be asked to contact the researchers within a defined time period if they are interested in participating or require further information before making a decision. They will be informed in the invitation letter that a follow-up phone call will be made to those who do not respond within the initial time period. Orientation and mobility (O&M) instructors employed by Guide Dogs NSW/ACT working in the community will be given a standard information sheet enabling them to answer basic questions about the study during unrelated visits but asked to refer the person to the researchers for further information and provide the appropriate contact details. Confidentiality, impartiality and the voluntary nature of participation will be emphasised by all staff at every step.

Inclusion criteria
The inclusion criteria are as follows:
1. People over 50 years of age with visual impairments that affect their mobility will be eligible for recruitment to the study.
2. Their visual impairment must be such that they have received mobility training from O&M instructors at Guide Dogs NSW/ACT within the past 5 years to maintain their independent mobility.
3. Mobility aids may include identification canes, long white canes, support canes, walking frames and guide dogs.
4. Participants must live in greater metropolitan Sydney.
5. They must have conversational English.

Exclusion criteria
The exclusion criteria are as follows:
1. Any clients who require an interpreter will be excluded as conversational English is necessary for participation in the intervention arm of the study.
2. Clinically diagnosed dementia or a short mental status questionnaire37 score of <8, as the intervention is a re-education
process requiring cognitive ability, and this could place unnecessary stress on such subjects.

3. Those not independently mobile with the aids already mentioned. This would exclude people confined to wheelchairs, stationary chairs or beds.
4. Those planning cataract surgery in the next 12 months are also excluded as this can significantly improve their vision and mobility.

**Baseline assessment**
The baseline assessment will be conducted by trained O&M instructors from Guide Dogs NSW/ACT. The instructors have all completed a Master of Special Education (sensory disability) and regularly supervise clients in complex situations requiring attention to balance and safety when providing mobility-related services. Additionally the O&M instructors will attend a 2-day training course on the study assessment procedures with one of the researchers, who will accompany them on their first assessment before randomisation to ensure conformity to protocol.

Demographic information on participants will be collected at the initial visit before screening and assessment. Information on mobility status, visual impairment, residence type, living arrangement, country of birth, primary language and level of education will be used to characterise the population. Additional comorbidities and medication status will also be collected at baseline and at the 3- and 12-month assessments to follow their health status over time.

**Primary outcome measures**
The three physical ability measures from the short physical performance battery (SPPB) will be used as individual primary outcome measures and investigated as a change from baseline. The study is not powered to use the three tests as a composite score. The SPPB has been validated in a large study within the general older population as a measure of lower limb function which can distinguish risk of future nursing home admission. It can be administered by a single investigator in the person’s home, takes about 10 min to complete and has been found to be reliable and sensitive to change. The SPPB comprises the following:

1. Timed five times sit-to-stand test.
2. Timed 4 m walk.
3. A standing balance test which includes side-by-side, semi-tandem, tandem and single limb balance test.
4. Tests will be administered before randomisation and after the 12-week intervention period by a trained O&M instructor from Guide Dogs NSW/ACT who is unaware of group allocation.

**Secondary outcome measures**
The secondary outcome measures are as follows:

1. The three tests from the SPPB used as a primary outcome will be re-administered at 12 months as a secondary outcome and an indicator of the duration of any effect.
2. The postural sway test and maximal balance tests from the physiological profile assessment will also be used as secondary outcome measures at the 3- and 12-month time points. The extent of sway during 30 s of standing will be measured with four conditions: on floor with eyes open, on floor with eyes closed, on a foam mat with eyes open and on a foam mat with eyes closed. All measurements are taken on a grid paper and body sway excursions will be measured in millimetres for analysis.
3. Fall rates will be measured by falls calendars. The study will be too small to detect an effect on fall rates but will give a useful indication of the presence and size of an effect on falls, which will assist with sample size
calculations for future larger trials in this study population and could be made available for future meta-analysis.

4. Fear of falling will be assessed with the Falls Efficacy Scale—International at baseline, 3 and 12 months.

5. Mood will be assessed with the Geriatric Depression Scale, the Positive and Negative Affect Scale, and the Emotional Well-Being subscale of the Impact of Vision Impairment Scale at baseline, 3 and 12 months.

6. Functional mobility will be assessed with the Perceived Visual Ability Scale at baseline, 3 and 12 months.

7. Community participation will be assessed with the Keele Assessment of Participation at baseline, 3 and 12 months.

Sample size
A sample size of 60 individuals in each of the two groups will give the study adequate power to detect a 15% between-group difference at a 5% level of significance with a power of 80% allowing for 15% drop-out during the 12 month study. The power calculations are based on data from a study in a similar population group. The estimates of between-group differences used in power calculations for the three primary outcomes measures are as follows:

- Five times sit-to-stand (effect 3.6 s, SD 9.0, correlation between baseline and final measure 0.7).
- Timed 4 m walk (effect 0.1 m/s, SD 0.25, correlation between baseline and final measure 0.7).
- Standing balance test (effect 3.6 s, SD 9.0, correlation between baseline and final measure 0.7).

Substudy
A subgroup of participants will undergo movement analysis of their walking style using a GAITrite pressure-sensitive mat in the laboratory before randomisation and after the 12-week intervention period of the study. The reliability of the GAITrite system as a measure of averaged and individual step parameters used in gait analysis has been demonstrated and the data collected will be used as a pilot study to determine whether gait analysis would be of value in future studies of the AT.

DISCUSSION
Ageing populations in industrialised countries have seen an increase in the prevalence of age-related visual impairments that affect physical ability, postural stability and social functioning and increase the risk of falls. Projections for Australia show that in the over-40 population the rate of vision impairment will rise from 5.4% in 2004 to 6.5% by 2024, and the rate of blindness is projected to increase by 73% from 50 000 in 2004 to 87 000 in 2024. Fall prevention programmes based on well-designed exercise programmes have reduced falls in the general population, but to date the only intervention that has been shown to be effective in the community-dwelling visually impaired population is a home modification programme. Many fall prevention programmes are community-based group activities and this limits their suitability for older adults with visual impairments. Home-based programmes that take account of visual impairment may be better suited to improving balance and mobility in this population.

Falls costs more than one billion dollars in medical treatment, disability, lost output and mortality in Australia each year. As no strategy has been proven to be effective in the community-dwelling population with visual impairments, there is an urgent need to identify interventions that are tailored to, and suitable for, the growing number of older adults whose lives are complicated by failing vision. Fall prevention programmes are being made available to the general population and these services need to be provided in a range of formats so that they are accessible to all sections of the population at risk.

Because the AT uses manual guidance and verbal feedback, it does not require vision to learn, and so may be a useful approach for people with visual impairments. The VISIBILITY study has been designed to determine whether the AT can improve balance and mobility in this population. If shown to be effective, a further larger study would be required to determine whether this would result in reduced fall rates within the population with visual impairments.

Acknowledgements The authors would like to acknowledge Guide Dogs NSW/ACT for their support for this study.

Contributors MG, CS, and LK were responsible for the conception and design of the study, MG and EB were responsible for the study management and data acquisition. MG, CS, LK and EB were all involved in the drafting, revision and final approval of the paper.

Funding Guide Dogs NSW/ACT provided substantial ‘in-kind’ support. The Australian Society of Teachers of the Alexander Technique and the FM Alexander Trust (UK) both provided small grants to support the study. MG received an Australian postgraduate award scholarship from the Australian Federal Government.

Competing interests None.

Ethics approval Human research ethics committees at the University of Sydney (Protocol No 12985) and the University of New South Wales (HREC10277).

Provenance and peer review Not commissioned; internally peer reviewed.

REFERENCES


Improving balance and mobility in people over 50 years of age with vision impairments: can the Alexander Technique help? A study protocol for the VISIBILITY randomised controlled trial

Michael Gleeson, Catherine Sherrington, Ewa Borkowski, et al.

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References
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Appendix 3

Ethic approval

VISIBILITY study
Ref: IM/KR
28 July 2010

Dr Lisa Keay
The George Institute for International Health
Missenden Road NSW 2050
Email: lkeay@george.org.au

Dear Dr Keay

Thank you for your correspondence dated 19 July 2010 addressing comments made by the Human Research Ethics Committee (HREC). The Executive Committee of the HREC, at its meeting of 23 July 2010, considered this information and approved the protocol entitled “Improving balance and mobility in people over 50 years of age with vision impairments: Can the Alexander Technique help?”.

Details of the approval are as follows:

Protocol No.: 12985
Approval Period: July 2010 to July 2011
Authorised Personnel: Dr Lisa Keay
Dr Catherine Sherrington
Mr Michael Gleeson

Documents approved:
Audio Newsletter (Version 1, 16/06/10)
Recruitment Letter (Version 1, 16/06/10)
Participant Information Statement (Version 1, 16/06/10)
Participant Consent Form (Version 1, 16/06/10)
Revocation of Consent (Version 1, 16/06/10)
Initial Telephone Screening Form Version 1
Baseline Data Collection Form Version 1
3 month data collection Form Version 1
Final data collection Form Version 1
Falls Calendar, Version 1

The HREC is a fully constituted Ethics Committee in accordance with the National Statement on Ethical Conduct in Research Involving Humans-March 2007 under Section 5.1.29.

The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans. N.B. A report on this research must be submitted every 12 months from the date of the approval, or on completion of the project, whichever occurs first. Failure to submit reports will result in the withdrawal of consent for the project to proceed. Your report will be due on 31 July 2011, please put this in your diary.

Special Condition/s of Approval

Please forward ethics approval from the UNSW HREC when they become available.
Chief Investigator / Supervisor’s responsibilities to ensure that:

1. All serious and unexpected adverse events should be reported to the HREC within 72 hours for clinical trials/interventional research.

2. All unforeseen events that might affect continued ethical conduct of the project should be reported to the HREC as soon as possible.

3. Any changes to the protocol must be approved by the HREC before the research project can proceed.

4. All research participants are to be provided with a Participant Information Statement and Consent Form, unless otherwise agreed by the Committee. The following statement must appear on the bottom of the Participant Information Statement: Any person with concerns or complaints about the conduct of a research study can contact the Manager, Research Integrity (Human Ethics), University of Sydney on +61 2 8627 8176 (Telephone); + 61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).

5. Copies of all signed Consent Forms must be retained and made available to the HREC on request.

6. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

7. The HREC approval is valid for four (4) years from the Approval Period stated in this letter. Investigators are requested to submit a progress report annually.

8. A report and a copy of any published material should be provided at the completion of the Project.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

[Signature]

Associate Professor Ian Maxwell
Chair
Human Research Ethics Committee

cc Mr Michael Gleeson [Email: mgleeson@george.org.au]
Appendix 4

Statistical Analysis Plan

VISIBILITY study
Improving balance and mobility in people over 50 years of age with vision impairments: Can the Alexander Technique help?

Statistical Analysis Plan

Version 2 All outcomes

By Michael Gleeson, Lisa Keay, Cathie Sherrington and Serigne Lo

Date: 14 July 2012
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1. INTRODUCTION

In addition to the impact vision impairment has on the lack of environmental preview for hazard avoidance, vision is also a key input to postural stability as we age. This puts adults with vision impairments at an even greater risk of falls. To date physical interventions to prevent falls in the general community have not been shown to be effective in the vision impaired population. This randomised controlled trial will investigate whether the Alexander Technique can improve balance and mobility in the vision impaired population to reduce physical falls risk. 120 people with vision impairments over 50 years of age will be recruited from the database at Guide Dogs NSW/ACT. Participants will be independently mobile and cognitively able to engage in a re-education program. Following the baseline assessment participants will be randomly assigned to one of 2 groups. The control group will receive usual care from Guide Dogs NSW/ACT, and the intervention group will receive a home-based weekly lesson in the Alexander Technique for 12 weeks. The primary outcome measures will be physical measures from the Short Physical Performance Battery at 3 months. Secondary outcome measures will be balance, mobility, social participation and emotional well-being at 3 and 12 months. The protocol for this study is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12610000634077)
The protocol paper has been submitted to the International Journal of Orientation and Mobility.

2. DATASET ANALYSED

The main (ITT) dataset analysed will be constituted of all participants randomised on the study irrespective of their allocations (intervention or control).

A sensitivity analysis of the primary endpoint will be carried out on the per-protocol (PP). The PP dataset includes all participants who completed at least 50% of prescribed interventions. The primary outcome measures were mobility-related disability (measured with the Short Physical Performance Battery) at 3 months. The Short Physical Performance Battery was re-administered at 12 months as a secondary measure and an indicator of the duration of any effect. Other secondary outcomes were the postural sway test and maximal balance tests from the Physiological Profile Assessment, mood, fall-related self efficacy, community-service contact, community participation, assistance from others, and functional mobility. Falls data (measured with 12 monthly calendars) was collected but the study is not powered to detect a difference in fall rates.

Assessors were unaware of group allocation. Participants were instructed not to inform the assessors of their intervention status. Participants were asked to record falls on calendars which were mailed to the research centre each month. If a fall was reported on a calendar, the participant was telephoned and information regarding the circumstance and consequence...
of the fall(s) was recorded. Phone calls were also used to seek information from participants who did not return calendars.

4. STATISTICAL ANALYSIS

4.1 Analysis principles

- Analyses will be conducted on an intention-to-treat (ITT) basis and a per-protocol basis.
- All tests are two-sided and the nominal level of α will be 5%.
- All statistical analyses will be unadjusted except where indicated.
- A limited number of pre-specified subgroup analyses will be carried out irrespective of whether there is a significant treatment effect on the primary outcome.
- Where data are missing, we will report the number of observations; we will not impute missing values unless specified otherwise.
- P-values will not be adjusted for multiplicity. However, the outcomes are clearly categorised by degree of importance (primary and secondary).

As the primary analysis is based on 3 different endpoints, the results will be interpreted with caution if the statistical significance is borderline (i.e., a p-value between 1.66% and 5%) due to multiplicity issues.

4.2 Short Physical Performance Battery analysis (primary outcome)

a) primary analysis

The primary analysis will be on the three separate components of the Short Physical Performance Battery [1, 2] and the time taken for each of the individual mobility tasks. These will include the total standing time with the feet in different positions (together, side by side, semi-tandem, tandem and single leg stance), 4-metre walk time and time to rise from a chair five times.

The primary analyses will be conducted using linear regression models and will compare the groups on 3 assessment scores adjusted for baseline scores.

For individuals unable to carry out the tests due to physical impairments a score of 0 will be given for the timed standing balance components (as a low score is a poor score), 0 m/s for gait (as a low score is a poor score) and the maximum time for sit to stand (i.e., 32.1 secs). Individuals who are able to complete the tests but whose sit to stand time is greater than 32.1 secs will be assigned a time of 32.1 secs.

The primary analysis will be adjusted only for baseline scores. A secondary adjusted analysis will be conducted adjusting for the stratification factors of
past falls, type and duration of vision loss. Further adjusted analyses will be conducted if major imbalances between the groups at baseline are present.

If outliers are present in the data or the model assumptions are grossly violated after treatment is included in the model, some sensitivity analyses will be conducted.

b) subgroup analyses

Subgroup analysis will be conducted for

- number of past falls (0-1 versus 2 or more).
- cognitive impairment (above and below median MMSE score)
- type of vision impairment (central/peripheral/total)
- duration of vision impairment (above and below the median duration)

Unadjusted p-values will be reported but the number of declared subgroups analyses will be specified in all publications. The main analysis for each subgroup will be an interaction test in a linear regression model to determine whether the effect of treatment differs significantly across categories for that particular subgroup. The coefficients for each of the subgroups will be reported as well as the coefficients (i.e., effect on the effect) and p-value for the interaction test.

d) Per protocol analyses

A sensitivity analyses will be undertaken to explore the impact of the intervention in those who received the intervention and those who adhered more fully to the intervention. A per-protocol analysis will be conducted on the corresponding dataset. Again the linear regression model will be used to final performance adjusted for baseline performance in intervention group participants who completed at least 25% of prescribed interventions.

e) Exploratory analysis

We will inspect the data for clinically important differences

4.3 Secondary outcomes

The Short Physical Performance Battery was re-administered at 12 months as a secondary measure and an indicator of the duration of any effect. The analysis will be conducted using linear regression models and will compare the groups on 12-month assessment scores adjusted for baseline scores.

Other secondary measures were tests of balance [3], mobility [4], social participation [5], emotional wellbeing [6, 7, 8], fall-related self efficacy [9] and assistance from community-services and family. Appendix 1 lists all
secondary outcome measures. Falls data (measured with 12 monthly calendars) was collected but the study is not powered to detect a difference in fall rates.

Separate analyses will be conducted for 3 and 12-month assessments. The main analyses for continuously-scored outcomes will be conducted using linear regression models and will compare the groups on 3 or 12-month assessment scores adjusted for baseline scores. Ordinally-scored data will be analysed for between group differences using ordinal regression.

For individuals unable to carry out the tests due to physical impairments, a score of 0 will be given for the variables where a low score indicates poor performance and a score of the mean plus 3 SD will be given for variables where poor performance is indicated by a high score (see Appendix 1 for details). Individuals who completed the tests but whose performance was worse than the mean plus 3 SD will be assigned a value of the mean plus 3 SD.

The main analyses will be adjusted only for baseline scores. An adjusted analysis will be conducted adjusting for the stratification factors of past falls, type and duration of vision loss. Further adjusted analyses will be conducted if major imbalances between the groups at baseline are present.

If outliers are present in the data or the model assumptions are grossly violated after treatment is included in the model, some sensitivity analyses will be conducted.

Subgroup analysis will be conducted for

- number of past falls (0-1 versus 2 or more).
- cognitive impairment (above and below median MMSE score)
- Type of vision impairment (central/peripheral/total)
- Duration of vision impairment (above and below median)

Unadjusted $p$-values will be reported but the number of declared subgroups analyses will be specified in all publications. The main analysis for each subgroup will be an interaction test in a linear regression model to determine whether the effect of treatment differs significantly across categories for that particular subgroup. The coefficients for each of the subgroups will be reported as well as the coefficients (i.e., effect on the effect) and $p$-value for the interaction test.

**d) Per protocol analyses**

A sensitivity analyses will be undertaken to explore the impact of the intervention in those who received the intervention and those who adhered more fully to the intervention. A per-protocol analysis will be conducted on the corresponding dataset. Again the linear regression model will be used to
final performance adjusted for baseline performance in intervention group participants who completed at least 25% of prescribed interventions. Further exploration based on propensity to exercise may also be conducted.

4.4 Falls analysis (study not powered to detect a difference in fall rate)

a) rate of falls

The number of falls per person-year will be analyzed using negative binomial regression in Stata to estimate the difference in fall rates between the two groups (primary outcome). The incidence rate ratio and its 95% CI will be reported.

The primary analysis will be unadjusted. A secondary adjusted analysis will be conducted adjusting for the stratification factors of past falls, type and duration of vision loss. Further adjusted analyses will be conducted if major imbalances between the groups at baseline are present.

A blind review revealed that the negative binomial model was appropriate. The model output will be further examined when treatment is included in the model to check if negative binomial regression is more appropriate than Poisson regression. If not, Poisson regression will be used. Days of follow-up will be included as an exposure term in these models.

If outliers are present in the data or the model assumptions are grossly violated after treatment is included in the model, some sensitivity analyses will be conducted.

b) Subgroup analyses on rate of falls

All subgroups will be defined by data collected prior to randomisation.

Subgroup analysis will be conducted for

- number of past falls (0-1 versus 2 or more).
- cognitive impairment (above and below median MMSE score)
- Type of vision impairment (central/peripheral/total)
- Duration of vision impairment (above and below the median duration)

Unadjusted $p$-values will be reported but the number of declared subgroups analyses will be specified in all publications. The main analysis for each subgroup will be an interaction test in a negative bionomial regression model to determine whether the effect of treatment differs significantly across categories for that particular subgroup. The incidence rate ratios for
each of the subgroups will be reported as well as an incidence rate ratio (i.e., effect on the effect) and \( p \)-value for the interaction test.

c) proportion of fallers

The proportion of fallers in the two groups will also be compared using logistic regression models (secondary outcome). Odds ratios and their 95% CIs will be reported.

d) subgroup analyses on proportion of fallers

The same sub-group analyses outlined above will be undertaken using interaction terms in logistic regression models. Odds ratios and their 95% CIs for each of the subgroups will be reported as well as the odds ratios (i.e., effect on the effect) and \( p \)-value for the interaction test.

e) type of fall

Secondary analyses will be conducted on the ITT dataset to compare the rate and proportion of people experiencing of indoor falls and falls requiring health care intervention (i.e., GP visit, ED visit, hospital admission) between groups.

f) Monthly fall rates

Monthly fall rates will be graphed. Secondary analyses will be conducted to separately assess the between group difference in the rate of falls in the first 3 months and the between group difference in the rate of falls in the later 9 months of the 12-month follow up period.

g) Per protocol analyses

Secondary analyses will be undertaken to explore the impact of the intervention in those who received the intervention and those who adhered more fully to the intervention. A per-protocol analysis will be conducted on the corresponding dataset Again the negative binominal model will be used to compare falls rates in intervention group participants who completed at least 50% of prescribed interventions.
References


## Appendix 1: Secondary outcome measures

<table>
<thead>
<tr>
<th>Category</th>
<th>Secondary outcome</th>
<th>Missing data due to participant being physically unable to perform the test</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance</td>
<td>Maximal Balance Range</td>
<td>Assign 0*</td>
<td>From PPA: Lord, Menz &amp; Tiedmann (2003) Continuous</td>
</tr>
<tr>
<td>Balance</td>
<td>Firm surface, eyes open</td>
<td>Assign Mean+3SD*</td>
<td>From PPA: Lord, Menz &amp; Tiedmann (2003) Continuous</td>
</tr>
<tr>
<td>Balance</td>
<td>Firm surface, eyes closed</td>
<td>Assign Mean+3SD*</td>
<td>From PPA: Lord, Menz &amp; Tiedmann (2003) Continuous</td>
</tr>
<tr>
<td>Balance</td>
<td>Foam surface, eyes open</td>
<td>Assign Mean+3SD*</td>
<td>From PPA: Lord, Menz &amp; Tiedmann (2003) Continuous</td>
</tr>
<tr>
<td>Balance</td>
<td>Foam surface, eyes closed</td>
<td>Assign Mean+3SD*</td>
<td>From PPA: Lord, Menz &amp; Tiedmann (2003) Continuous</td>
</tr>
<tr>
<td>SPPB components</td>
<td>Assign 0* for gait velocity and standing balance</td>
<td>Assign Mean+3SD* for sit to stand</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>Single leg stance time</td>
<td>Assign 0*</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>Number of steps in a 4 meter walk</td>
<td>Assign Mean+3SD*</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>Use of hands for sit to stand</td>
<td>Do not impute</td>
<td>Ordinal</td>
</tr>
<tr>
<td></td>
<td>Walking aid used</td>
<td>Do not impute</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Category</td>
<td>Secondary outcome</td>
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<td>Notes</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Health and community service use</td>
<td>Frequency of service usage</td>
<td>Do not impute</td>
<td>ordinal categories asked at baseline, 3 months and 12 months</td>
</tr>
<tr>
<td>Disability</td>
<td>Frequency of help from others (family)</td>
<td>Do not impute</td>
<td>ordinal categories asked at baseline, 3 and 12 months</td>
</tr>
<tr>
<td>Community participation</td>
<td>Keele Assessment of Participation</td>
<td>Do not impute</td>
<td>ordinal categories asked at baseline, 3 and 12 months</td>
</tr>
<tr>
<td>Community participation</td>
<td>Socialization 6 questions</td>
<td>Do not impute</td>
<td>ordinal categories asked at baseline, 3 and 12 months</td>
</tr>
<tr>
<td>Emotional well-being</td>
<td>Positive and Negative Affect Scale</td>
<td>Do not impute</td>
<td>Watson &amp; Clark (1988)</td>
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<tr>
<td>Emotional well-being</td>
<td>Geriatric Depression Scale (5 item)</td>
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<td>Rinaldi, Mecocci, et al. (2003)</td>
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<td>Emotional well-being</td>
<td>Falls Efficacy Scale International (7 item)</td>
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<td>Separate analysis without Q4 (?)</td>
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<td>Falls Efficacy</td>
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<td>Do not impute</td>
<td>Continuous (Kempen, Yardley et al, 2008)</td>
</tr>
</tbody>
</table>

*When data is missing due to the participant being physically unable to perform the test, the missing data is systematic, not random and this data will be imputed using the following procedures. For tests where a low score reflects poor performance, a value of 0 will be assigned. For tests where a high score reflects poor performance, then a value of the mean+3SD will be assigned. The mean and SD will be calculated from the scores of all participants who could complete the test at pre-test. The same mean and SD will be used for any post-test scores where the participant could not perform the test. Where any other participants’ scores (at pre-test or post-test) are greater than the mean+3SD at pre-test, these scores will be adjusted to the mean+3SD.
Appendix 5

VISIBILITY study
Lesson Plan
ALEXANDER TECHNIQUE FOR BALANCE AND MOBILITY
VISION IMPAIRMENT BALANCE AND MOBILITY STUDY

ALEXANDER TEACHER’S
LESSON PLAN

Participant: ____________  Start Date:______________  End Date:______________

LESSON PLAN CHECKLISTS

Notes:

- Lesson plans have been provided for 12 Alexander lessons
- Each lesson plan includes the topics to be covered in the lesson
- The teacher is to use the lesson plan as a guide, but also need to respond to individual differences in learning style and general health and fitness conditions
- The teacher is to check off if they covered the topics listed and add any comments regarding the teaching of topics and any useful feedback etc.
- As all lessons will be provided by the same teacher this will allow for a level of consistency of instruction across the participants in the intervention group. The lesson plans help to formalize this process so it is important that themes in the lesson plans are followed and checklists are completed to make sure the quality of instruction and information provided to the participants is consistent throughout the study.
<table>
<thead>
<tr>
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<td><strong>Intro 5 min</strong></td>
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<td>• What is the Alexander Technique?</td>
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<td></td>
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<tr>
<td>• Habitual movement patterns</td>
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<td></td>
</tr>
<tr>
<td>• Paying attention</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Having intention</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Demonstration 5 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Guided movement and facilitated release</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Movement 10 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Standing and sitting: the commonest things we do</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Principle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Relating to Gravity - going up or going down?</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Releasing UP</td>
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<td></td>
</tr>
<tr>
<td><strong>Self-observation 10 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Accepting support</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Useful feedback / tips for home practice</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Review &amp; Implement 10min</strong></td>
<td></td>
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<tr>
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<tr>
<td><em>Lengthening</em></td>
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<tr>
<td><em>Going UP</em></td>
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<tr>
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<td><em>Did you practice through the week?</em></td>
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<tr>
<td><strong>Demonstration</strong></td>
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<td><em>Directing your attention</em></td>
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<tr>
<td><strong>Movement</strong></td>
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<td><em>Standing and sitting: the commonest thing we do</em></td>
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<td><em>The head/neck relationship</em></td>
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<td></td>
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<tr>
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<tr>
<td><strong>Self Observation</strong></td>
<td></td>
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<tr>
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<td></td>
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<tr>
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<tr>
<td><strong>Review</strong></td>
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<td>Sending the crown away from the heels</td>
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<td>Developing intention</td>
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<tr>
<td>Directing attention and intent</td>
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<td>Demonstration 5 min</td>
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<tr>
<td>Guided movement and facilitated release</td>
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<tr>
<td>Freeing the neck</td>
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<td>Finding support from the sitting bones and the ground</td>
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<td>Sending the 2 ends away from each other</td>
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<td>Bringing conscious intention to movement</td>
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<td>Folding and unfolding</td>
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<td>Semi-Supine &amp; Self Observation 10 min</td>
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<td>Lying down</td>
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<td>Let the back widen as it lengthens</td>
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<td>Facilitated release</td>
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<td>The above</td>
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<td></td>
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<tr>
<td><strong>10 min</strong></td>
<td></td>
<td></td>
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<tr>
<td>Giving directions</td>
<td>☐</td>
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<tr>
<td>Freeing the neck</td>
<td>☐</td>
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<tr>
<td>Lengthening and widening the back</td>
<td>☐</td>
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<tr>
<td>Coordinating the hips and knees</td>
<td>☐</td>
<td></td>
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<tr>
<td><strong>Demonstration 5 min</strong></td>
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<tr>
<td>Guided movement and facilitated release</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>Widening through the torso as the back lengthens</td>
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<tr>
<td><strong>Movement 5 min</strong></td>
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</tr>
<tr>
<td>Sitting is an interrupted squat</td>
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<td>Stopping along the way to sitting is an Alexander procedure called “Monkey”</td>
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<tr>
<td>Stopping gives an opportunity to notice how we stiffen and collapse</td>
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<td><strong>Principle</strong></td>
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<td><strong>Semi-supine &amp; Self Observation 10 min</strong></td>
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<td>Accepting support</td>
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<tr>
<td>Lengthening and widening the back</td>
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<td></td>
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<tr>
<td>Directing your attention to your legs</td>
<td>☐</td>
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<tr>
<td><strong>Review 5 min</strong></td>
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<tr>
<td>The above</td>
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<td>• Giving directions</td>
<td>☐</td>
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<tr>
<td>• Freeing the neck</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Lengthening and widening the back</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Directing your attention to your legs</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Demonstration 5 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Guided movement and facilitated release</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• What happens in the legs when you move</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Movement 5 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sit → Stand → Sit is folding and unfolding</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td><strong>Principle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Maintain the lengthening and widening of the back as you think about releasing your knees ‘forward and away’ as you move: don’t stiffen the legs unnecessarily</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Learning to ‘inhibit’ unnecessary tension</td>
<td>☐</td>
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</tr>
<tr>
<td><strong>Semi-supine &amp; Self Observation 10 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Accepting support in order to lengthen.</td>
<td>☐</td>
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</tr>
<tr>
<td>• Send the crown away from the heels</td>
<td>☐</td>
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</tr>
<tr>
<td>• Freeing the hips knees and ankles</td>
<td>☐</td>
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</tr>
<tr>
<td><strong>Review 5 min</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The above</td>
<td>☐</td>
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<td>Week 6 - Lesson 6: Inhibition</td>
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<tr>
<td><strong>Review last week 10 min</strong></td>
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<td></td>
</tr>
<tr>
<td>• Accepting support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sending the crown away from the heels – lengthening &amp; widening</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>• Freeing the hips, knees and ankles in order to ‘fold and unfold’</td>
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<td><strong>Demonstration 5 min</strong></td>
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<tr>
<td>• Paying attention to unnecessary effort</td>
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<td>• Guided movement and facilitated release</td>
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<tr>
<td>• Becoming aware of habitual tension during movement</td>
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<tr>
<td>• Learning to ‘do’ less in activity</td>
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<tr>
<td><strong>Movement 5 min</strong></td>
<td></td>
<td></td>
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<tr>
<td>• Moving between sitting and standing</td>
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</tr>
<tr>
<td>• Stopping in ‘monkey’ along the way to notice how tension develops as we move</td>
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<tr>
<td>• Inhibition in activity</td>
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<tr>
<td><strong>Semi-supine &amp; Self Observation 10 min</strong></td>
<td></td>
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</tr>
<tr>
<td>• Freeing the neck</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>• Lengthening and widening the torso</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>• Directing the knees away from the hips and ankles</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td><strong>Review 5 min</strong></td>
<td></td>
<td></td>
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<tr>
<td>• The above</td>
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<td></td>
</tr>
<tr>
<td>Week 7 - Lesson 7: The ribs</td>
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<tr>
<td><strong>Review last week 10 min</strong></td>
<td>- Giving directions</td>
<td>□</td>
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<tr>
<td></td>
<td>- Accepting support</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>- Freeing the neck</td>
<td>□</td>
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<tr>
<td></td>
<td>- Lengthening &amp; widening the torso</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>- Sending the knees away from the hips and ankles</td>
<td>□</td>
</tr>
<tr>
<td><strong>Demonstration 5 min</strong></td>
<td>- Guided movement and facilitated release</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>- Free the ribs to allow the breath to enter</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>- Notice what happens to the breathing if you tighten anywhere in your body</td>
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<tr>
<td><strong>Movement 5 min</strong></td>
<td>- Breathe out totally and allow the new breath to enter without effort</td>
<td>□</td>
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<tr>
<td><strong>Principle</strong></td>
<td>- Inhibiting unnecessary tension that interferes with the natural flow of the breath</td>
<td>□</td>
</tr>
<tr>
<td><strong>Semi-supine &amp; Self Observation 10 min</strong></td>
<td>- Give directions</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>- Pay attention to unnecessary tension</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>- 'Inhibit' tension – release undue tension in muscles that may be interfering with the breath</td>
<td>□</td>
</tr>
<tr>
<td><strong>Review 5 min</strong></td>
<td>- The above</td>
<td></td>
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</table>
### Week 8 - Lesson 8: Using the arms

| **Review last week** 10 min | • Giving directions to lengthen & widen  
  • Paying attention – thinking in activity  
  • Inhibiting undue tension to free the breath | □ | 
|---------------------------|-------------------------------------------------|---|---|
| **Demonstration 5 min**   | • Guided movement and facilitated release  
  • Letting go of the arms | □ | 
| **Movement**              | • Taking weight through the arms | □ | 
| **Principle 5 min**       | • Releasing the arms out of the torso  
  • Notice how this affects your breathing  
  • Using appropriate tension in activity | □ | 
| **Semi-supine & Self Observation 10 min** | • Notice what happens when you lift your arm up  
  • Can you do the activity with less effort  
  • Inhibit unnecessary tension in the back and notice if the activity interferes with your breathing | □ | 
<p>| <strong>Review 5 min</strong>          | • The above | |</p>
<table>
<thead>
<tr>
<th><strong>Week 9 - Lesson 9: Using the arms</strong></th>
<th>Check</th>
<th>Comments</th>
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<td><strong>Review last week 10 min</strong></td>
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<tr>
<td><em>Paying attention.</em></td>
<td>☐</td>
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<tr>
<td><em>Giving directions and inhibiting unnecessary tension to lengthen, widen and free the breathe</em></td>
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<tr>
<td><em>Releasing the arms out of the torso</em></td>
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<tr>
<td><strong>Demonstration 5 min</strong></td>
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<tr>
<td><em>Guided movement and facilitated release</em></td>
<td>☐</td>
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<tr>
<td><em>'Monkeying around'. Bending at the hips knees and ankles to reach for a bag</em></td>
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<tr>
<td><strong>Movement 5 min</strong></td>
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<tr>
<td><em>Bending to pick up a small bag</em></td>
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<td><strong>Principle</strong></td>
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<tr>
<td><em>Coordinating the use of the arms with rest of the body</em></td>
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<tr>
<td><em>Maintaining length in activity</em></td>
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<tr>
<td><em>Inhibiting interference with the breath</em></td>
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<tr>
<td><em>Do not pre-empt the weight, allow the weight to condition your response</em></td>
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<td><strong>Semi-supine &amp; Self Observation 10 min</strong></td>
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<td><em>Accept support</em></td>
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<td><em>Pay attention</em></td>
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<tr>
<td><em>Direction &amp; Inhibition</em></td>
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<td><em>Releasing interference with the breath when using the arms</em></td>
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<td><strong>Review 5 min</strong></td>
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<td><em>The above</em></td>
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<td><strong>Week 10 - Lesson 10: Walking</strong></td>
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<td>• Paying attention</td>
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<td>• Directing intention</td>
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<td>• Inhibiting unnecessary tension</td>
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<td>• Allowing the breath to flow</td>
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<td><strong>Demonstration 5 min</strong></td>
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<tr>
<td>• Guided movement and facilitated release</td>
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<tr>
<td>• Notice tendency to tighten in neck and lower back as you move</td>
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<tr>
<td><strong>Movement 5 min</strong></td>
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<tr>
<td>• Walking</td>
<td>☐</td>
<td></td>
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<tr>
<td><strong>Principle</strong></td>
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<tr>
<td>• ‘Staying back as you move’</td>
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<tr>
<td>• Thinking in activity</td>
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<tr>
<td>• Keeping your length as you move</td>
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<tr>
<td><strong>Semi-supine &amp; Self Observation 10 min</strong></td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>• Directing &amp; Inhibiting</td>
<td>☐</td>
<td></td>
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<tr>
<td>• Notice what happens when you lift a leg</td>
<td>☐</td>
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<tr>
<td>• Can you reduce the amount of effort you use</td>
<td>☐</td>
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<tr>
<td>• Can you release through the torso and reduce the tension in the tummy muscles</td>
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<tr>
<td><strong>Review 5 min</strong></td>
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<td>• The above</td>
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<td><strong>Week 11 – Lesson 11: Stairs</strong></td>
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<td>• Staying back as you move</td>
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<tr>
<td>• Keeping your length as you move</td>
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<td>• Breathing easily as you move</td>
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<td>• Free the neck and lower back as you move</td>
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<tr>
<td>• Guided movement and facilitated release</td>
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<tr>
<td>• What happens when we step up?</td>
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<td><strong>Movement 5 min</strong></td>
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<td>• Stairs: climbing up stairs</td>
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<tr>
<td><strong>Principle</strong></td>
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<tr>
<td>• Staying back on the back leg</td>
<td></td>
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<tr>
<td>• Letting the heels drop</td>
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<tr>
<td>• Using both legs to climb</td>
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<tr>
<td><strong>Semi-supine &amp; self observation 10 min</strong></td>
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<td></td>
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<tr>
<td>• Putting all the directions together</td>
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<tr>
<td>• One after another, all at the same time</td>
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<tr>
<td><strong>Review 5 min</strong></td>
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<td>• The above</td>
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<td>Week 12 - Lesson 12: Any questions?</td>
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<tr>
<td><strong>Review 10 min</strong></td>
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<td>• Directing</td>
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<td>• Inhibition</td>
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<tr>
<td>• Lengthening as we move</td>
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<tr>
<td><strong>Demonstration 5 min</strong></td>
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<tr>
<td>• Guided movement and facilitated release</td>
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<tr>
<td>• Standing and sitting</td>
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<td><strong>Movement 5 min</strong></td>
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<td>• Standing and sitting</td>
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<td>• Walking</td>
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<td>• Climbing stairs</td>
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<tr>
<td><strong>Principle</strong></td>
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<tr>
<td>• Thinking in activity</td>
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<tr>
<td><strong>Semi-supine &amp; self observation 10min</strong></td>
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<tr>
<td>• Review the use of semi-supine as a self-help tool</td>
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<tr>
<td>• Useful feedback / tips for home practice</td>
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<tr>
<td><strong>Last thoughts</strong></td>
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<tr>
<td>• Any questions?</td>
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Appendix 6

VISIBILITY study
Post-intervention Questionnaire
INTERVENTION GROUP ONLY

POST-INTERVENTION QUESTIONNAIRE

Telephone interview one month from end of intervention period:

1. Did you feel comfortable having lessons in the Alexander Technique?
2. How did you feel about the level of touch involved?
3. How do you feel your mobility has changed as a result of having the lessons?
4. Were there any unexpected outcomes from having the lessons?
5. What is the main thing you learned from the lessons?
6. How has this impacted on your everyday activity?

<table>
<thead>
<tr>
<th>1. I enjoyed learning the Alexander Technique.</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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</thead>
<tbody>
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<table>
<thead>
<tr>
<th>2. I found the Alexander Technique easy to apply.</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<table>
<thead>
<tr>
<th>3. I feel the Alexander Technique is helpful in improving or maintaining my everyday mobility.</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<table>
<thead>
<tr>
<th>4. I feel the Alexander Technique is helpful in improving my awareness of my body.</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<thead>
<tr>
<th>5. I pay more attention to how I perform everyday activities.</th>
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<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<th>6. The Alexander Technique was easily included in my daily routine.</th>
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<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<thead>
<tr>
<th>7. I have a better understanding of how my body moves.</th>
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<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<tr>
<th>8. I am confident that I can continue to practice the Alexander Technique in my daily life.</th>
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<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<tr>
<th>9. I would recommend the Alexander Technique to others</th>
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<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
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