Falls Risk Factors in Community-Dwelling Older Australians

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Faculty of Health,

University of Canberra, Australia
In loving memory of Anthony “Poss” Pryor

7.2.1942 - 24.4.2014
Abstract

Introduction

Falls by older adults often have serious health consequences for those who fall and economic consequences that are of concern to governments and private health care providers. With the number of adults over the age of 65 years increasing as a proportion of the population, and with greater life expectancy, the number of falls occurring annually will escalate unless effective intervention occurs. Through better understanding of current falls risk assessment tools and intrinsic falls risk factors that potentially predict falls, it may be possible to proactively dampen the anticipated increase in the occurrence of falls within community-dwelling older adults. The aim of this thesis was to explore intrinsic falls risk factors in community-dwelling older Australians and assess their impact on falls risk assessment measures.

Methods

Over 275 community-dwelling older adults, aged 60-92 years, volunteered throughout the course of this research program. Each of the five empirical studies, presented as part of this thesis, utilised a variety of falls risk assessment tools; self-assessment - the Falls Efficacy Scale-International (FES-I) and the Activities-specific Balance Confidence (ABC), and objective - Physiological Profile Assessment (PPA) and the Berg Balance Scale (BBS). In addition, combinations of the following intrinsic falls risk factor assessment measures were also utilised: Short Performance Physical Battery (SPPB) or Continuous Scale Physical Functional Performance-10 (CS-PFP10); Six-Item Cognitive Test (6-CIT); 12-Item Short-Form Health Survey (SF12); Physical Activity Survey for Elderly (PASE); dual X-ray absorptiometry (DXA); and the Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2). Using these measures it was possible to evaluate the contribution of physical function, cognition, general health, physical activity, body composition and diet as falls risk factors and examine their relationships with the self-assessment and objective falls risk tools. Statistical analysis was undertaken using a variety of methods, including: One-Way Analysis of Variance, Pearson Product-Moment Correlation, and Multiple Regression analysis.
Results

Three major findings have emerged from this research:

1) The importance of sex when assessing falls risk - an individual’s sex has been identified, not just as an independent falls risk factor but also as a contributor to other predictor characteristics (functional, body composition or health-related);

2) The complexity of the relationship between falls risk and physical function - the nature of the relationship between physical function and falls risk was revealed as bidirectional. Whilst impaired physical function is confirmed as a falls risk factor, the reverse is also true: heightened falls risk impairs physical function; and

3) The need for population-appropriate assessment tools – the FES-I is more appropriate than the ABC for use when self-assessing falls risk in community-dwelling older adults. The BBS is better suited for objectively assessing older, less-functioning adults, whereas the PPA is the objective tool of choice when assessing higher functioning females.

Conclusion

The body of research highlights significant interactions between numerous intrinsic falls risk factors, falls risk measures and their inherent complex interrelationships. This thesis contributes to knowledge regarding falls risk, not only by strengthening the evidence for known intrinsic risk factors (age, sex, history of falls) but also by identifying additional potential risk factors (fat mass, bone density and diet quality). Finally, the important finding of the differences between sexes, observed in aspects of falls risk, physical function and diet quality, highlights the need for the development and implementation of sex-specific falls prevention programs, to enable both male and female community-dwelling older adults to benefit equally from programs.
Declaration for Thesis Chapters 4-8

In the case of Chapters 4, 5, 7 and 8 the nature and extent of my contribution to the work was the following:

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<tr>
<td>Research design, all data collection, data analysis and interpretation, manuscript preparation, editing and submission</td>
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In the case of Chapters 4, 5, 7 and 8 the nature and extent of the co-authors contribution to the work was as follows:

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<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Professor Helen Berry</td>
<td>Research design, data analysis and interpretation and manuscript review</td>
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</tr>
<tr>
<td>Dr Judith Anson</td>
<td>Research design and manuscript review</td>
<td>7.5%</td>
</tr>
<tr>
<td>Professor Gordon Waddington</td>
<td>Research design and manuscript review</td>
<td>5%</td>
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In the case of Chapter 6 the nature and extent of my contribution to the work was the following:

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<td>Research design, all data collection, data analysis and interpretation, manuscript preparation, editing and submission</td>
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In the case of Chapter 6 the nature and extent of the co-authors contribution to the work was as follows:

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<tr>
<td>Dr Kate Pumpa</td>
<td>Data analysis and interpretation, manuscript preparation and editing</td>
<td>15%</td>
</tr>
<tr>
<td>Dr Fiona Lithander</td>
<td>Manuscript review</td>
<td>5%</td>
</tr>
<tr>
<td>Morgan Falchi</td>
<td>Data analysis</td>
<td>5%</td>
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</tbody>
</table>
Declaration by co-authors

The undersigned hereby certify that:

- the above declaration correctly reflects the nature and extent of the candidate’s contribution to this work, and the nature of the contribution of each of the co-authors.
- they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;
- they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;

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<td>Morgan Falchi</td>
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Publications and Presentations

Publications by the Candidate Relevant to the Thesis


Conference Presentations by the Candidate Relevant to the Thesis


Disa J. Smee. (2012) Heartmoves and falls risk, ACT Health Directorate's Falls Prevention Program, ACT, Australia

Disa J. Smee. (2012) Bone density and falls risk, North Canberra Rotary Club, ACT, Australia
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I would like to express my deepest gratitude to my four supervisors: Prof Helen Berry; Dr Judith Anson; Prof Gordon Waddington, and Dr Roger Adams. Helen, your guidance and patience provided me with an early knowledge in writing and statistics that ensured that this thesis is of the highest standard. Judith, your contributions of time, ideas and editing skills, throughout the entire process, made my PhD experience productive and stimulating. Gordon, your gentle encouragement and relaxed demeanour made for a good working relationship. Roger, without your focus on finishing, big picture ideas and thorough editing I would have not had a timely finish. Without these four supervisors I would not have been able to complete my PhD. Thank you to you all. I could not be prouder of my academic roots and hope that I can, in turn, pass on the research values and skills that you have given me.

To my co-authors Dr Kate Pumpa, Morgan Falchi and Dr Fiona Lithander, thank you for your guidance and enthusiasm throughout the evolution of the diet quality chapter. An extra mention to Kate (and Julie) without you, coming to work would be far less fun and enjoyable.

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## Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>6-CIT</td>
<td>Six-Item Cognitive Impairment Test</td>
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<tr>
<td>ABC</td>
<td>Activities-specific Balance Confidence Scale</td>
</tr>
<tr>
<td>ADL</td>
<td>Activities of Daily Living</td>
</tr>
<tr>
<td>APspine</td>
<td>Anterior-posterior lower lumbar spine</td>
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<tr>
<td>BBS</td>
<td>Berg Balance Scale</td>
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<tr>
<td>BMD</td>
<td>Bone Mineral Density</td>
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<td>BMI</td>
<td>Body Mass Index</td>
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<td>CS-PFP</td>
<td>Continuous Scale Physical Functional Performance</td>
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<tr>
<td>CS-PFP10</td>
<td>Continuous Scale Physical Functional Performance-10 (short)</td>
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<td>DQES v2</td>
<td>Dietary Questionnaire for Epidemiological Studies Version 2</td>
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<td>Dual energy X-ray Absorptiometry</td>
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<td>FES</td>
<td>Falls Efficacy Scale</td>
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<td>FES-I</td>
<td>Falls Efficacy Scale-International</td>
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<td>HDI</td>
<td>Healthy Diet Index</td>
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<td>HEI</td>
<td>Healthy Eating Index</td>
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<td>ICC</td>
<td>Intraclass Correlation Coefficient</td>
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<td>Physical Activity Scale for the Elderly</td>
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<td>PPA</td>
<td>Physiological Profile Assessment</td>
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<td>MenSF-12</td>
<td>SF12® mental component</td>
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<td>PhysSF-12</td>
<td>SF12® physical component</td>
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<td>SMA-pre</td>
<td>Sports Medicine Australia pre-exercise screen</td>
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<td>SPPB</td>
<td>Short Performance Physical Battery</td>
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<td>WHO</td>
<td>World Health Organization</td>
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Chapter 1 Introduction

1.1 An Ageing Population – a Population at Risk

The number of people aged 65 years or older will grow globally from an estimated 524 million in 2010 to almost 1.5 billion by 2050, according to the World Health Organization (WHO) (2002). In Australia, the proportion of the population aged 65 years and over is projected to increase from 13% (2.8 million people) in 2007 to between 23% and 25% (7.8–10.4 million people) by 2056 (Australian Bureau of Statistics, 2013b). Accompanying this rise will be a greater than three-fold increase in the proportion of individuals who will be over the age of 85 years (from 1.6% in 2007 to 4.9% in 2056) (Australian Bureau of Statistics, 2013b). Health problems increase with age (Yashin et al., 2007), with a substantial number of these problems arising from falls (World Health Organization, 2008).

Around the world, about one-in-three community-dwelling adults over the age of 65 fall each year (Tinetti, 1988, Stevens et al., 2012, Mirelman et al., 2012, Nevitt et al., 1991) and 50% fall more than once (Tinetti, 1988, Mirelman et al., 2012). Falling means coming unintentionally to rest on the ground (or on a lower level) and is a major cause of morbidity in older adults including: injury (Hartholt et al., 2011, Himes and Reynolds, 2012, Jensen et al., 2002); increased fear of falling (Boyd and Stevens, 2009, Painter et al., 2012, Schmid et al., 2010, Tinetti et al., 1994); reduced mobility (Sherrington et al., 2011); social isolation and depression (Boyd and Stevens, 2009, Masud and Morris, 2001) and an increased need of assisted living (Boyd and Stevens, 2009) (Figure 1.1). The incidence of injurious falls could be as high as 57.8% (Fitzharris et al., 2010). Although few falls result in serious injury (head, spinal cord or fracture), the psychological consequences of falling can be severe (O’Loughlin et al., 1993). In addition, older adults are more likely than younger people to suffer a fracture when they fall, due to age-related declines in bone mineral density (Cummings and Melton, 2002) (Figure 1.1). Over three-quarters (76%) of injury hospitalisations for people aged 65 and over occurred in 2009-2010 as a result of a fall (AIHW: Bradley, 2013). Of these admissions, hip fractures are particularly dangerous, resulting in 20%-30% mortality within the first 12 months (Magaziner et al., 1990). The risk of fall-related mortality also increases with age, particularly for those over 70 years of age (Rubenstein and Josephson, 2006). Figure 1.2 illustrates this increase in mortality rates after 70 years, and given the continuing increase in the
population over the age of 70, it is expected that fall-related mortalities will also escalate. To contextualise the significance of falling in Australia, falls cause more injury-related deaths than transport crash fatalities (Australian Bureau of Statistics, 2012).

Figure 1.1 Proportion of older adults experiencing different consequences of falling (%) (+ 60 years of age, community-dwelling) in São Paulo, Brazil (adapted from Fabricio et al. (2004))
1.2 The Knock-on Cost of Falls

Beyond the physical cost to the individual, falls place a substantial burden on society and contribute to the rapidly increasing costs of the health care system. The economic costs per individual associated with falls in older adults are on par with costs associated with more prominent health issues, such as obesity (Wang et al., 2008). However, public awareness of falls as a health issue pales in comparison, perhaps because it predominantly affects only older people (a small but growing percentage of the population). Fall-related economic costs have been suggested to range between 0.85% and 1.5% of the total health care expenditures in Australia, as well as in other countries such as the United States of America (USA) and the United Kingdom (Heinrich et al., 2010). In the USA, falls have an estimated annual cost of $23.3 billion (Davis et al., 2010). This is considerable given it is associated with only 19% of the population (United States Census Bureau, 2012).

A recent Australian report revealed that one in ten days spent in hospital is due to a fall by an individual over the age of 65 years, with the average length of stay per fall injury being 15.5 days (AIHW: Bradley, 2013). It has also been estimated that 12% of older adults who fall require assisted living afterwards (Tinetti and Williams, 1997) and, when the fall results in a hip fracture, only 24% are able to ambulate on their own 6 months after falling (Eastwood et al., 2002). In addition, hip fractures can reduce life expectancy by 1.8 years compared with expectancy for age-
and sex-matched peers in the general population (Braithwaite et al., 2003) and 15-35% of individuals who fracture their hip die within the following 12 months (Ooms et al., 1994). Furthermore, with the predicted increasing proportion of older people, and applying the current fall rate, by 2051 an additional 2500 hospital beds and 3320 nursing home places will be required for people who have fallen in Australia (Moller, 2003).

1.3 Aim

These statistics reveal the significance of falls as a major public health concern for older adults and also foreshadow escalating demands on a health care system already under pressure. It is therefore essential that falls risk factors are identified and interventions aimed at reducing the risk among older people are implemented. The aim of this thesis is to explore falls risk factors in community-dwelling older Australians and the association between these factors and falls risk measures. Within this aim, five specific objectives have been identified:

1. To understand the relationships between self-assessed falls risk and functional, body composition and health-related characteristics.
2. To understand the relationships between objectively measured falls risk and functional, body composition and health-related characteristics.
3. To understand the associations between diet quality and falls risk, physical function and body composition characteristics.
4. To describe the specific relationship between falls risk and physical function.
5. To examine the benefits of a balance-specific training program on both physical function and falls risk.

1.4 Significance of the Thesis

This body of research reported here highlights significant overlaps and interactions between numerous intrinsic falls risk factors, falls risk measures and their inherent complex interrelationships. This thesis is comprised of two components: falls risk factor identification and an intervention. This thesis contributes to knowledge regarding falls risk, not only by strengthening the evidence for known intrinsic risk factors (age, sex, history of falls) but also by identifying additional potential risk factors (fat mass, bone density and diet quality). Its findings will have direct and
practical applications in the accurate identification of those community-dwelling older Australians at risk of falling to facilitate mediation prior to or after a fall. Furthermore, the findings will provide in-depth knowledge for the appropriate selection of falls risk assessment tools. The second part of the thesis incorporates a balance-specific intervention aimed at investigating falls risk reduction and improved physical function. In clinical settings, these findings could aid in the development and implementation of more appropriate falls prevention programs.

### 1.5 Synopsis of the Thesis

This thesis contains nine chapters. Each empirical chapter (*Chapters 4 to 8*) is presented in a consistent format, and is preceded with a title page, indicating publication status and contributing authors.

Following this chapter (*Chapter 1 – Introduction*), *Chapter 2 – Literature Review* explores the evidence surrounding intrinsic falls risk factors (known and potential). In addition, background studies pertaining to assessment tools commonly used to determine falls risk is discussed and evaluated for suitability to explore the thesis aim and objectives.

*Chapter 3 – Methods* provides an overview of the assessment tools, statistical analysis and procedures carried out in *Chapters 4 to 8*.

*Chapter 4 – The relationship between subjective falls risk measures and physiological, functional and health characteristics* explores the relationship between two commonly used self-assessed falls risk measures (*Falls Efficacy Scale – International* (FES-I) and *Activities-specific Balance Confidence* (ABC) scale) and a range of potential falls risk predictor characteristics, such as functional, health-related and body composition characteristics.

*Chapter 5 – The relationship between objective falls risk assessment tools and functional, health-related and body composition characteristics* explores the complex interaction between the results obtained by objective falls risk assessment tools and the individuals’ characteristics. It directly compares two falls risk objective measures (*Physiological Profile Assessment* (PPA) and *Berg Balance Scale* (BBS)), with each other as well as with potential falls risk predictors, including functional, health-related and body composition characteristics.
Chapter 6 – The relationship between diet quality and falls risk, physical function and body composition in older adults utilises diet quality indices to assess the importance of total diet quality on health outcomes, including falls risk and physical function. Furthermore, the importance of sex and diet quality upon these health outcomes is considered in order to provide insight into future dietary interventions.

Chapter 7 – Association between physical functionality and falls risk in community-living older adults focuses on the relationship between falls-risk and physical function, as assessed by the PPA and the Continuous Scale Physical Functional Performance-10 (CS-PFP10), respectively. The chapter explores whether falls risk and physical function are separate entities and, if so, whether they should be assessed independently.

Chapter 8 – A balance-specific exercise intervention improves falls-risk but not total physical functionality in community-dwelling older adults determines if a balance-specific intervention (wobble-board) is effective in reducing falls risk and improving physical function. It further clarifies potential differences between two assessment measures: PPA and the CS-PFP10.

Chapter 9 – Discussion reviews the findings of this thesis, its contribution to current knowledge and future research regarding falls risk and community-dwelling older adults.
Chapter 2 Literature Review

2.1 Background

Falls in older people often result in serious injury and hospitalisation and constitute a significant threat to their health, safety and independence. Typically, risk factors have been grouped into two main categories (Todd and Skelton, 2004):

- Intrinsic factors (within the individual) including both demographic and health factors; and
- Extrinsic factors, which involve either the physical environment or socioeconomic environment.

Specifically, intrinsic risk factors refer to age-related physiological and pathological changes in the sensory, neurological and musculoskeletal systems, whereas extrinsic risk factors include the environment or activities associated with a high risk of falling, such as uneven footpaths, poor lighting or loose mats on the floor. Falls can be caused by extrinsic risk factors, intrinsic risk factors or a combination of both, which together may have further interactions (Hill and Schwarz, 2004).

Additionally, falls risk factors may also be classified as modifiable or non-modifiable. Modifiable risk factors are those that can be altered, such as physical inactivity, impaired vision or medication. The ability to positively change modifiable risk factors potentially reduces the risk. Falls risk factors that are not modifiable, for example, age or past history of falls, are useful to identify those at greater risk and who may potentially benefit from general falls prevention strategies. In this case, the falls risk factor is not modifiable however, the outcome may be.

Much of the research to date in this field has been conducted with Caucasian individuals over 65 years of age, from both ‘community-dwelling’ and ‘residential care’ populations. Individuals in residential care are at greater risk of falling, with up to 50% of residents experiencing a fall annually. This is in comparison to the generally-accepted falls incidence of 33% in community-dwellers (Tinetti, 1987), but this can vary from 25% (Centre for Health Advancement and Centre for Epidemiology and Research, 2010) to 40% (Rubenstein, 2006). Comprehensive understanding of falls risk factors in community-dwelling older adults could prevent the escalation to residential falls
risk rates within the older population, thus easing both the economic impact on society and the physical and psychological impact on the individual.

The aim of this literature review is to provide information about the evidence concerning known and potential intrinsic falls risk factors in community-dwelling older adults.

2.2 Falls Risk Factors - Overview

The aetiology of falling is seen to be multifactorial, and numerous falls risk factors have been identified (Lord et al., 2007, Delbaere et al., 2006). Many studies have attempted to assess the impact of these falls risk factors; however, due to the sheer number of factors, specifying the impact of each is not possible. Moreover, with the combination of multiple risk factors the risk of falling in older adults is elevated (Barrett-Connor et al., 2009) – the more risk factors the more likely an older individual is to fall. Furthermore, the complexity of inter-factor relationships increases when multiple falls risk factors are present. Although strong evidence is available for some falls risk factors (e.g. sex, age, history of falls), others are seldom reported in the literature (e.g. body composition or lack of physical activity) and are therefore possibly overlooked by investigators.

A narrative review of the literature was conducted to identify reported factors associated with falls risk. This refined review provides key evidence pertaining to falls risk factors that are directly relevant to this thesis. Medline and Scopus databases were searched using the following terms: ‘falls in old age’, ‘falls’, ‘risk’, ‘community’ and ‘factors’. The search was further restricted to peer-reviewed publications produced in English with participants aged 60 years and over during the past 25 years (1980-2015). One hundred and ninety one papers were initially identified. Articles were excluded if only a single risk factor was assessed. A further elimination, based on title, yielded 53 papers. These were further culled based on abstract contents including if specific disease conditions were assessed. This resulted in 17 papers being selected for inclusion in this narrative review. From these papers, the identified falls risk factors have been extracted and are presented in Table 2.1.
Table 2.1 Falls Risk Factors in Community-dwelling Older Adults (topics in order of reported frequency)

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<thead>
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<th>Topic</th>
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<td>1. Age</td>
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<td>2. Functional limitations</td>
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<td>3. Sex (being female)</td>
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<td>5. History of falls</td>
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<td>8. Other disease conditions§</td>
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<td>9. Walking/Mobility aids</td>
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<td>16. Fear of falling</td>
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<td>20. Other sensory (hearing)</td>
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<td>23. Other (alcohol, vitamin D and reaction time)</td>
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§ Other Disease conditions – Parkinson’s Disease, Stroke, Arthritis, Diabetes, Urinary Incontinence

° Living alone or residential care/assisted living
Manuscripts identified as part of the narrative review

1 – Barrett-Connor et al (2009); 10 - Mitchell et al (2013);  
2 - Biderman et al (2002); 11 - Nevitt et al (1991);  
3- Campbell et al (1981); 12 - O'Loughlin et al (1993);  
4 - Cesari et al (2002); 13 - Rossat et al (2010);  
5 - Deandrea et al (2010); 14 - Rubenstein (2006);  
6 - Delbaere et al (2010b); 15 - Stalenhoef et al (2002);  
7 - Faulkner et al (2009); 16 - Tinetti et al (1988);  
8 - Graafmans et al (1996); 17 - Tromp et al (2001);  
9 - Iinattiniemi et al (2009);  

Table 2.1 indicates the coverage of identified falls risk factors and this information is represented graphically in Figure 2.1. Based on these identified falls risk factors, opportunities for further research, where the literature pertaining to falls risk factors is infrequent or unexplored are evident. These include: muscle strength, Body Mass Index (BMI)/body composition, fear of falling and lack of physical activity. In regards to diet and nutrition, vitamin D levels have been previously identified as a potential falls risk factor (Muir and Montero-Odasso, 2011) and nutritional status is an independent predictor of falls (Chien and Guo, 2014). However there is limited information pertaining to diet quality and falls and thus this area of diet and nutrition requires specific attention. 

This literature review explores not only those falls risk factors with limited evidence, but also those that have been investigated more thoroughly, such as the effect of age on falls risk. Falls risk factors explored further within this literature review have been categorised as follows:

1. Demographic risk factors  
2. Physiological & psychological risk factors  
3. Functional risk factors  
4. Body composition risk factors  
5. Diet & nutrition
Figure 2.1 Percentage of reported risk factors as identified in narrative review

(1) Demographic (2) Physiological & Psychological (3) Functional (4) Body composition (5) Medically related (6) Other.

# Other disease conditions – Parkinson’s Disease, Stroke, Arthritis, Diabetes, Urinary Incontinence

^ Living alone or residential care/assisted living
2.3 Demographic Risk Factors

A variety of demographic risk factors have been found to be associated with falls, including: age (Delbaere et al., 2010a); sex (Deandrea et al., 2010); history of falls (Muir et al., 2013, Stalenhoef et al., 2002); race (Ambrose et al., 2013); being unmarried; living alone, and having an income less than US$15,000 per year (Brassington et al., 2000). However, the three most often investigated subcategories within this domain are age, sex, and history of falls, and for the purpose of this literature review, only these are explored further.

2.3.1 Age

Ageing is associated with a number of physiological and functional declines that can contribute to increased falls and reduced physical function (Seguin and Nelson, 2003). The rate of falling increases above the age of 65 years, with one in three individuals in this age group falling at least once annually (Lord et al., 2007, Tinetti et al., 1988) with the annual risk of falling increasing to 50% in individuals over the age of 80 years (Prevention, 2008). Individuals who have had one fall are more likely to suffer subsequent falls compared to those who have never fallen (Lord et al., 2007, Pluijm et al., 2006, Tromp et al., 2001, Inouye et al., 2009). Falls often cause injury and sometimes they cause death. The risk of fall-related morbidity and mortality increases with age, particularly for those over 70 years (Rubenstein and Josephson, 2006). The fracture consequences of falls also increase with age: in the 65–75 year age group, wrist fractures are the most common, while hip fractures predominate in the over 75 year age group (Rubenstein, 2006). This increased falls risk with age is due in part to age-specific decline in a variety of systems that are required for adequate balance control, including those involved with vestibular, visual, somatosensory and motor control systems as well as changes in response times and strength (Todd and Skelton, 2004, Lord et al., 2007). Age, as an intrinsic falls risk factor in community-dwelling older adults, is continually highlighted within the literature (Mitchell et al., 2013, Deandrea et al., 2010) and is one of the most important considerations in regards to falls risk.
2.3.2 Sex

Being female increases risk of falling (Delbaere et al., 2010b, Mitchell et al., 2013), such that females (64.7% fallers) are at 20% higher risk of falling than males (44.1% fallers), particularly in their own homes (Campbell et al., 1990). Females also experience disproportionately more non-fatal fall-related injuries than do males (AIHW: Bradley, 2013), 2.2 times more fractures (Stevens and Sogolow, 2005) and most of the hospitalisations resulting from injurious falls (AIHW: Bradley, 2013). Indeed, hospitalisation may be up to 1.8 times higher for females compared to males (Stevens and Sogolow, 2005). This could be due to sex differences in regards to physiology, including poorer muscular strength (Lindle et al., 1997, Evans and Hurley, 1995) and lower bone mineral density (Cawthon, 2011), the fact that females live longer (Clifton, 2014) or a combination of these. The reasons underlying the sex differences in falls rates are not fully understood. Information regarding sex differences would be useful for developing and implementing targeted fall-prevention strategies.

2.3.3 History of Falls

It has been established that individuals have an increased risk of falling if they have had a previous fall (estimates of the odds ratio for previous fallers compared with non-fallers varies between 2.70 (Delbaere et al., 2010a) and 3.86 (Bloch et al., 2013)). Given that 50% of fallers are recurrent fallers (Mirelman et al., 2012, Tinetti and Williams, 1998), that is, they fall repeatedly, falls history is an important risk factor for future falls in older adults. Often, after an initial fall, due to an increased fear of falling, individuals reduce their level of physical activity, which can, ironically, result in an increased falls incidence rate (Tinetti et al., 1994).

2.3.4 Summary – Demographic Falls Risk Factors

Being older is a risk factor for falling, as is being female with a past history of falling: females are at greater risk of falling than their male peers, especially if they have previously fallen. Despite strong and reliable evidence that being older and female greatly increases falls risk, the interplay between these demographic factors and other intrinsic risk factors (see below) has yet to be fully clarified.
2.4 Physiological and Psychological Risk Factors

The list of falls risk factors involving physiological or psychological characteristics is extensive. While a large number of factors within these areas have been explored, as is evident in Figure 2.1, changes in physiological balance and strength associated with sarcopenia, together with depression, impaired cognition and fear of falling have not been extensively addressed. Our current understanding of these areas is the focus of the present section.

2.4.1 Physiological Factors

2.4.1.1 Balance

Balance or postural stability is fundamental to functionality and encompasses both static and dynamic elements. ‘Static’ or stationary balance involves the maintenance of upright posture (when an individual is not overtly moving). By contrast, ‘dynamic’ balance is required when moving to allow for control of the centre of mass; for example when turning, stepping, or when the individual has a slip or trip and they need to make adjustments to return to ‘normal’ balance.

The ability to maintain balance requires a complex interplay between the sensory systems (vision, vestibular and somatosensory) on the one hand and the muscular system on the other. To ensure that the subsequent response is smooth and appropriate, co-ordination of both perception and interpretation of environmental stimuli along with appropriate motor output is necessary. Postural sway arises when this co-ordination is disrupted and may occur because of changes in sensory input, central nervous system integration or motor programming execution (Shumway-Cook and Woollacott, 2000). Normal ageing is, however, associated with changes in functions of both the muscular and sensory systems (Lord et al., 2007), thus increasing the likelihood of balance deficits.

In order to control postural stability, older adults tend to make smaller, more frequent changes to their centre of mass when standing stationary compared with younger adults (Alexander et al., 1992). Postural instability is further evident after a fall, with older adults having increased side-to-side (medio-lateral) sway (Melzer et al., 2010).
Vestibular

The vestibular system is made up of the semicircular canal system, which indicates rotational movements (dynamic), and the otoliths, which detect linear (static) movement. Combined with visual inputs, this system helps us to maintain an upright posture. Ageing in the peripheral vestibular apparatus shows a decline similar to ageing effects occurring in other parts of the nervous system (Shaffer and Harrison, 2007).

Sensory epithelium and primary efferent neurons degenerate and are not replaced (Babin and Harker, 1982), thus the system becomes less effective. In addition, otolith function decreases with age and in women appears to decline at a faster rate than men (Serrador et al., 2009). Increases in medio-lateral sway appear to be associated with loss of vestibular otolith function, indicating that this loss contributes to falls risk among the elderly (Serrador et al., 2009). It is the combination of these declines in dynamic and static movement that leads to reduced balance and an increase in falls risk.

Visual

The visual system is critically important for balance control among the elderly (Hytönen et al., 1993), and age-associated vision impairments tend to increase the number of trips and stumbles (Rubenstein, 2006). Studies have shown that poor vision reduces postural stability and significantly increases the risk of falls and fractures in older people (Lord et al., 2010). Declines in a variety of visual abilities – including visual acuity, contrast sensitivity and depth perception – are linked to increased risk of falls (Lord, 2006).

Somatosensory

The somatosensory system plays an important role in balance control, and age-related declines in somatosensory function have been implicated in falls incidence (Qiu et al., 2012). Declines in this system include loss of distal large myelinated sensory fibres and receptors as well as impaired lower limb proprioception (Lord and Ward, 1994), vibration and touch (Shaffer and Harrison, 2007). In addition, age-related atrophy of sensory fibres occurs earlier than in motor fibres (Shaffer and Harrison, 2007).
In summary, each of the components of the sensory system – vestibular, visual and somatosensory and altered motor programming – have their own effect on reducing balance in older adults and, in combination, can significantly increase falls risk.

2.4.1.2 Sarcopenia

An important factor for falls risk is the age-related loss of muscle mass, and associated loss of strength (Landi et al., 2012). In 2010, the European Working Group on Sarcopenia in Older People proposed a diagnosis of sarcopenia that required low muscle mass (according to the Baumgartner criteria (Baumgartner et al., 1998)) to be accompanied by either low muscle strength or low physical performance (Cruz-Jentoft et al., 2010). Pre-sarcopenia was defined as low muscle mass, with either loss of strength (lowest quartile of handgrip strength in sample distribution) or poor physical performance (gait speed ≤ 0.8 m/s). Severe sarcopenia was defined when all three aspects were present. However, recent evidence from the Foundation for the National Institute of Health Sarcopenia Project has provided a more defined identification method for sarcopenia (Studenski et al., 2014). Sarcopenia is now diagnosed in those individuals with a grip strength of < 26 kg for men and < 16 kg for women, and appendicular lean mass adjusted for BMI of < 0.789 for men and < 0.512 for women (Dam et al., 2014, McLean et al., 2014). Individuals meeting these cut-points for weakness and low muscle mass have higher rates of functional limitation (Correa-de-Araujo and Hadley, 2014).

Muscle mass and strength change throughout the lifespan, with the rate of loss accelerating after the age of 75 years. It also appears that men lose muscle mass at a greater rate than women (0.80%–0.98% and 0.64%–0.70% per year, respectively) (Figure 2.2). While women do not generally acquire the same level of muscle mass (or strength) as men, concentric strength in women starts to decline sooner (prior to age 60 years) but at a slightly slower rate than in men (Hurley and Roth, 2000, Lindle et al., 1997).
Muscle strength is lost more rapidly than muscle mass. By the age of 75 years muscle strength is lost at a rate of 3.0% – 4.0% per year in men and 2.5% – 3.0% per year in women (Mitchell et al., 2012). In addition, the loss of strength in the lower limbs appears to occur sooner than other areas of the body, thus this factor may have a more marked impact on falls (Bemben et al., 1991) than loss of general muscle strength. Changes in muscle strength do not necessarily mirror those of muscle mass (Goodpaster et al., 2006), however declines in mass are usually associated with declines in strength (Chastin et al., 2012).

It has been reported that limited lower leg strength is associated with approximately a five-fold increase in the risk of falling (Rubenstein, 2006). This holds true regardless of age, as studies included a range of ages, with 50% of the participants being over the age of 65 (Rubenstein, 2006). This suggests lower limb strength decline is a significant factor for increased risk of falling. There is also a strong negative slope in the relationship between lower leg muscle strength and functional capacity indices, such as walking speed (Evans and Campbell, 1993, Wolfson et al., 1995), balance (Wolfson et al., 1995),

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**Figure 2.2 Changes in Muscle Mass with Age (adapted from Janssen (2000))**
chair rises (Alexander et al., 1991) and stair climbing (Bassey et al., 1992) for both community-dwelling and residential-care older adults. This indicates the critical importance of maintaining muscle strength and mass to ensure a) maintenance of postural control/balance and b) ability to recover after a trip, as well as c) to preserve functional capabilities. High levels of physical activity can aid in the retention of both muscle strength and muscle mass (Hairi et al., 2010).

2.4.1.3 Muscle Fibres and Motor Units

Motor performance deficits for older adults appear to be due to dysfunction and reduced co-ordination of the central and peripheral nervous systems and the neuromuscular system (Seidler et al., 2010). Both the number and size of muscle fibres decrease with age, particularly type II fibres. As muscles in the back, hamstrings and quadriceps are predominately type II fibres, these muscles groups are the first to atrophy (Jones, 2005). In addition, the loss of motor units, even in physically active and healthy individuals, will also contribute to the reduction in contractile strength (Doherty et al., 1993) and the loss of fine motor control (Smith et al., 1999). Apoptosis of motor neurons combined with inadequate re-innervation of fibres contributes to both the loss of muscle mass as well as muscular strength (Luff, 1998). Declines in balance and gait along with co-ordination deficits and slower movement may be due to age-related atrophy of the motor cortical regions (Seidler et al., 2010), motor fibre atrophy and motor unit declines, and these changes can have a negative impact on the ability of older adults to perform functional activities of daily living.

2.4.1.4 Other

Cardiovascular issues (Carey and Potter, 2001) and medications (Kwan et al., 2011) have also been implicated to increase an individual’s risk of falling. Of particular interest are orthostatic hypotension and polypharmacy and although these are beyond the parameters of this thesis, they have been included within this review.

Orthostatic Hypotension

Orthostatic Hypotension refers to a significant decrease in blood pressure immediately after assuming an upright position (Shaw and Claydon, 2014). The prevalence of orthostatic
hypotension increases with age with 30% of the general population of the age of 65 years affected and up to 70% of individuals in residential care facilities (Lipsitz, 1989) affected. Orthostatic hypotension is associated with increased morbidity and mortality (Carey and Potter, 2001) which may be in part due to the increased risk of falls. Individuals in residential care appear to be a greater risk (Ooi et al., 2000). However, in community-dwelling older adults, orthostatic hypotension alone does not increase the risk of falling; but, when combined with uncontrolled hypertension, individuals are at greater risk of falling (Gangavati et al., 2011).

Medication

Certain classes of medication, as well as polypharmacy, also place older adults at greater risk of falling. With increased age comes increased use of medication, further increasing the likelihood of falls-related incidents. Medications such as cardiovascular medications (Huang et al., 2012) and psychotropics (antidepressants, antianxiety, dementia-related products and antipsychotics) are believed to increase the risk of falling by up to 47% in community-dwelling older adults (Hartikainen et al., 2007). Evidence in relation to the impact of other medications, such as nonsteroidal anti-inflammatory drugs, diabetic medication and antiepileptics, is less strong (Ambrose et al., 2013).

Whilst polypharmacy has been shown to increase risk of falling, particularly with four or more medications (Slomski, 2012), it is the inclusion of at least one psychotropic or cardiovascular medication that is associated with a significant increase in risk (Ziere et al., 2006). Furthermore, it has been demonstrated that multiple psychotropic drugs further increase falls risk (Woolcott et al., 2009).”

2.4.2 Psychological Factors

Falls-related psychological issues may increase the risk of future falls by negatively influencing activity levels, which may cause losses in strength, mobility, physical function, and independence (Howland et al., 1998). Psychological factors such as being afraid of falling, experiencing depression, having impaired cognition and engaging in risk-taking behaviours are all associated with increased falls risk (Moreland et al., 2004).
2.4.2.1 **Impaired Cognition**

Impaired cognition and confusion are associated with falls (Tinetti, 1988). Approximately 60% of older people with mild cognitive impairment fall annually, which is approximately twice the rate of individuals without cognitive impairment (van Dijk et al., 1993) with older adults with more severe cognitive impairment being five times more likely to fall when compared to those without cognitive impairment (Tinetti, 1988). This appears to be due to a number of factors including: impaired judgment; the individual’s engagement in riskier behaviours; the side-effects of medication (Rubenstein et al., 1994); changes in gait, and declines in balance (Blackwood et al., 2013).

In addition, increasing cognitive load while performing activities that may challenge balance, especially with spatial tasks, increases the risk of falling (Barra et al., 2006). Balancing is harder for older adults than for younger people and more cognitive resources are needed to balance (Shumway-Cook and Woollacott, 2000); if additional cognitive tasks are undertaken simultaneously, maintaining balance can become more difficult (Brauer et al., 2002). That is, maintaining balance requires more concentration when one is older and when multi-tasking, insufficient attention may be given to the task of balancing.

2.4.2.2 **Depression**

Symptoms of depression are prevalent in the older adult population, with 15% of older individuals reporting clinically-relevant symptoms (Beekman et al., 1995). Depression is associated with significant morbidity in older individuals: increased disability (Broadhead et al., 1990); poor physical function (Gallo et al., 1997); low bone density (Cizza et al., 2012, Michelson et al., 1996), and falls (Mossey, 1985, Campbell et al., 1981, Vind et al., 2010) (Iaboni and Flint, 2013). Depression may also be the result of a fall (Biderman et al., 2002) and severe depression is common among those who have experienced multiple falls (Nevitt et al., 1991).
2.4.2.3 Fear of Falling

Fear of falling is one of the major psychological factors related to falls. Falls and fear of falling are interrelated problems: each is a risk factor for the other (Friedman et al., 2002). While it has been suggested that fear of falling and falls efficacy are incongruent with each other (Hadjistavropoulos et al., 2011), fear of falling is often studied within a self-efficacy framework (Li et al., 2005). Self-efficacy is a construct that relates to situational self-confidence, and falls self-efficacy concerns individuals’ perception of how well they are able to partake in activities of daily living without falling or losing balance (Powell and Myers, 1995, Tinetti et al., 1990). It is ‘falls self-efficacy’ specifically that is frequently measured to assess an individual’s fear of falling.

Many older adults are afraid of falling (Barnett, 2003) and this fear becomes greater as people age (Arfken et al., 1994, Vellas et al., 1998, Howland et al., 1998), even among those who have not yet fallen. The prevalence of older individuals recognising this fear of falling ranges from 12%–65% among those not reporting recent falls (Lach, 2005, Howland et al., 1993, Lachman et al., 1998) to 29%–92% among recent fallers (Pluijm et al., 2010, Tinetti, 1988). There also appears to be a sex difference, with fear of falling being more common in women relative to men (Arfken et al., 1994).

The factors contributing to fear of falling in older adults are numerous and, although the exact causes remain unclear, it is thought to be associated with physical, psychological, and functional changes in older adults (Cumming et al., 2000). Indeed, the relationship between these factors and fear of falling may be bidirectional; some factors may actually cause fear of falling while others are caused by this fear (Scheffer et al., 2008).

The relationship between fear of falling and functional ability is often affected by an individuals’ beliefs in their own capabilities (Li et al., 2003). Ultimately, fear of falling limits the performance of daily activities and hence physical function (Tinetti and Powell, 1993, Doi et al., 2012). This fear is strongly associated with reduced physical and social function (Tinetti et al., 1994). Levels of physical activity are also decreased by fear of falling (Doi et al., 2012), which in turn may promote further declines in postural stability and quality of life (Fletcher and Hirdes, 2004).
Fear of falling and avoidance of activities due to this fear are strongly correlated with multiple falls (Zijlstra et al., 2007). In an attempt to reduce fear of falling, multifactorial interventions are often recommended (Legters, 2002). These include education, environmental safety considerations, assertiveness training and physical activity (Hill et al., 1996, Tennstedt et al., 1998). However, the exact nature of the relationship between fear of falling and physical activity is currently unknown.

### 2.4.3 Summary of Physiological and Psychological Falls Risk Factor

Clearly, physiological and psychological changes such as altered balance, impaired cognition and depression contribute to an elevated prevalence of falls. In addition, sarcopenia can have detrimental effects on physical activity levels, physical function, falls and falls risk. Specifically, older adults with sarcopenia are at increased risk of falling regardless of age or sex (Landi et al., 2012). However the precise relationship between sarcopenia and falls risk, and the impact of other falls risk factors (such as sex, bone mineral density and physical function) on this association have yet to be identified.

Fear of falling is one of the more serious psychological risk factors facing older adults and warrants further investigation (Cumming et al., 2000, McAuley et al., 1997). A better understanding of fear of falling may contribute to the early identification of the problem and those at risk, and enable the design of more efficient and effective interventions for the prevention of falls.

### 2.5 Functional Risk Factors

Function-based falls risk characteristics are those associated with specific activities of daily living or exercise tasks that individuals can perform and with how well they can do so. Performance of these types of tasks provides an indication of an individual’s overall functional capacity. The two characteristics that underpin functional risk factors are physical function and physical activity, both of which are central to quality of life, independent living and healthy ageing generally. ‘Physical function’ is an individual’s ability to perform activities of daily tasks, such as climbing stairs, dressing, and bathing, which are critical to the well-being of older adults (Cress et al., 1996, Cress and Meyer,
‘Physical activity’ has been defined as any bodily movement that results in the burning of calories, and ‘exercise’ as a subcategory of physical activity that is planned, structured and repetitive (Roubenoff, 2004).

### 2.5.1 Physical Function

Physical function is the ability of an individual to complete activities of daily living (ADL). Declines in physical function are associated with an increased inability to complete ADL (Hortobagyi et al., 2003, John et al., 2009) and an increased risk of falls (Ades et al., 2003), with a consequential greater risk of losing independence (Arnett et al., 2008, Dobek, 2006). In addition, a reduction in physical function can lead to the need for hospital and long-term nursing-home care, and premature death (Beswick et al., 2008). These outcomes have the potential to increase the burden on the individual and society (Iglesias et al., 2009, Heinrich et al., 2010).

With age, there is a decline in an individual’s physical functionality, with up to 33% and 64% of individuals over 65 years and 85 years, respectively, reporting limitations in their ability to complete ADL (Frisard et al., 2007). Physical function is reliant on an individual’s muscle strength, flexibility, balance, co-ordination and endurance (Cress, 1997), as well as aerobic capacity (LaRoche et al., 2007). Typically, all of these physiological capacities deteriorate with age but the rate of functional decline can be slowed by increased physical activity (LaRoche et al., 2007). Accompanying a decrease in physical activity are greater gains in body fat, which can further exacerbate physical function disability (Visser et al., 1998a). Those who are able to resist gaining fat (Visser et al., 1998b), or obese individuals who can lose weight (Villareal et al., 2011), may have improvements in strength and be better able than their peers to maintain physical function into old age (Tseng et al., 2014). Many of the associated risk factors relating to physical function including muscular strength, balance, body composition and physical activity, as well as prevention strategies, overlap with those for falls risk.
2.5.2 Physical Activity

High levels of physical activity at any age have been shown to improve health and wellbeing, help to reduce the likelihood of obesity, delay functional decline, reduce the need for assisted living and reduce the risk of falls (American College of Sports Medicine, 2013). A sedentary lifestyle that includes inadequate physical activity can increase the risk of osteoporosis and diabetes (Warburton et al., 2006a), and associations have been found between physical inactivity and increased obesity and depression (Roberts et al., 2003).

More than one-half of Australians who are aged 65 years and over do not undertake physical activity at the level recommended in the National Physical Activity Recommendations for Older Australians (Sims et al., 2010). According to the Australian Bureau of Statistics (ABS), in 2007–2008 the proportion of Australians who did not meet the physical activity guidelines was highest (76%) for those aged 75 years and over, and 83% of people aged 75 and over were classified as sedentary or having low exercise levels (Australian Bureau of Statistics, 2008).

With increasing age, research indicates that older adults tend to engage in fewer high intensity activities and demonstrate increasing levels of sedentary behaviour (Dipietro, 2001). This trend is especially evident among older women (DiPietro, 2001). The age-related decline in physical activity is particularly concerning as physical activity is inversely related to all-cause mortality in older adults (Brown et al., 2012). Again, this relationship appears to be stronger in women than men across all levels of physical activity (Brown et al., 2012).

Physical activity is also known to improve cognition (Kelly et al., 2014) at all ages (Rattray and Smee, 2013, Angevaren et al., 2008) and also reduces depression, anxiety (Teixeira et al., 2013) and falls risk (Landi et al., 2012, Sherrington et al., 2004) in older adults. Given this information, ascertaining the emotional well-being of older adults and their level of physical activity is highly pertinent when investigating falls risk.

Increasing physical activity would most likely help minimise the social and economic burden of poor health (Davis and Fox, 2007, Chodzko-Zajko et al., 2009). Physical activity
could enable healthy ageing by maintaining muscle strength and muscle mass in older people (Goodpaster et al., 2006), which in turn helps retain physical function, independence (Hughes et al., 2001, Evans and Campbell, 1993), mobility (Daley and Spinks, 2000, Brandon L. Jerome 2003), aids in weight management (Schaap et al., 2013, Villareal et al., 2011) and the prevention of falls (Landi et al., 2012, Bogaerts et al., 2011). Current recommended guidelines for older adults include 30 minutes of moderate activity daily, with a mix of cardiovascular fitness, strength, balance and flexibility (Sims et al., 2010). It remains unclear what contribution each of these components provides and if any improvement in physical function simultaneously reduces falls risk.

2.5.4 Summary – Functional Risk Factors

Many of the risk factors associated with declining physical function are also risk factors for falls. Basic physical activity interventions are able to reduce the rate of functional decline and may maintain or even increase physical function (Frisard et al., 2007, Morley et al., 2001). Indeed, it has been demonstrated that targeted exercise programs offer significant improvements in an individual’s performance (Dobek, 2006). To date, it has not yet been established if a single exercise intervention can simultaneously improve both the falls risk and physical function of an individual.

2.6 Body Composition Factors

The potential for a relationship between changes in body composition and falls incidence, considered together, has recently created a degree of interest in the research community. However, the significance of any relationship between body composition and falls risk is currently unknown. The ageing process leads to adverse changes in body composition, with increases in fat mass (Flegal et al., 2012) and decreases in both skeletal muscle mass (Koster et al., 2011) and bone mineral density (BMD) (Steiger et al., 1992). These changes in body composition result in increased risk of disability (Tseng et al., 2014) and loss of independence (Brady et al., 2013). The complex association between body composition, physical function, bone density and falls risk is thought to be further complicated by sex differences, which impact all these factors. The relationships between these factors have yet to be fully explored.
2.6.1 Fat Mass

The ageing process is accompanied by changes in body composition – specifically, an increase in adipose tissue and a decrease in muscle mass (Goodpaster et al., 2006). It is estimated that in the USA ~37% of men and 42% of women > 60 years are obese, as defined by having a BMI ≥ 30 kg/m\(^2\) (Ogden et al., 2012) with similar findings in Australia (Cameron et al., 2003). Furthermore, as older women tend to possess greater amounts of fat mass, which impact directly on their physical function (Villareal et al., 2011), they are at increased risk of physical disability (Valentine et al., 2009, Tseng et al., 2014). Obesity is also associated with a greater risk of falling in older adults (Fjeldstad et al., 2008, Himes and Reynolds, 2012, Madigan et al., 2014, Mitchell et al., 2014), and a greater decline in physical function after a fall (Himes and Reynolds, 2012). It is not only the amount of fat, but the distribution of the fat that can potentially impact on falls and other functional outcomes. Adiposity, specifically central or abdominal adiposity, is associated with an increased risk of chronic diseases, such as cardiovascular disease, diabetes and cancer (Dixon, 2010, Zhang et al., 2008). These diseases indirectly contribute to functional declines (Hung et al., 2011, Hung et al., 2012). Body fat distribution shifts toward a more central location in post-menopausal women (Ley et al., 1992), potentially increasing their falls risk and functional declines. To compound these outcomes, a greater amount of fat is associated with lower muscle mass and strength, and is indicative of accelerated loss of lean mass (Koster et al., 2011). Therefore, minimising any increase in fat mass with increasing age may aid in lean mass retention and maintenance of muscle quality, thus reducing disability and declines in physical function (Koster et al., 2011). Given this, further investigation of the impact of obesity on falls, physical function and other health-related outcomes is warranted.

2.6.2 Bone Mineral Density

Bone mineral density (BMD) is most commonly characterised as low bone density, namely osteopenia and osteoporosis (Eastell, 2013). As individuals age, bone mass declines and the incidence of osteoporosis in the older population increases. The degree of BMD in later life is dependent on a number of factors, including: peak bone mass achieved during growth (Nguyen et al., 1998); physical activity (Bolam et al., 2014); genetics (Edwards et al.,
2013); hormones (Hurley and Roth, 2000); impaired neuromuscular function (Hurley and Roth, 2000); diet (Muraki et al., 2007), and sex (Duncan et al., 2003).

When assessing BMD of the older individual it is usually compared to the average BMD of a person of the same sex at age 30 and the results are expressed in standard deviations units or ‘t-score’. If an individual’s t-score is between −1.0 and −2.5 they are said to have osteopenia, and those with t-scores below −2.5 are diagnosed with osteoporosis (Eastell, 2013). It has been estimated that a woman loses about 50% of her trabecular bone and 33% of her cortical bone during her lifetime (Riggs et al., 1981). At least half of this loss occurs in the first 10 years after menopause (Finkelstein et al., 2008). The main clinical consequence of low BMD is an increased risk of fracture, and fractures that result from osteoporosis cause considerable morbidity and mortality (Eastell, 2013). Osteoporosis is often considered to be a “women’s condition”, because it is much more common in females than in males. However, men also experience osteoporosis and its clinical consequences (Hurley and Roth, 2000).

Although osteoporosis and the risk of falling are distinct conditions that are often evaluated and managed separately, they share a number of common risk factors and both have the potential clinical endpoint of a fracture (Hurley and Roth, 2000). It has been suggested that combining the assessments of falls risk and osteoporosis may have a greater impact on reducing the associated morbidity and mortality in older adults (Cummings-Vaughn and Gammack, 2011).

The relationship between BMD, body composition, physical function, physical activity and falls or falls risk is complex. It is known that a greater percentage of women with post-menopausal osteoporosis have a history of one or more falls within the previous 12 months relative to women without osteoporosis (Beserra Da Silva et al., 2010). In addition, greater body mass is associated with greater BMD and lower fracture risk (Yang et al., 2013). An individual’s level of physical activity is also pertinent to their bone loss. Relative to sedentary individuals, more physically active older adults have less bone loss (Daly et al., 2008) and have a 20%–40% reduced risk of a hip fracture (Gregg et al., 2000). Different
types of exercise have shown benefits, with both resistance or weight-bearing exercises assisting in slowing the progression of osteoporosis (Guadalupe-Grau et al., 2009).

2.6.3 Summary – Body Composition Factors

Current understanding of the relationships between body composition (including BMD) and falls risk, physical activity and physical function is incomplete. There are reported direct associations between obesity and falls, BMD and falls, and between physical activity and body composition; a comprehensive analysis with a focus on the specific impact of these characteristics on the risk of falling has yet to be undertaken.

2.7 Diet and Nutrition

The importance of diet and nutrition for healthy ageing has become increasingly apparent. Often the approach in this area is to study individual dietary components, especially the intake of protein (Paddon-Jones and Leidy, 2014, Houston et al., 2008), vitamin D (Stockton et al., 2011, Mithal et al., 2013) and dairy products (McCabe et al., 2004, Sahni et al., 2013). This is because nutritional intake can influence muscle mass, fat mass and bone density. Data from the most recent national dietary survey in Australia (2011–2012) indicates that only 8% of adults were eating the recommended daily serves of vegetables, and 49% were eating the recommended daily serves of fruit (Australian Bureau of Statistics, 2013a). As appropriate dietary intake generally declines with age (Morley, 2001), it is possible that poor diet quality could exacerbate the risk of falling. Much of the research that links nutrition and falls risk focuses on the intake of single nutrients, notably dietary protein, calcium and vitamin D (Zoltick et al., 2011, Uusi-Rasi et al., 2012, Bischoff-Ferrari et al., 2004, Bischoff et al., 2003).

The evidence to support the hypothesis that poor nutrition increases the propensity to fall is limited, but it is believed that the relationship is indirect (Vellas et al., 1991), such that poor diet leads to decreased muscle mass and increased fat mass, which in turn leads to declines in physical capabilities (Mitchell et al., 2014). Recent work has shown that in a residential care setting, individuals who were malnourished had poorer physical performance and increased depression and risk of falling than did those with better diet quality (Singh et al.,
2014). Similarly, residential care individuals with a diet high in variety have better body composition measures (Bernstein et al., 2002). For individuals to maintain balance and postural stability, it is necessary for multiple systems (visual, vestibular, somatosensory, musculoskeletal, cognitive and neuromuscular) to interact and it is known that all of these systems can be compromised by nutritional deficiencies (Vellas et al., 1991).

### 2.7.1 Protein

It is well-established that protein is important for maintaining muscle mass (Mithal et al., 2013), and retention of muscle mass is vital for maintenance of strength, physical function and declines in falls risk (Li and Heber, 2012). Initial results from the Framingham study highlighted that the odds of falling were reduced with higher levels of dietary protein (OR=0.80) but follow-up assessment did not produce such clear-cut results (Zoltick et al., 2011). The interaction between protein intake and falls risk warrants further investigation (Zoltick et al., 2011). Protein supplementation (in malnourished older adults) is associated with a decrease in the number of falls (Neelemaat et al., 2012) and hence falls risk is reduced. Further to this, it has been suggested that adequate intake of dietary protein is vital for older adults to maintain levels of physical function and, indeed, the current recommendations of dietary protein may be insufficient (Volpi et al., 2013) and need revising.

### 2.7.2 Vitamin D

Vitamin D deficiency has been associated with muscle weakness (Schott and Wills, 1976), lower muscle mass (Fielding et al., 2011, Mithal et al., 2013) and decreased bone mineral density (Lips and van Schoor, 2011). The impact that vitamin D has on muscle mass and strength suggests that lower levels is a factor in falls risk. Vitamin D supplementation reduces an individual’s risk of falling by between 14% (Kalyani et al., 2010) and 49% (Bischoff et al., 2003). Doses of vitamin D between 800 to 1000 International Units (IU) improve both strength and balance (Muir and Montero-Odasso, 2011), reducing an individual’s potential risk of falling. Furthermore, enhanced physical function coincides with improved strength after vitamin D supplementation (Janssen et al., 2002). However, recent evidence suggests that vitamin D’s role in reducing falls and fractures may be related
to improved levels of cognition (Marcelli et al., 2014). In summary, it is likely that the benefits of vitamin D on falls risk are due to improvements in musculoskeletal function (Bischoff-Ferrari et al., 2004) and in cognition (Marcelli et al., 2014).

2.7.3 Dairy

Dairy product intake is another important dietary component that is often investigated in regards to older adults and healthy ageing. As dairy foods are a complex source of essential nutrients, such as protein, carbohydrates and calcium, and because they may be fortified with vitamin D (Sahni et al., 2013), they too may influence falls risk. However, high dairy intake is associated with greater hip BMD in men but not in women (McCabe et al., 2004). There is evidence that body composition, specifically greater lean body mass, and physical function may be improved with higher dairy intake in older women (Radavelli-Bagatini et al., 2013). It may be that the benefits obtained from dairy products are enhanced due to the unique combination of nutrients (protein, calcium and carbohydrate) in the food group rather than from any one individual component (Sahni et al., 2013). However, recent results from the Framingham study showed that not all dairy products are equally beneficial, with milk and yoghurt implicated in improved hip BMD (but not spine), whilst cream appears to be detrimental to hip BMD (Sahni et al., 2013).

2.7.4 Summary – Diet and Nutrition

Most of the studies to date have used dietary supplementation (protein, vitamin D), analysis of specific macronutrients (protein, carbohydrate) or food groups (dairy) rather than overall diet quality (adequacy of all components and food groups) to obtain information pertaining to muscle mass, bone density, physical function and falls or falls risk. What is unknown is how overall diet quality, as opposed to individual nutritional component, may benefit health and body composition and affect falls risk.

2.8 Summary – Falls Risk Factors

Large sample-size studies have identified multiple falls risk factors which lie within the categories described above: demographic; physiological and psychological; functional, body composition characteristics and diet and nutrition. All of these contribute to an
elevated risk of falling, although the quantity of evidence supporting these falls risk factors varies. The quality of the evidence also varies and has been assessed based on the four-level rating system from Lord and colleagues (2007) (Table 2.2):

- Strong evidence of association (consistently found in good studies);
- Moderate evidence of association (usually but not always found);
- Weak evidence of association (occasionally but not usually found); plus
- Little or no evidence of association (not found in published studies despite research to examine the issue).

The strength of evidence for some of the risk factors presented in Table 2.2 has been rated as ‘unknown’ where information required for making relevant judgements is limited or not known.
Table 2.2 Summary Table of Falls Risk Characteristics, Level of Evidence and Modifiability (based on Lord et al (2007) and updated from more recent literature).

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Level of Evidence</th>
<th>Modifiability</th>
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<tbody>
<tr>
<td><strong>Demographic</strong></td>
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<tr>
<td>Advanced Age</td>
<td>Strong</td>
<td>Non-modifiable</td>
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<tr>
<td>Female Sex</td>
<td>Moderate</td>
<td>Non-modifiable</td>
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<tr>
<td>History of Falls</td>
<td>Strong</td>
<td>Non-modifiable</td>
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<tr>
<td><strong>Physiological</strong></td>
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<tr>
<td>Impaired Balance</td>
<td>Moderate</td>
<td>Modifiable</td>
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<tr>
<td>Reduced Vestibular Function</td>
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<td>Unlikely</td>
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<td>Possible</td>
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<td>Impaired Cognition</td>
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<td>Possible</td>
</tr>
<tr>
<td>Depression</td>
<td>Moderate</td>
<td>Modifiable</td>
</tr>
<tr>
<td>Fear of Falling</td>
<td>Strong</td>
<td>Modifiable</td>
</tr>
<tr>
<td><strong>Functional Characteristics</strong></td>
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<tr>
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<td>Modifiable</td>
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<tr>
<td>ADL/Physical Function limitation</td>
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<td>Modifiable</td>
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<tr>
<td><strong>Body Composition</strong></td>
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<tr>
<td>Bone Mineral Density</td>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Diet and Nutrition</td>
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</tr>
</tbody>
</table>

Many falls risk factors are widely accepted, such as age and history of falls, whilst others, such as body composition and diet, are less clear and require further research to gauge their significance. Being female increases falls risk and may also detrimentally affect body composition, yet the combined influence of sex, body composition and diet quality on falls
risk and physical function is unknown. Data pertaining to the interrelationships between falls risk factors, as well as interventions that are able to reduce falls risk and improve outcomes in community-dwelling older adults, are currently inadequate. The complexity and the overlapping nature of many of these risk factors make the identification of those at greatest risk of falling a difficult task. Further information, specifically on those risk factors that are modifiable, that can assist clinicians to better assess the risk of falls in older adults is urgently needed.

2.9 Assessment Tools used in Research

2.9.1 Overview

This section identifies the main assessment tools used by studies in the literature that have been concerned with measuring falls risk and measuring physical functionality.

This section of the literature review includes both self-assessed and objective measures of falls risk, physical function, physical activity and general health measures.

Assessment tools reviewed here were selected based on the following criteria:

- Previous use in literature/populations;
- Relevance;
- Availability of normative data;
- Time taken to administer;
- Ease of administration;
- Availability; and
- Cost.

2.9.2 Falls Risk Measures

Falls risk can be self-assessed or measured objectively. Self-assessment falls risk measures explore fear of falling (which may be a consequence of falling) or an individual’s level of self-efficacy with regards to falling, with instruments such as the Falls Efficacy Scale-International (FES-I) (Appendix A1) or the Activities-specific Balance Confidence (ABC)
Scale (Appendix A2). Objective assessment tools place an emphasis on a variety of measurable characteristics, with a focus on balance and leg strength, such as evident in the Physiological Profile Assessment (PPA) (Appendix A3) and the Berg Balance Scale (BBS) (Appendix A4).

2.9.2.1 Self-Assessed Falls Risk Assessment

Fear of falling is an important risk factor associated with falls in older people. Studies suggest that fear of falling is common among older people, both those who have and have not experienced a fall, with the prevalence of elderly individuals acknowledging this fear ranging from 40% to 73% (Lachman et al., 1998, Tinetti et al., 1994). Individuals who are afraid of falling tend to have a history of falling, do poorly on tests of gait and balance, have poor vision, need assistance with activities of daily living (ADLs), and rate their own health as poor (Maki et al., 1991, Howland et al., 1998). Further, fear of falling may limit function beyond that which might be expected from the effects of an injury per se or inherent functional capacity. This reduces quality of life (Lachman et al., 1998), further exacerbating falls risk. The correlation between falls and fear of falling has been well documented (Tinetti et al., 1994, Howland et al., 1993).

Questionnaires assessing fear of falling are based on a self-efficacy framework, which demonstrates sufficient sensitivity to discriminate between different levels of fear, and are useful within both clinical and research settings. Questionnaires can help to provide information to accurately detect whether levels of fear change over time, for example following an intervention aimed at reducing the risk of falls or decreasing fear of falling. Two self-assessed falls risk measures commonly used are the FES-I and the ABC.

The Falls Efficacy Scale-International (FES-I)

The first of the self-assessment or self-efficacy scales to be developed and used within the older adult population is the ‘Falls Efficacy Scale’ (FES) (Tinetti et al., 1990). This tool measures how confident an individual feels in regards to their likelihood of falling when performing a range of activities of daily living. This scale has been shown to be valid and has excellent reliability (Tinetti et al., 1990). It correlates well with measures of balance and gait (Yardley and Smith, 2002, Tinetti et al., 1990) and the FES can predict future falls
as well as declines in functional capacity (Tinetti et al., 1994, Cumming et al., 2000, Tinetti et al., 1990). Most importantly, the FES can identify change following interventions in relation to an individual’s level of fear of falling (Petrella et al., 2000). It is historically considered the best validated self-assessment tool and has been the most widely used method of measuring fear of falling (Yardley et al., 2005). However, the FES has limitations – specifically the potential for inconsistent interpretation of the activities and a lack of ability to discriminate loss of balance confidence in higher functioning older adults (Powell and Myers, 1995).

Subsequently, the original FES has been further developed and modified to include the following: 1) a four category answer scheme; 2) additional categories that encompass a) more difficult activities, thus developing discrimination for more functional adults, and, b) categories that directly assess the fear of falling associated with social consequences; and, 3) more internationally standard terminology. This led to the development of the FES-I which addresses limitations identified within the FES (Yardley et al., 2005). The FES-I has since been shown to have acceptable internal reliability (Cronbach alpha coefficient from 0.90 to 0.97) (Kempen et al., 2007) and construct validity in different samples in different countries (Kempen et al., 2007) including fall-prone older adults (Helbostad et al., 2010), as well as having longitudinal validity (Delbaere et al., 2010c). The FES-I discriminates between subgroups better than the original ten-item FES scale (Kempen et al., 2007). Due to these findings, it has been suggested that the FES-I can be used successfully in cross-cultural rehabilitation research and clinical trials (Kempen et al., 2007). However, others suggest that further research is required into the responsiveness-to-change of the FES-I during intervention studies (Delbaere et al., 2010c). Current cut-points are defined to differentiate between low and high concern of falling (16-item FES-I: 16 – 22 and 23 – 64, respectively) and between low, moderate and high concern of falling (16-item FES-I: 16 – 19, 20 – 27 and 28 – 64, respectively) (Delbaere et al., 2010c).

Compared to the FES, the FES-I has improved falls risk discrimination between different levels of functioning adults, has more appropriate language compared to the original FES, is freely available, and is easy and fast to administer. Further, it is appropriate for use in large populations of community-dwelling independent individuals.
Activities-specific Balance Confidence (ABC) Scale

The second of the commonly-used self-assessment falls risk tool is the ABC scale. The ABC was developed in order to overcome some of the limitations of the original FES (inconsistent interpretation and lack of discrimination in higher functioning older adults (Powell and Myers, 1995)). In Powell and Myers’ 1995 study, the authors conclude that use of a dichotomous scale is not appropriate in either research or clinical practice. In addition, the multiple items make the ABC a far more reliable assessment tool. In contrast to the original FES, the ABC has greater item specificity and a wider continuum of item difficulty, including situations or activities of daily living (ADLs) performed outside the home (Powell and Myers, 1995). The wider range of item difficulty makes the ABC potentially more suitable for seniors with a moderate to high level of balancing and walking abilities and for individuals whose daily activities include those outside the home (Powell and Myers, 1995).

This scale has a two-week test–retest reliability of Intraclass Correlation Coefficient (ICC) = 0.92 and internal consistency Cronbach’s alpha of 0.96 (Liu-Ambrose et al., 2004a). The ABC distinguishes between individuals of low and high mobility, and correlates well with balance performance measures (Myers et al., 1998). Differential cut-points have been determined for both functioning and falling as outlined below.

Functioning:

- 80% = high level of physical functioning;
- 50%–80% = moderate level of physical functioning; and
- < 50% = low level of physical functioning (Myers et al., 1998).

Falling:

- < 67% = older adults at risk for falling; predictive of future falls (Lajoie and Gallagher, 2004).

The ABC has been widely used within research settings, is freely available, and easy and fast to administer. The ABC has been deemed suitable for higher functioning older adults and thus is appropriate for use within community-dwelling older adults.
2.9.2.2 **Objective Falls Risk Assessment**

In contrast to self-assessed falls risk assessments, objective assessment tools focus on a variety of measurable characteristics not altered by an individual’s self-efficacy, with a focus on balance and leg strength, as is evident in the PPA (Cress et al., 2005) and the BBS (Berg et al., 1989). These objective measures can be used to identify people who may gain benefits from falls prevention interventions (Shimada et al., 2011). Other objective tools that measure single components of falls risk, such as the Timed-Up-and-Go (Shumway-Cook et al., 2000, Buatois et al., 2008), the Sit-to-Stand (Buatois et al., 2008), or gait changes (Maki, 1997) were considered too limited for the aim of this research.

**Physiological Profile Assessment (FallScreen)**

The PPA has high external validity and test–retest reliability for assessing falls risk in older adults (Lord et al., 1991, Lord et al., 2003). There are currently two versions of the PPA: a long- and short-form. The long-form consists of 15 assessment items and takes about 45 minutes to administer. This form includes: three assessments of lower limb muscle groups (knee extensors, knee flexors and ankle dorsiflexors); three assessments of vision (high and low contrast visual acuity and edge contrast sensitivity); three assessments of peripheral sensation (tactile sensitivity, vibration sense and proprioception); assessments of both hand and foot reaction times, and four assessments of body sway/postural stability (sway on floor and foam with eyes open and closed).

In contrast, the PPA short-form is relatively quick (15 minutes) and simple to administer, readily accepted by older subjects and is portable, with less equipment to transport (Lord et al., 2003). It consists of only five assessment items, one measure from each physiological grouping: assessment of lower limb muscle groups (knee extensors/quadriceps strength); vision assessment (edge contrast sensitivity); assessment of peripheral sensation (proprioception); hand reaction time, and body sway/postural stability (sway on foam with eyes open). A score of less than 0 indicates no increased risk of falling while higher scores denote increased risk of falling. Specifically, scores of 0–1 indicate a mild increase in risk, 1–2 a moderate increase in risk, 2–3 a marked increase in risk and > 3 a very marked increase in risk of falling (Lord et al., 2003).
Falls risk scores derived from the short-form PPA are sensitive to changes induced by interventions, including resistance and balance exercises (Liu-Ambrose et al., 2004b, Lord and Castell, 1994) or strategies for maximising vision and proprioception (Lord et al., 2005). The short-form falls risk score has been shown to predict those at risk of falling with 75% accuracy in both community and institutional settings (Lord et al., 1991, Lord and Castell, 1994).

The short-form PPA provides a valid and reliable multifactorial falls risk assessment tool, assessing five of the physiological domains associated with falls. Although it requires a user license and a small amount of equipment, these limitations are outweighed by its accuracy and ability to be used in multiple settings.

**Berg Balance Scale**

The BBS was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks (Thorbahn and Newton, 1996, Berg et al., 1989, Berg et al., 1991). It is used as a clinical test of an individual’s static and dynamic balance abilities (Blum and Korner-Bitensky, 2008) and is currently considered to be the gold standard for objective functional balance tests (Langley and Mackintosh, 2007).

The BBS is a valid instrument for evaluation of the effectiveness of interventions and for quantitative description of functions in clinical practice and research (Conradsson et al., 2007). The BBS has been evaluated in several reliability studies. A change of eight BBS points (out of a possible 56) is all that is required to reveal a true change in function among older people who are dependent and living in residential care facilities (Conradsson et al., 2007).

The BBS has been shown to have excellent inter-rater (ICC = 0.98) and intra-rater reliability (ICC = 0.98), is internally consistent (0.96) (Berg et al., 1989, Berg et al., 1991), correlates with other balance measures, such as postural sway, and has good construct validity (Berg et al., 1991). However, much of this work has been completed in post-stroke patients. The BBS was recently identified as the most commonly used assessment tool across the continuum of stroke rehabilitation. In addition, beyond this specific population,
it is considered a sound measure of balance impairment in all other populations (Blum and Korner-Bitensky, 2008).

Despite the positive attributes of this assessment tool and its proposed suitability in a range of populations, there are still several factors which indicate that the BBS should be used in conjunction with other balance measures (Blum and Korner-Bitensky, 2008). For example, few tasks in the BBS test dynamic balance, which may limit its ability to challenge older adults who live independently in the community (Langley and Mackintosh, 2007). An inability to span the “ability” continuum may lead to notable ceiling and floor effects when used with community-dwelling older adults (Blum and Korner-Bitensky, 2008). Indeed, it has been suggested that the BBS may be more appropriate for use with frail older adults rather than community-dwellers (Langley and Mackintosh, 2007). Although the BBS has been shown to be poor at specifically predicting falls in community-dwelling older adults (Boulgarides et al., 2003), it has been used extensively in research pertaining to balance and falls (Blum and Korner-Bitensky, 2008, Conradsson et al., 2007, Donoghue and Stokes, 2009, Downs et al., 2013, Godi et al., 2013, Lajoie and Gallagher, 2004, Muir et al., 2008, Oppewal et al., 2013, Pereira et al., 2013, Steffen et al., 2002, Thorbahn and Newton, 1996). The BBS is used as a multilevel tool: scores of below 45 indicate an increased risk of multiple falls and significantly increasing falls risk when scores are below 40 (Muir et al., 2008). In fact, with BBS scores below 40, the risk of falling is nearly 100% (Shumway-Cook et al., 1997a). Following on from this, specific falls risk cut-points provide differentiation between low, medium and high fall risk: 41–56; 21–40; and 0–20, respectively (Berg et al., 1989).

In summary the BBS is widely used within research, is freely available and has minimal equipment requirements, but the usefulness of this tool in community-dwelling individuals warrants further investigation.

2.9.3 Physical Function Measures

Older people are at increased risk of worsening health, have declining physical function and are likely to access more healthcare services (Studenski et al., 2003). Appropriate assessment of physical function of the ageing is vitally important in both the clinical and
research settings. Functional status can provide important information about the needs for assistance in personal care and the ability to live independently. Accurately assessing changes in functional status before and after interventions is critical if changes to practice are to be recommended (Reuben and Siu, 1990). It is vital to ensure that the performance-based assessment tools are precise, accurate and sensitive in their ability to measure physical function in older adults (Cress et al., 2005). Two physical function tools that meet these requirements are the Continuous Scale Physical Functional Performance-10 (CS-PFP10) and the Short Physical Performance Battery (SPPB).

2.9.3.1 Continuous Scale Physical Functional Performance-10

In 1996, Cress and colleagues developed a functional performance tool that allowed researchers and clinicians to objectively evaluate physical function (Cress et al., 1996). The Continuous Scale Physical Functional Performance (CS-PFP) consists of a series of 15 everyday tasks that can be measured in units of weight, time or distance. The series of tasks encompasses five separate physical domains – upper body strength, lower body strength, upper body flexibility, balance and co-ordination, endurance – each measured by at least two tasks. Each physical domain can be analysed individually or combined to provide an accurate global measure of individual functionality. The scale allows a variety of functional levels to be tested (Cress et al., 1996) and has been utilised by a number of research groups to investigate a range of normal (Cress et al., 1999, Miszko et al., 2003) and clinical conditions: for example, Parkinson’s disease (Hearty, 2007), stroke (Oliver et al., 1997) and hip fractures (Oliver et al., 2004). The CS-PFP is a valid, reliable and sensitive measure of multiple facets of cardiorespiratory and neuromuscular physiology with apparently no floor or ceiling effects (Cress et al., 2005, Oliver et al., 1997, Oliver et al., 2004). Scores are strongly correlated with self-reported physical functioning measures (Cress et al., 1999). Test–retest correlations range from 0.84 to 0.97, inter-rater reliability from 0.92 to 0.99 for the CS-PFP total scores as well as the five domain scores, and internal consistency is high, with a Cronbach's alpha coefficient of 0.74 to 0.97 (Cress et al., 1996). Since its original development, the CS-PFP tool has been refined, reducing the number of tests from 15 to 10 to produce the CS-PFP10 (Appendix 5). The shortened version has also been shown to be valid, reliable and sensitive to change (Cress et al., 2005). Reducing the number of
everyday tasks from 15 to 10 makes the CS-PFP10 far easier to administer in a clinical setting and it is able to be completed in 30 minutes rather than in one hour.

Low-difficulty tasks include carrying a weighted pot a distance of 1.0 m, donning and removing a jacket, and placing and removing a sponge from an adjustable shelf. The moderate-difficulty tasks include sweeping the floor with a broom and dustpan, transferring laundry from a washer to a dryer, and then from the dryer to a basket and picking up four scarves from the floor. Finally, the high-difficulty tasks include carrying groceries 52.3 m, a 6-minute walk, sitting down and standing up from the floor and climbing stairs (Cress et al., 2005).

Activities of daily living are multifactorial, thus any assessment tool that evaluates these activities has distinct advantages. The CS-PFP10 measures total body physical function by taking into account, in an integrated manner, both cardiorespiratory and neuromuscular systems, rather than relying on one or two separate measures, thereby giving an overall picture of physical capabilities.

Although the CS-PFP10 has been used in a number of clinical populations, given the overlap between the CS-PFP10 domains and falls risk factors, concurrent assessment with falls risk is warranted. Furthermore, while it is known that aerobic exercise, such as walking (Rossat et al., 2010), and progressive home-based resistance training (Thibaud et al., 2012) improve physical function and reduce falls risk, specific balance training interventions has yet to be investigated using the CS-PFP10.

The CS-PFP10 requires specialist training, licensing, equipment and space; however, this tool has the ability to accurately assess physical function and discriminate capabilities amongst older adults, even highly-functioning individuals. In addition, the use of real-world tasks and the short administration time makes it a logical choice for exploring physical function in research.

2.9.3.2 Short Physical Performance Battery

The Short Physical Performance Battery (SPPB) (Appendix A6) is used widely by both researchers and clinicians to examine levels of physical function in older adults.
measures of lower extremity function, as assessed by the SPPB, characterise function across a broad range of healthy older adult populations (Guralnik et al., 2000, Clark et al., 2011), and in clinical populations such as with stroke (Nandy et al., 2004) or chronic obstructive pulmonary disease patients (Lord et al., 1994). The SPPB is reliable, valid (1 week ICC ranged from 0.88 to 0.92; 6-month average ICC was 0.77 (range 0.72–0.79)) (Ostir et al., 2002) and sensitive to change (Perera et al., 2006).

The SPPB includes walking speed over 2.4 m (8ft), five sit-to-stands, and standing balance tests (tandem, semi-tandem and side-by side) (Guralnik et al., 1994). A score on a scale from 0 (unable to complete) to 4 (completed within allocated time) is assigned to each performance within these three task categories. By summing the three individual category scores, a summary performance score is created for each participant (range: 0–12), with higher scores indicating better lower body function (Guralnik et al., 1994).

The SPPB requires little equipment, has no associated licensing costs, is easy to administer in a short time frame (5 to 10 min) and can be used in a clinical setting. Due to these factors and its wide reporting in the literature, it complements and extends the attributes captured by other tests.

2.9.4 General Health and Quality of Life Measures

Many tools exist to measure general health and quality of life. Measures may include self-reported health, cognition and physical activity levels. All of these are important if the overall general health of a target population is being investigated.

2.9.4.1 12-Item Short-Form Health Survey

The 12-Item Short-Form Health Survey (SF-12) (Appendix A7) is a brief generic instrument that assesses participants’ self-reported quality of life and is increasingly applied both in daily care and in clinical research (Hartholt et al., 2011). This paper-based questionnaire comprises 12 questions pertaining to an individual’s physical and emotional or mental health. The SF-12 tool provides valid and reliable information about functional well-being (Ware Jr et al., 1996, Tremblay et al., 2011) and scores are virtually identical to those obtained using the longer SF-36 (Marsh et al., 2011). Scores range from 0 to 100 such that
50 is an average score, with higher scores indicating better perceived health, and lower scores, poorer reported health (Ware Jr et al., 1996).

Advantages of this tool include that scores on both the physical (PhySF-12) and mental (MenSF-12) sub-scales can be calculated (Ware Jr et al., 1996), the questionnaire can be completed within 5–10 minutes, and normative data is available.

2.9.4.2 Sports Medicine Australia (SMA) pre-exercise screening system

The Sports Medicine Australia (SMA) pre-exercise screening system (Appendix A8), rather than a functional assessment tool (Appendix A8) was developed for exercise professionals to use when deciding if a person requires medical clearance prior to commencing an exercise program (Norton, 2005). The SMA screen is a modification of the American College of Sports Medicine guidelines for pre-exercise screening and testing (Lopez et al., 2011). Those individuals deemed not to be at high risk can begin low or moderate level physical activity without the need for medical clearance (Norton, 2005). The SMA pre-exercise screening system has a short administration time and is freely available.

2.9.4.3 Six-item Cognitive Impairment Test

Cognitive ability can be assessed using the Six-item Cognitive Impairment Test (6-CIT) (Appendix A9). The 6-CIT is valid and reliable assessment tool in older adults (Brooke and Bullock, 1999), with scores ranging from 0 (good cognition) to 12 (poor cognition). The 6-CIT is especially useful in the identification of milder dementia (Brooke and Bullock, 1999) and when screening individuals for participation in research where informed consent is required. This assessment tool is fast and easy to administer and there are no associated costs.

2.9.5 Physical Activity Measures

Physical activity over a given time period can be measured either by self-assessment, using a questionnaire, or objectively, by an electronic device such as a pedometer or accelerometer. There are a number of self-assessment tools available including the Physical Activity Survey for the Elderly (PASE) (Appendix A10).
2.9.5.1 The Physical Activity Scale in the Elderly

The PASE is a brief and easily scored tool for the assessment of physical activity in older people. It uses a seven-day recall of activities and includes frequency, duration and intensity levels for a variety of activities typical in older adults (walking, housework, gardening or exercise) with scores ranging from 0 to 793. Higher scores indicate greater physical activity levels (Washburn et al., 1993), with a higher PASE scores significantly associated with better physiological and performance characteristics (Washburn et al., 1999). Administration time for the PASE is 5–10 minutes. Washburn et al (1993) identified, in a healthy population between 65 and 100 years of age, normative values for males and females within three age ranges (65-69 years, 70-75 years and 76-100 years). Across the age continuum, the average is 102.9 hr/week (Washburn et al., 1993).

PASE is a valid and reliable 12-item self-administered assessment tool (Washburn et al., 1999, Washburn et al., 1993). It has a test–retest reliability, assessed over a three to seven week interval of ICC = 0.75 (95% CI 0.69–0.80) (Washburn et al., 1993). In addition, the PASE has a moderate correlation with pedometer readings in individuals over the age of 70 years old ($r = 0.84$) (Washburn and Ficker, 1999).

Due to its short administration time, no associated costs and availability of normative data, the PASE assessment tool is ideal for assessing physical activity, a known falls risk factor, in community-dwelling individuals.

2.9.6 Body Composition Measures

Research exploring body composition measures and their impact on falls, falls risk and physical function is increasing in the literature (Genton et al., Svantesson and Ranheim, 2001, Palvanen et al., 2014, Smee et al., 2014). Body composition measures include BMD, percentage fat mass, percentage lean mass, distribution of fat (android versus gynoid) and body mass index (BMI). The most efficient method for assessing these characteristics is Dual-energy X-ray Absorptiometry (DXA) (Buffa et al., 2011, Keogh and MacLeod, 2012). Although the original purpose of DXA was to measure bone mineral density, its ability to analyse three compartments – fat, lean soft tissues and bone mineral (Genton et al., 2002) has increased its use in research. Furthermore, DXA has been used with a range of study
population ages (De Kam et al., 2009, Bea et al., 2011, Tseng et al., 2014, Klakk et al., 2013) and disease states (Bea et al., 2011, Petroni et al., 2003).

### 2.9.7 Diet

In an effort to unravel the complex interaction surrounding dietary intake, it is becoming more common to record dietary patterns and diet quality (McNaughton et al., 2012). To ascertain how well an individual is meeting current recommended dietary guidelines, a range of diet quality indices can be employed (Kant, 1996) and these indices can be used in examining the benefits of nutritional, medical and environmental interventions (Bernstein et al., 2002). Two such measures are the Healthy Diet Indicator (HDI) and the Healthy Eating Index (HEI). These measures are calculated based on information generated from food frequency questionnaires.

The HDI is based on the WHO dietary guidelines for the prevention of chronic disease (World Health Organization, 1990). It utilises a dichotomous scale, where a score of 1 is allocated if the individual meets the guidelines and a 0 if they are outside the limits (Huijbregts et al., 1997).

The HEI is a valid and reliable tool designed to encompass dietary behaviours rather than to study single nutrients in isolation (Kennedy et al., 1995, United States Department of Agriculture, 1995). The HEI score is based on ten components: grain, vegetable, fruit, meat, milk consumption, total fat, saturated fat, cholesterol, sodium intake, and food variety. The first five components of the HEI measure the degree to which a person’s diet conforms to the recommended number of servings based on age and sex, of grains, fruits, vegetables, meats and dairy products. HEI scores range from 0 to 100, with higher scores equating to higher quality diet (Weinstein et al., 2004).

The Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2) (Giles and Ireland, 1996) from the Cancer Council Victoria, Australia, is a widely used instrument and assesses dietary intake over a long period of time (Keogh et al., 2010, Hodge et al., 2000). It is a valid 74 item semi-quantitative self-administered questionnaire that includes questions regarding habitual dietary variety. Items explore: fruit and vegetable intake; the amount and
types of milk, bread, spreads used; alcohol; the amount of sugar consumed daily; weekly egg intake, and amount of cheese eaten (Ireland et al., 1994).

The use of diet indices provides a unique opportunity to assess total diet quality in community-dwelling older adults. In addition, the impact of diet quality, assessed by these indices, on falls risk and physical function as well as on body composition measures, can be assessed.

2.9.8 Summary – Assessment Tools

From the abundance of assessment tools available; 11 assessment tools were identified as needed to comprehensively assess a population of community-dwelling older adults (Table 2.3). These were chosen in light of the seven selection criteria for potential use of such tools: previous use in literature/populations; relevance; availability of normative data; time taken to administer; ease of administration; availability; and, cost. Each tool described offers insight into a particular potential aspect of falls risk, physical function and related functional, health-related or body composition characteristics. Currently, no published research exists that has compared these assessment tools to ascertain optimal ways of assessing falls risk among community-dwelling older people, nor is there currently any evidence demonstrating their relationships with multiple falls risk predictors.
Table 2.3 Summary of Assessment Tools

<table>
<thead>
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<th>Equipment H/L/N#</th>
<th>Administration time</th>
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<td>✓</td>
<td>F</td>
<td>N</td>
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<td>-</td>
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<tr>
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<td>-</td>
<td>F</td>
<td>L</td>
<td>10 min</td>
<td>-</td>
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<tr>
<td>6-CIT</td>
<td>✓ ✓</td>
<td>-</td>
<td>F</td>
<td>N</td>
<td>10 min</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PASE</td>
<td>✓ ✓</td>
<td>✓ -</td>
<td>F</td>
<td>N</td>
<td>10 min</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>DXA</td>
<td>✓ ✓</td>
<td>✓ -</td>
<td>H</td>
<td>H</td>
<td>10–30 min</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

✓ - Yes, No

§ H = high cost, M = moderate cost, L = low cost, F = free

# H = high equipment requirements, L = low equipment requirements, N = no equipment requirement

(FES-I – Fall Efficacy Scale – International; ABC – Activities-specific Balance Confidence Scale; PPA-short – Physiological Profile Assessment short form; BBS – Berg Balance Scale; CS-PFP10 – Continuous Scale-Physical Functional Performance 10; SPPB - Short Performance Physical Battery; SMA-pre - Sports Medicine Australia pre-exercise screen; 6-CIT- 6-item Cognitive Impairment Test; PASE – Physical Activity Survey for the Elderly; DXA – Dual X-ray Absorptiometry)
2.10 Other

There are other areas that are pertinent to fall risk, body composition and healthy ageing. These include interventions, specifically those involved with exercise and sex.

2.10.1 Interventions – Exercise

Experimental research shows that interventions can reduce falls in older people in community, hospital and residential care settings (Hill and Dorevitch, 2004, Gillespie et al., 2012). As part of the National Falls Prevention for Older People Initiative, the Australian Government Department of Health and Ageing has outlined several broad falls prevention strategies (Hill and Dorevitch, 2004):

- Exercise programs – individualised home-based strength and balance exercises, group-based balance, strength and fitness exercises, Tai Chi;
- Medical/Clinical – reduction in psychotropic medications and medication reviews, cataract removal, proactive nursing interventions, improved post-hospital discharge management;
- Environmental – home hazard assessments, modifications by occupational therapists; and
- Other – falls risk assessment and vitamin D supplementation.

Multi-factorial intervention programs, which combine two or more of the above single interventions, have also been found to be effective (Scott et al., 2007, Shumway-Cook et al., 2007, Vind et al., 2010, Hill and Dorevitch, 2004). Although a recent systematic review by Gillespie suggests that the effect of exercise as a single falls prevention intervention is comparable to the effect from multifaceted interventions (Gillespie et al., 2012, Campbell and Robertson, 2007), there is still much debate about this. Multifactorial interventions have shown a relative risk score of 0.76 compared to the exercise-only interventions score of between 0.68 and 0.72, depending on the exercise (Cumming, 2013). This suggests that increasing activity levels may be more effective when used in conjunction with another intervention.
Sherrington and colleagues (2008) found that appropriately-designed exercise programs can prevent up to 42% of falls. There are many different forms of exercise interventions used to reduce falls risk and improve general physical function. These include interventions that are home-based (Nelson et al., 2004, Vestergaard et al., 2008, Vogler et al., 2009), community-based (Cress et al., 2005, DeVito et al., 2003, Munro et al., 1997, Wallace et al., 1998), or that focus on one particular aspect of physical activity, such as strength (DeVito et al., 2003, Ades et al., 2003, Sherrington et al., 2004), cardiovascular fitness (Deley et al., 2007, Telford, 2007, Warburton et al., 2006b) or balance (Nelson et al., 2004, Sherrington et al., 2004). Functional-based exercises may not only reduce falls but also improve physical function (Clemson et al., 2012). In addition, group-based Tai Chi has been found to be effective for falls prevention in a number of trials (Taylor et al., 2012, Tousignant et al., 2013). Recent work has also demonstrated that both yoga (Kelley et al., 2014, Schmid et al., 2010) and Pilates (Appell et al., 2012, Cancela et al., 2014) show promise in improving balance and reducing falls in older adults.

It has been reported that the exercises with the biggest effect on fall rates are those that challenge balance abilities when undertaken frequently (e.g. for more than 2 hours a week over a 6-month period) (Sherrington et al., 2011). Specifically, a twice-weekly program appears to be most effective for improving physical function, and long-term (>12 months, relative to short-term, <3 months) exercise adherence leads to greater improvements in physical function, as well as a greater reduction in falls risk (Sherrington et al., 2008, Rubenstein, 2006). It has been determined that a minimum dose of 50 hours of exercise is required before a reduction in falls risk can be achieved (Sherrington et al., 2008), and that programs should potentially be tailored to each individual’s level of capability (Shubert, 2011). This suggests that the total exercise dose explains the effectiveness of exercise programs aimed at reducing falls risk (Sherrington et al., 2008). Despite extensive evidence regarding exercises that provide ‘health’ benefits in relation to falls, it is still not clear which option or options best improve balance, reduce falls and potentially prevent falls altogether.
2.10.2 Sex

There are fundamental biological differences between the sexes including genetics, immune system responses, hormones and disease patterns (Oksuzyan et al., 2008). These differences can have implications on body composition (fat mass, muscle mass and bone mineral density) and muscular strength. For example changes in weight are associated with significantly greater loss of lean mass in males compared to females (Newman et al., 2005). In addition, other aspects of ageing associated with falls including gait speed (Cesari et al., 2005) and urinary incontinence (Jackson et al., 2004) also show sex differences. These sex differences need to be considered when assessing older adults for falls risk as well as in the development and implementation of interventions.

2.11 Conclusion

It is well established that amongst community-dwelling older adults many different factors combine to increase or decrease the risk of falling. The greater the number of individual risk factors, the greater the likelihood of falling within this population. The evidence supporting the importance of demographic risk factors, age, sex and history of falls is strong but evidence regarding the interplay among these and other falls risk factors, including physical activity, physical function, body composition and diet and nutrition, is limited. Specific information relating to body composition and diet and nutrition as independent falls risk factors has also yet to be comprehensively assessed within community-dwelling older adult populations. Furthermore, it is not well established, when investigating multiple falls risk predictors, how the predictive nature of these characteristics is associated with falls risk assessment tools. Finally, although the overlap between falls risk and physical function predictor characteristics appears logical, and similarly the concept that these two health outcomes may be able to be measured as a single entity, the validity of this approach has yet to be assessed. The aim of this thesis is to fill these gaps by exploring falls risk factors, specifically functional, body composition and health-related characteristics as well as diet quality in community-dwelling older Australians, and aims to assess their impact on falls risk assessment measures.
Chapter 3 Methods

This chapter identifies the general methods used across all studies, with the specific methodology reported in subsequent chapters.

3.1 Study Design

The studies presented within this thesis have a variety of designs. Table 3.1 outlines the study designs for each.

Table 3.1 Study Designs

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Duration</th>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Cross-sectional</td>
<td>N/A</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>II</td>
<td>Cross-sectional</td>
<td>N/A</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>III</td>
<td>Cross-sectional</td>
<td>N/A</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>IV</td>
<td>Cross-sectional</td>
<td>N/A</td>
<td>Chapter 7</td>
</tr>
<tr>
<td>V</td>
<td>Intervention (balance-specific)</td>
<td>16 weeks</td>
<td>Chapter 8</td>
</tr>
</tbody>
</table>

3.2 Recruitment

Participants in Studies I and II (Chapters 4 and 5) were recruited through fliers at community centres, community groups such as book clubs, exercise groups and volunteer associations, residential communities and by word-of-mouth. All participants met the selection criteria (n=245). The set of participants in Study III (Chapter 6) was a smaller subset of Studies I and II, who completed the specific dietary survey (n =171)

Participants in Studies IV and V (Chapters 7 and 8) were recruited from an independent-living community. An invitation was sent to all residents after which an information evening was held. If individuals were interested, they provided their details to the PhD
candidate (n=36). Following screening, three potential participants were excluded due to chronic disease and one eligible participant subsequently chose not to continue due to lack of time, leaving 32 participants willing and able to participate.

3.2.1 Participants

Study I and II participants were aged 60-88 years (n=245, 70% females). Participants had to meet the following selection criteria: able to ambulate independently, be community-dwelling, cognitively sound, able to undergo a Dual-energy X-ray Absorptiometry (DXA) scan and able to follow simple English instructions. Study III (n=171, 72% female) was a subset of Studies I and II and thus had the same selection criteria.

Studies IV and V included individuals aged 65-92 years who resided in an independent-living community, of which 53% were males. All participants were able to ambulate independently, and able to follow simple instructions in English. All participants had to successfully complete the Sports Medicine Australia (SMA) pre-exercise screen.

3.3 Measures

A variety of measures were used throughout Studies I-V. Measures included falls risk (both objective and self-assessed), physical function, and general health assessments. In addition, Studies I-III incorporated physical activity levels and body composition measures (bone mass density (BMD), fat mass and lean mass) using a DXA. An overview of the assessment tools and measures for each study are listed in Table 3.2.
Table 3.2 Assessment tools and measures for Studies I-V

<table>
<thead>
<tr>
<th></th>
<th>Study I</th>
<th>Study II</th>
<th>Study III</th>
<th>Study IV</th>
<th>Study V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers</td>
<td>n=245</td>
<td>n=245</td>
<td>n=171</td>
<td>n=32</td>
<td>n=32</td>
</tr>
<tr>
<td>Falls Risk</td>
<td>PPA (short); FES-I; ABC; BBS</td>
<td>PPA (short); FES-I; ABC; BBS</td>
<td>PPA (short); FES-I; ABC; BBS</td>
<td>PPA (short)</td>
<td>PPA (short)</td>
</tr>
<tr>
<td>Past history of falls</td>
<td>Previous 12 months</td>
<td>Previous 12 months</td>
<td>Previous 12 months</td>
<td>Previous 12 months</td>
<td>Previous 12 months</td>
</tr>
<tr>
<td>Physical Function</td>
<td>SPPB</td>
<td>SPPB</td>
<td>SPPB</td>
<td>CS-PFP10</td>
<td>CS-PFP10</td>
</tr>
<tr>
<td>General health/Quality of Life</td>
<td>SF-12</td>
<td>SF-12</td>
<td>SF-12</td>
<td>SF-12 SMA-pre</td>
<td>SF-12 SMA-pre</td>
</tr>
<tr>
<td>Physical Activity</td>
<td>PASE</td>
<td>PASE</td>
<td>PASE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Composition</td>
<td>DXA</td>
<td>DXA</td>
<td>DXA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diet</td>
<td></td>
<td></td>
<td></td>
<td>DQES v2</td>
<td></td>
</tr>
</tbody>
</table>

(FES-I – Fall Efficacy Scale – International; ABC – Activities-specific Balance Confidence Scale; PPA-short – Physiological Profile Assessment short form; BBS – Berg Balance Scale; CS-PFP10 – Continuous Scale-Physical Functional Performance 10; SPPB - Short Performance Physical Battery; SMA-pre - Sports Medicine Australia pre-exercise screen; 6-CIT- 6-item Cognitive Impairment Test; PASE – Physical Activity Survey for the Elderly; DXA – Dual X-ray Absorptiometry; DQES v2 Dietary Questionnaire for Epidemiological Studies Version 2)
3.4 Ethics

Approval of the conduct for all studies was obtained from the Human Research Ethics Committee at the University of Canberra (ACT, Australia). The protocol approval numbers were #12-39 and #10-60 for Studies I through III and Studies IV and V, respectively, and regular reporting to the local ethics committee was completed. All participants provided written informed consent prior to commencement of testing. In addition, the Declaration of Helsinki was adhered to throughout the research.

3.5 General Assessment Procedure

3.5.1 Studies I-III

The candidate completed all of the assessments and administered all of the surveys. All assessments were completed at the University of Canberra (in a purpose-designed suite, room 3B40), with the average length of each session approximately 1 hour and 15 minutes.

After completing the informed consent form, participants completed the assessments in the following order.

1. Falls in the previous 12 months
2. Cognition – 6-CIT (Appendix A9)
3. Quality of Life – SF-12v2 (Appendix A7)
4. Physical Activity Levels (PASE) – the PhD candidate asked participants the questions. This ensured consistency of activity allocation within the different intensity levels. (Appendix A10)
5. Physical Function – SPPB (Appendix A6)
6. Self-assessed Falls Risk Assessments
   a. FES-I – Use of the FES-I within this project required the researcher to ask individuals, “How concerned are you about falling whilst completing the following
activities……?”. The scores were recorded and a total score for the FES-I was obtained by adding the scores together, to give a possible total that ranged from 16 (no concern about falling) to 64 (severe concern about falling). (Appendix A1) 

ABC – Use of the ABC assessment tool required the researcher to ask participants to rate, “How confident are you that you will NOT lose your balance or become unsteady, when you undertake the following activities…..”, on a scale of 0% (not confident) to 100% (completely confident). An average score across the 16 tasks was calculated to obtain each participant’s ‘ABC score’ (Powell and Myers, 1995). (Appendix A2).

7. Objective Falls Risk Assessments

a. PPA – All participants completed the PPA (short-form) following instruction by the authors as per Lord et al. (2003). Results were calculated and all participants received a copy of their fall-risk report. (Appendix A3)

b. BBS – Similarly to the PPA, participants were all provided with the same instructions for completion of the BBS and the assessment was completed as per Thorbahn and Newton (1996). Results were recorded on a five-point scale, and a total score was calculated by adding all item scores with totals ranging from 0 to 56. (Appendix A4)

8. Body Composition

a. Height – This was measured by a fixed stadiometer (Seca 240, Germany), ensuring that individual was standing flat-footed, feet together with their head in the Frankfort plane. Results are presented in centimetres (cm).
b. **Body mass** – All participants were measured using an electronic scale (Tannita BC-541, Australia) with participants looking straight ahead. Results are presented as kilograms to the nearest 0.01kg (kg).

c. **Body Mass Index (BMI)** – This was calculated using the above data \[\text{BMI} = \frac{\text{body weight}}{\text{height}^2}\] and reported as kg/m².

d. **Dual energy X-ray Absorptiometry – DXA** was completed by using a Lunar Prodigy Pro scanner (GE Lunar Corp., Madison, WI USA). After certification by the Australian and New Zealand Bone and Mineral Society (ANZBMS) and becoming licensed by ACT health, the PhD candidate conducted all participant scans. The DXA machine underwent daily quality control checks and was calibrated prior to use each day, using a phantom spine and the recommended machine protocol. In addition reliability measures (on-off table) were completed on 5% of the cohort. Three different scans were undertaken as listed below.

i. **Lumbar Spine (APSpine)** – lumbar 1–4

ii. **Femur** – both total femur and femoral neck data was collected.

iii. **Total body** – head to toe assessment of body composition

Analysis was carried out with the software enCORE™ v 14.1 which provides the breakdown results. Bone Mass Density (BMD) scores for the APSpine, Femur and Total Body were reported as gm/cm². Additional measures for total body included total body fat mass percentage, android fat mass percentage, gynoid fat mass percentage and relative skeletal mass index (RSMI).
3.5.2 Study III

In addition to the other measures Study III also utilised the Victorian Cancer Council’s Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2) (Giles and Ireland, 1996). This dietary information was then used to assess participants’ diet quality using the following two scales. The Health Diet Indicator (HDI) is based on the World Health Organization dietary guidelines for the prevention of chronic disease (World Health Organization, 1990). The Healthy Eating Index (HEI) is a valid and reliable tool designed to encompass dietary behaviours rather than study single nutrients in isolation (Kennedy et al., 1995, United States Department of Agriculture, 1995).

3.5.3 Studies IV & V

The candidate completed all of the assessments and administered all of the surveys. All assessments were completed in the community hall at Kangara Waters (IRT, Bruce Canberra) with the average length of each session approximately 1 hour.

During their initial visit, participants completed their informed consent and then in order the following assessments:

1. Sports Medicine Australia Pre-Exercise Screen (SMA-pre) – to ensure the individual was able to participate in the exercise intervention. (Appendix A8)
2. Cognition (6-CIT) – to ensure that participants were cognitively sound.
3. Quality of Life (SF-12) – to assess their perceived physical and mental health.
4. CS-PFP10 – to assess the individual’s level of physical function. (Appendix A5)
5. PPA – to assess the individual’s risk of falling.

Participants were allocated to either the control or balance (wobble-board) training group; group allocation was completed by alternating allocation at time of test-session booking.

Results were recorded electronically. Participants were asked to continue with their daily routines (control) or supplemented this with the balance training consisting of three sets of exercises, of two minutes each exercise, every second day (details in Chapter 8).
Participants were provided with instructions on how to complete the exercises along with a wobble-board and a training log-book for recording their sessions. After 16-weeks, participants were invited back for re-testing (SF-12, CS-PFP10 and PPA), with attempts made to ensure participants were tested at the same time of day.

### 3.5.3.1 Balance Intervention

All participants prior to undertaking the control period and training program were provided with a brief period of instruction in the safe and proper use of the wobble board. Participants were asked to undertake 6 minutes of wobble-board practice, three days per week for the duration of project. Wobble board exercises consist of maintaining the deck of the standard commercially-available wobble board horizontal to the floor surface for as long as possible with touches of the rim to the floor kept to a minimum during the exercise time period. The program consisted of a graduated program of wobble board exercises that commenced in a doorway (holding the door frame for support), progressed to holding onto walking poles (which are less stable than door frames), to finally using the wobble board with no arm support (Figure 3.1 Wobble Board intervention instructions). At all times the exercises were performed on carpet.
<table>
<thead>
<tr>
<th>Time</th>
<th>Exercise</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mins</td>
<td><strong>Sideways rocks</strong></td>
<td>Balance with feet apart 30cm. Rock the board from one side to another.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 mins</td>
<td><strong>Lunge Rock</strong></td>
<td>Lunge position, one foot forward, one foot back</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gently lunge forward and back</td>
</tr>
<tr>
<td>2 min</td>
<td><strong>Stable Two leg balance</strong></td>
<td>Balance with feet apart 30cm as long as possible keeping board horizontal</td>
</tr>
</tbody>
</table>

Figure 3.1 Wobble Board intervention instructions
3.6 Statistical Analysis

All statistical analyses were carried out using IBM SPSS Statistics software (version 21). To provide an overview of the cohort, descriptive statistics were produced and presented as mean scores and standard deviations in all studies. Both between and within group differences were examined using a One-way Analysis of Variance. This was completed so as to identify the level of homogeneity among the sample population as well as any areas where they were statistically significant differences. Pearson product-moment correlation coefficients were used to examine bivariate relationships between the falls risk assessment tools (Studies I-IV) and the other potential predictor characteristics.

Multiple hierarchical regression analysis was undertaken (Studies I, II and IV) to investigate the relationships between the predictor variables. Multiple hierarchical linear regression analyses (Tabachnick and Fidell, 2001) estimated the contribution of health and physical characteristics to variance in falls risk. Predictor characteristics were clustered as non-modifiable and modifiable. Separate analyses were conducted for each falls risk measure. Items were added in two blocks: non-modifiable predictors (for example age or number of falls in the past 12 months) were added in block one. Non-significant predictors were removed from the model one-by-one and the model refitted until only variables that made a unique and significant contribution to explaining variance in the outcome remained in the model. Modifiable potential falls risk predictors were then added in block two and the model was refitted in the manner described above.

Preliminary exploratory analysis of the data in Studies I and II indicated substantial and systematic sex differences in participants’ health-related, physiological and functional characteristics. This sex difference was explored further via investigation of interaction terms in regression models and upon confirmation further analyses were conducted separately for males and females. This decision to analyse males and females separately is common and is particularly relevant when examining body composition (Tseng et al., 2014).
In Study V, a number of participants failed to complete the intervention program. To prevent bias and ensure statistical power was maintained, an intention-to-treat methodology was employed where participants’ original results were recorded as their post-test scores if they failed to return for re-testing. An intention-to-treat analysis potentially underestimates the effectiveness of the treatment or intervention in situations where not all participants complete a protocol (Peduzzi et al., 2002). Repeated measures t-test was then used to evaluate any differences between the groups and One-way Analysis of Variance was used to investigate within-group and between-group differences pre- and post-testing. Results are presented as mean scores and standard deviations.

Normality of data was assessed using the Kolmogorov-Smirnov test as well as visual inspection of distribution curves. As expected, not all data were normally distributed (greater number of younger people, greater number of individuals with 0 or 1 fall compared to 4 falls). This was addressed in appropriate ways. In some instances, individuals were grouped based on age (young-old, old-old and oldest-old) and between-groups analyses were undertaken to investigate whether different age groups attained different scores on the measures used and/or whether they demonstrated different patterns of associations among variables. In addition many of the statistical processes that were utilised are robust to violations of normality (i.e., linear regression analysis, analyses of variance) and results were interpreted cautiously. Finally, the results reported are consistent with hypotheses and with previous studies carried out by others.
Chapter 4 The relationship between self-assessed falls risk assessment tools and functional, health-related, and body composition characteristics

Manuscript submitted to Journal of Applied Gerontology – published


This first empirical study investigates the relationship between self-assessed falls risk – Falls Efficacy Scale-International and Activities-specific Balance Confidence scale – and intrinsic falls risk factors including physical function, physical activity and body composition.

For consistency within the thesis, the term subjective falls risk as used in the accepted manuscript has been replaced with self-assessed falls risk.
4.1 Abstract

This study sought to explore the relationship between two self-reported falls risk assessment tools (Falls Efficacy Scale-International and Activities-specific Balance Confidence scale) and functional, health-related and body composition characteristics.

Two hundred and forty five community-dwelling people aged 60-88 years underwent assessments for: Self-reported falls risk (Falls Efficacy Scale-International and Activities-specific Balance Confidence scale), health-related (cognitive, SF-12), functional (physical activity and physical function), and body composition characteristics (measured by dual x-ray absorptiometry).

Falls Efficacy Scale-International and Activities-specific Balance Confidence scale are strongly correlated with each other for females and males ($r = -.70 \ p < .001; \ r = -.65 \ p < .001$), respectively. There are substantial differences between males and females when they self-assess their risk of falling as well as what characteristics contribute to explaining these self-assessments. Females are potentially more self-aware of their functional, body composition and health-related characteristics to better estimate their own risk of falling. Falls Efficacy Scale-International correlates better with functional, body composition and health-related characteristics and thus may be more appropriate for use than the ABC in community-dwelling older adults.
4.2 Introduction

Falls are of serious concern for older adults, with one-in-three adults over the age of 65 years falling annually (Tinetti, 1988, Mirelman et al., 2012, Stevens et al., 2012). Injuries associated with falls can lead to dramatically reduced quality of life with increased social isolation and depression (Tinetti and Williams, 1998) due to fear of future falling (Tinetti et al., 1994).

Fear of falling (either as a consequence of actually falling or due to age-related declines) may further limit function beyond what might be expected from the effects of injury or underlying physical ability alone (Tinetti et al., 1994). In addition fear of falling is, in itself, an important risk factor associated with falls in older people (Tinetti et al., 1994, Delbaere et al., 2010a). The prevalence of older persons recognising this fear of falling ranges from 12% to 73%, among those not reporting recent falls (Lach, 2005, Howland et al., 1993, Lachman et al., 1998) with 36.2% of this population indicating that they were moderately to very afraid of falling (Boyd and Stevens, 2009). There also appears to be a sex difference, with fear of falling more common amongst women than men (Arfken et al., 1994). Furthermore, individuals who report fear of falling tend to have a history of falling and do poorly on tests of gait and balance, have poor vision, need assistance with activities of daily living, and/or rate their health as poor (Maki et al., 1991, Howland et al., 1998). It has been previously suggested that information pertaining to fear of falling’s impact on morbidity and functional dependence is required (Todd and Skelton, 2004), yet these relationships have not been identified. Continuing on from this, the specific relationships between fear of falling and predictor characteristics, particularly body composition, have yet to be investigated in a cohort of community-dwelling older adults.

It has been concluded that, since few falls risk assessment tools have been tested more than once or in more than one setting, it is not possible to recommend a single falls risk assessment tool for use in all settings or for all subpopulations across settings (Scott et al., 2007). Nevertheless, there are several assessment tools that can be used with confidence as part of a falls risk assessment. Two of these self-assessed falls risk
assessment tools, are the Falls Efficacy Scale - International (FES-I) and the Activities-
specific Balance Confidence (ABC) scale. The ABC was developed in order to
overcome some of the limitations of the original FES, specifically the potential for
inconsistent interpretation of the activities and the lack of the FES’s ability to
discriminate loss of balance confidence in higher functioning older adults (Powell and
Myers, 1995). However, the original FES was further developed and modified to include
the following: 1) a four category answer scheme; 2) additional categories that encompass
a) more difficult activities, thus developing discrimination for more functional adults,
and, b) categories that directly assess the fear of falling associated with social
consequences; and, 3) more internationally standard terminology. This led to the
development of the Falls Efficacy Scale-International (FES-I) which addresses
limitations identified within the FES (Yardley et al., 2005). Previous studies have
demonstrated that the ABC and FES correlate well with each other (Hotchkiss et al.,
2004) but, to date, there is no published research comparing the ABC and the FES-I
assessment tools with each other and with respondents’ body composition, functional,
and health-related characteristics.

With ageing come changes in body composition, as well as functional and health-related
c characteristics. Specifically, older adults have declines in muscle mass and strength
(LaRoche et al., 2007), bone mineral density (Verschueren et al., 2013), physical activity
levels (Milanović et al., 2013) and slimness (Goodpaster et al., 2006). After 50 years of
age, muscle strength starts to decline at an estimated rate of 15% per decade (Hughes et
al., 2001). By the time adults are in their mid-70s, they may have lost up to 50% of their
previous muscle strength with potentially substantial consequences for an individual’s
function. Bone mineral density starts to decline between the ages of 40-50 years and
women may lose up to half throughout their lifetime (Heaney et al., 2000). In addition,
physical activity levels decline with age (Dipietro et al., 1993), which negatively impacts
on body composition (individuals have increased levels of fat with poorer bone mineral
density) and muscle function, and is associated with decrements in muscle strength and
physical function (Evans, 2010). The proportion of adipose tissue increases and muscle
mass decreases (Goodpaster et al., 2006). In the USA, about 37% of men and 42% of
women aged over 60 years are obese, as defined by a BMI \( \geq 30 \text{ kg/m}^2 \) (Ogden et al., 2012), with similar findings in Australia (Cameron et al., 2003). Adiposity, specifically central adiposity, is associated with an increased risk of chronic diseases, such as cardiovascular disease, diabetes and cancer (Chang et al., 2012) and is associated with an increase in hip fracture risk (Nguyen et al., 2005). These age-related changes have the potential to increase the risk of falling and the severity of the consequences of a fall.

The aim of this study was to explore the relationship between two self-assessed falls assessment tools (the FES-I and the ABC) and a variety of functional, body composition and health-related characteristics in order to provide clinicians with enhanced decision-making capacity on the appropriateness of a given self-assessed falls risk assessment tool.

### 4.3 Method

#### 4.3.1 Participants

Participants were recruited through fliers at community centres, community groups such as book clubs, exercise groups and volunteer associations, and by word-of-mouth. Over a 6-month period two hundred and forty-five community-dwelling individuals were recruited to participate. All participants met the following criteria: over the age of 60 years, able to walk independently (with/without walking aid), able to undergo a bone density scan (DXA), able to speak English and able to follow simple instructions. All gave their written informed consent to participate in the study, which was approved by the local Committee for Ethics in Human Research (protocol 12-39). Each participant attended the testing centre where all assessments were conducted by the same investigator.

#### 4.3.2 Falls Risk and Falls

##### 4.3.2.1 Self-assessed falls risk assessment tools

The FES-I assessment tool is a 16-item scale based on answers to the question: “How concerned are you about falling whilst completing the following activities?” Total score
for the FES-I were obtained by summing the items to give scores that range from 16 (no concern about falling) to 64 (severe concern about falling) (Scott et al., 2007). The ABC assessment tool rates, on a scale of 0% (not confident) to 100% (completely confident): “How confident are you that you will NOT lose your balance or become unsteady, when you undertake the following activities?” Average scores across the 16 tasks were calculated to obtain each participant’s ‘ABC score’ (Powell and Myers, 1995).

4.3.2.2 Reported falls

Participants’ retrospective self-reported number of falls over the previous 12 months was recorded.

4.3.4 Health-Related and Functional Characteristics

4.3.4.1 General health

General health was measured using the 12-Item Short-Form Health Survey (SF-12) with the physical (PhySF-12) and mental (MenSF-12) sub scales calculated (Ware Jr et al., 1996).

4.3.4.2 Physical activity

Participants completed the Physical Activity Scale of the Elderly (PASE), which is a valid and reliable 12-item self-administered assessment tool (Washburn et al., 1999, Washburn et al., 1993). It uses a seven-day recall of activities and includes frequency, duration and intensity levels from a variety of activities typical in older adults (walking, housework gardening or exercise) with scores ranging from 0 to 793 with higher scores indicating greater physical activity levels (Washburn et al., 1993). A higher PASE score is significantly associated with better physiological and performance characteristics (Washburn et al., 1999). Scores are presented as hours per week (hr/w).
4.3.4.3 Cognition

Cognitive ability was assessed using the Six-item Cognitive Impairment Test (6-CIT), a valid and reliable assessment tool in older adults (Brooke and Bullock, 1999), with scores ranging from 0 (good cognition) to 12 (poor cognition).

4.3.4.4 Physical function

The Short Physical Performance Battery (SPPB) was used to assess each individual’s level of physical function. The SPPB provides estimates of future risk for hospitalisation and for decline in health and function in older adults (Guralnik et al., 1994).

4.3.5 Body Composition Characteristics

Body mass was assessed using an electronic scale (Tannita BC-541, Australia) and height by a stadiometer (Seca 240, Germany). Android, gynoid and total body fat mass were measured by dual-energy X-ray absorptiometry (DXA) using a Lunar Prodigy Pro scanner (GE Lunar Corp., Madison, WI USA). Relative skeletal muscle index (RSMI) was calculated based on the definition by Baumgartner and colleagues (1998), and body mass index (BMI) was also determined.

Bone Mineral Density (BMD) (g/cm$^2$) values of both the femur and anterior-posterior spine of lumbar 1-4 (APspine) were measured by DXA (as above). Individuals with either hip replacements or spinal fusions were not assessed for bone mineral density at those locations.

4.3.6 Statistical Approach

A one-way Analysis of Variance was used to produce descriptive statistics and Pearson product-moment correlation coefficients were calculated to examine bivariate relationships. Correlations ($r$) were described as weak (.10 to .29), moderate (.30 to .49) and strong (.50 to 1.00) (Cohen, 1988). IBM SPSS Statistics software (version 21) was used in all analyses. In descriptive and correlation analyses $p < .05$ was considered statistically significant.
Preliminary exploratory analysis indicated substantial and systematic sex differences in the functional, body composition, and health-related characteristics and this was confirmed by investigation of interaction terms in regression models. Analyses were therefore conducted separately for males and females. The decision to analyse males and females separately is commonly made, and is particularly relevant when examining body composition. (Tseng et al., 2014, Stevens et al., 2012). Similar differences in mean scores and relationships between many variables and age were non-linear and differed between age groups. These were accounted for by using quadratic terms for age in the multiple hierarchical linear regression models. Multiple hierarchical linear regression analyses (Tabachnick and Fidell, 2001) for females and males estimated the contribution of health and physical characteristics to variance in falls risk. Predictor characteristics were clustered as non-modifiable and modifiable. Separate analyses were conducted for each falls risk measure (the FES-I and the ABC). Items were added in two blocks: non-modifiable predictors (age, number of falls in the past 12 months and height) were added in block one. Non-significant predictors were removed from the model one-by-one and the model refitted until only variables that made a unique and significant contribution to explaining variance in the outcome remained in the model. Modifiable potential falls risk predictors were then added in block two (6-CIT, PASE, PhysSF-12, MenSF-12, Weight, BMI, BMDAPspine, BMDFemur, RSMI, Android fat %, Gynoid fat % and total body fat mass %), and the model was refitted in the manner described above.

4.4 Results

Participant characteristics are presented in Table 4.1. Females were more concerned about falling relative to males (FES-I - \( F_{1,243} = 5.7, p = .02 \); ABC - \( F_{1,243} = 8.9, p = .003 \)). Males were significantly taller and heavier than were females (\( F_{1,243} = 212.0, p < .001 \) and \( F_{1,243} = 95.1, p < .001 \) respectively) and were more likely to report better mental health (MenSF-12, \( F_{1,243} = 6.3, p = .03 \)) and higher levels of physical activity (\( F_{1,243} = 5.6, p = .01 \)). Males had higher BMI (\( F_{1,243} = 4.1, p = .05 \)), bone mineral density at both femur and APspine (\( F_{1,243} = 29.7, p < .001 \) and \( F_{1,243} = 42.9, p < .001 \) respectively) and relative skeletal mass index scores (\( F_{1,243} = 65.6, p < .001 \)) whereas females had a
significantly greater proportion of android ($F_{1,243} = 5.4, p < .02$), gynoid ($F_{1,243} = 279.7, p < .001$) and total body fat mass ($F_{1,243} = 82.9, p < .001$).
Table 4.1 Descriptive characteristics (presented as Mean ± SD) of female, male and total participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Females (n=171)</th>
<th>Males (n=74)</th>
<th>Total (n=245)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>FES-I</td>
<td>20.97* (4.17)</td>
<td>19.64 (3.16)</td>
<td>20.57 (4.05)</td>
</tr>
<tr>
<td>ABC</td>
<td>91.59 **(8.52)</td>
<td>94.82 (5.71)</td>
<td>92.57 (7.92)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>68.00 (6.29)</td>
<td>68.51 (6.04)</td>
<td>68.12 (6.21)</td>
</tr>
<tr>
<td>Falls in past 12 months</td>
<td>.34 (.74)</td>
<td>.26 (.71)</td>
<td>.31 (.73)</td>
</tr>
<tr>
<td>6-CIT</td>
<td>1.13 (1.76)</td>
<td>1.7 (2.44)</td>
<td>1.30 (2.00)</td>
</tr>
<tr>
<td>PASE (hr/wk)</td>
<td>124.49 (51.50)</td>
<td>142.19* (59.36)</td>
<td>129.84 (54.48)</td>
</tr>
<tr>
<td>PhySF-12</td>
<td>49.71 (8.41)</td>
<td>47.60 (10.56)</td>
<td>49.07 (9.14)</td>
</tr>
<tr>
<td>MenSF-12</td>
<td>53.83 (7.05)</td>
<td>57.92* (18.34)</td>
<td>55.07 (11.80)</td>
</tr>
<tr>
<td><strong>Short Performance Physical</strong></td>
<td>11.43 (1.01)</td>
<td>11.53 (.96)</td>
<td>11.46 (1.00)</td>
</tr>
<tr>
<td>Battery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.85 (6.90)</td>
<td>177.95*** (7.10)</td>
<td>168.11 (9.50)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66.97 (11.82)</td>
<td>82.73*** (11.13)</td>
<td>71.73 (13.67)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.97 (4.38)</td>
<td>26.12* (3.16)</td>
<td>25.32 (4.08)</td>
</tr>
<tr>
<td>BMD (APspine g/cm²)</td>
<td>1.10 (.19)</td>
<td>1.23*** (.21)</td>
<td>1.15 (.21)</td>
</tr>
<tr>
<td>BMD (Femur g/cm²)</td>
<td>.90 (.14)</td>
<td>1.07*** (.18)</td>
<td>.95 (.18)</td>
</tr>
<tr>
<td>RSMI (kg/m²)</td>
<td>6.05 (.55)</td>
<td>8.27*** (3.5)</td>
<td>6.72 (2.22)</td>
</tr>
<tr>
<td>Android fat mass (%)</td>
<td>40.43* (11.14)</td>
<td>37.05 (8.64)</td>
<td>39.41 (10.55)</td>
</tr>
<tr>
<td>Gynoid fat mass (%)</td>
<td>45.58*** (7.23)</td>
<td>29.51 (6.08)</td>
<td>40.72 (10.11)</td>
</tr>
<tr>
<td>Total body fat mass (%)</td>
<td>37.86*** (8.60)</td>
<td>27.62 (6.69)</td>
<td>34.77 (9.33)</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .001
The results also trended towards a significant difference between females and males with respect to their self-reported physical health and cognition: females reported better physical health ($F_{1,243} = 2.8$, PhySF-12, $p = .09$) and males had slightly better cognition ($F_{1,243} = 3.7$, 6-CIT, $p = .05$). 15% of males and 25% of females reported at least one fall in the previous 12 months, consistent with national prevalence of falls in Australia (Centre for Health Advancement and Centre for Epidemiology and Research, 2010).

There was a strong association between the FES-I and ABC ($r = -.70$, $p < .001$ and $r = -.65$, $p < .001$) for females and males, respectively (Table 4.2). The self-assessed falls risk measures were also associated with age, functional, body composition and health-related characteristics.
Table 4.2 Correlation analysis between self-assessed falls risk measures, health-related, functional and clinical characteristics for female and male participants (aged 60-88 years)

<table>
<thead>
<tr>
<th></th>
<th>Females (n=171)</th>
<th>Males (n=74)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-assessed Falls risk Assessment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FES-I</td>
<td>-.70***</td>
<td>-.65***</td>
</tr>
<tr>
<td>Age (years)</td>
<td>.09</td>
<td>-.25**</td>
</tr>
<tr>
<td><strong>Health-Related Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of falls</td>
<td>.38***</td>
<td>-.05</td>
</tr>
<tr>
<td>6-CIT</td>
<td>.00</td>
<td>.07</td>
</tr>
<tr>
<td>PhySF-12</td>
<td>-.25**</td>
<td>-.25*</td>
</tr>
<tr>
<td>MenSF-12</td>
<td>-.16**</td>
<td>-.19</td>
</tr>
<tr>
<td><strong>Functional Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PASE</td>
<td>-.26**</td>
<td>-.21</td>
</tr>
<tr>
<td>SPPB</td>
<td>-.34***</td>
<td>-.24*</td>
</tr>
<tr>
<td><strong>Body Composition Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>.03</td>
<td>-.24*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>.21**</td>
<td>-.07</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>.20**</td>
<td>.05</td>
</tr>
<tr>
<td>BMD –APspine (g/cm²)</td>
<td>.03</td>
<td>.20</td>
</tr>
<tr>
<td>BMD – femur (g/cm²)</td>
<td>-.12</td>
<td>.05</td>
</tr>
<tr>
<td>RSMI (kg/m2)</td>
<td>-.06</td>
<td>-.16</td>
</tr>
<tr>
<td>Android fat mass (%)</td>
<td>.22**</td>
<td>.15</td>
</tr>
<tr>
<td>Gynoid fat mass (%)</td>
<td>.20**</td>
<td>.12</td>
</tr>
<tr>
<td>Total body fat mass (%)</td>
<td>.25**</td>
<td>-.15*</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .001

For females, self-assessed falls risk was related to a large number of health-related characteristics, such that those with better health tended to perceive themselves as having less risk of falling (Table 4.2). The FES-I had moderate associations with the number of
falls in the previous 12 months and physical function (SPPB) and weak negative associations with physical activity levels and both components (physical and mental) of self-reported health (SF-12). In addition, higher scores on the FES-I (i.e., more perceived risk of falling) were weakly positively associated with weight, BMI and android, gynoid and total body fat mass where females who were heavier and had more fat reported greater concern with respect to falling. The ABC showed weak relationships with the same functional and health-related characteristics, however of the body composition characteristics only total fat mass was weakly negatively associated.

Males showed different patterns of association when compared to females with fewer associations between the self-assessed falls risk measures and predictor characteristics (Table 4.2). The FES-I was positively associated with age and height (the older and taller an individual the greater their fear of falling) with similar outcomes for the ABC that showed a negative association with age and height (again older and taller had greater concern). The FES-I was weakly negatively associated with self-reported physical health scores (PhySF-12) and physical function with lower reported physical health and poorer physical function indicating greater concern of falling. Overall, for females, there are significant associations between assessments of fear-of-falling, and a variety of health-related, functional and body composition characteristics. In contrast, for males, fewer associations were evident.

For females, the number of falls in the past 12 months contributed 15% to explaining the FES-I scores, indicating that more frequent recent falls were related to increasing concern about falling (Table 4.3). An additional 13% was provided by both the self-reported physical and mental health, as well as physical function and total body fat mass ($F_{5, 164} = 13.71, p < .001$). No measure of bone mineral density contributed independently to explaining the variance in FES-I derived risk of falling.
Table 4.3 Multiple hierarchical regression estimates for the prediction of variance in FES-I falls-risk score by age, health-related, functional and body composition characteristics for female participants.

<table>
<thead>
<tr>
<th>Model 1: Non-modifiable predictors</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of falls in the past 12 months</td>
<td>2.2</td>
<td>0.40</td>
<td>.38***</td>
<td>.15***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model 2: Potential Predictors</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of falls in past 12 months</td>
<td>1.57</td>
<td>.38</td>
<td>.28***</td>
<td>.28***</td>
</tr>
<tr>
<td>SF physical component</td>
<td>-.08</td>
<td>.04</td>
<td>-.16*</td>
<td></td>
</tr>
<tr>
<td>SF mental component</td>
<td>-.13</td>
<td>.04</td>
<td>-.21**</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>-.77</td>
<td>.30</td>
<td>-.18**</td>
<td></td>
</tr>
<tr>
<td>% total body fat mass</td>
<td>-.07</td>
<td>.03</td>
<td>.14*</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01, *** p < .001

Variance of risk of falling in females, as measured by ABC (Table 4.4), showed that the number of falls in the past 12 months explained 6% of the variance. Health-related (SF physical component, SF mental component), functional (PASE and SPPB) and BMI contributed an additional 24% of the variance in the ABC falls risk score (F_{6, 163} = 12.14, p < .001).
Table 4.4 Multiple hierarchical regression estimates predicting variance in ABC falls-risk score by age, health-related, functional and body composition characteristics for female participants

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1: Non modifiable predictors</strong></td>
<td>.06**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of falls in the past 12 months</td>
<td>-2.97</td>
<td>.86</td>
<td>-.23**</td>
<td></td>
</tr>
<tr>
<td><strong>Model 2: Potential Predictors</strong></td>
<td>.30***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of falls in the past 12 months</td>
<td>-1.33</td>
<td>.80</td>
<td>-.12*</td>
<td></td>
</tr>
<tr>
<td>SF physical component</td>
<td>.22</td>
<td>.07</td>
<td>.21**</td>
<td></td>
</tr>
<tr>
<td>SF mental component</td>
<td>.36</td>
<td>.08</td>
<td>.29***</td>
<td></td>
</tr>
<tr>
<td>Physical Activity Score Elderly</td>
<td>.02</td>
<td>.01</td>
<td>.12*</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>2.18</td>
<td>.61</td>
<td>.25***</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>-.39</td>
<td>.14</td>
<td>-.19**</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05, ** p < .01, *** p < .001

The regression analysis produced substantially different results for males compared to females, with 16% of the variance explained by quadratic age and height (Table 4.5). Thus, the older and taller a man is, the higher his perceived falls risk using the FES-I. SPPB and bone mineral density of the APspine made only a small contribution (1%) to the overall variance of the FES-I (F₄,₆⁹ = 5.09, p = .001). No measure of fat mass or self-perceived health contributed to explaining any variance in falls risk.
Table 4.5 Multiple Hierarchical regression estimates for the prediction of variance in FES-I falls-risk score by age, health-related, functional and body composition characteristics for male participants

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictors</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1: Non modifiable predictors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.16**</td>
</tr>
<tr>
<td>Quadratic Age in years</td>
<td>0.00</td>
<td>0.00</td>
<td>.23**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (in cm)</td>
<td>-.10</td>
<td>.06</td>
<td>-.20*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model 2: Potential Predictors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.17*</td>
</tr>
<tr>
<td>Quadratic Age in years</td>
<td>0.00</td>
<td>0.00</td>
<td>.22*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (in cm)</td>
<td>-.11</td>
<td>.06</td>
<td>-.22*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>-.87</td>
<td>.44</td>
<td>-.23*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMD (APspine g/cm²)</td>
<td>3.42</td>
<td>1.94</td>
<td>0.20*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01, *** p < .001

Quadratic age and height explained 14% of the variance in results for the males’ falls risk score as assessed by ABC (Table 4.6). SPPB contributed a further 5% (F₃,₇₀ = 5.23, p = .003) and no other health-related, functional or body composition characteristics contributed to explaining variance in falls risk.
Table 4.6 Multiple hierarchical regression estimates for the prediction of variance in ABC falls-risk score by age, health-related, functional and body composition characteristics for male participants.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1: Non modifiable predictors</strong></td>
<td></td>
<td></td>
<td></td>
<td>.14**</td>
</tr>
<tr>
<td>Quadratic Age in years</td>
<td>-.00</td>
<td>.00</td>
<td>-.30**</td>
<td></td>
</tr>
<tr>
<td>Height in cm</td>
<td>.16</td>
<td>.09</td>
<td>.20*</td>
<td></td>
</tr>
<tr>
<td><strong>Model 2: Potential Predictors</strong></td>
<td></td>
<td></td>
<td></td>
<td>.19*</td>
</tr>
<tr>
<td>Quadratic Age in years</td>
<td>-.00</td>
<td>.00</td>
<td>-.23*</td>
<td></td>
</tr>
<tr>
<td>Height in cm</td>
<td>.16</td>
<td>.09</td>
<td>.20*</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>1.20</td>
<td>.69</td>
<td>.20*</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01, *** p < .001

4.5 Discussion

This study aimed to explore the relationship between two self-assessed falls risk measures (the FES-I and the ABC) and body composition, functional, and health-related characteristics. Falls risk measures were found to be strongly correlated with one another indicating that these assessment tools measure similar constructs. However, there are substantial differences in how males and females self-assess their risk of falling and what characteristics contribute to explaining these self-assessments.

While previous studies have demonstrated that the FES and the ABC are highly correlated (Powell and Myers, 1995, Hotchkiss et al., 2004), this is the first study that has shown a correlation between the new version of the FES, the FES-I, and the ABC. The ABC was originally derived to ameliorate some of the inadequacies of the original FES (Powell and Myers, 1995); we have shown that the FES-I and the ABC offer similar outcomes for clinicians. However, the FES-I correlates better with body composition measures and may thus be more appropriate in a clinical environment.
Females’ functional, body composition and health-related characteristics are more strongly related to self-assessed falls risk measures when compared to males, particularly when the FES-I is the assessment tool. Potentially this could indicate that females are more self-aware of their functional, body composition and health-related characteristics to better estimate their own risk of falling.

It is possible that females with greater mass and body fat have an increased self-reported risk of falling in the present study because they believe that being heavier (and with more fat) means they have worse physical function. These findings are consistent with a recent report that females with greater body fat have poorer function than their slimmer peers and are thus at greater risk of disability (Tseng et al., 2014). Certainly, when evaluating their risk of falling, women in the present study appeared to take into account a greater range of functional, body composition and health-related characteristics than did men.

It is known that physical function and age are strong predictors of falls risk (Smee et al., 2012). Indications of age-related changes in functional and body composition characteristics and falls risk have been previously described. In brief, older adults have an increased risk of falling (Nevitt et al., 1991, Rubenstein, 2006) which is increased when they have lower levels of physical activity (Hughes et al., 2001, Wagner et al., 1992) and decreased physical function (Smee et al., 2012). Compared to younger adults, they also exhibit less skeletal mass (Hughes et al., 2001) and poorer results in the physical component of the SF-12 (Ware Jr et al., 1996).

It is noteworthy that, for females, age alone did not help predict self-assessed falls risk when considered alongside a range of other predictors. It is likely that the relationship between changes in age and self-assessed falls risk is more complicated than previously thought. In females, age may cause predictors characteristics (increased fat mass, reduced physical activity, poorer bone mineral density) to worsen which leads to an increased concern regarding falls to such an extent that the change in these predictors mediate the relationship between age and falls risk. In males, however, age directly impacts self-assessed falls risk. In addition, age-related changes may occur in a stepwise fashion and the predictors (number of falls, percentage of fat and physical activity)
therefore outweigh the variance explained by age alone.

From a clinical perspective, it is important to be aware that female’s falls risk is better explained by functional, body composition and health-related characteristics than is male’s falls risk. It was shown that certain supplementary information can assist in making more accurate falls risk predictions. This information includes the number of falls in the previous 12 months, the physical and the mental components of the SF-12 and the level of physical activity.

This is the first study to provide a comprehensive analysis of body composition, functional and health-related characteristics as potential contributors to self-perceived falls risk. The FES-I and the ABC tools appear to measure self-assessed falls risk, and both tools are related to functional, body composition and health-related characteristics. However given the FES-I’s relationship with multiple predictor characteristics, this provides evidence for the use of the FES-I over the ABC in community-dwelling older adults.

Females who have a had a fall in the previous 12 months have a poorer self-assessment of their own health (both physical and mental), participate in less physical activity, have reduced physical function and are more concerned about having a fall than their more robust male counterparts. Older, taller males with poorer physical function and lower BMD (lumbar spine) are also at risk of falls. In general, women are better able than men to intuitively integrate their body composition, functional and health-related characteristics when evaluating their risk of falling.

Because the cohort of participants was self-selecting, there is some likelihood of systematic error, as those individuals who volunteer to participate may be healthier, have better physical function and have less risk of falling than non-volunteers. To further consolidate the understanding of these relations future research should consider a longitudinal study. Regardless, the findings from this study – that falls risk predictors are different for males and females – can aid practitioners in clinical settings who are developing and implementing sex-specific falls programs.
Chapter 5 Association between Berg Balance, Physiological Profile Assessment and physical activity, physical function and body composition: A cross-sectional study

Manuscript submitted to *The Journal of Frailty & Aging* - accepted


Association between Berg Balance, Physiological Profile Assessment and physical activity, physical function and body composition: A cross-sectional study

The previous chapter highlighted the differences between the sexes in regards to the self-assessment of falls risk as well as between intrinsic falls risk factors. It concluded that appropriate falls risk assessment tool choice is vital – the Falls Efficacy Scale-International is the falls risk self-assessment tool of choice in community-dwelling older adults. The following chapter continues the investigation into falls risk and intrinsic falls risk factors. The study uses objective assessment tools: Physiological Profile Assessment and Berg Balance Scale.

Abstract presentation is that required by the journal.
5.1 Abstract

BACKGROUND: Falls are of great concern to older adults and costly to the health system. In addition, the relationship between falls risk and falls risk predictor characteristics is complex.

OBJECTIVE: This study aimed to explore the relationship between two objective fall-risk measures tools, the Physiological Profile Assessment and the Berg Balance Scale and to determine how an individual’s sex, level of physical function, health-related and body composition characteristics impact these objective falls risk measures.

DESIGN: A cross-sectional, observational study.

PARTICIPANTS: Two hundred and forty five community-dwelling older adults (Mean age = 68.12 years, SD = 6.21; 69.8% female).

MEASUREMENTS: Participants were assessed for falls-risk (Physiological Profile Assessment and the Berg Balance Scale), physical activity, physical functional and body composition characteristics. Pearson product-moment correlation coefficients were calculated to examine bivariate relationships and hierarchical multiple linear regression modelling was used to estimate the contribution of each predictor in explaining variance in falls-risk.

RESULTS: In females, there was a weak association between the two objective falls-risk measures ($r = -.17 p < .05$). The number of falls in the previous 12 months explained 6% of variance in Physiological Profile Assessment scores, with bone density of the lumbar spine contributing a further 1%. In males and females, variance in the Berg Balance Scale showed that age (25%) and physical function (16% for females, 28% for males) contributed significantly to the explaining variance in the falls-risk measure.

CONCLUSION: Sex differences are apparent and as such males and females should be assessed (and potentially treated) differently with regards to falls risk. Results indicate that both falls risk assessment tools measure aspects of balance but are not interchangeable. The Berg Balance Scale may be more discriminative in older, less
functioning adults and the Physiological Profile Assessment more useful in assessing falls risk in females.

KEY WORDS: falls risk, body composition, community-dwelling, older adults
5.2 Introduction

Falls are a common and potentially serious problem for older people resulting in injury (Hendriks et al., 2008), reduced physical function (Cress et al., 1999), increased need for assisted living (Boyd and Stevens, 2009) and even death (Campbell and Robertson, 2007). One-in-three community-dwelling adults over the age of 65 years fall annually (Mirelman et al., 2012), with many older individuals having multiple risk factors predisposing them to falls. Indeed, the complex interaction between risk factors is not fully understood. It is, however, recognised that the greater the number of falls risk factors, the greater the chance that individuals will fall (Barrett-Connor et al., 2009).

As body systems age, falls risk factors associated with functional and health-related characteristics change. These include: declines in muscle mass and strength (Cruz-Jentoft et al., 2010), as well as reduced cognition (Ochs-Balcom et al., 2013) and physical function (Buatois et al., 2008). These negative changes can lead to reduced physical activity levels which, in turn, increase the rate of decline in these characteristics (Delbaere et al., 2004). Body composition is also affected by age, including increases in fat mass percentage (Goodpaster et al., 2006) and declines in bone mineral density (Verschueren et al., 2013). These age-related changes have the potential to increase the risk of falling and the severity of the consequences of a fall. Recent research has highlighted the impact of obesity on increasing an individual’s risk of falling (Himes and Reynolds, 2012). Beyond this, little is known about body composition measures and falls risk. In addition, as these changes in potential falls risk factors are not the same between sexes (Day, 2013), it seems logical that falls risk will differ between the sexes.

There are several assessment tools that can be used with confidence as part of a falls risk assessment. Two of these are objective falls risk assessment tools which measure identified falls risk factors: the Berg Balance Scale (BBS) and the Physiological Profile Assessment (PPA). Other objective tools are available but tend to be less comprehensive in measurement scope, explaining only a single component of falls risk,
such as the Timed-Up-and-Go or the Sit-to-Stand (Buatois et al., 2008), and gait changes (Maki, 1997); or they are specifically designed for people in residential care settings rather than independent community-dwelling individuals (Nandy et al., 2004) who are the focus of the present study. Although these tools both assess aspects of falling, to date, there is no published research comparing the BBS and the PPA assessment tools with each other or with respondents’ body composition, functional and health-related characteristics.

This study aimed to explore the relationship between two well-validated and widely-used objective fall-risk measures tools, the Physiological Profile Assessment and the Berg Balance Scale. In addition, how an individual’s sex, level of physical function, plus health-related and body composition characteristics impact these objective falls risk measures in a population of community-dwelling older adults was investigated.

5.3 Methods

5.3.1 Participants

Participants were recruited through fliers at community centres, community groups such as book clubs, exercise groups and volunteer associations, and by word-of-mouth. Over a 6-month period 245 community-dwelling individuals were recruited to participate. All participants met the following criteria: over the age of 60 years, able to walk independently (with/without walking aid), able to undergo a bone density scan (DXA), able to speak English and able to follow simple instructions. All gave their written informed consent to participate in the study, which was approved by the local Committee for Ethics in Human Research (protocol 12-39). Each participant attended the testing centre where all assessments were conducted in person by the same investigator.
5.3.2 Measures

5.3.2.1 Falls risk Assessment

Participants completed the PPA (short-form) following instruction by the primary author. A score of less than 0 indicates no increased risk of falling while higher scores denote increased risk of falling. Specifically, scores of 0–1 indicate a mild increase in risk, 1–2 moderate increase in risk, 2–3 marked increase in risk and > 3 very marked increase in risk of falling (Lord et al., 2003). The PPA total score is derived from five assessment items, one measure from each physiological grouping: assessment of lower limb muscle groups, vision assessment, assessment of peripheral sensation (proprioception), hand reaction time, and body sway/postural stability (Lord et al., 2003). The Berg Balance Scale is a 14-item test designed to measure the balance of older adults by assessing their performance of specific functional tasks. Scores range from 0 to 56 and cut-points provide differentiation between low, medium and high fall risk: 41–56; 21–40; and 0–20, respectively (Berg et al., 1989).

5.3.2.2 Reported Falls

Participants were asked to report the number of falls (any event where the individual came to rest on a lower level) incurred over the previous 12 months.

5.3.2.3 Health-Related

Assessments of general health and cognitive ability were undertaken as a means to ascertain any individual health-related issues. General health of the participants was measured using the 12-Item Short-Form Health Survey (SF-12). Both the physical (PhysSF-12) and mental (MenSF-12) sub-scale values were calculated (Ware Jr et al., 1996).

Cognitive ability was also assessed using the Six-item Cognitive Impairment Test (6-CIT), a valid and reliable assessment tool in older adults (Brooke and Bullock, 1999), with scores ranging from 0 (good cognition) to 12 (poor cognition).
5.3.2.4 **Functional Characteristics**

Two functional characteristics (physical activity and physical function) were analysed to ascertain the overall functional capacity of the participants. Physical activity was assessed using the Physical Activity Scale of the Elderly (PASE) a validated, reliable tool (Washburn et al., 1999, Washburn et al., 1993). Scores range from 0 to 793, with higher scores indicating greater physical activity levels (Washburn et al., 1993). A higher PASE score is significantly associated with better physiological and performance characteristics (Washburn et al., 1999). Scores were recorded as hours per week (hr/w).

Physical function was measured using the Short Physical Performance Battery (SPPB). Inability to complete a task results in a score of 0, with task completion, based on the time taken to complete result in scores from 1–4. A maximum score of 12 is possible over the three task categories.

5.3.2.5 **Body Composition Characteristics**

Body mass was measured using an electronic scale (Tannita BC-541, Australia) and height by a stadiometer (Seca 240, Germany). Android and gynoid fat mass proportions as well as total body fat were assessed by dual-energy X-ray absorptiometry (DXA) using a Lunar Prodigy Pro scanner (GE Lunar Corp., Madison, WI USA). Bone Mineral Density (BMD) (g/cm²) values of both the femur and anterior-posterior spine of lumbar 1–4 (APspine) were also measured by DXA. Individuals with hip replacements or spinal fusions were not assessed for BMD. Body Mass Index (BMI) and Relative Skeletal Muscle Index (RSMI) scores were obtained from the DXA results. Analysis was carried out with the software enCORE™ v 14.1.

5.3.3 **Procedure**

After giving their informed consent, participants provided a basic medical history, undertook the cognitive assessment and underwent the battery of assessment tools as presented above. All assessment tools and other measures were administered in the same order by the same investigator using identical instructions. Results were recorded electronically.
5.3.4 Statistical Approach

A one-way Analysis of Variance was used to produce descriptive statistics and Pearson product-moment correlation coefficients were calculated to examine bivariate relationships. Correlations ($r$) were described as weak (.10 to .29), moderate (.30 to .49) and strong (.50 to 1.00). Descriptive statistics are presented as means ± standard deviations. Preliminary exploratory analysis indicated substantial and systematic sex differences in participants’ health-related, physiological and functional characteristics. Upon confirmation, analyses were conducted separately for males and females. This decision, to analyse males and females separately, is common and is particularly relevant when examining body composition (Tseng et al., 2014). Multiple hierarchical linear regression analyses for females and males estimated the contribution of health and physical characteristics to variance in falls risk (Tabachnick and Fidell, 2001).

Predictor characteristics were clustered as non-modifiable and modifiable. Separate analyses were conducted for each falls risk measure (the BBS and PPA). Items were added in two blocks: non-modifiable predictors (age, number of falls in the past 12 months and height) were added in block one. Non-significant predictors were removed from the model one-by-one and the model refitted until only variables that made a unique and significant contribution to explaining variance remained in the model. Modifiable potential falls risk predictors were then added in block two (6-CIT, PASE, PhysSF-12, MenSF-12, Weight, BMI, BMDAPspine, BMDFemur, RSMI, Android fat %, Gynoid fat % and total body fat mass %), and the model was refitted in the manner described above. IBM SPSS Statistics software (version 21) was used in all analyses. Statistical significance was set at $p < .05$.

5.4 Results

Participant characteristics are presented in Table 5.1. Males were more likely to report better mental health (MenSF-12, $p = .03$) and higher levels of physical activity ($p = .01$) than were females. Some 15% of males and 25% of females reported at least one fall in the previous 12 months, consistent with published Australian falls prevalence data (Milat et al., 2011).
Table 5.1 Participants Characteristics (Mean ± SD) Showing Significant Differences between Females and Males in Levels of Physical Activity and Self-Reported Mental Health

<table>
<thead>
<tr>
<th>Variable</th>
<th>Females (n=171)</th>
<th>Males (n=74)</th>
<th>Total (n=245)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>PPA</td>
<td>.15 (.70)</td>
<td>-.17 (.77)</td>
<td>.05 (.74)</td>
</tr>
<tr>
<td>BBS</td>
<td>55.29 (1.72)</td>
<td>55.24 (2.04)</td>
<td>55.28 (1.82)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>68.00 (6.29)</td>
<td>68.51 (6.04)</td>
<td>68.12 (6.21)</td>
</tr>
<tr>
<td>Falls in past 12 months</td>
<td>.34 (.74)</td>
<td>.26 (.71)</td>
<td>0.31 (.73)</td>
</tr>
<tr>
<td>6-CIT</td>
<td>1.13 (1.76)</td>
<td>1.7 (2.44)</td>
<td>1.30 (2.00)</td>
</tr>
<tr>
<td>PASE (hr/wk)</td>
<td>124.49 (51.50)</td>
<td>142.19* (59.36)</td>
<td>129.84 (54.48)</td>
</tr>
<tr>
<td>PhySF-12</td>
<td>49.71 (8.41)</td>
<td>47.60 (10.56)</td>
<td>49.07 (9.14)</td>
</tr>
<tr>
<td>MenSF-12</td>
<td>53.83 (7.05)</td>
<td>57.92* (18.34)</td>
<td>55.07 (11.80)</td>
</tr>
<tr>
<td>Short Performance Physical Battery</td>
<td>11.43 (1.01)</td>
<td>11.53 (.96)</td>
<td>11.46 (1.00)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.85 (6.90)</td>
<td>177.95*** (7.10)</td>
<td>168.11 (9.50)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66.97 (11.82)</td>
<td>82.73*** (11.13)</td>
<td>71.73 (13.67)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.97 (4.38)</td>
<td>26.12* (3.16)</td>
<td>25.32 (4.08)</td>
</tr>
<tr>
<td>BMD (APspine g/cm²)</td>
<td>1.10 (.19)</td>
<td>1.23*** (.21)</td>
<td>1.15 (.21)</td>
</tr>
<tr>
<td>BMD (Femur g/cm²)</td>
<td>.90 (.14)</td>
<td>1.07*** (.18)</td>
<td>.95 (.18)</td>
</tr>
<tr>
<td>RSMI (kg/m²)</td>
<td>6.05 (.55)</td>
<td>8.27*** (3.5)</td>
<td>6.72 (2.22)</td>
</tr>
<tr>
<td>Android fat mass (%)</td>
<td>40.43* (11.14)</td>
<td>37.05 (8.64)</td>
<td>39.41 (10.55)</td>
</tr>
<tr>
<td>Gynoid fat mass (%)</td>
<td>45.58*** (7.23)</td>
<td>29.51 (6.08)</td>
<td>40.72 (10.11)</td>
</tr>
<tr>
<td>Total body fat mass (%)</td>
<td>37.86*** (8.60)</td>
<td>27.62 (6.69)</td>
<td>34.77 (9.33)</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01, ***p < .001
Associations between the objective falls risk measures and functional, health-related and body composition characteristics are presented in Table 5.2.
Table 5.2 Correlation Analysis between Physiological Profile Assessment and Berg Balance Scale, Age, Functional, Health-Related and Body Composition Characteristics for Females (aged 60–88 years) and Males (aged 60–83 years)

<table>
<thead>
<tr>
<th></th>
<th>Females (n=171)</th>
<th>Males (n=74)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective Falls Risk Assessment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiological Profile Assessment</td>
<td>-.17*</td>
<td>-.09</td>
</tr>
<tr>
<td>Age (years)</td>
<td>.15*</td>
<td>-.50**</td>
</tr>
<tr>
<td><strong>Health-Related Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falls in past 12 months</td>
<td>.25**</td>
<td>.06</td>
</tr>
<tr>
<td>6-CIT</td>
<td>-.02</td>
<td>-.18*</td>
</tr>
<tr>
<td>PhySF-12</td>
<td>.00</td>
<td>.20**</td>
</tr>
<tr>
<td>MenSF-12</td>
<td>.11</td>
<td>-.11</td>
</tr>
<tr>
<td><strong>Functional Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PASE</td>
<td>-.08</td>
<td>-.09</td>
</tr>
<tr>
<td>SPPB</td>
<td>-.16*</td>
<td>.57**</td>
</tr>
<tr>
<td><strong>Body Composition Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>.05</td>
<td>.02</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>.00</td>
<td>-.13</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>-.03</td>
<td>-.12</td>
</tr>
<tr>
<td>BMD – AP spine (g/cm²)</td>
<td>-.13</td>
<td>-.17*</td>
</tr>
<tr>
<td>BMD – femur (g/cm²)</td>
<td>-.12</td>
<td>.05</td>
</tr>
<tr>
<td>RSMI (kg/m²)</td>
<td>-.13</td>
<td>-.09</td>
</tr>
<tr>
<td>Android fat mass (%)</td>
<td>-.01</td>
<td>-.08</td>
</tr>
<tr>
<td>Gynoid fat mass (%)</td>
<td>.03</td>
<td>-.13</td>
</tr>
<tr>
<td>Total body fat mass (%)</td>
<td>-.01</td>
<td>-.17*</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01
In females, there was a weak but significant positive association between the two objective falls risk measures. In addition, increasing age was associated with increased risk of falling as measured by both the PPA (weak, $r = .15$) and BBS (strong, $r = -.5$). Both falls in the past 12 months and physical function (as measured by SPPB) were weakly associated with the PPA falls risk score such that a history of falls and poorer physical function increased the risk of falling. Berg Balance Scale, in females, was weakly negatively associated with cognition, BMD of the lumbar spine and total percentage fat mass and positively associated with physical activity and self-assessed physical health.

Males showed even fewer associations between the falls risk measures and the predictor characteristics than did females. In this sample, the BBS and the PPA did not correlate with each other and the PPA showed no association with any measure. Physical function was strongly and significantly positively correlated with the BBS scores: those with better physical function also had better functional balance and were thus at less risk of falling.

Assessment of the physiological domain components of the PPA that are potentially modifiable (quadriceps strength and body sway) showed a number of significant correlations in both males and females (Table 5.3) when assessed with functional, health-related and body composition characteristics. For females, body sway was positively associated with age and negatively associated with physical function, demonstrating body sway (poorer postural stability) increases with increased age and worse physical function. Finally, both weight and BMI were positively correlated with quadriceps strength such that heavier females had stronger quadriceps. For males, quadriceps strength was negatively associated with age and positively associated with physical function and BMI. Older males had less strength, moderated by having a higher BMI and better physical function. In addition, postural stability was also positively associated with age, with older men having greater sway.
Table 5.3 Associations between Physiological Profile Assessment Domain Scores and Age, Functional, Health-Related and Body Composition Characteristics for Females (aged 60–88 years) and Males (aged 60–83 years)

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Edge contrast</td>
<td>Quadriceps strength</td>
<td>Body Sway</td>
</tr>
<tr>
<td>Age (years)</td>
<td>-.28***</td>
<td>-.03</td>
<td>.18***</td>
</tr>
<tr>
<td>SPPB</td>
<td>.07</td>
<td>.01</td>
<td>-.18*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>-.09</td>
<td>.17*</td>
<td>-.06</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>-.09</td>
<td>.15*</td>
<td>-.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>-.06</td>
<td>-.40***</td>
<td>.30**</td>
</tr>
<tr>
<td>SPPB</td>
<td>-.07</td>
<td>.28*</td>
<td>-.09</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>.03</td>
<td>.26*</td>
<td>-.11</td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01, *** p < .001

For females, variance in PPA scores was predicted by the number of falls in the previous 12 months and by bone density of the lumbar spine (Table 5.4). The number of falls in the previous 12 month explained 6% of variance in scores, with bone density of the lumbar spine contributing a further 1%. No other physical, functional or health-related characteristic made a significant and independent contribution to the model. For males, none of the predictors contributed significantly to explaining variance in the PPA scores.
Table 5.4 Multiple Hierarchical Regression Estimates for the Prediction of Variance in Physiological Profile Assessment Falls risk Score by Functional, Health-Related and Body Composition Characteristics for Female Participants

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1: Non modifiable predictors</td>
<td></td>
<td></td>
<td></td>
<td>.06**</td>
</tr>
<tr>
<td>Number of falls in the past 12 months</td>
<td>.24</td>
<td>.07</td>
<td>.251**</td>
<td></td>
</tr>
<tr>
<td>Model 2: Predictors</td>
<td></td>
<td></td>
<td></td>
<td>.07*</td>
</tr>
<tr>
<td>Number of falls in the past 12 months</td>
<td>.24</td>
<td>.07</td>
<td>.26**</td>
<td></td>
</tr>
<tr>
<td>BMD APspine</td>
<td>-.51</td>
<td>.27</td>
<td>-.14*</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01

The alternative objective measure, the BBS also revealed a sex-specific explanatory model. For both females and males (Table 5.5), the variance in the BBS objective falls risk measure showed that age (25%) and physical function (16% for females and 28% for males) contributed significantly to the falls risk measure with physical function being substantially more important for males. This indicates that older and less functional people are more likely to have poorer functional balance. No other predictors made a significant independent contribution to either model.
Table 5.5 Multiple Hierarchical Regression Estimates for the Prediction of Variance in Berg Balance Scale Falls risk Score by Functional, Health-Related and Body Composition Characteristics for Female and Male Participants

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEMALES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model 1: Non modifiable predictors</strong></td>
<td>.25***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age in years</td>
<td>-.14</td>
<td>.02</td>
<td>-.50***</td>
<td></td>
</tr>
<tr>
<td><strong>Model 2: Predictors</strong></td>
<td>.41***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age in years</td>
<td>-.09</td>
<td>.02</td>
<td>-.32***</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>.75</td>
<td>.11</td>
<td>.44***</td>
<td></td>
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<tr>
<td><strong>MALES</strong></td>
<td></td>
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<tr>
<td><strong>Model 1: Non modifiable predictors</strong></td>
<td>.25***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age in years</td>
<td>-.17</td>
<td>.03</td>
<td>-.50***</td>
<td></td>
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<tr>
<td><strong>Model 2: Predictors</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Age in years</td>
<td>-.11</td>
<td>.03</td>
<td>-.33***</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>1.21</td>
<td>.18</td>
<td>.57***</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01, *** p < .001

5.5 Discussion

This study shows that while the BBS and the PPA both objectively measure aspects of balance, lower limb strength and other parameters purported to be important for falls risk, in a community-dwelling older adult population, the two tools are not interchangeable. Sex differences are apparent due to the constructs of these two assessment tools and this indicates that components critical to falls risk differ between the sexes. The small but significant correlation evident between the tools in females, however, suggests that for females, the two falls risk tools do overlap, potentially tapping into similar underlying constructs.
Previous research has shown that males perform significantly better than females in the PPA items of muscle strength, sway and some areas of vision (Lord et al., 1994). Additional analysis of the PPA physiological domains confirmed that independent, community-dwelling males have better quadriceps strength and postural stability than females. The results in this body of work agrees with others that superior quadriceps strength is associated with greater physical activity and that quadriceps strength declines with age (Skelton et al., 1994). Regardless of sex, individuals with a higher BMI seem to derive a protective benefit for strength, retaining higher relative quadriceps strength for their age.

Relatively less physical activity by females compared to males likely exacerbates their greater postural instability. Indeed, this increase in postural instability may explain the relationship between the number of falls in the previous 12 months and PPA scores for females. Only two of the five physiological domains (postural sway and quadriceps strength), used to derive the total PPA score are likely to be impacted by functional, health-related or body composition characteristics. This perhaps explains the reduced number of associations in males and to a lesser extent in females between the PPA score and predictor characteristics. The relative contributions of these physiological domains to falls risk warrants further investigation, particularly in light of the sex differences reported here.

Older individuals with poorer self-perceived health, physical activity and physical function performed poorly in the BBS. These findings are reinforced in the multiple hierarchical regression models showing that physical function, along with age, contributes significantly to explaining the variance in BBS falls risk scores. This is consistent with evidence reported by others (Langley and Mackintosh, 2007). It is thus critical that, regardless of sex, individuals maintain physical function. This will not only reduce their risk of falling but will also allow them to retain independence and mobility (Clark et al., 2011).

While physical activity shows moderate correlations with the BBS, it provides no significant explanation of the variance in the BBS falls risk scores. Physical activity is a
contributor to physical function (Villareal et al., 2011) and lower levels of physical activity are associated with increased age (Hughes et al., 2001), particularly in the areas of strength and flexibility (Caspersen et al., 2000). The negative contribution that increasing age and the associated declines in physical function provide to explaining the difference in BBS falls risk scores may potentially negate any beneficial effects exerted by physical activity alone. It appears that BBS only differentiates between those individuals that are older and have poorer physical function and physical activity. This supports the argument for caution when using the BBS to assess falls risk in higher functioning community-dwelling older adults, as it has been previously suggested that the BBS may be more appropriate for use with frail older adults in residential care rather than community-dwellers (Langley and Mackintosh, 2007).

The research presented here provides further understanding about the usefulness of objective falls risk assessment tools. However, it does not answer the question of how these assessment tools might predict to falls risk longitudinally in a population of community-dwelling older adults. In addition, the importance of functional, health-related and body composition characteristics longer term needs to be investigated to be able to better guide clinicians in assessing overall health and the likelihood of falls over time.

The interactions between the falls risk predictor characteristics and the subsequent impact on falls risk measures is complex. Sex differences are apparent and as such males and females should be assessed (and potentially treated) differently with regards to falls risk. In addition, the need for choosing an appropriate assessment tool in different populations is apparent: with the Berg Balance Scale potentially useful to discriminate older, less functioning adults and the PPA more useful in assessing falls risk in females.
Chapter 6: The relationship between diet quality and falls risk, physical function and body composition in older adults


Again differences between the sexes were highlighted in regards to objectively measured falls risk and intrinsic falls risk factors. The Berg Balance Scale is the assessment tool of choice for older, less functioning adults and the Physiological Profile Assessment is potentially more effective in discriminating falls risk in females. The next chapter focuses specifically on diet quality as a previously unexplored potential falls risk factor and its potential impact on measures of falls risk, physical function and body composition.

Abstract presentation is that required by the journal.
6.1 Abstract

**Objectives:** This study aimed to examine associations between diet quality, falls risk, physical function, physical activity and body composition.

**Design:** Cross-sectional study.

**Setting and Participants:** Data collected from 171 men and women, aged 60–88 years old, as part of the Falls Risk and Osteoporosis Longitudinal Study.

**Measurements:** Dietary Intake (Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2)), Falls Risk (Falls Efficacy Scale-International (FES-I), Activities-specific Balance Confidence (ABC), Berg Balance Scale (BBS) and Physiological Profile Assessment (PPA)), Physical Function (Short Performance Physical Battery (SPPB)), Physical Activity (Physical Activity Survey for the Elderly (PASE)) and Body Composition (fat mass, lean mass, bone mineral density (BMD), body mass index (BMI), android/gynoid ratio) were ascertained. Diet quality was determined using two measures (Healthy Eating Index (HEI) and Healthy Diet Indicator (HDI)). One-way Analysis of Variance was used to compare mean scores between females and males and Pearson product-moment correlation coefficients were calculated to examine bivariate relationships.

**Results:** Although females and males were analysed separately, the HDI-total score showed more associations that the HEI in both sexes. The HDI showed, in females weak negative associations with BMI ($p = .04$), gynoid fat ($p = .01$), total fat mass ($p = .02$), with a weak positive association between HDI and percentage lean mass ($p = .03$). Males showed positive associations between HDI and age ($p = .02$), physical function (SPPB) ($p = .04$) and self-assessed falls risk (ABC) ($p = .03$). In addition, in males, a negative association was found between HDI and FES-I ($p = .04$). The only measure that was significantly associated with the HEI-total score was the android/gynoid ratio in males ($p = .04$).

**Conclusions:** The relationship between dietary quality and body composition, falls risk and physical function in older community dwelling, higher functioning adults appear to
be sex specific. Better diet quality in females, is associated with lower BMI and fat mass, and higher lean mass, compared to male’s that are older and appear to have better physical function, are less likely to self-report falls risk and have a better fat distribution i.e. a lower android/gynoid ratio have better diet quality. These sex differences may be clinically relevant and could aid in the delivery of targeted interventions.

Key words: Diet quality, community-dwelling, sex, ageing.
6.2 Introduction

Falls are the leading cause of unintentional injury and injury-related death among older adults, with one-in-three adults over the age of 65 years falling annually (Uusi-Rasi et al., 2012). Injuries associated with falls impact on physical function and may have psychological implications such as social isolation and depression due to the fear of future falling (Tinetti et al., 1994, Tinetti, 1988). Falling may restrict habitual physical activity, inciting a further decline in physical function, consequently reducing functional ability and quality of life (Uusi-Rasi et al., 2012).

Appropriate nutrition and physical activity have the potential to prevent or delay many conditions of later life, including sarcopenia and osteoporosis, which contribute to an increased mortality from falling (Batsis et al., 2013, Wright et al., 2014). Sarcopenia significantly increases the risk of an older adult falling (Zoltick et al., 2011), and furthermore, older adults with a reduced bone mineral density (BMD) are also at an increased risk of fracture (Ostertag et al., 2013). Minimising the risk or progression of sarcopenia and osteoporosis can be achieved through appropriate physical activity (Bolam et al., 2014) and good nutrition, such as the consumption of fruit, vegetables, grains, dairy, and lean meat (Zoltick et al., 2011, Tucker et al., 1999, Kerstetter et al., 2000).

Assessing an individual’s dietary intake can be challenging (Bingham, 1987). Rather than simply examining the relationship between the intake of individual nutrients and health, diet quality indices allow the assessment of both the quality and diversity of the diet and its’ association with health status (McNaughton et al., 2008, Wirt and Collins, 2009). Two such indices are the Healthy Diet Indicator (HDI) which is based on the World Health Organization dietary guidelines for the prevention of chronic disease (Huijbregts et al., 1997, World Health Organization, 1990), and the Healthy Eating Index (HEI), a valid and reliable tool designed to encompass dietary behaviours rather than study single nutrients in isolation (United States Department of Agriculture, 1995). These two indices have previously provided insight into the prevention of chronic disease through assessing nutritional intake (Huijbregts et al., 1997, Jacques and Tucker, 2001).
Much of the research that links nutrition and falls risk focuses on the intake single nutrients particularly dietary protein, calcium, and vitamin D (Zoltick et al., 2011, Uusi-Rasi et al., 2012, Bischoff-Ferrari et al., 2004, Bischoff et al., 2003). How dietary intake as a whole affects falls risk, perception of falls risk, or physical function, has yet to be examined. Data from the most recent national dietary survey in Australia (2011-2012) demonstrated that only 8% of adults were eating the recommended daily serves of vegetables, and 49% were eating the recommended daily serves of fruit (Australian Bureau of Statistics, 2013a). A decrease in the intake of foods from these food groups has been linked to a reduced BMD, which in turn increases the risk of fracture (Ostertag et al., 2013). As appropriate dietary intake generally declines with age (Morley, 2001) it is possible that poor diet quality could exacerbate the risk of falling.

Another modifyable risk factor that has been linked to an individual’s risk of falling is obesity (Fjeldstad et al., 2008, Himes and Reynolds, 2012, Madigan et al., 2014), which is increasing in the Western world at a rapid rate (Australian Bureau of Statistics, 2013a). Beyond the fact that poor dietary intake can contribute to excess body weight, the link between body composition, diet quality and falls risk has yet to be examined, even though it is well established that both diet and physical activity are modifyable independent risk factors for unfavourable changes in body composition. With age, risk factors associated with functional and health-related characteristics change which include declines in muscle mass (Cruz-Jentoft et al., 2010, Aloia et al., 1991) and strength (Au yeung et al., 2014, Schaap et al., 2013) as well physical function (Frisard et al., 2007, Smee et al., 2012). Body composition is also affected by age, including increases in fat mass percentage (Goodpaster et al., 2006) and declines in bone mineral density (Verschueren et al., 2013).

The aim of the current study was to develop an understanding of the associations between falls risk, physical function, body composition and diet quality in a cohort of older adults.
Chapter 6 – Diet quality and falls risk, physical function and body composition

6.3 Methods

6.3.1 Participants

Participants were 171 cognitively unimpaired, community-dwelling individuals aged 60 years and over, able to walk independently (with/without walking aid), willing to undergo a bone density scan, spoke English, and able to follow simple instructions. All gave their informed written consent to participate in the study, which was approved by the University of Canberra Committee for Ethics in Human Research (protocol 12-39).

6.3.2 Measures

6.3.2.1 Falls risk Assessment

Participants completed four falls risk assessments. Two self-assessment tools, Falls Efficacy Scale - International (FES-I) scale, was administered as outlined by Yardley et al (2005) and Activities-specific Balance Confidence (ABC) as outlined by Powel and Myers (1995). Participants completed two objective falls risk assessments, the Physiological Profile Assessment (PPA), adhering to the protocol as described by Lord et al. (2003) and the Berg Balance Scale (BBS), which was administered as outlined by Thorbahn and Newton (1996).

6.3.2.2 Reported Falls

Participants were asked to report the number of falls (any event where the individual came to rest on a lower level) incurred over the previous 12 months.

6.3.2.3 Health-Related Characteristics

Assessments of general health and cognitive ability were undertaken as a means to ascertain any individual health-related issues. General health of the participants was measured using the 12-Item Short-Form Health Survey (SF-12). Both the physical (PhysSF-12) and mental (MenSF-12) sub-scale values were calculated (Ware Jr et al., 1996).
6.3.2.4 Functional Characteristics

Two functional characteristics (physical activity and physical function) were analysed to ascertain the overall functional capacity of the participants. Physical activity was assessed using the Physical Activity Scale of the Elderly (PASE) a validated, reliable tool (Washburn et al., 1999, Washburn et al., 1993). Scores were recorded as hours per week (hr/w). Physical function was measured using the Short Physical Performance Battery (SPPB) (Guralnik et al., 1994).

6.3.2.5 Body Composition Characteristics

Body weight was measured using an electronic scale (Tannita BC-541, Australia) and height by a stadiometer (Seca 240, Germany). Android, gynoid and total body fat mass as well as lean mass were assessed by dual-energy X-ray absorptiometry (DXA) using a Lunar Prodigy Pro scanner (GE Lunar Corp., Madison, WI USA). Bone Mineral Density (BMD) (g/cm²) values of both the femur and anterior-posterior spine of lumbar 1–4 (spine) were also measured by DXA. Individuals with hip replacements or spinal fusions were not assessed for BMD. Analysis was carried out with the software enCORE™ v 14.1.

6.3.2.6 Dietary intake

The Dietary Questionnaire for Epidemiological Studies, Version 2 (DQES v2) (Giles and Ireland, 1996) is widely used to assess dietary intake over a long period of time, which has been described in detail elsewhere (Hodge et al., 2000, Keogh et al., 2010). Briefly, it is a valid 74 item semi-quantitative self-administered questionnaire which includes questions regarding habitual fruit and vegetable intake, the amount and types of milk, bread, spreads used, the amount of sugar consumed daily, weekly egg intake and cheese eaten. The questionnaire contains photos depicting average serving sizes, and a list of 74 food items with frequency options ranging from never to 3 or more times per day (Ireland et al., 1994).
6.3.2.7 Dietary Quality Indices

The Health Diet Indicator (HDI) is based on the World Health Organization dietary guidelines for the prevention of chronic disease (World Health Organization, 1990). The HDI utilises a dichotomous scale, where a score of one is allocated if the individual meets the guidelines and a zero if they are outside the limits. A detailed description can be found elsewhere (Huijbregts et al., 1997).

The Healthy Eating Index (HEI) is another valid and reliable tool designed to encompass dietary behaviours rather than study single nutrients in isolation (United States Department of Agriculture, 1995). Data from food frequency questionnaires were utilised to calculate a HEI score based on ten components: grain, vegetable, fruit, meat, and milk consumption, total fat, saturated fat, cholesterol and sodium intake and food variety. The first five components of the HEI measured the degree to which a person’s diet conformed to the recommended number of serving (based on age and sex) of grains, fruits, vegetables, meats and dairy products. HEI scores range from 0 to 100, with higher scores equating to higher quality diet (Weinstein et al., 2004).

6.3.3 Procedure

After giving their informed consent, participants provided a basic medical history, undertook the cognitive assessment and underwent the battery of assessment tools as described above. All assessment tools and other measures were administered in the same order by the same investigator using identical instructions. Results were recorded electronically.

HEI and HDI scores were calculated by two independent researchers (DS and KP) for all responding participants.

6.3.4 Statistical Approach

A One-way Analysis of Variance was used to compare mean scores between females and males and Pearson product-moment correlation coefficients were calculated to examine bivariate relationships. Preliminary exploratory analysis indicated substantial and systematic sex differences in participants’ health-related, physiological and functional
characteristics and so was explored further. Upon confirmation, analyses were hereafter conducted separately for males and females. Descriptive statistics are presented as means ± standard deviations.

Pearson product-moment correlation coefficients ($r$) are reported as follows: weak (.10 to .29), moderate (.30 to .49) and strong (.50 to 1.00) (Cohen, 1988). Statistical significance was taken at $p$ value of 0.05.

### 6.4 Results

Participant characteristics are presented in Table 6.1. Males were significantly taller and heavier than females ($p < .001$) and were more likely to report better mental health ($p = .03$) and higher levels of physical activity ($p = .01$). Males had higher BMI ($p = .05$), BMD at both femur and APspine ($p < .001$) and relative skeletal mass index scores ($p < .001$) whereas females had a significantly greater proportion of android ($p < .02$), gynoid ($p < .001$), total body fat mass ($p < .001$) and lower percentage lean mass ($p < .001$) than the male cohort. HDI-total score was significantly higher in females compared to males, indicating that females had better diet quality. However there was no significant difference in HEI-total scores between males and females.
Table 6.1 Descriptive characteristics (presented as Mean ± SD) of female, male and total participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Females (n=123)</th>
<th>Males (n=48)</th>
<th>Total (n=171)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>68.00 (6.29)</td>
<td>68.51 (6.04)</td>
<td>68.12 (6.21)</td>
</tr>
<tr>
<td>PhySF-12</td>
<td>49.71 (8.41)</td>
<td>47.60 (10.56)</td>
<td>49.07 (9.14)</td>
</tr>
<tr>
<td>MenSF-12</td>
<td>53.83 (7.05)</td>
<td>57.92* (18.34)</td>
<td>55.07 (11.80)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.85 (6.90)</td>
<td>177.95*** (7.10)</td>
<td>168.11 (9.50)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66.97 (11.82)</td>
<td>82.73*** (11.13)</td>
<td>71.73 (13.67)</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>24.97 (4.38)</td>
<td>26.12* (3.16)</td>
<td>25.32 (4.08)</td>
</tr>
<tr>
<td>BMD (APspine g/cm$^2$)</td>
<td>1.10 (.19)</td>
<td>1.23*** (.21)</td>
<td>1.15 (.21)</td>
</tr>
<tr>
<td>BMD (Femur g/cm$^2$)</td>
<td>.90 (.14)</td>
<td>1.07*** (.18)</td>
<td>.95 (.18)</td>
</tr>
<tr>
<td>Total body fat mass (%)</td>
<td>37.86*** (8.60)</td>
<td>27.62 (6.69)</td>
<td>34.77 (9.33)</td>
</tr>
<tr>
<td>Android fat mass (%)</td>
<td>40.43* (11.14)</td>
<td>37.05 (8.64)</td>
<td>39.41 (10.55)</td>
</tr>
<tr>
<td>Gynoid fat mass (%)</td>
<td>45.58*** (7.23)</td>
<td>29.51 (6.08)</td>
<td>40.72 (10.11)</td>
</tr>
<tr>
<td>Lean Mass (%)</td>
<td>59.76 (8.31)</td>
<td>69.48*** (6.42)</td>
<td>62.69 (8.97)</td>
</tr>
<tr>
<td>HEI-total score</td>
<td>75.77 (8.82)</td>
<td>73.87 (8.84)</td>
<td>75.34 (8.84)</td>
</tr>
<tr>
<td>HDI-total score</td>
<td>2.83* (.77)</td>
<td>2.51 (1.04)</td>
<td>2.75 (.85)</td>
</tr>
</tbody>
</table>

*p < .05, ** p < .01, *** p < .001

Males had significantly higher daily energy intake and alcohol consumption compared to females ($p < .001$), however, females had a higher intake of protein ($p < .001$). There
were no significant differences between the sexes in carbohydrate or fat intake (Table 6.2).

Table 6.2 Dietary data (presented as Mean ± SD) of female, male and total participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Females (n=123)</th>
<th>Males (n=48)</th>
<th>Total (n=245)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Energy (kJ/day)</td>
<td>6785 (1874)</td>
<td>8366*** (1658)</td>
<td>7229 (1941)</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>81.01 (31.50)</td>
<td>85.24 (18.12)</td>
<td>82.20 (28.40)</td>
</tr>
<tr>
<td>Protein % En</td>
<td>20.2*** (3.4)</td>
<td>17.4 (2.4)</td>
<td>19.4 (3.4)</td>
</tr>
<tr>
<td>Carbohydrate (g/day)</td>
<td>173.21 (50.62)</td>
<td>206.23 (50.67)</td>
<td>182.48 (52.63)</td>
</tr>
<tr>
<td>Carbohydrate % En</td>
<td>41.0 (5.4)</td>
<td>39.4 (5.3)</td>
<td>40.6 (5.4)</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>62.43 (21.20)</td>
<td>76.66 (19.34)</td>
<td>66.43 (21.61)</td>
</tr>
<tr>
<td>Fat % En</td>
<td>33.9 (4.6)</td>
<td>33.8 (4.0)</td>
<td>33.8 (4.4)</td>
</tr>
<tr>
<td>Alcohol (g/day)</td>
<td>11.2314 (10.55)</td>
<td>26.90 (23.48)</td>
<td>15.65 (16.79)</td>
</tr>
<tr>
<td>Alcohol % En</td>
<td>4.9 (4.6)</td>
<td>9.4*** (7.2)</td>
<td>6.2 (5.8)</td>
</tr>
</tbody>
</table>

% En = Percentage of total Energy intake, *** p < .001

Healthy Diet Indicator

In females, the HDI-total score showed a weak negative association with BMI (p = .04) and percentage of both gynoid fat (p = .01) and total fat mass (p = .02) (Table 6.3). There was also a weak positive association between HDI and percentage lean mass (p = .03) for females. Males showed moderate positive associations between HDI with age (p = .02), and weak positive association with physical function (SPPB) (p = .04) and self-assessed falls risk (ABC) (p = .03) and a weak negative association between HDI and FES-I (p = .04).
When controlling for age in females, a different pattern of associations arise. Females demonstrated weak positive associations between gynoid \( r = .19\) \( p = .02\), android \( r = .19\) \( p = .02\) and total fat mas \( r = .20\) \( p = .02\) as well as weak negative correlation with lean mass \( r = 1.19\) \( p = .03\). Age also impacts on the FES-I \( r = .29\) \( p < .01\) and ABC \( r = -.23\) \( p < .01\) results indicating that those with better diet quality are more concerned with falling. No other associations were identified.

**Healthy Eating Index**

The HEI showed different relationship between diet quality and the physical and functional characteristics as well as fall-risk measures. The only measure that was significantly associated with the HEI-total score was the android/gynoid ratio in males \( p = .04\). This weak negative association indicates that those with better overall diet quality had a lower android/gynoid ratio (Table 6.3). When controlling for age no associations were found.
Table 6.3 Correlation of Healthy Diet Indicator (HDI) and Healthy Eating Index (HEI) total scores in females and males with potential diet outcome characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>No. of falls</th>
<th>PhysS F-12</th>
<th>MenS F-12</th>
<th>PASE</th>
<th>FES-I</th>
<th>ABC</th>
<th>BBS</th>
<th>PPA</th>
<th>SPPB</th>
<th>BMD Spine</th>
<th>BMD Femur</th>
<th>BMI</th>
<th>% Lean</th>
<th>% Android fat</th>
<th>% Gynoid fat</th>
<th>% Total fat</th>
<th>A/G ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>HDI</td>
<td>.07</td>
<td>-.07</td>
<td>.07</td>
<td>-.13</td>
<td>.02</td>
<td>-.13</td>
<td>.01</td>
<td>.09</td>
<td>-.07</td>
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<td>-.06</td>
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<td>.20*</td>
<td>-.13</td>
<td>-.20*</td>
<td>-.20*</td>
</tr>
<tr>
<td></td>
<td>HEI</td>
<td>-.04</td>
<td>-.03</td>
<td>.16</td>
<td>.10</td>
<td>-.02</td>
<td>-.11</td>
<td>.14</td>
<td>.15</td>
<td>-.05</td>
<td>.11</td>
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<td>-.15</td>
<td>.13</td>
<td>-.14</td>
<td>-.14</td>
<td>-.16</td>
</tr>
<tr>
<td>Male</td>
<td>HDI</td>
<td>.30*</td>
<td>-.08</td>
<td>-.07</td>
<td>.09</td>
<td>.17</td>
<td>-.25*</td>
<td>.26*</td>
<td>.24</td>
<td>.00</td>
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<td>.20</td>
<td>-.07</td>
<td>-.22</td>
<td>-.19</td>
</tr>
<tr>
<td></td>
<td>HEI</td>
<td>.15</td>
<td>-.03</td>
<td>.11</td>
<td>.13</td>
<td>-.24</td>
<td>-.10</td>
<td>.11</td>
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<td>.00</td>
<td>-.05</td>
<td>.12</td>
<td>.02</td>
</tr>
</tbody>
</table>

* p < .05
6.5 Discussion

The results from this study provide insight into the relationship between dietary quality and body composition, falls risk and physical function in older community dwelling, higher functioning adults. Better diet quality in females, is associated with lower BMI and fat mass, and higher lean mass. Males with better diet quality on the other hand are older and appear to have better physical function, are less likely to self-report falls risk and have a better fat distribution i.e. a lower android/gynoid ratio. Females may also have better diet quality compared to males which is in agreement with recent research that states that the presence of a female in the household improves the household’s overall diet quality (Santos et al., 2014, Power et al., 2014).

There are sex differences in body composition and these difference can impact physical function, for example individuals with greater fat mass have decreased physical function and increased disability (Tseng et al., 2014). Given this relationship between body composition and physical function and the results presented here, where in females’ diet quality is associated with body composition, it is of note that females’ diet quality does not appear to be related to physical function. This is likely to be due to the smaller sample size with a cohort of females with potentially higher physical function. Conversely, other than A/G ratio, males’ diet quality was not related to any body composition measures. The relationship with physical function and self-reported falls risk does indicate a link between diet and health outcomes, and that diet quality, is age related.

An unexpected finding of this study, when controlling for age, was the increased fat mass and lower lean mass identified in females, who had better diet quality. This finding warrants further investigation. Another interesting outcome was the increase in concern about falling, associated with better diet quality in females, when controlling for age. Previous research has demonstrated that the fear of falling increases with age (Arfken et al., 1994, Howland et al., 1998) therefore it may be this advancement in age and not diet quality impacting their perceived falls risk. This indicates that age is an important confounder when considering both diet and healthy ageing outcomes.
These results, in community-dwelling individuals, builds on recently published work which has indicated that undernourished individuals in residential care facilities are likely to have poorer physical performance, have depression and a greater risk of falls (Singh et al., 2014). It does appear, however, that the relationships observed are dependent on the diet quality scale used. From the results presented here, it appears that the dichotomous scale of the HDI provides evidence that elucidates stronger relationships with falls risk, physical function and body composition characteristics relative to the HEI total score.

In addition to poor diet, physical inactivity increases the risk for many costly medical conditions including falls and hip fractures (Pratt et al., 2014). Furthermore these modifiable lifestyle factors have a substantial financial and health burden in the community (Pratt et al., 2014). It could therefore be asked if a combination of improved diet quality and physical activity could synergistically reduce the risk of falling in older adults. It has recently been reported that older adults are increasingly seeking health information and are willing to make behavioural changes to maintain their health and independence into advanced old age more than any other age group, with the most important self-care behaviours being diet and physical activity (Davis, 1998). This may explain the positive/beneficial relationship between better diet quality and ageing, body composition, self-reported falls risk and physical function.

A primary goal of Healthy People 2020, as identified by the US Department of Health and Human Services, is to improve the health, function and quality of life of older adults (Davis, 1998). Older adults are among the fastest growing age groups, and are at a high risk for developing chronic illnesses and related disabilities (Lopez et al., 2006), it is therefore imperative to identify preventative health strategies and advice to assist older adults in maintaining quality of life and independence. Each year one-in-three older adults fall (Mirelman et al., 2012, Tinetti, 1988), leading to potential severe disability (Gill et al., 2013), fear of recurrent falling (Rossat et al., 2010), sedentary behaviour (Thibaud et al., 2012), which in turn leads to impaired physical function (Beavers et al., 2013) and reduced quality of life (Hartholt et al., 2011). Nutritional intake can influence the onset and progression of a range of chronic diseases. Osteoporosis and sarcopenia are two conditions that are influenced through lifestyle factors such as diet and exercise, and
are linked to a reduced physical functionality, increased risk of falling and reduced quality of life (Tarantino et al., 2013).

This paper is one of the first to examine diet quality in relation to falls risk, physical function and body composition. This line of inquiry warrants further investigation, with larger sample size and a more diverse cohort to tease out these relationships and also investigate, longitudinally the impact of age and diet quality on future health outcomes. Sex differences are apparent and clinically relevant as this is important and will aide health professionals in delivering appropriately targeted interventions.

**Acknowledgements**

The authors thank Professor Giles of the Cancer Epidemiology Centre of The Cancer Council Victoria, for permission to use the Dietary Questionnaire for Epidemiological Studies (Version 2), Melbourne: The Cancer Council Victoria, 1996.

**Conflict of Interest**

The authors report no conflict of interest.

**Ethical Standards**

The protocol for this research project was approved by the Committee for Ethics in Human Research, protocol number 12-39 and the undertaking of the research conformed to the Declaration of Helsinki.
Diet quality is associated with a number of falls risk measures, other falls risk predictor factors, such as physical function and, not surprisingly, body composition. Sex differences were again apparent, with both males and females demonstrating different associations. Physical function has been highlighted as an important intrinsic falls risk factor, yet the specific relationship between falls risk and physical function has yet to be comprehensively investigated. This next empirical study focuses on this relationship using the Physiological Profile Assessment and the Continuous Scale Physical Functional Performance-10.

For consistency within the thesis, physical functionality, as used in the accepted manuscript has been changed to physical function and Fallscreen has been changed to Physiological Profile Assessment. Other minor presentational changes have also been made to ensure consistency throughout the thesis.
7.1 Abstract

Declines in physiological attributes, such as muscle strength, due to ageing, can bring with them an increased risk of falls and subsequently greater risk of losing independence. These declines have substantial impact on an individual’s functional ability. However, the precise relationship between falls risk and physical function has not been evaluated. The aims of this study were to determine the association between falls risk and physical function using objective measures and to create an appropriate model to explain variance in falls risk. Thirty-two independently-living adults aged 65-92 years completed the Physiological Profile Assessment, the Continuous Scale Physical Functional Performance-10 tests and the 12-Item Short-Form Health Survey. The relationships between falls risk, physical function and age were investigated using correlational and multiple hierarchical regression analyses. Overall, total physical function accounted for 24% of variance in an individual’s falls risk while age explained a further 13%. The oldest-old age group had significantly greater falls risk and significantly lower physical functional performance. Mean scores for all measures showed that there were substantial (but not significant) differences between males and females. While increasing age is the strongest single predictor of increasing falls risk, poorer physical function was strongly, independently related to greater falls risk.
7.2 Introduction

Every year, 10% of adults aged 75 years and older become dependent because they cannot complete daily activities (Gill et al., 1995). Avoiding falls and being physically able to complete tasks necessary for everyday living are essential components of independent living with ageing (Daley and Spinks, 2000). One-in-three community-dwelling adults aged 65 years or older fall each year and about one-half suffer multiple falls (Martin, 1999). Among older adults, falls are the main cause of fractures, hospital admissions for trauma, loss of independence and injury-related deaths (Kannus, 1999). Falls injuries cause distress, pain and significant impact on quality of life due to isolation, disability and a loss of confidence (Karinkanta, 2010). Falls can also have a financial impact from associated health care costs (Rubenstein, 2006). Many older adults are afraid of falling (Barnett, 2003) and this fear becomes more common as people age, even among those who have not yet fallen. Falling and fear of falling are also potential contributing factors to decreased mobility and increased functional dependence (Martin, 1999).

Good physical function reduces need for care (Manini and Pahor, 2009), hospitalisation (Daley and Spinks, 2000) and risk of mortality (Manton, 1988) while declines in endurance and altered musculoskeletal integrity and body composition can substantially reduce a person’s functional ability or ‘activities of daily living’ (Jones, 2005). Typical declines in ageing include, but are not limited to, decreases in: muscle strength (John et al., 2009), flexibility (Hong et al., 2000), balance (Lord et al., 1995), reaction time (Fozard et al., 1994) and the function of the senses (vision and hearing) (Tinetti, 1988). All of these declines bring with them an increased risk of falls (Hsu et al., 2007) and reduced ability to complete daily activities (John et al., 2009) with a consequentially greater risk of losing independence (Arnett et al., 2008).

Most studies have used paper-based methods of falls assessment (Arai et al., 2007) or physical testing, to test an individual’s ability to complete a small number every-day tasks (such walking for 6 minutes, getting out of bed, functional reach, climbing stairs, rising from a chair, picking up small objects and foot-tapping) (Capodaglio et al., 2007) but few have concurrently investigated a range of functional tasks. Although these tests can measure individual physical abilities, they fail to measure an individual’s overall physical function. The Physiological Profile Assessment (PPA) (Lord et al., 2003) is a series of objective direct measures of physiological characteristics
associated with falls risk, whereas the Continuous Scale Physical Function Performance-10 (CS-PFP10) (Cress et al., 2005) is an assessment of functional capacity based on a combination of tasks.

While the risk factors associated with falls are well-established (Tinetti, 1988, Lord and Sturnieks, 2005, Rubenstein, 2006), as are the age-related declines in physical function (Arai et al., 2007), the relationship between these two has yet to be characterised objectively. The aims of this study were to (i) describe the relationship between falls risk and physical function using objective measures and (ii) investigate the relative contribution of age and physical function to explaining variance in falls risk.

7.3 Methods

7.3.1 Participants

Persons aged 65 years and older, able to speak English and were able to follow verbal directions were eligible to participate in the study. Thirty-two individuals residing in an independent-living urban community in Canberra, Australia volunteered to participate (53% male, 47% female) aged 65–92 years (mean = 77.9, SD = 7.7). Potential participants were contacted via email to attend an information evening about the study and, if willing to participate (n = 36), were invited to participate. Following screening, three potential participants were excluded due to chronic disease and a further one withdrew, leaving 32 participants willing and able to participate. Details of the study were explained prior to commencing with written consent obtained from all individuals.

7.3.2 Measures

Participants stated their age and sex. Three age categories were created: ‘young-old’ (65–74 years), ‘old-old’ (75–84 years) and ‘oldest-old’ (85+ years).

7.3.2.1 Falls Risk

The short-form of Physiological Profile Assessment (Lord et al., 2003), 5-item (vision, peripheral sensation, lower limb strength, reaction time and body sway) risk calculator that measures five determinants of falls risk was used. These assessments are readily accepted by
older people and have high external validity and test-retest reliability (Lord et al., 2003) and are reported to predict those at risk of falling with 75% accuracy in community and institutional settings (Lord and Sturnieks, 2005).

7.3.2.2 Reported falls

Participants’ number of falls over the previous 12 months was also recorded.

7.3.2.3 Health

General health was measured using the physical and mental health sub-scales from the 12-Item Short-Form Health Survey (SF12v2)(Ware Jr et al., 1996). Scores for each sub-scale range from 0 to 100 with higher scores indicating better health. Other health-related data included number of falls in the past 12 months, current medications and past history of health.

7.3.2.4 Physical Function

Physical function was assessed using the CS-PFP10, a valid, reliable and sensitive measure of multiple facets of cardiorespiratory and neuromuscular physiology with no floor or ceiling effects (Cress et al., 2005) and strongly correlated with self-reported physical functioning measures (Cress et al., 1999). It comprises five sub-scales (physical domains) – upper body strength, lower body strength, upper body flexibility, balance and coordination and endurance – each measured by at least two items. These items comprise ten everyday tasks from which outcomes can be measured as weight, time or distance (Cress et al., 1999). Each physical domain can be analysed individually or they can be combined to provide an accurate global measure of individual function.

7.3.3 Statistical Analysis

Using PASW 18 software (SPSS, Inc., 2009, Chicago, IL, www.spss.com), descriptive statistics were produced and Pearson product-moment correlation coefficients were used to examine bivariate relationships between all variables. Multiple hierarchical regression analysis was used to investigate multivariate relationships among predictors of falls risk. Progressive statistics were employed to interpret the magnitude of the effect sizes: < 0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large and > 2.0 very large (Hopkins, 2007). The probability was calculated by
accounting for the smallest worthwhile observed difference and typical error of measurement. Thresholds for assigning qualitative terms to chance were as follows: < 1% almost certainly not; < 5% very unlikely; < 25% unlikely; < 50% possibly not; > 50% possibly; > 75% likely; > 95% very likely; > 99% almost certain.

7.4 Results

Table 7.1 presents mean scores for age, falls risk, physical functional performance total scores (including the five domain scores) and the physical and mental component scores from the SF12. Substantial (but not always significant) differences were evident between males and females, with trends in mean scores for upper body flexibility, lower body flexibility, upper body strength and the physical component scores in the expected directions: females recorded significantly greater upper body flexibility than did males, whereas males had greater lower body strength and physical functioning, with nearly-significantly greater upper body strength ($p = .06$). Four males and four females reported at least one fall within the past 12 months (25% of the sample), consistent with national prevalence (Centre for Health Advancement and Centre for Epidemiology and Research, 2010) with two females reporting multiple falls.
### Table 7.1 Sex and Age-Group Differences in Falls Risk, Physical Functional Performance and Health for Sample Participants (aged 65–92 years).

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>Age-groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (n=17)</td>
<td>Male (n=15)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>76.8 ± 7.5</td>
<td>79.3 ± 8.0</td>
</tr>
<tr>
<td>Actual falls (12 months)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Falls Risk</td>
<td>1.28 ± 1.06</td>
<td>1.29 ± 1.42</td>
</tr>
<tr>
<td>Physical Functional</td>
<td>44.5 ± 14.1</td>
<td>46.8 ± 16.0</td>
</tr>
<tr>
<td>Performance Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Body Strength</td>
<td>38.2 ± 13.7</td>
<td>49.3 ± 18.4 asterisk[d]</td>
</tr>
<tr>
<td>Lower Body Strength</td>
<td>37.9 ± 18.0</td>
<td>42.0 ± 16.8</td>
</tr>
<tr>
<td>Upper Body Flexibility</td>
<td>59.2 ± 15.0</td>
<td>52.0 ± 12.7</td>
</tr>
<tr>
<td>Balance</td>
<td>47.6 ± 14.4</td>
<td>47.4 ± 16.7</td>
</tr>
<tr>
<td>Endurance</td>
<td>46.9 ± 14.6</td>
<td>47.7 ± 16.4</td>
</tr>
<tr>
<td>Physical Component Score</td>
<td>43.8 ± 12.1</td>
<td>47.3 ± 6.6</td>
</tr>
<tr>
<td>Mental Component Score</td>
<td>52.7 ± 9.3</td>
<td>53.8 ± 7.0</td>
</tr>
</tbody>
</table>

* * p < .10, * p < .01

- a Mean score is significantly higher (greater risk of falls) than for the young-old and old-old groups.
- b Mean score nears being significantly lower (worse) than the young-old group.
- c Mean score is significantly lower (worse) than for the young-old group.
- d Mean score nears being significantly higher (greater strength) than women.

Age-group mean scores differed significantly for falls risk, physical functional performance total score, upper body strength, lower body strength, balance and endurance. Those in the *young-old group* had significantly higher mean scores (better functioning) than did the *oldest-old group* in the following areas: physical functional performance total score, upper body strength, lower body strength, balance and endurance. Those in the *young-old group* had significantly lower mean scores than did the *oldest-old group* in falls risk scores. Those in the *old-old group* had...
significantly lower scores (lower falls risk) than did the *oldest-old group* for falls risk only, meaning that they were less likely to fall than were the *oldest-old group*. Mean scores for the physical and mental components did not differ significantly between the age groups.

Associations among measures of sex, age, falls risk, physical functional performance and health (Table 7.2). Significant associations (all moderate to strong) were apparent between: (i) age and falls risk, with younger participants showing a lower falls risk; and (ii) age and physical functional performance total score and the associated domain scores (upper body strength, lower body strength, upper body flexibility, balance and endurance), with younger people showing better function. Domain scores of the Continuous Scale Physical Functional Performance-10 were significantly positively correlated with physical functional total score because they contribute to the total score. There was no association between age and general health (physical or mental component) but there was a strong relationship between the physical component score of the SF12, total physical function and all five domains such that better functioning on one was associated with better functioning on all the others. There was no association between reported falls and falls risk.
Table 7.2 Correlation Analysis Between, Sex, Age, Falls Risk, Physical Functional Performance and Health for Sample Participants (aged 65-92 years).

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>i</th>
<th>ii</th>
<th>iii</th>
<th>iv</th>
<th>v</th>
<th>Falls Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>.17</td>
<td>-.28</td>
<td>-.04</td>
<td>-.61*</td>
<td>-.45**</td>
<td>-.52**</td>
<td>-.44*</td>
<td>-.63**</td>
<td>-.62**</td>
<td>.59**</td>
</tr>
<tr>
<td>2. Sex</td>
<td>.18</td>
<td>.07</td>
<td>.08</td>
<td>.34**</td>
<td>.12</td>
<td>-.26</td>
<td>-.01</td>
<td>.03</td>
<td></td>
<td>.01</td>
</tr>
<tr>
<td>3. Physical Component Score</td>
<td>-.08</td>
<td>.53**</td>
<td>51**</td>
<td>.56**</td>
<td>.47**</td>
<td>.49**</td>
<td>.52**</td>
<td></td>
<td>-.17</td>
<td></td>
</tr>
<tr>
<td>4. Mental Component Score</td>
<td>.04</td>
<td>-.03</td>
<td>.04</td>
<td>.11</td>
<td>.05</td>
<td>.04</td>
<td></td>
<td>.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Physical Functional Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>86**</td>
<td>.94**</td>
<td>.74**</td>
<td>.99**</td>
<td>.53**</td>
<td>.49**</td>
</tr>
<tr>
<td>i. Upper Body Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.83**</td>
<td>.44*</td>
<td>.77**</td>
<td>.79**</td>
<td>.40*</td>
</tr>
<tr>
<td>ii. Lower Body Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.72**</td>
<td>.92**</td>
<td>.92**</td>
<td></td>
<td>.41*</td>
</tr>
<tr>
<td>iii. Upper Body Flexibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.78**</td>
<td>.76**</td>
<td>.29</td>
<td></td>
</tr>
<tr>
<td>iv. Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.99**</td>
<td></td>
<td>-.51**</td>
</tr>
<tr>
<td>v. Endurance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-.51**</td>
</tr>
</tbody>
</table>

* p < .10, * p < .05, ** p < .01. Shaded areas are the domain score physical functional performance.
A multiple linear regression (Table 7.3) was undertaken to estimate the contribution of (i) physical functioning and (ii) age to explaining variance in falls risk. The two assessment tools used (PPA and CS-PFP10) are correlated \((r = -.492, p < .004)\) but not strongly, that is, the two measures are not collinear and do not measure the same thing. Total physical function accounted for 24% of variance in falls risk with age contributing a further 13%. Using progressive statistics, there is a 75% probability that physical functional performance is a true component of the model for falls risk. A multiple linear regression analysis using the five components of the falls risk assessment to predict falls risk showed that these components were intercorrelated; only ‘endurance’ made a significant independent contribution to explaining the variance in falls risk.

Table 7.3 Multiple linear regression model predicting falls risk

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Unstandardised B</th>
<th>SE B</th>
<th>Standardised Beta</th>
<th>(R^2) change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Function total</td>
<td>-0.04</td>
<td>0.01</td>
<td>-0.49**</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Function total</td>
<td>-0.02</td>
<td>0.02</td>
<td>-0.23</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.07</td>
<td>0.03</td>
<td>0.46</td>
<td>0.13*</td>
</tr>
</tbody>
</table>

* \(p < .05\), ** \(p < .01\)

Unstandardised Beta values obtained from the final regression model (physical function controlling for age) were used to estimate age-related falls risk and risk category (Table 7.4). The table shows how falls risk can be estimated by an individual’s age.
Table 7.4 Estimates of Age-Related Falls Risk (based on age and physical function)

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Estimated Falls Risk</th>
<th>Falls Risk Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>0.08</td>
<td>Low-Mild</td>
</tr>
<tr>
<td>70</td>
<td>0.54</td>
<td>Mild</td>
</tr>
<tr>
<td>75</td>
<td>1.0</td>
<td>Moderate</td>
</tr>
<tr>
<td>80</td>
<td>1.5</td>
<td>Moderate</td>
</tr>
<tr>
<td>85</td>
<td>1.9</td>
<td>Moderate-Marked</td>
</tr>
<tr>
<td>90</td>
<td>2.4</td>
<td>Marked</td>
</tr>
</tbody>
</table>

7.5 Discussion

This study is the first to investigate the relationship between falls risk and physical function using two objective and validated assessment tools. Although there were no significant differences between female’s and male’s physical function, males tended to have greater overall strength and physical functioning while female’s tended towards greater upper body flexibility. These findings are consistent with other studies which have found significant sex differences in functional tasks (Demura et al., 2003). The ‘sex gap’, with females being less physically able than males, is markedly increased with age. Age-related declines generally were also evident. The oldest-old group was more likely to fall compared to both of the younger groups. This is consistent with other studies finding that increasing age is accompanied by increasing risk of falling (Campbell et al., 1981). The decline from the young-old to oldest-old groups was marked. Not surprisingly, the oldest-old group were less physically able and were weaker in both their upper and lower body. They also had poorer balance and less endurance. This age-related decline was apparent in between-group trends from the young-old to the old-old and the old-old to the oldest-old groups. These declines in specific functionalities help explain previously observed deteriorations in overall ability to undertake activities in daily living (Demura et al., 2003).
Our findings are consistent with other studies that have demonstrated that, as people age, they have progressively poorer upper and lower body strength and endurance and greater risk of falling, with age-related declines in physical function contributing to falls risk (Ikezoe et al., 2009, Demura et al., 2003). This is the first study to demonstrate this pattern of results using all three measures simultaneously. Other studies have previously shown a relationship between physical capability and falls (Ikezoe et al., 2009), but none has associated falls risk with specific functional tasks. The present study shows that (i) objectively measured components of absolute strength (PPA subcomponents) and (ii) measures of functional capacity related to strength (CS-PFP10 subcomponents) overlap each other but contribute separately to understanding falls risk.

It was noted that no association between reported falls and falls risk were found. This is inconsistent with the findings of other studies (Tinetti, 1988) and most likely due to the very small sample size.

Because self-reported scores on the physical component of general health measure were strongly positively related to physical function and all associated domains, it can be inferred that individuals are capable of realistically assessing their own level of physical functioning. However, no relationships were found between self-reported physical functioning and the risk of falls, potentially indicating that the self-reported survey is not sensitive enough to elucidate impending falls.

The results from this study have been used to predict age-related falls risk (Table 7.4) which could prove a valuable tool for clinicians in providing evidence about falls to their older clients.

There are two main limitations of this study. Firstly, a number of the outcome results did not attain statistical significance, most likely due to the small sample size but, the results were never the less consistent with previous findings. The present preliminary study provides information on which to base power calculations for specifying sample size requirements in future studies. Secondly, although it is well-known that health can be influenced by social factors (Marmot et al., 2006), there was little socio-economic data to assist in accounting for unexplained variance in our model predicting falls risk. Also limited demographic information was available, thus evidence pertaining to social connectedness could not be incorporated into this study. Future
studies would be improved by including health and life-style measures, such as physical activity level, smoking, diet, alcohol consumption and social connectedness.

Despite these limitations, this study provides evidence for using physical function and age to predict falls risk in community-living older adults. Using objective measures, a strong relationship between falls risk and physical function has been demonstrated. In addition how ageing and falls risk are interdependently and independently associated with a number of physical impairment factors, such as reduced balance and muscle weakness has been shown.

As individuals age, their falls risk increases. Falls can have a devastating effect on independence and quality of life, often leading to a spiral of inactivity and even further decline in function, increased falls risk and greater likelihood of requiring assisted living. Using concurrent testing for falls risk and physical function we showed the negative relationship between the two but also that age is a critical determinant of falls risk. Importantly, this research has provide a simple, clinically-useful ‘ready-reckoner’ for service providers working with older people which could be used to help plan individual interventions to reduce falls risk. Encouraging older people to improve their physical function could help them to retain their independence and reduce the need for assisted living.
Chapter 8 A balance-specific exercise intervention improves falls risk but not total physical function in community-dwelling older adults

Manuscript submitted to Physical & Occupational Therapy in Geriatrics - published


The previous chapter identified that falls risk and physical function are separate entities. Using objective measures, a strong relationship between falls risk and physical function has been shown. The findings demonstrated that falls risk is associated with a number of physical impairment factors, such as reduced balance and muscle weakness. This final empirical chapter investigates whether a simple balance-specific exercise improves physical function and reduces falls risk.

For consistency within the thesis, physical functionality has been changed to physical function and Fallscreen has been changed to Physiological Profile Assessment.

Abstract presentation is that required by the journal.
8.1 Abstract

AIMS: The aim of this research was to investigate whether a simple balance-specific exercise simultaneously improves physical function and falls.

METHODS: Thirty-two community-dwelling individuals aged 65-92 years were assigned to either the control or wobble-board group. Participants were assessed pre- and post-intervention using the Physiological Profile Assessment (a measure of falls risk) and the Continuous Scale Physical Functional Performance-10 (a measure of physical function).

RESULTS: Participants in the intervention group, wobble-board training, had a decrease in their risk of falling by 36% ($p = 0.009, \eta^2 = 0.396$), whilst the control group recorded a slight but non-significant increase (6%). No change was seen in their total Continuous Scale Physical Functional Performance-10 score.

CONCLUSION: A balance-specific intervention decreased falls risk and improved balance but not sufficiently to affect total physical function.

Keywords: falls risk, physical function, balance intervention, older adults
8.2 Introduction

Declines in physiological capacity due to ageing can lead to an increase risk of falls and decreases in physical function. Adults over the age of 65 years have an increased risk of falling with one-third of community-dwelling individuals falling annually (Tinetti, 1988, Nevitt et al., 1991, Stevens et al., 2012, Mirelman et al., 2012). Of those that fall, 50% are repeat fallers (Tinetti, 1988, Mirelman et al., 2012), with women’s injury rates 40-60% higher than men of similar age (Stevens and Sogolow, 2005). Injuries associated with falls can lead to increased, fear of falling (Tinetti et al., 1994, Cumming et al., 2000), social isolation and depression (Tinetti and Williams, 1998, Masud and Morris, 2001, Boyd and Stevens, 2009) and an increased need for assisted living (Tinetti and Williams, 1998, Boyd and Stevens, 2009). The increase in fear of falling has also been associated with changes in mobility (Tinetti et al., 1994) and impaired physical function (Cress et al., 1999). Changes in an individual’s physical function can reduce their ability to complete activities of daily living (Miszko et al., 2003).

Both falls risk and physical function are multi-factorial and have been assessed by a range of tools. Falls risk encompasses both physical and cognitive factors including, but not limited to, abnormal balance and gait, foot problems, reduced vision (Tinetti, 1988), increased reaction time (Fozard et al., 1994), and decreased balance (Lord et al., 1995), flexibility (Hong et al., 2000) and lower leg strength (John et al., 2009). In addition, postural reflexes and voluntary movement decline with age (Stelmach et al., 1989) and these problems are heightened when standing on an unstable surface (Alexander, 1994).

There are a number of falls risk assessment tools currently available. Some are paper-based and ask individuals to self-assess their risk of falling, for example, the Activities-specific Balance Confidence scale (Powell and Myers, 1995) and the Falls Efficacy Scale-International (Yardley et al., 2005) measures. Others are objective-based and test physical capabilities with many focusing on only balance and/or strength, such as the Berg Balance Scale (or BBS), which is a widely used clinical test of a person’s static and dynamic balance abilities (Berg et al., 1991) or 30 second Chair-Stand test a valid indicator of lower extremity strength (Jones et al., 1999). A multi-faceted test such as the Physiological Profile Assessment (PPA) (Lord et al., 2003) may also be informative as it incorporates multiple physiological risk factors.
Aerobic capacity and aspects of musculoskeletal function deteriorate with age, leading to decreased strength and flexibility (LaRoche et al., 2007). This deterioration has been related to the ageing process partly because of a decrease in physical activity (LaRoche et al., 2007). After 50 years of age, muscle strength starts to decline at an estimated rate of 15% per decade (Hughes et al., 2001). By the time adults are in their mid-70s, they may have lost up to 50% of their previous muscle strength, which has substantial consequences for an individual’s function. A person’s ability to live independently depends on their ability to complete daily functional tasks; declining physical functioning reduces people’s ability to complete these activities (Hortobagyi et al., 2003, John et al., 2009), consequently increasing the risk of losing independence (Arnett et al., 2008, Dobek, 2006). This outcome is not inevitable however, as reducing the rate of decline and maintaining or even increasing physical capabilities can be achieved with basic exercise interventions (Frisard et al., 2007, Morey et al., 2008). Indeed, it has been demonstrated that targeted functional training programs offer significant improvements in an individual’s performance (Dobek, 2006).

Self-report for determining physical functioning is commonly documented in the literature (Nelson et al., 2004, Ades et al., 2003, Brochu et al., 2002, Tager et al., 1998, Villareal et al., 2011) but individual self-report may not be sensitive to change nor provide sufficient information about the type of limitations, such as whether the impairment is relating to flexibility or to strength (Fried et al., 1994). In contrast, objective measures such as the Continuous Scale Physical Functional Performance-10 (CS-PFP10) test may have greater discriminative ability in the older adult population (Hearty, 2007, Cress et al., 2005).

The use of regular exercise for improvements in general health are well documented (Warburton et al., 2006a). In addition, exercise has been shown to reduce falls risk (Barnett, 2003, Robertson and Gillespie, 2013) and improve physical function (Cress et al., 1999), but, to date, no authors have reported simultaneous changes in these two outcomes. It has been established that, for an intervention program to reduce falls risk, it is critical that it contain a specific balance component (Milat et al., 2011, Prevention and Panel, 2001). Postural reflexes slow and voluntary movements on unstable surfaces becomes more challenging with age (Alexander, 1994), and thus specific training that simulates the balance and reflex systems could improve the individual’s response. Unstable surface training can be simulated using the wobble- or balance-board. In older adults, wobble-boards have been used successfully in previous studies to improve balance (Ogaya et al., 2011, Nordt et al., 1999).
and improve ankle discrimination (Waddington and Adams, 2004). The use of unstable surface training leads to greater lower-leg muscle activation levels (Ivanenko et al., 1997, Fransson et al., 2007), which is associated with improved balance (De Ridder et al., 2014).

As physical function and falls risk have overlapping characteristics such as leg strength, balance and endurance (Smee et al., 2012), from a research and clinical perspective, it is important that the measurement tools used can discriminate between the two and evaluate any specific changes resulting from an intervention. This study aims to investigate whether a simple balance-specific exercise program can simultaneously improve physical function and reduce falls risk.

8.3 Methods

8.3.1 Participants

The participants were derived from a population of independent community-dwelling individuals and had to meet the inclusion criteria of: being over 65 years of age, able to speak English and to be able to follow instructions. In addition prior to participation all participants had to successfully complete a Sports Medicine Australia pre-exercise screen (Stage 1) (Norton, 2005), which incorporates components that flag any potential neuromuscular conditions that could affect performance on the wobble-board. All individuals provided informed written consent and the project was approved by the Committee for Ethics in Human Research (Protocol No: 10-60).

8.3.2 Measures

8.3.2.1 Health

General health was measured using the 12-Item Short-Form Health Survey (SF-12) with the physical (PhysSF-12) and mental (MenSF-12) subscales identified (Ware Jr et al., 1996). In addition the number of falls in the past 12 months was also recorded.

8.3.2.2 Physical Function

Physical function was assessed using the Continuous Scale Physical Functional Performance-10 (CS-PFP10) which is comprised of five separate physical domains – upper body strength, lower body strength, upper body flexibility, balance and coordination and endurance – which can be analysed individually or combined to provide an accurate assessment of an
individual’s function (Cress et al., 1999). A higher score indicates a higher level of functioning and a lower score denotes poorer functioning. The measure has no floor or ceiling effects (Cress et al., 1996) and scores achieved during CS-PFP10 testing have been shown to be valid, reliable and sensitive to change (Cress et al., 1999).

8.3.2.3 Falls Risk

The Physiological Profile Assessment (PPA) short-form is a 5-item version of the full measure and is designed to be a risk calculator that measures five physiological determinants of falls risk (vision, peripheral sensation, lower limb strength, reaction time and body sway). An advantage of the five assessments is that they are readily accepted by older people, have high external validity and test-retest reliability (Lord et al., 2003) and are reported to predict those at risk of falling with 75% accuracy in community and institutional settings (Lord and Sturnieks, 2005). The falls risk score is a single index score derived from a discriminant function analysis. A score of less than 0 indicates no increased risk of falling while higher scores denote increased risk of falling (Lord et al., 2003). Scores of 0–1 indicate a mild increase in risk, 1–2 moderate increase in risk, 2–3 marked increase in risk and >3 very marked increase in risk (Lord et al., 2003).

8.3.3 Testing

A single investigator completed all testing in the following order: SF-12, PPA then CS-PFP10, at approximately the same time for each testing session. All instructions provided to participants were scripted and consistent.

8.3.4 Intervention

Prior to undertaking the intervention program, participants were provided with a brief period of instruction in the safe and proper use of the wobble-board. Participants were asked to undertake six minutes of training, three days per week for 16 weeks at home. These parameters are based on previous studies that have investigated the use of unstable surface training (Waddington, 2003, Waddington and Adams, 2004, Nordt et al., 1999). Participants in the control group, were asked to continue with their normal day-to-day activities.

The wobble-board tasks consisted of three separate exercises (Figure 8.1): a lateral rock (Figure 8.1a), an anterior-posterior rock (alternating forward foot) (Figure 8.1b) and a horizontal balance (Figure 8.1c) using a standard, commercially available, wobble-board (42
cm diameter). All exercises were performed on carpet and in a doorframe for additional support and safety.

a) Lateral rock  
b) Anterior-posterior rock  
c) Horizontal balance

Figure 8.1 Wobble-board exercises undertaken for two minutes each exercise three times per week

8.3.5 Statistical Analysis

Participant data were analysed on an intention to treat basis using PASW 18 software (SPSS, Inc., 2009, Chicago, IL, www.spss.com), descriptive statistics were produced and a repeated measures t-test was used to evaluate any differences between the groups. Intention-to-treat analysis (all randomised participants were analysed according to their original assessment if they failed to return for re-testing) provides a conservative estimate of the effectiveness of the treatment in situations in which not all participants complete a protocol (Peduzzi et al., 2002). That is, when participants begin but dropout, their pre-intervention scores are used as post test scores, representing “no change” between pre- and post-testing. Within-group and between-group differences between pre- and post-testing and between intervention groups were analysed using a one-way Analysis of Variance. Results are presented as mean scores and standard deviations.

8.4 Results

Thirty-three individuals who met the selection criteria were assigned to either the control (n = 17) or wobble-board group (n = 16); group determination was completed by alternating allocation upon time of test-session booking. One participant failed to attend any testing.
sessions and as such the numbers in the wobble-board group were reduced to 15. The assessor was not blinded to the group allocation. There were no significant differences between the intervention and control groups for age, sex, general health (SF12 – physical and mental components) and falls in the previous 12 months. Individual’s in the wobble-board group, who completed participation undertook over 75% of the required wobble-board sessions.

The mean age of participants in the wobble-board and control group was $77.7 \pm 9.5$ (47% females) and $79.29 \pm 5.0$ (53% female) respectively. The scores for the physical and mental components of the SF-12 were not significantly different from the expected range for this population. Table 8.1 presents both the descriptive statistics and the pre and post measures (M $\pm$ SD) for both the control and intervention group on all aspects of both falls risk (PPA) and physical function (CS-PFP10 total). In addition the results for the specific balance domain of the CS-PFP10 have been included.

Table 8.1 Mean $\pm$ SD falls risk score, total physical function and balance component of physical function for the wobble-board and the control group.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Wobble-Board</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>N</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Age (y)</td>
<td>$77.7 \pm 9.5$</td>
<td>$79.3 \pm 5.0$</td>
</tr>
<tr>
<td>Sex</td>
<td>47% Female</td>
<td>53% Female</td>
</tr>
<tr>
<td>No. Falls previous 12 months</td>
<td>0.8 $\pm$ 1.0</td>
<td>0.8 $\pm$ 0.9</td>
</tr>
<tr>
<td>PhysSF-12</td>
<td>50.4 $\pm$ 8.4</td>
<td>48.7 $\pm$ 10.8</td>
</tr>
<tr>
<td>MenSF-12</td>
<td>52.9 $\pm$ 7.1</td>
<td>53.6 $\pm$ 9.9</td>
</tr>
<tr>
<td>PPA</td>
<td>1.8 $\pm$ 1.3</td>
<td>1.2 $\pm$ 1.0*</td>
</tr>
<tr>
<td>CS-PFP10 total</td>
<td>49.7 $\pm$ 12.42</td>
<td>51.7 $\pm$ 11.5</td>
</tr>
<tr>
<td>CS-PFP10 balance</td>
<td>51.0 $\pm$12.7</td>
<td>54.2 $\pm$11.8*</td>
</tr>
</tbody>
</table>

* $p < 0.05$
There were no significant differences in pre-test scores for the PPA or the CS-PFP10 total score between the wobble-board and the control group. At the completion of the 16-week intervention, those in the wobble-board group had a significantly lower risk of falling than (1) those in the control group ($M = 11.10\%$), $F(1, 30) = 5.829, \eta^2 = 0.022$) and (2) compared to baseline falls risk. For those in the wobble-board group the risk of falling decreased by 36% ($p = 0.009, \eta^2 = 0.396$), whilst the control group recorded a slight but non-significant increase (6%) (Figure 8.2).

![Figure 8.2](image.png)

Figure 8.2 Mean falls risk score for the wobble-board and the control group showing a significant reduction in falls risk score for the wobble-board group ($p < 0.05$) compared with both baseline falls risk score (†) and with the control group (‡).

The impact of the intervention on physical function was not clear-cut. Neither group showed any significant change between pre- and post-testing in the CS-PFP10 total score but the wobble-board participants did demonstrate a significantly higher balance domain score on the CS-PFP10 ($p = 0.029, \eta^2 = 0.297$) post-intervention (Table 8.1), indicating an improvement in balance resulting from the intervention.
8.5 Discussion

This study used a wobble-board balance training intervention in an attempt to simultaneously reduce falls risk and improve physical function. The findings from this study demonstrated that, among these participants, a single balance-specific intervention is sufficient to reduce falls risk and improve balance but not overall physical function.

The balance-specific intervention was shown to give rise to a significantly lower risk of falling after the 16-week intervention period. This is consistent with previous claims about the reduction in falls risk following unstable surface training (Rose, 2010) or balance training. Other studies that have utilised balance-specific programs to reduce falls risk in older adults found that individuals who complied with their exercise program decreased their falls risk by 38% (Shumway-Cook et al., 1997b), which is comparable to the improvements found in the current study. Specific unstable surface training protocols have been used successfully to reduce falls risk, but previous interventions were more technologically advanced, requiring additional resources (Ogaya et al., 2011). The use of an inexpensive and commercially available wobble-board, as described in this study, makes the protocol used here more viable and affordable to those interested in reducing their balance-related falls risk in a home-based setting.

Although total physical function did not change after the intervention, the balance and coordination domain of the CS-PFP10 did. Those in the intervention group had a significant increase in their balance/coordination domain score indicating an improved level of balance, although this increase was not substantial enough to affect the CS-PFP10 total score. It has been demonstrated that strength and endurance training independently and together can improve physical function when assessed by the CS-PFP10 (Cress et al., 1999, Miszko et al., 2003) and, thus, that the assessment tool itself is sensitive to change. Physical function is multifactorial in nature and so a single specific intervention targeted at only one domain or aspect of function, such as presented here, may be insufficient to effectively provide an adequate training effect to improve an individual’s overall function.

It has previously been demonstrated that falls risk and physical function are related but distinct (Smee et al., 2012) and, as such, the tools used to assess these must be appropriate to the testing domain and be able to detect change. Due to the large range of falls risk and physical function assessment tools available to the clinician, it is often difficult to identify the
most appropriate tool. This study demonstrates that it is essential to select the correct tool depending on the nature of the outcome to be assessed. Further investigation into the practicality and effectiveness of a variety of assessment tools, given a specific clinical environment, is still required.

The limitations of this study were the non-blinding of the group allocation, the small homogenous sample, and failure of individuals to return for post-intervention testing, reducing the statistical power. Although blinding the group allocation would have strengthened the scientific rigor of the study, in this case it was not feasible. Due to the objective nature of the assessment tools, and the strict adherence to both protocol and language used, the authors believe that the outcome measures are still valid and reliable. The most common reason cited for discontinuing participation with the wobble board intervention was not enjoying and, therefore, not completing the exercises on a regular basis. As it has been shown the positive benefits of these exercises, non-compliant individuals would be well advised to incorporate an exercise of this type into their daily life to reduce falls risk. Further work needs to be done on determining the minimum exposure time needed for wobble board training to be effective as well as in enhancing the experience of wobble board training. Finding suitable balance-challenge activities that could be incorporated into a program, (e.g., a video game) or used in a group environment may be ways of achieving increased enjoyment.

Despite this limitation, this study demonstrates the balance-related falls risk benefits of just a few minutes of balance training a few times a week over a relatively short term among older adults. It is recommended that the wobble-board or similar training may be used as a component of an exercise program that incorporates other tasks, such as strength and power training (Miszko et al., 2003, Hunter et al., 2004), to improve physical function generally and reduce falls risk. Future research into the translation of this training into real-world scenarios, such as walking on uneven ground, would be greatly beneficial.
Chapter 9 Discussion and future directions

Falls can be devastating for older adults, and information about factors that impact on an individual’s risk of falling is vital from the perspective of intervention and prevention. The aim of this thesis was to explore falls risk factors in community-dwelling older Australians and the associations between these factors and falls risk measures. The major findings from the body of research presented in this thesis contribute to and extend the existing literature pertaining to falls risk in community-dwelling older adults, by elucidating three major themes that should be taken into account when assessing this populations’ falls risk:

1) The substantial sex differences in falls risk and falls risk factors and the importance of being aware of these differences when assessing the falls risk of men and women;

2) The complex nature of the relationship between falls risk and physical function; and

3) The importance of using population-appropriate assessment tools for accurately measuring a person’s risk of falling.

This chapter summarises, under these three themes, the findings from this body of research and evaluates them in relation to previous research. The theoretical and practical implications of this overall body of work are highlighted and potential weaknesses noted. Important potential topics and questions for future research conclude this chapter.

9.1 Summary of research findings

9.1.1 Sex differences

Sex differences in falls risk are apparent in community-dwelling older adults regardless of the measurement tool used to assess falls risk. Females and males differ in the way they rate their own falls risk and this changes as they age. When females assess their falls risk, age alone does not help predict their risk of falling, especially when considered alongside a range of other predictors. Yet, for males, there is an increase in self-assessed falls risk with age, independent of a range of other predictors.
9.1.1.1 Falls risk

Overall body composition, functional and health related characteristics do affect falls risk in both women and men. Falls risk in females is consistently predicted by increasing age, physical function and a history of falls, whilst only increased age is a stable predictor of falls risk in males.

Self-assessment of falls risk shows that community-dwelling females are more inclined than are their male counterparts to think they might fall, especially if they have: reduced physical function; had a fall in the previous 12 months; poorer self-reported health (physical or mental, or both); and report lower levels of physical activity (Chapter 4). Conversely, males are more concerned with falling as they age, with taller males being more worried than shorter males. Males with poorer physical function are also more afraid of falling than are their better functioning peers.

When falls risk is measured objectively, in older adults (Chapter 5), sex differences are again implicated and different falls risk predictor factors are emphasised for females compared to males. The Berg Balance Scale (BBS) score is affected by a variety of body composition, functional and health-related characteristics in females, while only functional and health-related characteristics predict BBS scores in males. In females, using the Physiological Profile Assessment (PPA), only age, past falls and physical function display a relationship, such that older females with a history of falls and poorer physical function are at greater risk of falling. Conversely, no correlations were found between the PPA total score and body composition, functional and health-related characteristics in older males. However upon closer examination of the five independent PPA domains, the two potentially modifiable domains (postural stability and quadriceps strength) are impacted by age, physical function and body mass index (BMI) in males.

9.1.1.2 Diet quality

Sex differences are again highlighted when overall diet quality, as assessed by diet indices, is considered (Chapter 6). The findings indicate that diet quality can influence body composition and physical function, which are known falls risk predictor characteristics. In addition, diet quality itself may be a potentially important falls risk factor. Moreover these relationships are complicated by sex and age. Females with better diet quality (better diet indices scores (Huijbregts et al., 1997, United States Department of Agriculture, 1995)) have
lower BMI and fat mass and higher lean mass, indicating the importance of diet quality on females’ body composition. Better diet quality in males is associated with increased longevity, better physical function, a fat distribution characteristic of better health (reduced risk of cancer and cardiovascular disease (Trichopoulou et al., 2014, McNaughton et al., 2012)) and a lower likelihood that they will self-assess a concern about falling.

9.1.1.3 Summary of sex difference findings

To summarise, sex differences were found in community-dwelling older Australians for all measures of falls risk, both self-assessed and objective, as well as in diet quality, body composition, functional and health-related characteristics, which are all related to falls risk. The clinical relevance of sex differences could aid in the delivery of sex-targeted interventions as discussed in Section 9.5.

9.1.2 The complex nature of the relationship between falls risk and physical function

Physical function is a known falls risk factor (Delbaere et al., 2010a, Barrett-Connor et al., 2009) and is associated with a number of additional predictor characteristics that also contribute to increased falls risk. For example, older adults who have reduced muscle strength and balance are more likely than their age peers to demonstrate poorer physical function (Tinetti et al., 1995), and both muscle strength and balance are linked to greater falls risk. Falls risk and physical function are often concurrently assessed, with inferences made about both outcomes from the results of a single assessment tool. The research presented here (Chapters 7 and 8) demonstrates that, while there is indeed a relationship between falls risk and physical function, such that poorer physical function is associated with an increased falls risk when measured by self-assessment or objectively (Chapters 4, 5 and 7), the two constructs are independent, and should be assessed separately. However, specific components of falls risk, such as poor quadriceps strength in males and greater postural- sway in females, which worsen with age, are directly associated with poorer physical function.

Two important and modifiable risk factors for falling – exercise and diet quality – also show limited associations with physical function. A 16-week balance-specific exercise intervention, aimed at improving both physical function and reducing falls risk, improves the balance component of physical function and reduces falls risk, but does not improve overall physical function (Chapter 8). Better diet quality is associated with higher levels of physical
function in males (*Chapter 6*). These findings indicate that these important falls risk predictors can improve at least some components of physical function, as well as reduce falls risk in community-dwelling older adults.

### 9.1.3 Population-appropriate assessment tools

There are a number of assessment tools available for researchers and clinicians intending to assess falls risk or diet quality. The findings in this thesis highlight the importance of choosing the most appropriate assessment tool for the population under investigation. The Falls Efficacy Scale-International (FES-I) and the Activities-specific Balance Confidence (ABC) measure similar constructs in regards to self-assessed falls risk. However, the associations between the FES-I and multiple predictor characteristics, including functional, body composition and health-related, suggest that the FES-I may be accessing more appropriate information than the ABC when assessing falls risk in community-dwelling older Australians (*Chapter 4*).

Whilst the BBS and the PPA objectively measure aspects of balance, comparison of these instruments suggests that the two tools should not be used interchangeably and that the selection of objective falls risk assessments should be carefully considered. The research findings presented here suggest that the BBS is more appropriate for assessing older, less-functioning adults, whereas the PPA is the tool of choice when assessing potentially higher-functioning females (*Chapter 5*).

Using diet indices provides a unique way to assess total diet quality and its potential relationship with risk of falling. The dichotomous scale of the Healthy Diet Indicator (HDI) allows for the observation of stronger relationships with falls risk, physical function and body composition characteristics than does the Healthy Eating Index (HEI) total score (*Chapter 6*). The HDI is therefore a more appropriate option when assessing total diet quality with falls risk and other predictor characteristics in community-dwelling older Australians.

### 9.2 Comparison of findings with previous research and contribution to the field

Falling can impair, sometimes permanently, the quality of life of older adults, with negative physical, social and economic implications. Of the community-dwelling older adults participating in this research, 25% reported falling at least once in the previous 12 months,
which is slightly lower than the expected one-in-three adults reported a falling, however it is consistent with the prevalence of falls in Australia as reported but the Centre for Health Advancement and Centre for Epidemiology and Research (2010). This supports the contention that the cohort within this research project is representative of the wider population in regards to fall rates. The proportion of people reported as falling in Australia, and in the studies reported in this thesis, is slightly lower than the world-wide estimate that one-in-three adults over the age of 65 years fall annually (Rubenstein, 2006, Tinetti and Williams, 1998). The difference is most likely due to the inclusion of the young-old – individuals aged between 60 and 65 years – in the present project (Chapters 4 to 6). As age is a critical determinant of falls risk (Tinetti et al., 1988, Mitchell et al., 2014), inclusion of these younger individuals may reduce the overall rate of falls.

9.2.1 Risk factor findings and contribution to the field

Several risk factors have previously been identified in community-dwelling older adults (Table 2.1) with varying levels of evidence to support them. Generally, the findings from this research project are consistent with previous studies and demonstrate that individuals who are older (Rubenstein, 2006), female (Mitchell et al., 2013, Linattiniemi et al., 2009), with poorer physical function (Delbaere et al., 2010b, Rossat et al., 2010) and have a recent history of falls (Deandrea et al., 2010, Faulkner et al., 2009) are those who have an increased risk of falling.

This thesis contributes to knowledge regarding falls risk by strengthening the evidence for known risk factors (older age, being female and poorer physical function) and also by identifying additional potential risk factors (greater fat mass, lower bone density and diet quality). Furthermore, the findings reported in this thesis emphasise the importance of sex as well as physical function and provide clinicians with information about appropriate assessment tool choice. Table 9.1 provides a summary of falls risk characteristics, their supporting level of evidence and whether or not they are able to be modified. The falls risk factors in bold type are those that have been examined in this research project; their suggested relative contributions to falls risk have been adjusted according to the findings presented here.
Table 9.1 Summary Table of Falls Risk Characteristics, Level of Evidence and Modifiability (adapted from Lord et al. (2007) and encompassing recent literature and updated with thesis findings)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Level of Evidence</th>
<th>Modifiability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Age</td>
<td>Strong</td>
<td>Non-modifiable</td>
</tr>
<tr>
<td>Female Sex</td>
<td>Strong</td>
<td>Non-modifiable</td>
</tr>
<tr>
<td>History of Falls</td>
<td>Strong</td>
<td>Non-modifiable</td>
</tr>
<tr>
<td><strong>Physiological</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impaired Balance</td>
<td>Moderate</td>
<td>Modifiable</td>
</tr>
<tr>
<td>Reduced Vestibular Function</td>
<td>Weak</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Visual Impairments</td>
<td>Strong</td>
<td>Possible</td>
</tr>
<tr>
<td>Somatosensory Impairment</td>
<td>Strong</td>
<td>Non-modifiable</td>
</tr>
<tr>
<td>Sarcopenia</td>
<td>Strong</td>
<td>Modifiable</td>
</tr>
<tr>
<td><strong>Psychological</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impaired Cognition</td>
<td>Strong</td>
<td>Possible</td>
</tr>
<tr>
<td>Depression</td>
<td>Moderate</td>
<td>Modifiable</td>
</tr>
<tr>
<td>Fear of Falling</td>
<td>Strong</td>
<td>Modifiable</td>
</tr>
<tr>
<td><strong>Functional Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Inactivity</td>
<td>Strong</td>
<td>Modifiable</td>
</tr>
<tr>
<td>ADL/Physical Function Limitation</td>
<td>Strong</td>
<td>Modifiable</td>
</tr>
<tr>
<td><strong>Body Composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat Mass</td>
<td>Likely</td>
<td>Modifiable</td>
</tr>
<tr>
<td>Bone Mineral Density</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In summary, the current research has discovered three (3) new potential risk factors for falling (fat mass, bone mineral density (BMD) and diet quality) and strengthened the evidence for a further five (5) risk factors (advanced age, being female, history of falls, physical inactivity and functional limitations). Clinicians need to be aware of the importance of an individual’s sex and physical function level, not just as independent risk factors, but also be aware of their impact on other falls risk predictors. A holistic approach is required as consideration of sex and physical function limitations in isolation can be misleading or too simplistic. It is likely that body composition and diet are important falls risk predictors and clients presenting with increased fat mass and poorer diet quality may be at risk of falling.

### 9.2.2 Comparison and contribution of sex difference findings

It is well established that females are at higher risk of falling compared to males (Campbell et al., 1990) and that females are more likely to suffer a fracture (Stevens and Sogolow, 2005) or require hospitalisation after a fall (AIHW: Bradley, 2013). It has been suggested that this may be due to physiological differences, including lower muscle strength (Cooper et al., 2011, Lindle et al., 1997) and lower bone density (Riggs et al., 2004, Cawthon, 2011). The research presented in this thesis extends this knowledge by providing more detailed evidence about the nature of the significant differences between males and females in self-assessed and objectively measured falls risk and diet quality, as well by drawing attention to previously unreported body composition, functional and health-related characteristics that also predict falls risk. These latter results complement work conducted by Tseng et al. (2014) who report that females have poorer physical function (explained by having more fat mass) and reduced strength (having smaller muscle area). They conclude that intervention programs designed separately for females and males should be implemented to prevent functional decline to the point of disability (Tseng et al., 2014).

The present research also highlights that some previously identified generic falls risk factors are sex-specific. History of falls is a known risk factor for future falls within the older adult population (Tinetti et al., 1988, Delbaere et al., 2010b), but the results reported in this thesis are the first to suggest that aspects of this falls risk factor are sex-specific. That is, females, who have fallen are at greater risk of future falls compared to males. Similarly, some authors propose that in both males and females physical activity can reduce falls risk (Gregg et al.,...
Chapter 9 – Discussion and future directions.

2000, Sherrington et al., 2004) and the likelihood of hip fractures (Gregg et al., 1998, Kujala et al., 2000). The research reported here indicates that higher physical activity is only associated with a lower falls risk in females. Perhaps the males’ already higher level of physical functioning – potentially due to increased muscle mass, strength and reduced fat mass, compared to age matched females – outweighs any additional falls risk benefits normally gained with increased physical activity.

Eating a diet consistent with nutritional guidelines has been linked with lower risk of chronic diseases, such as coronary heart disease, obesity, diabetes and some forms of cancer (Drewnowski and Evans, 2001, Trichopoulou et al., 2014, McNaughton et al., 2012). Although diet quality in community-dwelling older adults has been previously assessed (Drewnowski et al., 1997, Ledikwe et al., 2004), its relationship with falls risk and other falls risk predictor characteristics was not previously known. Recent research in a residential-care setting suggests that those older individuals who are malnourished (an extreme consequence of poor diet quality) are at increased risk of falling and having poorer physical function (Singh et al., 2014). In addition, sex differences in fruit and vegetable intake (Baker and Wardle, 2003, Tucker et al., 2002), as well as in overall food choices and energy and nutrient intake (Bates et al., 1999) have been identified. Consuming a diet low in dairy, fruit and vegetable (i.e. potentially poorer diet quality) may be associated with reduced physical function in community-dwelling older adults (Houston et al., 2005, Duffy and MacDonald, 1990). Furthermore, the research presented here suggests that better diet quality does beneficially impact falls risk, physical function and fat mass, and that these results are sex-dependent. As a result, clinicians need to consider the diet quality of males and females separately, specifically in relation to falls risk and physical function.

9.2.3 Enhancing the understanding of the complex relationship between falls risk and physical function.

Older adults (over the age of 60 years) exhibit limitations in regard to their physical function or their ability to complete activities of daily living (ADL) (Frisard et al., 2007, Hortobagyi et al., 2003). Individuals who are able to maintain higher levels of physical function are at a decreased risk of falling (Ades et al., 2003), are more likely to remain independent (Arnett et al., 2008, Dobek, 2006) and are less likely to require assisted living (Beswick et al., 2008). The use of multiple falls risk assessments as well as different measures of physical function within the present research confirms earlier findings that identify physical function as a risk
factor for falling (Faulkner et al., 2009, Rossat et al., 2010, Campbell et al., 1981), although the relationship between physical function and falls risk is more complex than previously thought. The link between objectively measured falls risk and physical function is partly explained by the overlap of elements common to both types of measures, including sarcopenia (loss of muscle mass and strength), balance and flexibility (Cress, 1997, Landi et al., 2012, Chang et al., 2004). However, the impact of these elements on objectively measured falls risk and physical function is different (Smee et al., 2012), as demonstrated by the research presented here, and explains why a targeted intervention had different outcomes on falls risk and physical function (Smee et al., 2014). In addition, it is important to note that the self-assessed falls risk, associated with fear of falling, can also impact physical function. Whilst there is a correlation between physical function and self-assessed falls risk (Smee et al., 2015), improvements in physical function, after completion of an exercise intervention, does not necessarily correlate with an improvement in self-assessed falls risk nor a reduction in the fear of falling (Liu-Ambrose et al., 2004a). As a result, falls risk and physical function require separate and independent assessment, as demonstrated within the current body of work.

9.2.4 Comparison of population-appropriate assessment tools and contribution to the literature

The FES-I is able to discriminate between subgroups of older adults (Kempen et al., 2008), including those who are prone to falling (Helbostad et al., 2010). The ABC has been shown to be a reliable assessment tool for assessing loss of balance confidence (Powell and Myers, 1995) and is suitable for older adults with moderate to high levels of function (Myers et al., 1998). The studies presented in this thesis agree with the previously reported findings that both the FES-I and ABC are suitable for the identification of falls risk. However, this thesis extends this knowledge with the suggestion that for higher-functioning community-dwelling older adults, the FES-I is the self-assessment falls risk measurement tool of choice.

Of the two objective falls risk assessment tools utilised here, the PPA is deemed to be the tool of choice for detecting falls risk in community-dwelling older adults. This is consistent with previous research that states that the PPA can differentiate fallers (individuals who are at risk of falling) from non-fallers (those not at risk for falls) (Lord et al., 2003). The sex difference in regards to the falls risk identification is a unique finding, and further highlights the importance of considering sex differences when using this tool. The BBS has been
extensively used in research focusing on balance and falls (Lajoie and Gallagher, 2004, Donoghue and Stokes, 2009). This is despite it being shown to be relatively poor at predicting falls in higher-functioning, community-dwelling older adults (Boulgarides et al., 2003) and better suited to frail individuals (Langley and Mackintosh, 2007). The findings within this thesis further demonstrate the inability of the BBS to successfully assess falls risk in community-dwelling older adults, and support the work of Blum and Korner-Bitensky (2008), who noted considerable ceiling effects when the instrument was used in this population.

9.2.5 Summary of comparison of findings with previous research and contribution to the field

This thesis has endeavoured to capture the interrelationships between many of the falls risk predictors that have previously been studied in isolation. Past research has presented a somewhat simplified relationship between falls risk and functional, health-related and body composition characteristics. The findings from the research presented here highlight not only the significant overlaps and interactions between numerous falls risk predictors, but also the complexity of these relationships. Because there are so many factors and interrelationships present, the links between them are conceptually challenging. A mind-map showing those complex relationships identified in the literature review and within the present research is presented in Figure 9.1, to facilitate visual integration.
Figure 9.1 Proposed relationships between falls risk predictors and assessed risk of falling

The lines in black indicate contributions to the literature from this research: solid black lines represent previously unknown associations; and the broken black lines represent associations with previously limited evidence.
9.3 Theoretical implications

The major theoretical implication that has arisen from this research is the mismatch within community-dwelling older adults between objective and self-assessed falls risk measures on the one hand and the unfavourable changes to body composition, physical function, physical activity and diet on the other. That is to say, individuals are self-assessing a higher concern for falling based on their body composition, functional and health-related characteristics compared to their objectively measured falls risk.

Previous work has demonstrated that older adults can overestimate and underestimate their risk of falling, and that the discrepancy is dependent on psychological measures (Delbaere et al., 2010a). Changes that older adults may perceive as undesirable, such as changes to body composition (increased fat mass, decreased lean mass and BMD), poorer physical function, decreased activity or poorer diet quality, can be seen as ‘constraints’. With age or lifestyle factors these changes can worsen, or additional changes can occur and thus increase the level of constraint. Given the results presented in this thesis, Figure 9.2 may constitute a valid, non-numeric schematic representation of the relationship between these constraints and falls risk for the wider older adult community, when falls risk is quantified using objective and self-assessed tools. This theoretical relationship appears to hold true for the community-dwelling older adults assessed in this research. Future research should be undertaken in other populations, including less functional individuals, to verify if this relationship persists generally or is specific to community-dwelling older individuals.
Figure 9.2 Proposed curvilinear relationships between level of constraint and self-assessed and objective falls risk

9.4 Research limitations

There is a number of possible limitations to be considered within this research. Firstly, all studies aimed to recruit independently-living, community-dwelling older adults. A bias in the sample may be present, as volunteers committing to this type of research project can tend to be those who are more robust (physically and mentally) than the community members at large. As the pool from which participants were sourced (the Australian Capital Territory) generally has a higher socioeconomic background compared to other Australian regions, this could mean the participants also had an enhanced understanding of the requirements and financial means for a healthy life, including better total diet quality and partaking in regular exercise. The individuals within these studies may therefore have been more likely to be physically active and therefore have greater physical function scores than the wider community. Yet, given that the incidence of falls observed was comparable to that of the general population (Centre for Health Advancement and Centre for Epidemiology and Research, 2010), the findings are likely to be relevant to the wider Australian population.
Secondly, while physical activity as measured here was self-reported, it is widely accepted that self-reporting is not as accurate as objective methods (Prince et al., 2008). However, the PASE assessment tool is valid and reliable (Washburn et al., 1999) and provides a snapshot of individuals’ levels of physical activity. As physical activity was not the primary focus, and due to the large number of other assessments, the benefit of the short administration time of the PASE was taken into consideration when selecting a physical activity assessment tool. Similarly the use of retrospective recall of falls has its own limitations in that recall methods may underestimate the numbers of falls, particularly those of repeat fallers (Fleming et al., 2008).

Thirdly, the lack of inclusion of medical diagnoses and medication information means that we cannot assess the effect of comorbidities and polypharmacy on the overall outcome. However, the population was robust, as indicated by high scores in the SPPB indicating good physical function and slightly lower than predicted falls risk. Thus, if medical conditions or medication do indeed cause an increase in falls risk then this is unlikely to be a major problem in the present sample. However, future studies should control for these possible confounders.

Finally, due to the relatively small sample size in some studies (Chapters 7 and 8) there was not sufficient power to investigate sex differences in regards to the falls risk and physical function relationship, or to identify if sex differences were also implicated in the outcomes from the balance-specific intervention. In addition, the smaller sample size of males in Chapters 4, 5 and 6 may have not allowed the identification of previously unknown relationships among predictor variables. This should be elucidated in future studies. To help counteract the small sample size, an intention-to-treat analysis (Chapter 8), which generally provides a conservative estimate of the effectiveness of the treatment, was carried out. Despite this, the research findings demonstrated significant benefits in falls risk reduction and improved balance after the 16-week balance-specific intervention.

9.5 Practical implications of falls risk research findings

There are significant practical implications for researchers and clinicians in regards to falls risk, that are generated from the findings reported in this thesis. Firstly, given the proposed relationships between self-assessed and objective falls risk (Figure 9.2), the selection of an assessment tool must be carefully considered. An individual’s level of constraint will
influence both their perceived and actual risk of falling. The appropriate choice of assessment tool depends on the time, space and financial support allocated to the assessment. The FES-I self-assessment tool is ideal if the assessor has limited time, space and budget. However, clinicians should be aware of the potential increased level of perceived concern regarding falling exhibited by individuals with increasing levels of constraints (poorer diet, physical function, physical activity and body composition). The objective PPA is the assessment tool of choice if there is adequate time, space and budget. The PPA provides a more holistic and objective assessment and is able to discriminate meaningfully between individuals with greater functional capacities.

Secondly, sex differences were identified in all measures of falls risk assessment. Based on the current research findings, appropriate tool selection could be based on either the sex of the individual or group under investigation. In addition, there were noticeable sex differences that emerged when assessing total diet quality. Combining this information with the known sex differences in body composition, as explored in this research, should aid in the design and delivery of more effectively targeted interventions. These interventions should be sex-specific and be dietary and or exercise-based, to enhance success and thus improve the quality of life of older adults, potentially allowing them to maintain their independence for longer.

Finally, the research presented here shows that falls risk and physical function are not the same and should not be assessed with a single ‘multiple-purpose’ tool. Each should be independently evaluated so as to ensure a nuanced approach to research and an accurate and helpful diagnosis for clinical purposes.

9.6 Directions for future research in falls risk

This research was conducted with higher-functioning, independent, community-dwelling older adults. It produced important findings with respect to falls risk predictor factors, sex difference and the relationship between falls risk and physical function. These factors and issues may also be important – perhaps more so – to older adults who are less functional, who are in residential care, or who have other more serious health issues. To reduce the social, economic and physical burden associated with falls and to improve quality of life, these populations need to be assessed independently in future research.
In addition, the findings reported here suggest that taller males are significantly more concerned about falling compared to their shorter counterparts. This issue, combined with the fact that taller males are at greater risk of hip fracture (Schwartz et al., 1998, Grisso et al., 1997), suggests that this association warrants further investigation: specialised targeted intervention programs may be required to reduce the incidence of hip fracture and associated consequences in this group. It has been suggested that attempts to reduce hip fracture should not only incorporate wide-ranging risk factor assessment but also treatment for concomitant conditions such as sarcopenia, depression or balance impairment (Singh, 2014).

This body of work describes sex differences in diet quality which may be more thoroughly explained by analysis of dietary components. Whilst this research investigated the impact of diet quality on falls risk, functional, body composition and health-related characteristics, further analysis of food groups (dairy and meat/protein) along with macro- and micro-nutrients is justified. It is also worthwhile to consider specific supplementation, for example calcium and vitamin D, and examine their effects on falls risk, functional, body composition and health-related characteristics. These evaluations and the resulting information would be beneficial in both general and at-risk populations to provide dietary guidance to reduce falls risk and improve physical function and body composition.

Given that the physical activity record was self-reported, it is worthwhile considering further research into objectively-measured physical activity, with the use of accelerometers, and how outputs from such measures relate to falls risk and other functional, body composition and health-related characteristics. This readily-available measuring equipment allows for further exploration of the sex relationships between falls risk and physical activity, in order to devise suitable programs with the appropriate level of activity and potentially enhance the education of older adults in the benefits of physical activity.

The combination of the balance-specific training (as presented in this thesis) and recommendations made by Sherrington et al. (2011) still do not provide sufficient evidence for the precise prescription of exercise (frequency, intensity, time and type) within the community-dwelling older population. Additional information pertaining to the simultaneous improvement of physical function and reduction of falls risk, and combining this information with the individual’s sex, would be beneficial. In this regard, research focusing on sex-targeted, specific, well-executed, cost-effective and deliverable programs is essential.
Finally, in order to fully understand the importance of risk factors, a longitudinal study of falls risk, falls risk predictor characteristics and subsequent falls would be invaluable. Though time-demanding (and, therefore, expensive), such longitudinal exploration within community-dwelling older adults would enable better understanding of theoretical underpinnings and inform applied outcomes. Theoretical benefits would include:

- Determining if the difference between self-assessed and objective falls risk changes with age;
- Strengthening the level of evidence regarding body composition and diet with age;
- Evaluating the changes in physical activity and physical function with age in males and females; and,
- Unravelling the complex interplay between risk factors enhancing applied outcomes.

Applied outcomes from this future research could provide:

- Clinicians with an enhanced understanding of the factors contributing to falls risk as individuals age;
- Evidence as to the most accurate combinations of measures predicting falls risk to use with women and men, and how to interpret the results for clinical advice and action; and,
- Meaningful, comprehensible, coherent information to older adults to help give them a more appropriate armoury to combat falls risk and declining physical function.

### 9.7 Conclusion

Studies in this thesis identify previously unremarked upon falls risk predictors with a particular focus on those associated with body composition and diet quality. The work here extends knowledge and understanding about previously identified fall risk factors and highlights the importance of age and sex. Age is an independent falls risk factor (Lord et al., 2007). In addition, age and sex contribute to outcomes associated with other predictor characteristics (functional, body composition or health-related).” Using multiple falls risk assessment tools (objective and self-assessed) concurrently provides improved understanding of which tools to use with a particular population and how to interpret them. Furthermore, this body of work demonstrates the benefits of a balance-specific intervention, and lays a foundation for enhancing exercise programs. This, in turn, informs program design to allow for maximum benefits for ongoing improvements or maintenance of the health of older
adults. This thesis provides evidence to enhance clinicians’ abilities to appropriately assess community-dwelling older adults for their risk of falling, and improve their intervention design. Finally, implementation of information within this thesis could potentially reduce falls risk in older adults and increase the likelihood of positive healthy ageing outcomes.


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References


References

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References


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References


Appendix A – Assessment tools

Appendix A1 – Falls Efficacy Scale-International (FES-I)

**FES-I**

Now we would like to ask some questions about how concerned you are about the possibility of falling. Please reply thinking about how you usually do the activity. If you currently don’t do the activity (e.g. if someone does your shopping for you), please answer to show whether you think you would be concerned about falling IF you did the activity. For each of the following activities, please tick the box which is closest to your own opinion to show how concerned you are that you might fall if you did this activity.

<table>
<thead>
<tr>
<th></th>
<th>Not at all concerned</th>
<th>Somewhat concerned</th>
<th>Fairly concerned</th>
<th>Very concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cleaning the house (e.g. sweep, vacuum or dust)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Getting dressed or undressed</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Preparing simple meals</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Taking a bath or shower</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Going to the shop</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Getting in or out of a chair</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Going up or down stairs</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Walking around in the neighbourhood</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Reaching for something above your head or on the ground</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Going to answer the telephone before it stops ringing</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Walking on a slippery surface (e.g. wet or icy)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Visiting a friend or relative</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Walking in a place with crowds</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Walking up or down a slope</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Going out to a social event (e.g. religious service, family gathering or club meeting)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

FES-I: Prof Lucy Yardley and Prof Chris Todd
Appendix A2 – Activity-specific Balance Confidence Scale (ABC)

Instructions to Participants:
For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports. If you have any questions about answering any of these items, please ask the administrator.

The Activities-specific Balance Confidence (ABC) Scale*
For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>no confidence</td>
</tr>
<tr>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td></td>
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<tr>
<td>50%</td>
<td></td>
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<tr>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>completely confident</td>
</tr>
</tbody>
</table>

“How confident are you that you will not lose your balance or become unsteady when you…
1. …walk around the house? ____%
2. …walk up or down stairs? ____%
3. …bend over and pick up a slipper from the front of a closet floor ____%
4. …reach for a small can off a shelf at eye level? ____%
5. …stand on your tiptoes and reach for something above your head? ____%
6. …stand on a chair and reach for something? ____%
7. …sweep the floor? ____%
8. …walk outside the house to a car parked in the driveway? ____%
9. …get into or out of a car? ____%
10. …walk across a parking lot to the mall? ____%
11. …walk up or down a ramp? ____%
12. …walk in a crowded mall where people rapidly walk past you? ____%
13. …are bumped into by people as you walk through the mall? ____%
14. …step onto or off an escalator while you are holding onto a railing? ____%
15. …step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%
16. …walk outside on icy sidewalks? ____%
Appendix A3 – Physiological Profile Assessment (PPA)

“Visual function is measured using a dual contrast visual acuity chart, the "Melbourne Edge Test" and a device for measuring depth perception. Lower limb sensation is assessed with tests of proprioception, touch sensitivity and vibration sense. The strength of three muscle groups in both legs is measured: the knee flexors and extensors and ankle dorsiflexors. Simple reaction time is assessed using movement of the finger as the response, and choice reaction time is assessed using a step as the response. Body sway on a firm and compliant (foam rubber) surface with eyes open is assessed using a swaymeter that measures displacements of the body at the level of the waist.” From: https://www.neura.edu.au/fbrg#internet-program

<table>
<thead>
<tr>
<th>Contrast sensitivity</th>
<th>Proprioception</th>
<th>Lower limb strength</th>
<th>Reaction time</th>
<th>Postural sway</th>
</tr>
</thead>
</table>

https://www.neura.edu.au/fbrg#internet-program
Appendix A4 – Berg Balance Scale (BBS)

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS has been evaluated in several reliability studies. A recent study of the BBS, which was completed in Finland, indicates that a change of eight (8) BBS points is required to reveal a genuine change in function between two assessments among older people who are dependent in ADL and living in residential care facilities.

**Description:**
14-item scale designed to measure balance of the older adult in a clinical setting.

**Equipment needed:** Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 ft walkway

**Completion:**

<table>
<thead>
<tr>
<th>Time:</th>
<th>15-20 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoring:</td>
<td>A five-point scale, ranging from 0-4. “0” indicates the lowest level of function and “4” the highest level of function. Total Score = 56</td>
</tr>
</tbody>
</table>

**Interpretation:**

- 41-56 = low fall risk
- 21-40 = medium fall risk
- 0 – 20 = high fall risk

A change of 8 points is required to reveal a genuine change in function between 2 assessments.
Appendix A – Assessment tools

**Berg Balance Scale**

Name: ___________________________  Date: ____________________

Location: _________________________  Rater: __________________

<table>
<thead>
<tr>
<th>ITEM DESCRIPTION</th>
<th>SCORE (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting to standing</td>
<td></td>
</tr>
<tr>
<td>Standing unsupported</td>
<td></td>
</tr>
<tr>
<td>Sitting unsupported</td>
<td></td>
</tr>
<tr>
<td>Standing to sitting</td>
<td></td>
</tr>
<tr>
<td>Transfers</td>
<td></td>
</tr>
<tr>
<td>Standing with eyes closed</td>
<td></td>
</tr>
<tr>
<td>Standing with feet together</td>
<td></td>
</tr>
<tr>
<td>Reaching forward with outstretched arm</td>
<td></td>
</tr>
<tr>
<td>Retrieving object from floor</td>
<td></td>
</tr>
<tr>
<td>Turning to look behind</td>
<td></td>
</tr>
<tr>
<td>Turning 360 degrees</td>
<td></td>
</tr>
<tr>
<td>Placing alternate foot on stool</td>
<td></td>
</tr>
<tr>
<td>Standing with one foot in front</td>
<td></td>
</tr>
<tr>
<td>Standing on one foot</td>
<td></td>
</tr>
</tbody>
</table>

Total  __________

**GENERAL INSTRUCTIONS**

Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject’s performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item #12.
Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds
Appendix A – Assessment tools

Berg Balance Scale continued...

REACHING FORWARD WITH OUTSTretched ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slippers, which is in front of your foot.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.)
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold ≥ 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try or needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)
**Appendix A5 – Continuous Scale Physical Functional Performance-10 (CS-PFP10)**

<table>
<thead>
<tr>
<th>Physical Functional Performance Tasks (Short name)</th>
<th>Upper Body Strength</th>
<th>Upper Body Flexibility</th>
<th>Lower Body Strength</th>
<th>Balance &amp; Coordination</th>
<th>Endurance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Difficulty</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carry a weighted pot a distance of 1 meter (Pan Carry)</td>
<td>weight</td>
<td></td>
<td></td>
<td>time</td>
<td></td>
</tr>
<tr>
<td>Donning and Removing a jacket (Jacket)</td>
<td>time</td>
<td></td>
<td></td>
<td>time</td>
<td></td>
</tr>
<tr>
<td>Place and remove a sponge from an adjustable shelf (Shelf reach)</td>
<td>distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Moderate Difficulty</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor Sweeping with broom and dustpan (Floor sweep)</td>
<td>time</td>
<td>time</td>
<td></td>
<td>time</td>
<td></td>
</tr>
<tr>
<td>Transfer clothes from washer to dryer (Laundry 1) Transfer clothes from dryer to basket (Laundry 2)</td>
<td>time</td>
<td>time</td>
<td>time</td>
<td>time</td>
<td>time</td>
</tr>
<tr>
<td>Pick up four scarves from the floor (Scarf)</td>
<td>time</td>
<td>time</td>
<td></td>
<td>time</td>
<td></td>
</tr>
<tr>
<td><strong>High Difficulty</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit and stand up from the floor (Floor down/up)</td>
<td>time</td>
<td>time</td>
<td></td>
<td>time</td>
<td></td>
</tr>
<tr>
<td>Climb stairs (Stairs)</td>
<td>time/step</td>
<td>time/step</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carry groceries (Grocery)</td>
<td>weight</td>
<td>weight</td>
<td></td>
<td>time</td>
<td></td>
</tr>
<tr>
<td>Six minute walk (Walk)</td>
<td></td>
<td></td>
<td></td>
<td>distance</td>
<td></td>
</tr>
<tr>
<td>Total PFP time</td>
<td></td>
<td></td>
<td></td>
<td>time</td>
<td></td>
</tr>
</tbody>
</table>

Appendix A6 – Short Performance Physical Battery (SPPB)

1. Repeated Chair Stands

Instructions: Do you think it is safe for you to try and stand up from a chair five times without using your arms? Please stand up straight as quickly as you can five times, without stopping in between. After standing up each time, sit down and then stand up again. Keep your arms folded across your chest. Please watch while I demonstrate. I’ll be timing you with a stopwatch. Are you ready? Begin

Grading: Begin stop watch when subject begins to stand up. Count aloud each time subject arises. Stop the stopwatch when subject has straightened up completely for the fifth time. Also stop if the subject uses arms, or after 1 minute, if subject has not completed rises, and if concerned about the subject’s safety. Record the number of seconds and the presence of imbalance. Then complete ordinal scoring.

Time: _____ sec (if five stands are completed)
Number of Stands Completed: 1  2  3  4  5

Chair Stand Ordinal Score: ______

0 = unable
1 = > 16.7 sec
2 = 16.6-13.7 sec
3 = 13.6-11.2 sec
4 = < 11.1 sec

2. Balance Testing

Begin with a semitandem stand (heel of one foot placed by the big toe of the other foot). Individuals unable to hold this position should try the side-by-side position. Those able to stand in the semitandem position should be tested in the full tandem position. Once you have completed time measures, complete ordinal scoring.

a. Semitandem Stand

Instructions: Now I want you to try to stand with the side of the heel of one foot touching the big toe of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you. Please watch while I demonstrate.

Grading: Stand next to the participant to help him or her into semitandem position. Allow participant to hold onto your arms to get balance. Begin timing when participant has the feet in
position and let’s go.

**Circle one number**

2. Held for 10 sec
1. Held for less than 10 sec; number of seconds held ______
0. Not attempted

**b. Side-by-Side stand**

*Instructions:* I want you to try to stand with your feet together, side by side, for about 10 sec. Please watch while I demonstrate. You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.

*Grading:* Stand next to the participant to help him or her into the side-by-side position. Allow participant to hold onto your arms to get balance. Begin timing when participant has feet together and let’s go.

*Grading*

2. Held of 10 sec
1. Held for less than 10 sec; number of seconds held ______
0. Not attempted

**c. Tandem Stand**

*Instructions:* Now I want you to try to stand with the heel of one foot in front of and touching the toes of the other foot for 10 sec. You may put either foot in front, whichever is more comfortable for you. Please watch while I demonstrate.

*Grading:* Stand next to the participant to help him or her into the side-by-side position. Allow participant to hold onto your arms to get balance. Begin timing when participant has feet together and let’s go.

*Grading*

2. Held of 10 sec
1. Held for less than 10 sec; number of seconds held ______
0. Not attempted

**Balance Ordinal Score:**

0 = side by side 0-9 sec or unable
1 = side by side 10, <10 sec semitandem
Appendix A – Assessment tools

2 = semitandem 10 sec, tandem 0-2 sec
3 = semitandem 10 sec, tandem 3-9 sec
4 = tandem 10 sec

3. 8’ Walk (2.44 meters)

Instructions: This is our walking course. If you use a cane or other walking aid when walking outside your home, please use it for this test. I want you to walk at your usual pace to the other end of this course (a distance of 8’). Walk all the way past the other end of the tape before you stop. I will walk with you. Are you ready?

Grading: Press the start button to start the stopwatch as the participant begins walking. Measure the time take to walk 8’. Then complete ordinal scoring.

Time: _____ sec

Gait Ordinal Score: _____

0 = could not do
1 = >5.7 sec (<0.43 m/sec)
2 = 4.1-6.5 sec (0.44-0.60 m/sec)
3 = 3.2-4.0 (0.61-0.77 m/sec)
4 = <3.1 sec (>0.78 m/sec)

Summary Ordinal Score: _____

Range: 0 (worst performance) to 12 (best performance). Shown to have predictive validity showing a gradient of risk for mortality, nursing home admission, and disability.

Appendix A – Assessment tools

Appendix A7 – SF-12v2

This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Thank you for completing this survey!

1. In general, would you say your health is:

<table>
<thead>
<tr>
<th>Excellent</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

<table>
<thead>
<tr>
<th></th>
<th>Yes, limited a lot</th>
<th>Yes, limited a little</th>
<th>No, not limited at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>b. Climbing several flights of stairs</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

3. During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

<table>
<thead>
<tr>
<th></th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Accomplished less than you would like</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>b. Were limited in the kind of work or other activities</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

4. During the past 4 weeks, how much of the time have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

<table>
<thead>
<tr>
<th></th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Accomplished less than you would like</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>b. Did work or other activities less carefully than usual</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

5. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little bit</th>
<th>Moderately</th>
<th>Quite a bit</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks...

<table>
<thead>
<tr>
<th></th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Have you felt calm and peaceful?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>b. Did you have a lot of energy?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

about:blank

11/12/2014
c. Have you felt downhearted and depressed?  ○  ○  ○  ○  ○  ○

**7. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?**

<table>
<thead>
<tr>
<th>All of the time</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
### Appendix A8 – Sports Medicine Australia Pre-Exercise Screen (SMA-pre)

Pre-Exercise Screening System 2005 Sports Medicine Australia

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Have you ever had a heart attack, coronary revascularization surgery</td>
<td>No, Yes</td>
</tr>
<tr>
<td>2  Has your doctor ever told you that you have heart trouble or vascular</td>
<td>No, Yes</td>
</tr>
<tr>
<td>3  Has your doctor ever told you that you have a heart murmur?</td>
<td>No, Yes</td>
</tr>
<tr>
<td>4  Do you ever suffer from pains in you chest, especially with exercise?</td>
<td>No, Yes</td>
</tr>
<tr>
<td>5  Do you ever get pains in your calves, buttocks or at the back of your</td>
<td>No, Yes</td>
</tr>
<tr>
<td>legs during exercise which are not due to soreness of stiffness?</td>
<td></td>
</tr>
<tr>
<td>6  Do you ever feel faint or have spells of severe dizziness, particularly</td>
<td>No, Yes</td>
</tr>
<tr>
<td>with exercise?</td>
<td></td>
</tr>
<tr>
<td>7  Do you experience swelling or accumulation of fluid about the ankles?</td>
<td>No, Yes</td>
</tr>
<tr>
<td>8  Do you ever get the feeling that your heart is suddenly beating faster,</td>
<td>No, Yes</td>
</tr>
<tr>
<td>racing or skipping beats, either at rest or during exercise?</td>
<td></td>
</tr>
<tr>
<td>9  Do you have chronic obstructive pulmonary disease, interstitial lung</td>
<td>No, Yes</td>
</tr>
<tr>
<td>disease, or cystic fibrosis?</td>
<td></td>
</tr>
<tr>
<td>10 Have you ever had an <em>attack</em> of shortness of breath that developed</td>
<td>No, Yes</td>
</tr>
<tr>
<td>when you were not doing any thing strenuous, at any time in the last</td>
<td></td>
</tr>
<tr>
<td>12 months?</td>
<td></td>
</tr>
<tr>
<td>11 Have you ever had an <em>attack</em> of shortness of breath that developed</td>
<td>No, Yes</td>
</tr>
<tr>
<td>after you stopped exercising, at any time in the last 12 months?</td>
<td></td>
</tr>
<tr>
<td>12 Have you ever been woken at night by an <em>attack</em> of shortness of</td>
<td>No, Yes</td>
</tr>
<tr>
<td>breath, at any time in the last 12 months?</td>
<td></td>
</tr>
<tr>
<td>13 Do you have diabetes IDDM or NIDDM?</td>
<td>No, Yes</td>
</tr>
<tr>
<td>If so, do you have trouble controlling your diabetes?</td>
<td></td>
</tr>
<tr>
<td>14 Do you have any ulcerated wounds or cuts on your feet that do not</td>
<td>No, Yes</td>
</tr>
<tr>
<td>seem to heal?</td>
<td></td>
</tr>
<tr>
<td>15 Do you have any liver, kidney or thyroid disorders?</td>
<td>No, Yes</td>
</tr>
<tr>
<td>16 Do you experience unusual fatigue or shortness of breath with usual</td>
<td>No, Yes</td>
</tr>
<tr>
<td>activities?</td>
<td></td>
</tr>
<tr>
<td>17 Is there any other physical reason or medical condition which could</td>
<td>No, Yes</td>
</tr>
<tr>
<td>prevent you from undertaking an exercise program, or that you are</td>
<td></td>
</tr>
<tr>
<td>concerned about?</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Answers marked 'Yes' should be referred to a health professional for further investigation.*
Appendix A9 – Six-Item Cognitive Impairment Test (6-CIT)

Test #:___________ Tester:_______ Subject ID:_____________
Date:________________

<table>
<thead>
<tr>
<th></th>
<th>Maximum</th>
<th>weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Score</td>
</tr>
<tr>
<td>1. What year is it now?</td>
<td>1</td>
<td>______</td>
</tr>
<tr>
<td>2. What month is it now?</td>
<td>1</td>
<td>______</td>
</tr>
</tbody>
</table>

Memory Phase – repeat after me:

John/Brown/42/West Street/Bedford

3. About what time is it (within 1 hr)? 1 | ______ | x | 3 | = |
4. Count backwards 20 to 1 | 2 | ______ | x | 2 | = |
5. Say months in reverse order | 2 | ______ | x | 2 | = |
6. Repeat the memory phase | 5 | ______ | x | 2 | = |

Score 1 for each incorrect response

TOTAL = _____
Appendix A10 – Physical Activity Survey for Elderly (PASE)

PHYSICAL ACTIVITY SCALE FOR THE ELDERLY

(PASE)

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INSTRUCTIONS:

Please complete this questionnaire by either circling the correct response or filling in the blank. Here is an example:

During the past 7 days, how often have you seen the sun?

[0.] NEVER (1-2 DAYS)  [1.] SELDOM (3-4 DAYS)  [2.] SOMETIMES (5-7 DAYS)  [3.] OFTEN

Answer all items as accurately as possible. All information is strictly confidential.
**LEISURE TIME ACTIVITY**

1. Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV or doing handcrafts?

   [0.] NEVER  
   ↓  
   (1-2 DAYS)  
   ↓  
   [1.] SELDOM  
   (3-4 DAYS)  
   ↓  
   [2.] SOMETIMES  
   (5-7 DAYS)  
   ↓  
   [3.] OFTEN  
   GO TO Q.#2

   1a. What were these activities?

   1b. On average, how many hours per day did you engage in these sitting activities?

   [1.] LESS THAN 1 HOUR  
   [2.] 1 BUT LESS THAN 2 HOURS  
   [3.] 2-4 HOURS  
   [4.] MORE THAN 4 HOURS

2. Over the past 7 days, how often did you take a walk outside your home or yard for any reason? For example, for fun or exercise, walking to work, walking the dog, etc.?

   [0.] NEVER  
   ↓  
   [1.] SELDOM  
   [2.] SOMETIMES  
   [3.] OFTEN  
   (1-2 DAYS)  
   (3-4 DAYS)  
   (5-7 DAYS)  
   GO TO Q.#3

   2a. On average, how many hours per day did you spend walking?

   [1.] LESS THAN 1 HOUR  
   [2.] 1 BUT LESS THAN 2 HOURS  
   [3.] 2-4 HOURS  
   [4.] MORE THAN 4 HOURS
3. Over the past 7 days, how often did you engage in light sport or recreational activities such as bowling, golf with a cart, shuffleboard, fishing from a boat or pier or other similar activities?

[0.] NEVER (1-2 DAYS) (2.] SOMETIMES (3-4 DAYS) (3.] OFTEN (5-7 DAYS)
GO TO Q #4

3a. What were these activities?

______________________________

3b. On average, how many hours per day did you engage in these light sport or recreational activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS
[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

4. Over the past 7 days, how often did you engage in moderate sport and recreational activities such as doubles tennis, ballroom dancing, hunting, ice skating, golf without a cart, softball or other similar activities?

[0.] NEVER (1-2 DAYS) (2.] SOMETIMES (3-4 DAYS) (3.] OFTEN (5-7 DAYS)
GO TO Q #5

4a. What were these activities?

______________________________

4b. On average, how many hours per day did you engage in these moderate sport and recreational activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS
[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS
5. Over the past 7 days, how often did you engage in strenuous sport and recreational activities such as jogging, swimming, cycling, singles tennis, aerobic dance, skiing (downhill or cross-country) or other similar activities?

[0.] NEVER  [1.] SELDOM  [2.] SOMETIMES  [3.] OFTEN
       (1-2 DAYS)  (3-4 DAYS)  (5-7 DAYS)
GO TO Q.#6

5a. What were these activities?

5b. On average, how many hours per day did you engage in these strenuous sport and recreational activities?

   [1.] LESS THAN 1 HOUR  [2.] 1 BUT LESS THAN 2 HOURS
   [3.] 2-4 HOURS  [4.] MORE THAN 4 HOURS

6. Over the past 7 days, how often did you do any exercises specifically to increase muscle strength and endurance, such as lifting weights or pushups, etc.?

[0.] NEVER  [1.] SELDOM  [2.] SOMETIMES  [3.] OFTEN
       (1-2 DAYS)  (3-4 DAYS)  (5-7 DAYS)
GO TO Q.#7

6a. What were these activities?

6b. On average, how many hours per day did you engage in exercises to increase muscle strength and endurance?

   [1.] LESS THAN 1 HOUR  [2.] 1 BUT LESS THAN 2 HOURS
   [3.] 2-4 HOURS  [4.] MORE THAN 4 HOURS
7. During the past 7 days, have you done any light housework, such as dusting or washing dishes?

[1.] NO  [2.] YES

8. During the past 7 days, have you done any heavy housework or chores, such as vacuuming, scrubbing floors, washing windows, or carrying wood?

[1.] NO  [2.] YES

9. During the past 7 days, did you engage in any of the following activities?

Please answer **YES** or **NO** for each item.

<table>
<thead>
<tr>
<th>Activity</th>
<th>NO</th>
<th>YES</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Home repairs like painting, wallpapering, electrical work, etc.</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>b. Lawn work or yard care, including snow or leaf removal, wood chopping, etc.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>c. Outdoor gardening</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>d. Caring for an other person, such as children, dependent spouse, or an other adult</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
WORK-RELATED ACTIVITY

10. During the past 7 days, did you work for pay or as a volunteer?

[1.] NO  [2.] YES

10a. How many hours per week did you work for pay and/or as a volunteer?

__________________ HOURS

10b. Which of the following categories best describes the amount of physical activity required on your job and/or volunteer work?

[Examples: office worker, watchmaker, seated assembly line worker, bus driver, etc.]

[2] Sitting or standing with some walking.
[Examples: cashier, general office worker, light tool and machinery worker.]

[3] Walking, with some handling of materials generally weighing less than 50 pounds.
[Examples: mailman, waiter/waitress, construction worker, heavy tool and machinery worker.]

[Examples: lumberjack, stone mason, farm or general laborer.]