



MONASH University

Footwear, falls and older adults

Annette Davis

Bachelor of Applied Science (Podiatry)

A thesis submitted for the degree of

Doctor of Philosophy

Monash University 2018

School of Medicine, Nursing and Health Sciences
Department of Physiotherapy

Copyright notice

© *Annette Davis (2018)*

Except as provided in the Copyright Act 1968, this thesis may not be reproduced in any form without the written permission of the author.

I certify that I have made all reasonable efforts to secure copyright permissions for third-party content included in this thesis and have not knowingly added copyright content to my work without the owner's permission.

Table of Contents

ABBREVIATIONS	6
ABSTRACT	7
RESEARCH AIMS:	7
OUTLINE	7
DECLARATION	9
PUBLICATIONS	10
ORAL PRESENTATIONS	10
POSTER PRESENTATIONS	11
AWARDS	11
THESIS INCLUDING PUBLISHED WORKS DECLARATION	12
ACKNOWLEDGEMENTS	14
CHAPTER 1 – BACKGROUND	15
1. FALLS IN OLDER ADULTS	15
1.2 FALLS PREVENTION STRATEGIES	16
1.3 FALLS AETIOLOGY	17
1.4. FOOTWEAR	18
1.5 RELATIONSHIP BETWEEN FOOTWEAR STYLES AND GAIT PARAMETERS RELATED TO FALLS	20
1.6 REFERENCES	23
CHAPTER 2 - DO FOOTWEAR STYLES CAUSE FALLS OR INCREASE FALLS RISK IN HEALTHY OLDER ADULTS? A SYSTEMATIC REVIEW	25
2.1 PREAMBLE	25
2.2 ABSTRACT	26
2.3 INTRODUCTION	27
2.4 METHOD	28
2.5 ANALYSIS	33
2.6 RESULTS	33
2.7 DISCUSSION	40
2.8 CONCLUSION	43
2.9 REFERENCES	44
CHAPTER 3 - DO FOOTWEAR FEATURES CAUSE FALLS OR INCREASE FALLS RISK IN HEALTHY OLDER ADULTS? A SYSTEMATIC REVIEW	46
3.1 PREAMBLE	46
3.2 INTRODUCTION	46
3.3 AIMS	47
3.4 METHOD	47
3.5 ANALYSIS	49

3.6 RESULTS	49
3.7 DISCUSSION	57
3.8 CONCLUSION	60
3.9 REFERENCES	61

CHAPTER 4 – AIMS AND METHODOLOGY **64**

4.1 PREAMBLE	64
4.2 PARTICIPANTS AND RECRUITMENT STRATEGY	65
4.3 STUDY DESIGNS	66
4.4 INTERVENTIONS	68
4.5 MEASUREMENT	68
4.6 ANALYSIS	70
4.7 REFERENCES	74

CHAPTER 5 – EFFECT OF FOOTWEAR ON MINIMUM FOOT CLEARANCE, HEEL SLIPPAGE AND SPATIOTEMPORAL MEASURES OF GAIT IN OLDER WOMEN **75**

5.1 PREAMBLE	75
5.2 ABSTRACT	76
5.3 INTRODUCTION	77
5.4 METHOD	78
5.5 RESULTS	84
5.6 DISCUSSION	86
5.7 CONCLUSION	89
5.8 REFERENCES	90

CHAPTER 6 – “GOOD FOR OLDER LADIES, NOT ME”: HOW ELDERLY WOMEN CHOOSE THEIR SHOES **91**

6.1 PREAMBLE	91
6.2 ABSTRACT	93
6.3 INTRODUCTION	94
6.4 METHOD	96
6.5 RESULTS	98
6.6 DISCUSSION	100
6.7 LIMITATIONS	102
6.8 CONCLUSION	103
6.9 REFERENCES	104

CHAPTER 7 – OLDER ADULTS CONSIDERATION OF SAFETY IN FOOTWEAR CHOICES IN RELATION TO FALLS **106**

7.1 PREAMBLE	106
7.2 ABSTRACT	108
7.3 BACKGROUND	108
7.4 OBJECTIVES	109
7.5 METHODS	109
7.5.1 PARTICIPANTS	110
7.5.2 SURVEY TOOL	110
7.6 PROCEDURE	112
7.7 DATA ANALYSIS	113
7.8 RESULTS	113
7.9 DISCUSSION	117

7.10 CONCLUSION	119
7.11 REFERENCES	120
CHAPTER 8 DISCUSSION	122
8.1 CHAPTER SUMMARY	122
8.2 SUMMARY OF FINDINGS	122
8.3 CLINICAL IMPLICATIONS	126
8.4 LIMITATIONS	128
8.5 FUTURE DIRECTION	129
8.6 CONCLUDING REMARKS	131
8.7 REFERENCES	133
APPENDICES	135
APPENDIX 1 ETHICS APPROVAL	135
APPENDIX 2. EFFECT OF FOOTWEAR ON MINIMUM FOOT CLEARANCE, HEEL SLIPPAGE AND SPATIOTEMPORAL MEASURE OF GAIT IN OLD WOMEN (PUBLICATION)	136
APPENDIX 3. "GOOD FOR OLDER LADIES, NOT ME". HOW ELDERLY WOMEN CHOOSE THEIR SHOES. (PUBLISHED)	141
APPENDIX 4 – CHAPTER 5 BACKGROUND INFORMATION	147

Abbreviations

AD	Annette Davis
CW	Cylie Williams
MFC	Minimum foot clearance
min	Minimum
m	metre
s	second
m/s	metres per second
RCT	Randomised controlled trial
SD	Standard deviation
TH	Terry Haines
UK	United Kingdom
USA	United States of America

Abstract

Falls have a profound effect on the quality of life of older adults. As the population ages, falls are also an increasing financial burden for health services and the community worldwide. Footwear styles and particular footwear features have been implicated as risk factors for falls. When recommending footwear for prevention of falls, health practitioners rely on falls guidelines that are based on the available evidence. There is limited robust evidence supporting footwear recommendations as a discrete falls prevention strategy. This thesis aims to review the available evidence on footwear styles and features and provide evidence in regard to particular footwear styles and their effect on gait parameters. This thesis will also examine footwear styles commonly worn by older adults and their drivers for footwear selection.

Research Aims:

1. Examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking.
2. Compare spatiotemporal parameters of gait when wearing slippers, well-fitted footwear and walking bare foot.
3. Identify factors that drive footwear selection and use amongst older community-dwelling women, aged 60 to 80 years who had no previous history of falls.
4. Examine the relationship between footwear preferences and whether older adults (men and women) fell or not during the preceding 12-month period.

Outline

This thesis is presented as a series of manuscripts that have been published or submitted to peer reviewed journals for publication. Additional information has been

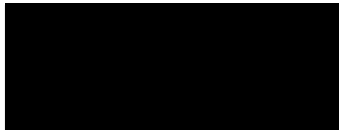
provided in the form of introductory and supplementary chapters to allow for a cohesive explanation of the study.

This thesis begins with an explanation of falls aetiology, falls prevention strategies and the relationship between footwear styles and gait parameters related to falls. Chapter 2 presents a systematic review of footwear styles and their relationship to falls and falls risk that has been accepted for publication in the peer-reviewed journal, *Footwear Science*. Chapter 3 provides a narrative synthesis of footwear features and their association with falls-related gait parameters and falls. Chapter 5 presents footwear styles commonly worn by older adults and gait parameters related to falls. This study was published in *Gait and Posture*. Chapter 6 presents the drivers of footwear selection by older adults who participated in Chapter 5. This study was published in the *Journal of the American Podiatric Medical Association*. Chapter 7 presents a larger community-based study that investigated the footwear choices of older men and women and falls. The final chapter provides an overview of the thesis, summarising and integrating the results of the studies with previous literature, future directions for further research, and recommendations for health practitioners in regard to footwear and falls management.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signature:

A solid black rectangular box used to redact the signature.

Print Name: Annette Davis

Date:22/10/18

Publications

- Davis A, Murphy A, Haines TP. "Good for older ladies, not me": How elderly women choose their shoes. *Journal of the American Podiatric Medical Association* 2013. 103(6), 465-470.
- Davis A, Galna B, Murphy AT, Williams CM, Haines TP. Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women. *Gait & Posture* 2016, 44:43-47.
- Davis A, Williams CM, Haines TP. Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review. *Footwear Science*. (IN PRESS)
- Davis A, Williams CM, Haines TP. Older adults consideration of safety in footwear choices in relation to falls. *Research in Nursing & Health*. (UNDER CONSIDERATION)

Oral Presentations

- Annette Davis, Cylie Williams and Terry Haines. *Footwear. Is safety a thing?* Australia and New Zealand Falls Prevention Conference, Hobart 2018.
- Annette Davis, Cylie Williams and Terry Haines. *Good for older ladies, not for me: How elderly women choose shoes*. Australia and New Zealand Falls Prevention Conference, Sydney 2014.
- Annette Davis, Cylie Williams and Terry Haines. *Footwear selection in an elderly population in relation to falls*. Australian Podiatry Conference, Sydney 2013.
- Annette Davis, Brook Galna, Anna Murphy, Cylie Williams and Terry Haines. *Minimum toe clearance and falls in older ladies*. Victorian Podiatry Conference, Melbourne 2012.
- Annette Davis, Brook Galna, Anna Murphy, Cylie Williams and Terry Haines. *Minimum toe clearance and falls in older ladies*. Australasian Podiatry Conference, Melbourne 2011.
- Annette Davis, Brook Galna, Anna Murphy, Cylie Williams and Terry Haines. *Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women*. Monash Health Research Week, Cheltenham, 2011.

Poster Presentations

- Annette Davis, Cylie Williams and Terry Haines. *Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review.*
Australia and New Zealand Falls Prevention Conference, Hobart 2018
- Annette Davis, Cylie Williams and Terry Haines. *Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review.*
Victorian Allied Health Research Conference, Melbourne 2017.
- Annette Davis, Cylie Williams and Terry Haines. *Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review.*
Monash Health Research Week 2017.
- Annette Davis, Brook Galna, Anna Murphy, Cylie Williams and Terry Haines. *Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women.* Monash Health Research Week 2012

Awards

- 1st Place Winner Best Poster – Australian New Zealand Falls Prevention Conference (ANZFPC). *Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review.* \$500. Hobart 2018.
- Allied Health Research Week, 1st Place. Monash Health 2012.
- Emerging Research Grant \$30,000. Monash Health, February 2009.

Media

- Podchat Live – Social media (Facebook, YouTube) – 1.6K views
- “Slippers will slip you up” (2009) Leader News, Moorabbin, Vic, Australia

Thesis including published works declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes 3 original papers published in peer reviewed journals and 1 submitted publications. The core theme of the thesis is footwear and falls. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the student, working within the School of Medicine, Nursing and Health Sciences, Department of Physiotherapy under the supervision of Professor Terry Haines, Dr. Cylie Williams, and Dr. Anna Murphy.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of 4 publications my contribution to the work involved the following:

Thesis Chapter	Publication Title	Status (published, in press, accepted or returned for revision, submitted)	Nature and % of student contribution	Co-author name(s) Nature and % of Co-author's contribution*	Co-author(s), Monash student Y/N*
Chapter 3	Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review	Published	70% Concept development, acquisition of data, analysis of data, literature retrieval and draft and final manuscript writing	1) Dr Cylie Williams data analysis and literature review 20% 2) Professor Terry Haines, methodology and draft revision. All approved final manuscript 10%	No
Chapter 5	Effect of footwear on minimum foot clearance,	Published	70%. Concept development, collecting data	1) Dr Anna Murphy, Data analysis input into manuscript 15%	No

	heel slippage and spatiotemporal measures of gait in older women.		(all) and writing drafts	2) Dr. Brook Galna, data analysis 10% 3) Professor Terry Haines, concept and draft revision 5% All approved final manuscript	
Chapter 6	"Good for older ladies, not me": How elderly women choose their shoes.	Published	75% Concept development, collecting data, data analysis and writing drafts	1) Dr Cylie Williams, data analysis 15% 2) Professor Terry Haines, methodology advice and draft revision 10% All approved final manuscript	No
Chapter 7	Older adults consideration of safety in footwear choices and falls.	Under consideration	70% Design of study, analysis of data and review of literature, draft and final manuscript writing	1) Dr Cylie Williams data analysis, advice and review of draft manuscript 15% 2) Professor Terry Haines methodology, data analysis and review of draft manuscripts. All approved final manuscript 15%	No

I have renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Student signature:



Date: 22/10/18

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the student's and co-authors' contributions to this work.

Main Supervisor signature:



Date: 22/10/18

Acknowledgements

I would like to express my sincerest appreciation to my supervisors Professor Terry Haines and Dr Cylie Williams for their support and guidance, without them much of this work would not have happened, particularly in the dark days. They are my inspiration, my friends and the reason why allied health will continue to grow and prosper regardless of the challenges ahead.

I wish to thank Monash Health (formerly Southern Health) for awarding me one of the inaugural Emerging Researcher Grants. I am proof that from little things, big things grow, and great things can happen in research. I'd like to thank Brook Galna for giving me the push to do research and Anna Murphy for believing in me and letting me run riot in her gait lab. Many thanks to the Podiatrists at Monash Health for assisting in recruitment and having my back at all times. I also want to thank the beautiful ladies who were participants in my footwear studies. They showed me that age is no barrier to being amazing.

To my colleagues, your undying belief, support and encouragement have ensured that I made it to the end. Words cannot thank you enough and how privileged I am to have you all as my friends.

To my parents and family who are always there for anything I need, I thank you. Finally to my beautiful children and partner, your love has made this journey complete and is all I ever need.

This research was supported by an Australian Government Research Training Program (RTP) Scholarship.

Chapter 1 – Background

1. Falls in older adults

1.1 Definition of a fall

A fall, as defined by the World Health Organisation is as “an event which results in a person coming to rest inadvertently on the ground or floor or other lower level” [1]. Falls are an important health issue, as the global population increasingly ages and people are living longer. With increasing age, the risk of a fall rises, along with the frequency and severity of falls-related injury [2].

One in every three older adults, aged 65 years and over will fall each year. Falls are the most common reason for injuries requiring hospitalisation for older adults who are 65 years and over [3]. The most common reason for admission to hospital and presentations to the emergency department, for people over 65 years are falls and falls-related injuries [4].

Over 80% of injury-related hospital admissions adults aged 65 years and over are due to falls and falls-related injuries and falls are one of the leading causes of morbidity and mortality in older Australians [3]. A person's quality of life can be profoundly affected by a fall. Falls-related injuries sustained by older adults requiring hospital intervention are most commonly hip fracture, with 91% requiring hospital admission [4]. Consequences of falls for the older adult include loss of confidence in ambulatory activities, manifesting in a fear of falling, reduced independence and increased reliance on family and carers.

In addition, falls are also a financial burden on the health system globally across hospital acute, sub-acute, rehabilitation, community and residential care services. These costs include, but are not limited to, hospital and other facilities stays, diagnostic procedures and surgical procedures. The estimated health cost attributed to falls annually in Australia is \$498.2 million [5]. This is anticipated to increase to \$1.375

billion annually by 2051 as the population ages, with over 880 000 additional bed days per year to manage the projected demand [5].

1.2 Falls prevention strategies

Many falls prevention strategies are required to curb this increasing problem and cost. Falls program should be multifactorial and integrated into primary health care settings [6]. Health professionals rely on evidence-based falls guidelines, nationally and internationally, to provide guidance on falls intervention and management [5]. Individual health care drivers, reflective of the social model of care, must be taken into consideration by health professionals when working in partnership for individual falls prevention solutions. Research has found that even older adults who have previously fallen may be reluctant to make personal changes to reduce their risk of falling [7-10]. Therefore health professionals need to understand the changes, if any, that the older adult is prepared to make in regard to footwear and falls so that suitable and acceptable recommendations can be made.

Footwear is described in falls guidelines as one of many important considerations when providing information to older adults on falls management. The Australian Commission on Safety and Quality in Healthcare Best Practice Guidelines for Preventing Harm from Falls in Older People in hospitals [5] and community [11] states that “health care providers should provide education and information about footwear features that may reduce falls risk”. The guidelines report on the results of footwear research. Both guidelines also provide a qualifying statement that the studies informing this recommendation are of limited design and quality. Footwear styles that have been implicated as increasing falls risk include: slippers, high heels, bare feet and wearing socks. Footwear features that have been associated with increasing falls risk include: Medium and high heel height, narrow heels, and inadequate fixation, such as no laces

or buckle [11].

The guidelines state that the footwear associated with the lowest risk of falls are athletic footwear, referencing only one study by Koepsell et al in 2004 [12]. The falls prevention guidelines additionally provides information on footwear and falls with pictures of what is considered an optimal 'safe' shoe, and a theoretical 'unsafe' shoe. However, the guidelines state that the level of evidence is 'low' for the recommended optimal footwear for falls management [5]. The reason given is that there are no experimental studies with the described optimal footwear style that have examined falls as an outcome. It would be advantageous to evaluate the falls prevention guidelines with an appraisal tool to assess the guidelines quality dimensions [13]. The quality dimensions should include presentation of guideline content, transferability, information retrieval, scope, conflicts of interest of guideline developers, as well as patient involvement which may affect the trustworthiness of guidelines [14].

1.3 Falls aetiology

1.3.1 Intrinsic and extrinsic factors that cause falls

Falls are considered to be caused by a number of intrinsic and extrinsic factors. Intrinsic factors that are known to increase the risk of falls included medical conditions affecting mobility and balance such as Parkinson's disease [14,15], postural hypotension [16] and muscle weakness [17], cognitive issues such as dementia and delirium [5], continence problems [5], visual impairment [18,19], increasing age [5] and history of a previous fall [1].

There are many extrinsic factors known to cause increased risk of falls. These include but are not limited to polypharmacy [5,19] (taking more than 5 medications), poor lighting [18], inadequate exposure to sunlight (Vitamin D deficiency) [5], household

clutter [19], slippery and/or damaged flooring [19], living in rural and remote areas [5], and footwear [12, 19-20].

This thesis predominantly focuses on footwear as an extrinsic factor and its relationship to falls in healthy and community dwelling older adults.

1.4. Footwear

1.4.1 Footwear definition and taxonomy

There are many definitions of footwear and footwear styles. Internationally, there is inconsistency of language used to accurately define individual footwear styles. In the United Kingdom, a consensus method utilising experts in podiatry and the footwear industry, developed the Healthy Footwear Guide [22]. The guide defines the ideal footwear for optimum foot health in regard to the effective management of foot disorders. However, the Healthy Footwear Guide focused on foot pain and pathology rather than falls and a systematic review of the evidence was not performed as part of the methodology.

Low-heeled lace-up footwear is traditionally recommended by health care practitioners in regard to falls management. These include shoes described as Oxfords [12, 22], walking shoes, athletic shoes [23], sturdy shoes [10], safe shoes [5, 24] and optimal shoes [5]. Slippers have been described as being either enclosed or backless [19, 25, 26], as moccasins [27] or Ugg® boots [27]. Boots have been described as ladies dress style boots [19] and having variable collar height [20] or being Wellington boots with cut out heels [28].

Compounding this is the definition of a particular footwear style defined in one culture may be markedly different in other cultures. For example, Australian 'thongs' have an

equivalent called 'flip-flops' in the United States of America or 'jandals' in New Zealand. Moreover, the use of particular footwear styles indoors and outdoors also differed across cultures. For example, a "slipper" in western countries is soft, indoor footwear [26] whereas in Asian countries, it is outdoor footwear much like a sandal, with a solid base and strap to secure onto the foot [18].

High heeled footwear is often implicated in falls [21,24,29]. However, there is no agreed height for what constitutes 'high heeled' footwear. Several studies proposed heights of high heeled footwear, ranging from 50mm [30] to 73mm [31].

The collection of features/elements of footwear clustered together enables the creation of similar groupings of footwear. For the purpose of this thesis, working definitions for footwear styles were developed by the supervisory team and a review of the literature to facilitate synthesis of data.

- *Slipper*: a type of light, soft shoe, easily put on and taken off [22, 21]. They are frequently worn indoors however may be worn outdoors according to local cultural norms.
- *Lace up or Oxford footwear*: a type of low-heeled enclosed shoe usually made of leather that dorsally fastens with laces [21, 23].
- *High heels*: adopted the definition of a type of footwear that has an elevated heel position that, at its highest point, is 71mm greater than the forefoot. A 'mid-heeled' footwear has been defined as one that had a heel height of 37mm [31]. In applying this definition, we did not differentiate on the basis of heel profiles such as stiletto, pump, block, tapered, blade, or wedge.
- *A boot*: a type of shoe style that covers the whole foot and the lower part of the leg. A boot was differentiated from a lace-up/Oxford shoe on the basis of the boot extending above the level of the ankle joint [20, 23].

- A sandal: an unenclosed shoe consisting of a sole held in place by straps [22, 23].

A footwear feature is the particular aspect that may be present in one or more different footwear styles. Footwear features have a more accepted vernacular, however, for clarity we used the following operational definitions derived from a review of the literature and consensus of the supervisory team to describe footwear features.

- Heel counter: back of the footwear that wraps around the medial/lateral heel [26].
- Dorsal fixation: device that secures footwear over the top of the foot, e.g. laces, Velcro® or buckle [27].
- Outsole/tread: material on the bottom of the footwear [27].
- High heel: 55mm – 90mm greater than the forefoot [31].
- Mid heel: 35mm – 55mm greater than the forefoot [31].
- Toe Spring: the elevation of a shoe's toe box above the ground or supporting surface. The current industry standard for toe spring for most types of footwear is 15 degrees [33].

Footwear features that have been associated with falls have included high heels, absence of heel counter, absence of dorsal fixation and different outsole configurations. Footwear features also have a varying effect on falls-related gait parameters including foot clearance (with the ground), cadence, step velocity, step length, stride length and double limb support.

1.5 Relationship between footwear styles and gait parameters related to falls

The relationship between falls and footwear may be investigated by either the direct relationship between footwear and falls; or the relationship between footwear and the gait parameters that then link to falls. It is important to consider both of these

investigations separately, however it is ultimately the relationship between footwear and falls that is the important issue, whether it is mediated through gait parameters or not. As guidelines appeared sparse with tenuous evidence proposing a relationship between footwear and falls, it is considered prudent to investigate gait parameters that are linked to falls and are affected by footwear.

There are particular spatial and temporal gait parameters associated with falls. These include step length, cadence, step velocity, double support, step width, stride length and toe clearance [34, 36]. The gait parameters of velocity, step and stride length, decrease as age increases and gait parameters, step width and double support, increase with age [37]. Older adults also have greater variability in foot clearance therefore increasing the risk of a toe-trip related fall [38]. A toe trip can result in an injurious fall as the body's centre of gravity is moving forward and is less likely to rebalance its equilibrium [39].

Previous research has shown that bare feet, or the “unshod” foot may increase falls risk as compared to wearing footwear [21]. However, no particular footwear type has been adequately researched in comparison to bare feet, to determine a causal effect. A point for future research could be different footwear types versus no footwear. There is acknowledged infinite variations in the number of ways at the analysis level of dissecting the footwear and falls dilemma. It is impossible to separate out footwear features as part of the causative factors that lead to falls or as preventative strategies. In fact it is hard to separate out footwear as a single contributor to falls unless the research is carried out as an experimental laboratory-based study where many of the variables can be controlled.

In order to understand the relationship between footwear, falls and related gait parameters it is firstly important to establish if there are particular footwear styles that

cause or increase falls risk. Chapter 2 provides a systematic synthesis of the evidence in relation falls and footwear styles including slippers, lace up, high-heels, boots and sandals, in healthy older adults.

This thesis investigated footwear, falls and older adults with four distinct research aims:

1. Examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking.
2. Compare spatiotemporal parameters of gait when wearing slippers, well-fitted footwear and walking bare foot.
3. Identify factors that drive footwear selection and use amongst older community-dwelling women, aged 60 to 80 years who had no previous history of falls.
4. Examine the relationship between footwear preferences and whether older adults (men and women) fell or not during the preceding 12-month period.

In order to address the aims, the thesis is presented with two systematic reviews of the literature in regard to older adults, falls and footwear styles (published), and older adults, falls and footwear features. The reviews are followed by a detailed aims and methodology chapter that articulates the design and analysis elements for the proceeding chapters. Chapters 5, 6 and 7 are the quantitative and qualitative published research studies that specifically address the aims of the thesis and relevance to the stated outcomes. The final chapter is a discussion that provides linkages of findings and future recommendations.

1.6 References

1. World Health Organisation, *WHO Global Report on Falls Prevention in Older age*, 2007, World Health Organisation: France.
2. The Department of Health, *An Analysis of Research on Preventing Falls and Falls Injury in Older People: Community, Residential Care and Hospital Settings*, National Ageing and Research Institute, Editor 2004: Canberra, Australia.
3. Kannus, P. et al. *Prevention of falls and consequent injuries in elderly people*. The Lancet, 2005. **366**(9500): p. 1885-93.
4. Australian Institute of Health and Welfare. *Trends in hospitalised injury due to falls in older people 2003-4 to 2014-15*, Australian Government, Editor 2018, Australian Institute of Health and Welfare: Canberra, Australia.
5. Department of Health. *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Hospitals*, Australian Commission on Safety and Quality, Editor 2009: Australia.
6. Gillespie, L D. et al. *Interventions for preventing falls in older people living in the community*. Cochrane Database of Systematic Reviews, 2009(2).
7. Hornbrook, M.W. Dj. Stevens, VJ et al., *Reducing Frailty and Falls in Older Persons*. August 2008, University of Michigan USA: Thomas, 1991. 532.
8. Frey, C. *Foot health and footwear for women*. Clinical Orthopaedics and Related Research, 2000(372): p. 32-44.
9. Isaacs, B. *Clinical and Laboratory Studies of Falls in Old People: Prospects for Prevention*. Clinics in Geriatric Medicine, 1985. **1**(3): p. 513-524.
10. Dunne, R.G. et al., *Elderly persons' attitudes towards footwear - A factor in preventing falls*. Public Health Reports, 1993. **108**(2): p. 245-248.
11. Department of Health. *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Community Care*, Australian Commission on Safety and Quality in Healthcare, Editor 2009: Canberra, Australian Capital Territory, Australia.
12. Koepsell, T.D et al. *Footwear style and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(9): p. 1495-1501.
13. Siering, U., Eikermann, M., Hausner, E., Hoffmann-Eßer, W., & Neugebauer, E. A. (2013). Appraisal tools for clinical practice guidelines: a systematic review. *PloS one*, 8(12), e82915. doi:10.1371/journal.pone.0082915
14. Chastan, N. et al., *Gait and balance disorders in Parkinson's disease: impaired active braking of the fall of centre of gravity*. Mov Disord, 2009. **24**(2): p. 188-95.
15. Mak, M and Pang, M. *Parkinsonian single fallers versus recurrent fallers: different fall characteristics and clinical features*. J Neurol, 2010. **257**(9): p. 1543-51.
16. Matinolli, M. et al. *Orthostatic hypotension, balance and falls in Parkinson's disease*. Mov Disord, 2009. **24**(5): p. 745-51.
17. Spink, M.J. et al., *Effectiveness of a multifaceted podiatry intervention to prevent falls in community dwelling older people with disabling foot pain: randomised controlled trial*. BMJ (Clinical research ed.), 2011. **342**.
18. Tsur, A., et al. *Clinical profile of fallers with femoral neck fractures*. PM&R, 2014. **6**(5): p. 390-394.
19. Kuhirunyaratn, P. Prasomrak, P and Jindawong, B. *Factors related to falls among community dwelling elderly*. Southeast Asian Journal of Tropical Medicine & Public Health, 2013. **44**(5): p. 906-15.

20. Kelsey, J.L. et al. *Footwear and falls in the home among older individuals in the MOBILIZE Boston study*. Footwear Science, 2010. **2**(3): p. 123-129.
21. Tencer, A.F. et al. *Biomechanical properties of shoes and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(11): p. 1840-6.
22. Menz, H B and Lord, S R. *Footwear and postural stability in older people*. J Am Pod Med Assoc, 1999. **89**(7): p. 346-357.
23. Vernon, W. Borthwick, AM, Walker, J. et al. *Expert Group Criteria for the recognition of healthy footwear*. British Journal of Podiatry. 2007; **10**(4): p127-133.
24. Chien, H L. Lu, T W. and Liu, M W. *Control of the motion of the body's center of mass in relation to the center of pressure during high-heeled gait*. Gait and Posture, 2013. **38**(3): p. 391-396.
25. Keegan, T.H. et al. *Characteristics of fallers who fracture at the foot, distal forearm, proximal humerus, pelvis, and shaft of the tibia/fibula compared with fallers who do not fracture*. American Journal of Epidemiology, 2004. **159**(2): p. 192-203.
26. Menant, J.C. et al. *Optimizing footwear for older people at risk of falls*. 2008.
27. Karlsson, M.K. et al., *Prevention of falls in old people-a review*. Reviews in Clinical Gerontology, 2013. **23**(3): p. 206-222.
28. Vass, C. et al. *What do patients wear on their feet? A service evaluation of footwear in elderly patients*. International Journal of Therapy and Rehabilitation, 2015. **22**(5): p. 225-232.
29. Sherrington, C. and Menz, HB. *An evaluation of footwear worn at the time of fall-related hip fracture*. Age and Ageing, 2003. **32**(3): p. 310-314.
30. Gabell A, Simons M A, and Nayak U L S, *Falls in the healthy elderly: Predisposing causes*. Ergonomics, 1985. **28**(7): p. 965-975.
31. Gefen, A. et al. *Analysis of muscular fatigue and foot stability during high-heeled gait*. Gait & Posture, 2002. **15**(1): p. 56-63.
32. Chien H L, Lu T W, and Liu M W, *Control of the motion of the body's center of mass in relation to the center of pressure during high-heeled gait*. Gait Posture, 2013. **38**(3): p. 391-6.
33. <https://naturalfootgear.com>
34. Hansen, A.H. and D.S. Childress, *Effects of shoe heel height on biologic rollover characteristics during walking*. Journal of rehabilitation research and development. 2004. **41**(4): p. 547.
35. Mortaza, N. Abu Osman. N, and Mehdikhani. N, *Are the Spatio-temporal Parameters of Gait Capable of Distinguishing a Faller from a Non-faller Elderly?* European Journal of Physical and Rehabilitation Medicine, 2014 Apr 24
37. Gervásio FM, S.G., Ribeiro DM, de Menezes RL, *Falls risk detection based on spatiotemporal parameters of three-dimensional gait analysis in healthy adult women from 50 to 70 years old*. Fisioterapia e Pesquisa **23**(4).
38. Barrett R S, Mills P M, and Begg R K, *A systematic review of the effect of ageing and falls history on minimum foot clearance characteristics during level walking*. Gait & Posture, 2010. **32**(4): p. 429-435.
39. Pavol M J, et al. *Mechanisms Leading to a Fall From an Induced Trip in Healthy Older Adults*. The Journals of Gerontology, July 2001. **56**(Issue): p. M428–M437.

Chapter 2 - Do footwear styles cause falls or increase falls risk in healthy older adults? A Systematic Review

2.1 Preamble

Footwear is widely reported as a risk factor for falls in older adults. Falls guidelines inform health practitioners about footwear recommendations for older adults, as part of falls management strategies. However, there is a paucity of robust evidence linking particular footwear styles with an increase in falls in real life settings. This chapter is a systematic review that investigated whether there was a causal or correlational relationship between falls in older adults and particular footwear styles, including slippers, lace-up, high heels, boots and sandals.

Criteria for inclusion were the above mentioned footwear styles, real life settings and healthy older adults with no gait aids or medical issues that could be considered the causative factor for falls such as Parkinson's disease. A falls outcome measure was critical for inclusion to link the footwear style to falls. Quality and level of evidence tools were used to critically to determine the efficacy of included papers.

This chapter reviewed the association between particular footwear styles and falls risk in older adults, in real life settings.

This study was accepted for publication by Footwear Science in October, 2018.

2.2 Abstract

Falls in older adults is a major issue for health care organisations. Footwear is often reported as a contributing factor to falls in older adults however, the reporting of footwear styles that are proposed to increase falls and falls risk is confusing. Moreover, these reports have been used to inform falls guidelines and recommendations by health practitioners.

A systematic review was performed to identify and synthesise the available evidence examining whether there was support of a causal or correlational relationship between different styles of footwear and falls in older adults in real life settings.

The databases included in the search were Ovid MEDLINE, PubMed, Scopus and Web of Science. The inclusion criteria were papers with falls outcomes, healthy adults that were 65 years or older. The footwear styles included slippers, Oxford/lace ups, high heels, boots and sandals. The exclusion criteria were laboratory studies and papers with primary focus on gait issues that increased falls likelihood.

Nine studies met the inclusion criteria and were included in the review from a total of 363 papers identified in the database search. The results of this review suggest that there is inadequate evidence to link any particular footwear style with falls. However, it may be possible that it was not the style of footwear, rather how accustomed the individual was to wearing that particular style of footwear.

There is limited evidence supporting footwear recommendations as a discrete falls prevention strategy. Clinicians should be pragmatic in their advice to healthy older adults about footwear styles and their potential to reduce falls or falls risk.

2.3 Introduction

Over one third of people over the age of 65 years will have at least one fall per year [1, 2] and footwear has been implicated as a falls contributor [2, 3]. Health practitioners often provide advice on footwear as a falls prevention strategy. Australian best practice guidelines on falls in older people [4] recommend a well fitted, low-heel shoe with laces to secure the foot into the shoe. However there is tenuous evidence to support this recommendation [5].

References to specific footwear features and their impact on falls have been reported [6, 7], however the relationship between footwear styles and falls is not precisely clear. Footwear can be described in terms of style, e.g. slippers, Oxford/lace up, sandals or boots. Footwear can also be described as having specific features, e.g. heel counter, heel height and lace up (dorsal fixation). To establish a relationship between falls and footwear we need to identify the specific styles that elevate the risk of falls compared to a specified alternative style. Complicating factors in this endeavour are the different terms used to describe similar styles, which must be taken into account when reviewing the literature [8].

We can glean evidence to support a relationship between specific footwear styles with falls from laboratory and real life settings. One laboratory-based study of 30 women, found that wearing footwear of the slipper style, reduced minimum foot clearance during the swing phase of gait compared with Oxford/lace up footwear [3]. This relationship would indicate the potential for higher risk of falls while wearing slipper style footwear compared to Oxford style footwear in older women under the assumption that having a reduced minimum toe clearance increases the risk of tripping. However, this may not necessarily be the case in real life situations. Older adults may recognize the increased risk of tripping when wearing different footwear such as light weight slippers, and compensate by changing the activities they do while

wearing this footwear [9]. Therefore, information from these types of laboratory studies are insufficient to establish a relationship between footwear styles in real life. This creates the scenario where health care practitioners and best practice guidelines, which are based largely on laboratory studies, may be inappropriately telling older adults to change their footwear when there is an unknown effect on the individual's rate of falls. There is a need to use both laboratory and real life setting approaches in research to identify and synthesise available evidence examining the relationship between specific footwear styles with falls.

This review's main aim was to identify and synthesise available evidence examining causal or correlational relationships between different styles of footwear and falls in older adults in real life settings.

2.4 Method

The question for this systematic review was developed in a PICO format [10], "Does wearing certain footwear styles increase the occurrence of falls in older adults?" This question was separated into search terms (Table 1). The population was healthy older adults, inclusive of men and women. The intervention was footwear or shoe styles including slippers, Oxford/lace up footwear, high heels, boots and sandals. The outcome was falls, classified in concordance with the World Health Organisation (WHO) as 'an event which results in a person coming to rest inadvertently on the ground or floor or other lower level' [11]. The databases searched by the lead author, using combinations of the key search terms (Table 2) were Ovid MEDLINE, PubMed, Scopus and Web of Science. The search was performed from the database inception date to 30th of April 2016. The reference lists of all retained studies were then examined in an attempt to locate further studies and an additional 26 studies were identified from this list.

Table 1 Search strategy

Population		Intervention		Outcome
Old*	AND	Footwear	AND	Fall*
Age*		Shoe*		Trip*
Elderly*		Lace*		Slip*
Geri*		Oxford		
		Slipper*		
		Boot*		
		Sandal*		
		High heel		

* truncation character that allows the retrieval of varying endings of the search term.

Table 2 reports the inclusion and exclusion criteria. Inclusion criteria were adults aged 65 years or over with no gait aids and no known medical issues that increase falls or the risk of falls. Studies included any randomised control trials, quasi-experimental or clinical trials, cohort, case-control or case series studies that reported the intervention footwear styles (slippers, Oxford/lace up, high heels, boots or sandals) and falls outcomes. Reasons for exclusion of papers included no falls outcome, multifactorial intervention papers where footwear and falls outcomes were not delineated from other interventions, papers that investigated footwear features rather than footwear types, barefoot or sock conditions, narrative literature reviews, simulated life and laboratory studies, footwear screening or assessment tools and papers not published with the full text in English. Two researchers independently screened all articles by title and abstract. If there was any doubt as to an article's eligibility, the full text paper was retrieved. The full texts of all included studies were screened against the inclusion criteria.

Table 2 Inclusion/exclusion criteria

Inclusion criteria	Exclusion Criteria
Design: Randomised Control Trials (RCTs) Quasi-experimental trials Clinical trials Cohort studies Case control studies Case Series Participants: Adults aged 65 years or over No gait aids No known medical issues that increased falls or risk of falls Interventions: Footwear or shoes Slipper Lace up or Oxford footwear High heels Boots Sandals Outcome measure: Falls data reported	Study Design: Laboratory studies Simulated life situations Narrative literature review Papers that discussed particular footwear features in relation to falls Multifactorial interventions where specific data regarding footwear in relation to falls was not extrapolated. Other conditions: Barefoot conditions only Stocking or sock conditions only Footwear and falls screening or assessment tools Known medical conditions and gait issues that increased falls likelihood such as Parkinson's disease Research not published in English

The final included papers were heterogeneous in design therefore each article was assessed with criteria utilising a generic quality tool [12]. The lead author performed the original analysis that was then discussed with the other authors for concurrence. The papers were then classified into levels of evidence using the Oxford Centre for Evidence Medicine [13]. This classification provides levels of evidence, Level 1 (highest) to 5 (lowest), to define research at lowest risk of bias to guide decision-making (Table 3).

2.4.1 Definition of Footwear Styles

The authors of this review developed the following operational definitions of footwear styles to facilitate synthesis of data in this review.

- A slipper: a type of light, soft shoe, easily put on and taken off. They are frequently worn indoors however may be worn outdoors according to local cultural norms.
- An Oxford/lace up shoe: a type of low-heeled enclosed shoe usually made of leather that dorsally fastens with laces.
- A high heel shoe: adopted the definition of a type of shoe that has an elevated heel position that, at its highest point, is 71mm greater than the forefoot. A 'mid-heeled shoe' has been defined as one that had a heel height of 37mm [14]. In applying this definition, we did not differentiate on the basis of heel profiles such as stiletto, pump, block, tapered, blade, or wedge.
- A boot: a type of shoe style that covers the whole foot and the lower part of the leg. A boot was differentiated from an Oxford/lace up shoe on the basis of the boot extending above the level of the ankle joint.
- A sandal: an unenclosed shoe consisting of a sole held in place by straps.

Table 3 Quality Assessment

Author	Research question	Study subjects	'Data' collection methods	Completeness of 'data'	Confounding variables acknowledged	Analysis of results	Conclusions	Reproducibility	Prospective	Ethical issues	Triangulation	Total Score /11
Gabell[25] 1985	x	✓	x	✓	✓	x	x	x	x	x	x	3
Keegan[23] 2004	✓	✓	✓	✓	✓	✓	x	x	x	✓	x	7
Kelsey[16] 2010	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	x	9
Kerse, [19] 2004	✓	✓	x	✓	✓	✓	✓	x	x	x	x	6
Kuhirunyaratn [8],2013	✓	✓	x	✓	✓	✓	x	x	x	✓	x	6
Koepsell[15], 2004	✓	✓	x	✓	✓	✓	✓	x	x	x	x	6
Sherrington[2], 2003	✓	✓	✓	✓	x	✓	✓	✓	x	✓	x	8
Tencer[1], 2004	✓	✓	✓	✓	x	✓	x	x	✓	x	x	6
Tsur[17], 2014	✓	✓	✓	✓	x	✓	x	✓	x	x	x	6

2.5 Analysis

The planned analysis approach was to pool data from any randomized trials investigating footwear style interventions and their impact on the rate of falls. If no randomized trials were identified, the planned approach was to pool the results of quasi-experimental trials investigating footwear style interventions and their impact on the rate of falls. Failing the identification of any quasi-experimental studies, it was planned to pool any observational studies reporting associations between footwear styles worn and rates of falls while wearing those footwear styles. Failing the identification of any observational studies of this nature, a narrative synthesis of the remaining studies would be conducted.

2.6 Results

There were 363 articles identified for abstract and title screening and nine full texts included within the review. Figure 1 displays the screening process and reasons for exclusion. The study characteristics are reported in Table 4. There were no (zero) randomized controlled trials, or quasi-experimental trials investigating the specific relationship between footwear style interventions and rates of falls were found. All of the articles included were cohort studies or case series designs. All included studies had >50% female participants and studies were generated within Australia, USA, United Kingdom Israel, New Zealand and Thailand. The total participant numbers ranged from 95 to 2860.

Only one included study reported outcomes based on a single footwear type. All other studies included multiple footwear types (Table 4). Footwear naming conventions were matched from the description in the included articles to the working definitions.

Figure 1 – PRISMA Screening process & exclusion criteria

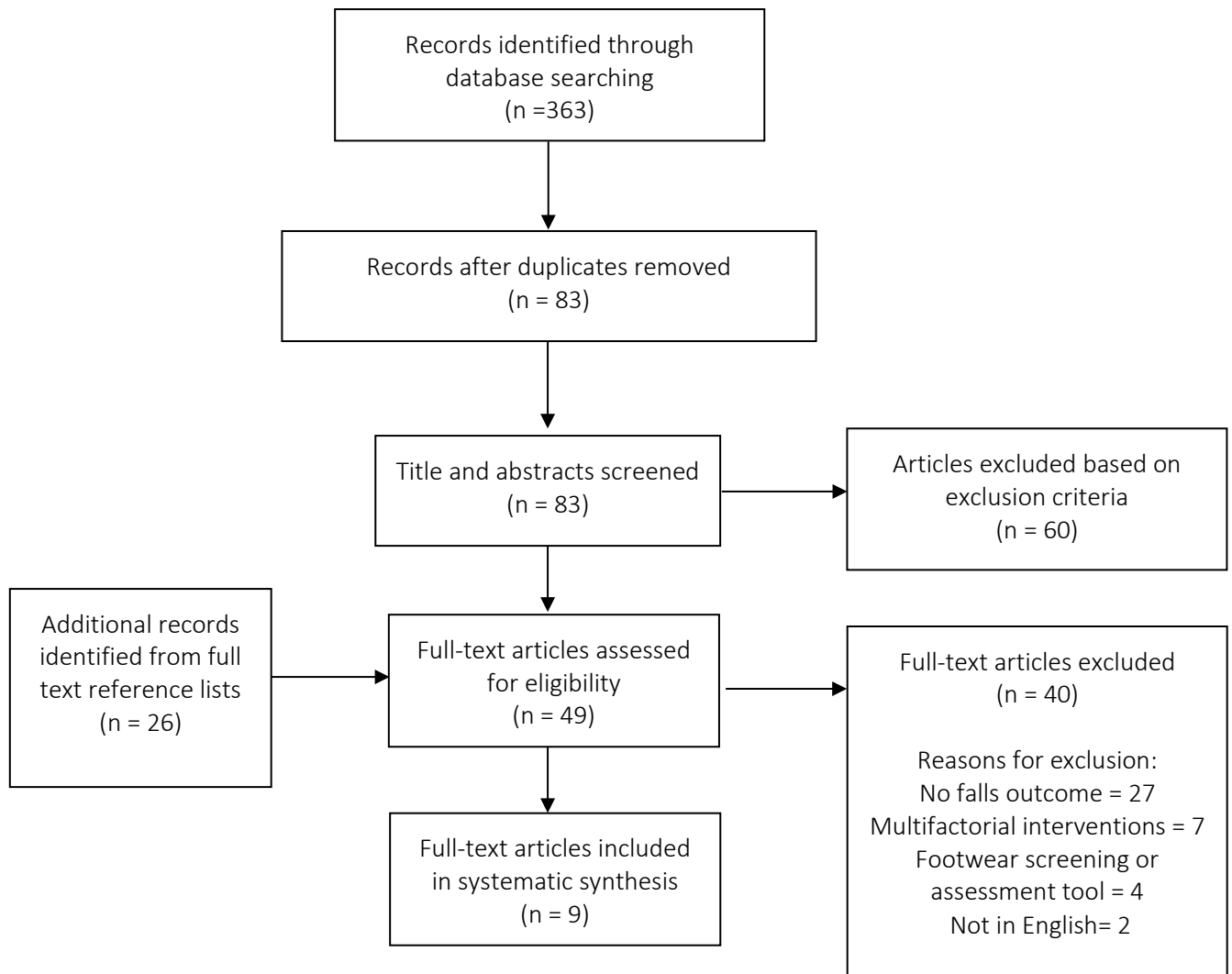


Table 4 Summary of Papers included

First Author	Study Design	Country/	Participant numbers n,% (female)	Outcome of footwear related to falls	Fall recall timeframe	Footwear described	Footwear exposure ^{<}	Reporter of fall (Self reported or Secondary)	Effect of intervention	Level of Evidence
Gabell [25]	Retrospective cohort	UK	100 (55%)	Involved in 31.25% of falls	At time of fall, 12 months	Wellington boots, slip-on, slippers, history of high heel shoe wear	No	Self reported	High heel shoes p <0.05	3
Keegan [23]	Case Control (Sub-set of fallers)	USA	2860 (76%)	Increased risk of fracture with slip in footwear 20.9% slippers/socks, 11.7%	12 months	Medium or high heeled shoes, slippers, slip-on shoes, sandals and other (not defined)	Yes [^]	Self reported	Not described	4
Kelsey [16]	Prospective cohort	USA	765 (64%)	27% wore Slippers, 26% athletic shoes, 10.5% Oxford at time of fall	Median 27.5 months (range=0.5 – 44.4 months)	Slippers, athletic, Oxfords, Loafers, sandals, pumps, boots	No [*]	Self reported	Not described	3
Kerse [19]	Cohort	New Zealand	606 (72%)	37% wore slippers at time of fall	At time of fall, 18 months	Slippers, hard soled shoes & soft-soled shoes	No [#]	Self reported or Secondary reporter	Not described	3
Kuhirunyaratan [8]	Case control	Thailand	333 (63%)	Wearing slippers was a factor relating to falls	60 days	Slippers ^{<}	No	Self reported	p<0.001	4
Koepsell, [15]	Nested Case –control (Same trial data as Tencer, 2004)	USA	654 (68%)	Athletic shoes lowered risk than all other shoes styles	Median 22 days post fall	Athletic, canvas, lace-up (Oxford), loafers, flats, boots, high heels, sandals, slippers, other shoe styles (not described) ⁺	No [#]	Self-reported	p<0.001	4
Sherrington [2]	Case series (Subset of fallers)	Australia	95 (76%)	Slippers 31%, court shoes 13%, moccasins 12%	3 weeks – 5 months	Slippers, walking, sandals, mules, Oxford, backless slippers, surgical boots, athletic shoes,	No	Self-reported	p=0.033	4

						Ugg® boots, high heels, thongs				
Tencer [1]	Nested-case control	USA	1371 (68%)	Associated with high heels $\geq$ to 2.5 cm)	3-4 weeks post fall	Athletic, Oxfords, loafers, slippers, flats, canvas, sandals, boots, high heels others (not defined)	No	Self-reported	p=0.03	4
Tsur [17]	Case series (Faller sub-set)	Israel	100 (63%)	72% wore slippers, socks or bare feet at time of fall	Up to 2 weeks post fall	Slippers, socks, bare feet, shoes (not defined) and sandals	No	Self-reported	p<0.001	4

[^] Shoes worn less than 3 times per week on average

^{*} Used usual footwear as referent

[#] Asked about usual footwear worn

⁺ Footwear categorized into 12, 5 and 3 broader categories for analysis

[±]Slipper defined as a semi closed indoor or outdoor shoe with a strap running over the toes or instep

The nine included observational studies provided information regarding footwear styles worn and falls. However, only one of these articles reported footwear style exposure (length of time footwear was worn) and no articles reported the rates of falls reported during this exposure. One study used a nested-case control design whereby older adults who had recently fallen (cases) were interviewed shortly following a fall and asked about the activity they were performing and the footwear style they wore at the time of the fall [15]. A control was then selected from the broader cohort study and matched for age (± 3 years) and gender. Controls reported the most recent time performing the same activity that the case-subject fell during and about the footwear they wore when they last performed that activity. This case-control design generated risk estimates of falls while wearing certain footwear types without having to directly measure exposure. However, no other studies used a comparable methodology that would have allowed pooling of results. Hence, the remaining articles were analysed through narrative synthesis rather than meta-analytic approaches.

The quality of evidence of the studies were variable, with high quality for one and very low for another, with the majority earning a fair to moderate quality from our evaluation (Table 3).

2.6.1 Slippers

Slippers were the most common type of footwear reportedly worn at the time of a fall in two of the included papers [16, 17]. Slippers were also reported as the most frequently worn footwear at the time of an injurious fall in four papers [2, 16-18]. One paper [19] reported that slippers were usual participant's footwear and another [3] found an association between participant's self-reported footwear (slippers) and falling ($p < 0.05$), but neither provided information that slippers were the footwear worn at the time of falling. Two studies reported that slippers were worn for the greatest amount of time, particularly whilst indoors [20]. Slippers in the secondary study were defined as a closed type of shoe with a sole held to the foot by a strap over the toes and instep.

No studies reported the relative rate of falls or injurious falls whilst wearing slippers relative to other footwear styles.

Slippers were reported to be the most common footwear worn by older people in the home [15, 16, 21, 22]. Many slipper studies relating to falls were again mostly self-reported questionnaire or interview type studies relying on memory recall and subjection from the participant. In one study [19] based in a residential aged care facility, nursing staff and carers reported and were interviewed on the patient falls.

2.6.2 Lace-up /Oxford shoes

A nested-case control study [15] found Oxford/lace up footwear to be no different to athletic footwear in terms of the risk of falls. The athletic shoes described within this research were found to result in a significantly lower risk of falls compared to the style described as 'stockinged feet'. We have ignored the data-driven polling of this study in our review due to the post hoc pooling decision potentially increasing risk of Type 1 error [15]. Keegan [23] concluded that wearing "proper" shoes with low, wide heels that cover and stay on the foot in the event of a fall may reduce the risk of fracture. Even though particular footwear styles were tested in this study, the author did not conclude a particular style as reducing falls risk, rather attributing this to features of the footwear.

2.6.3 High heels

High-heeled shoes have been implicated as a falls risk in a number of studies with older women [15, 23-25]. Koepsell et al [15] found that high heel shoes, when pooled with other non-athletic footwear were associated with falls. While this was reported as a strong trend (OR 2.4, 95%CI 0.8, 6.8) there was low statistical power, again potentially indicating a Type 1 error. It was difficult to compare studies that included high heels as an independent variable as no studies defined the heel height variable. High heeled footwear appeared unlikely to be the footwear style commonly worn by older women when they fall, with one study reporting only 2% of older women wearing

high heeled footwear when they fell [2]. However, this result does not mean that wearing high heels reduces the relative risk of falling, compared to wearing other styles of footwear in the same situations.

2.6.4 Boots

There were limited studies describing boots worn by older adults relating to falls. While there were four articles including boots as a footwear style, it is unknown how many participants within these studies were wearing boots when they fell due to unclear results reporting. A boot definition was not provided even though studies had the participants show the assessor their boots [1] or pictures of boots chosen from a list of footwear [16]. There were no studies investigating 'dress' boots. They were however included in the footwear styles of larger studies investigating footwear and falls. Few older adults were reported to wear boots as often as other footwear types such as slippers, lace up and walking style footwear [15]. One study [25], proposed that Wellington boots with cut-away heels as well as heavy Wellington and other boots, were 'unhelpful' in regard to falls in the healthy older adults.

2.6.5 Sandals

As with the other footwear types, sandals were included in the broad footwear type list having a relationship to falls [15]. Sandals have been worn by 8% of older women at the time of fall in one study [2]. It is unclear however as to whether sandals increased the risk of falling. Keegan reported sandals increased the risk of foot fracture as the result of falling (OR: 2.3 and 3.1 respectively) however did not report if wearing sandals increased the risk of falls [23]. Stiff soled sandals had little association with falls risk, however wear exposure time was not recorded [1].

2.7 Discussion

There was no evidence supporting causal relationships between particular footwear styles and falls rates in older adults. There may be a broad association between footwear styles and falls. Moreover, no evidence was identified from quasi-experimental studies or observational studies indicating that wearing particular footwear styles elevated falls risk in older adults. Evidence from observational studies was limited as it did not account for exposure time of participants to wearing different footwear styles during a fall.

The quality of evidence led to inherent bias in the reporting of outcomes. While nearly all had stated a research question and participant information, many studies did not fully explain the data collection methods. Reproducibility and triangulation was indeterminate for over half of the studies reviewed.

It is possible that it was not the particular style of footwear that was important when it comes to falls, rather, how accustomed the individual was to wearing that particular style of footwear. Only one study employed a surrogate measure of footwear exposure. This was collected through self-report of the footwear style worn if they fell after wearing particular footwear, and they wore this style of footwear less than three times per week [23]. An increased risk of fracture was then recorded if participants had fallen in shoes worn less than 3 times a week. Despite finding this association, it was unclear if falls occurred because participants were not used to wearing these shoes or whether this association was confounded by other factors such as participating in higher risk activities when wearing shoes that they wore irregularly. For example, falling while wearing high heels not normally worn, may be confounded by concurrently participating in high risk social activities such as drinking alcoholic beverages [26].

The association between wearing of high heels and falls may also be confounded by practice effects. Laboratory studies have found that habitually wearing high heeled

shoes reduces gait parameters impacts [20, 27]. Previous history of high heel wearing described in one paper as 'high heel habit' [25] and has been implicated as a falls risk, however, at the time of falling, participants were not wearing high heels shoes [25]. High heel habituation may not be as noteworthy in this population group.

The American and British Geriatrics Society Clinical Practice Guidelines for the Prevention of falls in Older Persons [28] included footwear assessment in the 2010 update of these guidelines. The guideline stated that specific recommendations for falls assessment are to include examination of the feet and footwear, recommending this be included as part of falls screening. The recommended advice to health practitioners was to provide 'management of foot problems and footwear', however there is no explanation as to what this should include. The Australian Commission on Safety and Quality in Healthcare Best Practice Guidelines for Preventing Falls and Harm from Falls in Older People [29] included images of 'theoretically' safe footwear. Safe footwear in this instance was Oxford/lace up style footwear and unsafe footwear were high heels.

Oxford/lace-up style footwear is widely reported in the literature as having 'optimal', 'safe' or 'ideal' footwear features [2, 30]. However, suggesting lace-up footwear as optimal shoes in relation to falls, has been based on retrospective questionnaires/interviews relying on recollection of footwear worn at the time of fall [2]. The footwear descriptors use in falls prevention, are often 'good', 'adequate', 'optimal', 'appropriate' or 'sturdy' without explanation of what these actually mean. The literature also suggests that wearing well fitting, low-heeled shoes [16, 31] are often recommended but there is limited evidence to support this. Cultural consideration was also necessary when considering the footwear definition of slippers. One study included in this review was based in Thailand and stated that older adults wear slippers as their outdoor footwear and are barefoot in their homes [8]. This may be different in other countries where a slippers are predominantly indoor footwear.

Most studies used questionnaires or structured interviews to collect time of fall or footwear worn at time of fall data without any validated data collection techniques or methods. Self-reporting over prolonged periods of time has previously shown to result in unreliable results due to participant recall [32]. Raw data on proportion of falls involving a certain footwear style was also presented within a number of studies [8,15,19]. There was no extrapolation of the footwear exposure of participants to particular shoe styles to inform if the style was potentially implicated in the fall. In future studies, it would be prudent to report a footwear denominator. That is, the participants usual footwear and amount of time that footwear is worn. This would be useful to more accurately assess the proportion of falls potentially attributed to footwear.

It is foreseeable that research involving accelerometers or Global Positioning System trackers built into or appended onto shoes could be used to address this in the not too distant future. Additional research designs may consider randomising participants to specific footwear types with consideration of wearing fidelity. It is very difficult to validate footwear worn at the time of fall unless there is an independent observer of the fall or closed-circuit television footage to verify the fall circumstance, especially given that this monitoring is a relatively recent innovation.

Ultimately, randomised controlled trials are required to establish a causal link between footwear style use and rates of falls amongst older adults. Such a trial would likely need to be pragmatic in nature where participants are recommended/encouraged to wear a particular style of footwear. This has been done in other fields [33], however, it would be difficult to force participants' to use of a particular footwear style. This sort of trial would replicate the clinical scenario where a health practitioner is recommending a particular style of footwear to an older adult under the assumption that doing so will reduce the risk of falling.

Laboratory-based studies are useful for hypothesis generation regarding footwear styles increasing the propensity to trip, slip or fall. However, laboratory-based hypotheses need to be tested in real-life conditions before health practitioners can be

confident in guidance provided to older adults. Inclusion of laboratory-based study findings in conjunction with real-life situational studies may offer a holistic picture of a footwear styles' relationship to falls.

The footwear definitions provided in this review were developed by the authors and therefore may be scrutinised for accuracy. These definitions were developed by examining definitions used by studies captured in this review and through open discussion by the research team. It is unlikely that inaccuracy in definitions would affect the conclusions due to paucity of high quality data. Further research involving consistent classification of footwear styles with accompanying photos or images may assist researchers to enhance reliability in classification of footwear styles.

2.8 Conclusion

There is limited evidence supporting footwear recommendations as a discrete falls prevention strategy. With this limited level of evidence, clinicians should be pragmatic in their advice to healthy older adults about footwear styles and their potential to reduce falls or falls risk.

2.9 References

1. Tencer, A.F. et al. *Biomechanical properties of shoes and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(11): p. 1840-1846.
2. Sherrington, C and Menz, H B. *An evaluation of footwear worn at the time of fall-related hip fracture*. Age and Ageing, 2003. **32**(3): p. 310-314.
3. Davis, A.M. et al. *Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women*. Gait and Posture, 2016. **44**: p. 43-47.
4. Department of Health. *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Hospitals*, Australian Commission on Safety and Quality. Editor 2009: Australia.
5. Menz, H B and Lord, S R. *Footwear and postural stability in older people*. J Am Pod Med Assoc, 1999. **89**(7): p. 346-357.
6. Menant, J.C. et al. *Optimizing footwear for older people at risk of falls*. 2008.
7. Aboutorabi, A. et al. *A systematic review of the effect of foot orthoses and shoe characteristics on balance in healthy older subjects*. Prosthetics and Orthotics International, 2016. **40**(2): p. 170-181.
8. Kuhirunyarath, P. Prasomrak, P and Jindawong, B. *Factors related to falls among community dwelling elderly*. Southeast Asian Journal of Tropical Medicine & Public Health, 2013. **44**(5): p. 906-15.
9. Haines, T.P. et al. *Why do hospitalized older adults take risks that may lead to falls?* Health Expectations, 2015. **18**(2): p. 233-249.
10. Huang, X. Lin, J and Demner-Fushman, D. *Evaluation of PICO as a Knowledge Representation for Clinical Questions*. AMIA Annual Symposium Proceedings, 2006. **2006**: p. 359-363.
11. World Health Organisation, *WHO Global Report on Falls Prevention in Older age*, 2007, World Health Organisation: France.
12. Buckley, S. et al. *The educational effects of portfolios on undergraduate student learning: a Best Evidence Medical Education (BEME) systematic review*. BEME Guide No. 11. Medical teacher, 2009. **31**(4): p. 282-298.
13. Howick, J. et al. *The Oxford 2011 Table of Evidence*. Oxford Centre of Evidence Based Medicine. 2016; Available from: <http://www.cebm.net/ocebml-levels-of-evidence/>.
14. Hansen, A.H. and Childress, D.S. *Effects of shoe heel height on biologic rollover characteristics during walking*. Journal of rehabilitation research and development, 2004. **41**(4): p. 547.
15. Koepsell, T.D. et al. *Footwear style and risk of falls in older adults*. Journal of the american geriatrics society, 2004. **52**(9): p. 1495-1501.
16. Kelsey, J.L. et al. *Footwear and falls in the home among older individuals in the MOBILIZE Boston study*. Footwear Science, 2010. **2**(3): p. 123-129.
17. Tsur, A. et al. *Clinical profile of fallers with femoral neck fractures*. PM&R, 2014. **6**(5): p. 390-394.
18. Menz, H B. Lord, S R and Close, J C. *Swapping slippers to prevent falls in older people: Where is the evidence?* Foot, 2004. **14**(4): p. 228-229.
19. Kerse, N. et al. *Wearing slippers, falls and injury in residential care*. Australian and New Zealand Journal of Public Health, 2004. **28**(2): p. 180-187.
20. Lee, C.M. Jeong, E.H. and Freivalds, A. *Biomechanical effects of wearing high-heeled shoes*. International journal of industrial ergonomics, 2001. **28**(6): p. 321-326.
21. Karlsson, M.K. et al. *Prevention of falls in old people-a review*. Reviews in Clinical Gerontology, 2013. **23**(3): p. 206-222.

22. Brenton-Rule, A. et al. *The evaluation of walking footwear on postural stability in healthy older adults: An exploratory study*. Clinical Biomechanics, 2011. **26**(8): p. 885-887.
23. Keegan, T.H. et al. *Characteristics of fallers who fracture at the foot, distal forearm, proximal humerus, pelvis, and shaft of the tibia/fibula compared with fallers who do not fracture*. American Journal of Epidemiology, 2004. **159**(2): p. 192-203.
24. Menz, H B and Lord, S R, *Footwear and postural stability in older people*. Journal of the American Podiatric Medical Association, 1999. **89**(7): p. 346-357.
25. Gabell, A. Simons, M A. and Nayak U L S. *Falls in the healthy elderly: Predisposing causes*. Ergonomics, 1985. **28**(7): p. 965-975.
26. Williams, C.M. and T.P. Haines, *An exploration of emergency department presentations related to high heel footwear in Victoria, Australia, 2006-2010*. J Foot Ankle Res, 2014. **7**(1): p. 4.
27. Opila-Correia, K. *Kinematics of high-heeled gait with consideration for age and experience of wearers*. Archives of physical medicine and rehabilitation, 1990. **71**(11): p. 905-909.
28. American Geriatrics Society, *Guideline for the prevention of falls in older persons*. Journal of the American Geriatrics Society, 2001. **49**(5): p. 664-672.
29. Ainsworth, B.E. Shaw, J.M. and Hueglin S. *Methodology of activity surveys to estimate mechanical loading on bones in humans*. Bone, 2002. **30**(5): p. 787-791.
30. Menz, H.B. Lord, S.R. and McIntosh, A.S. *Slip resistance of casual footwear: Implications for falls in older adults*. Gerontology, 2001. **47**(3): p. 145-149.
31. Menz, H.B. Morris, M.E. and Lord, S.R. *Footwear characteristics and risk of indoor and outdoor falls in older people*. Gerontology, 2006. **52**(3): p. 174-80.
32. Stone, A.A. and Shiffman, S. *Capturing momentary, self-report data: A proposal for reporting guidelines*. Annals of Behavioral Medicine, 2002. **24**(3): p. 236-243.
33. James, A.M. Williams, C.M. and Haines, T.P. *Effectiveness of footwear and foot orthoses for calcaneal apophysitis: a 12-month factorial randomised trial*. British journal of sports medicine, 2016: p. bjsports-2015-094986.

Chapter 3 - Do footwear features cause falls or increase falls risk in healthy older adults? A systematic review

3.1 Preamble

Chapter 2 reported on footwear styles that have been linked to falls and falls risk. There are also specific footwear features of the investigated footwear styles in Chapter 2 that have been attributed to falls risk. Footwear features that have been associated with falls have included high heels, absence of heel counter, absence of dorsal fixation and different outsole configurations. Footwear features also have a varying effect on falls-related gait parameters including foot clearance (with the ground), cadence, step velocity, step length, stride length and double limb support.

This chapter systematically investigates the relationship between specific footwear features and their impact on falls-related gait parameters. This chapter also examined whether footwear features impact the risk of falls in healthy older adults.

3.2 Introduction

Falls are a major issue for older adults and health services internationally. The prevalence and the frequency of gait alterations are known to increase with age [1] and there are specific gait characteristics implicated in falls [2-4]. Gait characteristics such as cadence, velocity, step length, stride length and foot clearance decrease with age while double support and stride time increase with age [2-6].

Footwear has been broadly reported as an impicator in falls for older adults [7-11]. Footwear features that have been implicated as a falls risk include, but are not limited to, high heels [7, 8], absence of dorsal fixation [12] and slippery outsoles [13]. Footwear styles such as Oxford styles (lace-up) and walking shoes are recommended in falls guidelines as 'optimal' footwear [14]. These footwear styles are considered preferable as they have specific features such as laces for dorsal fixation and a firm heel counter

to securely hold the foot. However the evidence that supports these recommendation, as pragmatic and logical as they may seem, appears nebulous. Gait alterations related to falls and falls risk in older adults and their relationship to specific footwear features has not been clearly identified.

3.3 Aims

The primary aim of this review was to determine whether footwear features impact gait parameters that are related to falls. The secondary aim was to determine whether footwear features impact the risk of falls in healthy older adults.

3.4 Method

The systematic review was registered with Prospero in April 2017. The question for this systematic review was developed in a PICO format [15], "In healthy older adults, what footwear features are related to gait parameters that are related to falls and what footwear features are related to falls?" This question was separated into search terms (Table 1). The population was healthy older men and women. The intervention was footwear features including heel height, elevated heels, heel counter, outsole, tread, sole, midsole, dorsal fixation, lace, buckle, strap and Velcro®. The first outcome was footwear features including foot clearance, cadence, step velocity, step length, step width, stride length and double support. Each of these gait parameters have previously been demonstrated to be associated with falls amongst community dwelling older adults [2-5]. An individual may reduce these parameters (except for double support) to adopt a protective gait style [16]. The outcome was slip, trip or fall, classified in concordance with the World Health Organisation (WHO) as 'an event which results in a person coming to rest inadvertently on the ground or floor or other lower level [17]. The databases searched by the lead author, using combinations of the key search terms (Table 1) were Ovid MEDLINE, PubMed, Scopus and Web of Science. The search was performed from the database inception date to 15th of May 2017. A second

author then reviewed articles. Data were extracted by two authors independently. Any discrepancies in assessment of study eligibility or data extraction were resolved by a third author.

Table 1 Search strategy

Population	Intervention/ Comparison	Outcome 1	Outcome 2
Old* AND Age* Elderly Geri*	Heel height AND Elevated heels Heel counter Heel collar Outsole Tread Dorsal fixation Lace* Buckle Strap Velcro	Foot clearance AND Cadence Step velocity Step length Step width Stride length Double support	Fall* Trip* Slip*

* truncation character that allows the retrieval of varying endings of the search term.

The inclusion and exclusion criteria are reported in Table 2. Two researchers independently screened all articles by title and abstract. If there was any doubt as to an article's eligibility, the full text paper was retrieved. The full texts of all included studies were screened against the inclusion criteria.

Table 2 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
<i>Design:</i> Randomised Control Trials (RCTs) Quasi-experimental trials Clinical trials Cohort studies Case control studies Case Series <i>Participants:</i> Data from adults aged 60 years or over able to be extracted separately from adults aged <60 years No known medical issues that increased falls or risk of falls <i>Interventions:</i>	<i>Study Design:</i> Narrative literature review Papers that did not discuss footwear or where the footwear conditions were inadequately described. Comparisons where the individual impact of the footwear feature could not be ascertained. <i>Other conditions:</i> Barefoot conditions only Stocking or sock conditions only Footwear and falls screening or assessment tools Research not published in English

Heel height, elevated heels, heel counter, outsole, tread, sole, dorsal fixation, lace, buckle, strap and Velcro <i>Outcome 1:</i> Foot clearance, cadence, step velocity, step length, stride length and double support <i>Outcome 2:</i> Falls data (faller, rate of falls, single faller, multiple faller, time until fall) reported	
---	--

3.4.1 Risk of Bias Assessment

Initial analysis was performed by the lead author then discussed with the other authors for concurrence. When consensus was reached, a generic quality tool [18] was utilised to assess the methodological quality of the final included papers. The papers were then classified into levels of evidence using the Oxford Centre for Evidence Medicine [19] to delineate research at lowest risk of bias to assist decision-making. Levels of evidence were classified from Level 1(highest) to 5 (lowest).

3.5 Analysis

Plans were initially made to undertake a meta-analysis of associations between footwear features and gait parameters associated with falls, and associations between footwear features and falls outcomes. However, due to the inconsistency in the reporting of footwear features, gait parameters and the absence of falls data reported, the planned meta-analyses could not be undertaken. Instead we conducted narrative synthesis of the results extracted.

3.6 Results

There were 4480 articles identified for abstract and title screening and six full texts included within the review. Figure 1 shows the article screening process and reasons for inclusion and exclusion. Table 3 displays the characteristics of the six included

studies. All six were laboratory-based investigations where participants had gait parameters measured while being exposed to different footwear conditions in an order determined using a randomisation procedure. Four of the included studies had 100% female participants. The remaining two studies had >50% total female participants however <50% of the female participants were 60 years or older. Two studies had older and younger participants in discrete groups. The countries of origin of the studies were Australia, Belgium and Germany. Total participant numbers from the included studies was 184.

Figure 1 – PRISMA Screening process & exclusion criteria

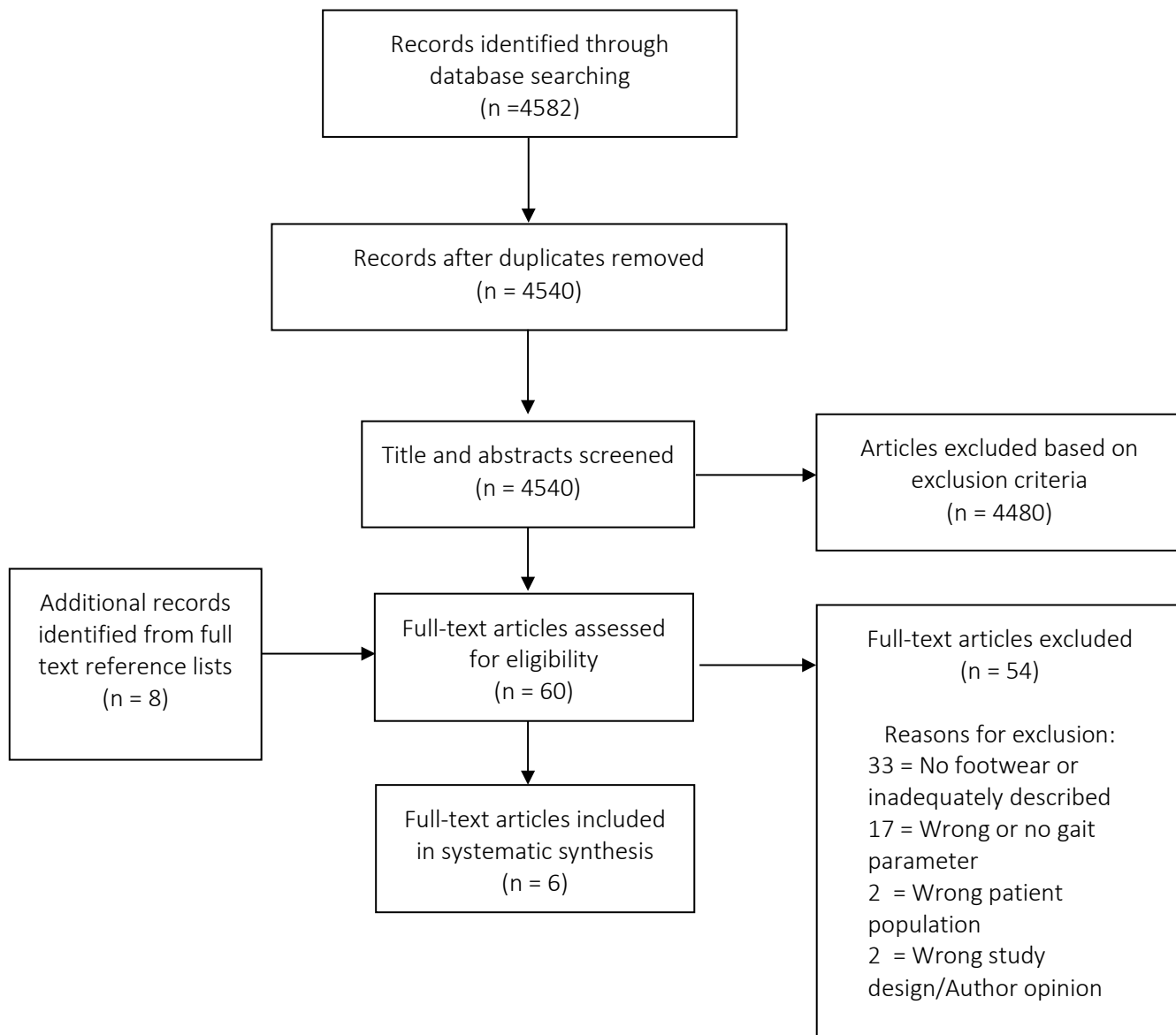


Table 3 Characteristics of included studies

First Author	Study Design	Country	n,(%female) mean (SD) age years	Footwear Feature/s described	Gait parameters described	Outcome measurement	Effect of intervention (p value)	Level of Evidence
Davis[20]	Within subject RCT*	Australia	30, (100), 69.1 (5.1)	Low-heeled lace-up with dorsal fixation, enclosed slipper	MFC [#] , step velocity, step length, Step duration, step width, double support time	Increased MFC [#] in low-heeled lace-ups compared with slippers. Increased step velocity, step length and reduced step width and double support time with low-heeled lace ups.	p<0.05	2
de Mettelinghe [21]	Within subject RCT	Belgium	57, (100), 68.0 (4.6)	Standard footwear (low- heeled lace-up) backless slipper, own high heels (min. 3.5cm)	Step velocity, cadence, stride time, stride length.	Increased cadence and stride length and reduced stride time with standard footwear compared to slippers and high heels	p<0.05	2
Lindemann [22]	Within subject RCT	Germany	26, (100), 87	Velcro [®] fastened shoes with elevated heels	Gait speed, double support time	No difference in gait speed or double support time with different footwear conditions	a=5%, p values are 2- sided	3
Menant [23]	Within subject RCT	Australia	26 (46), 78.5 (4.6)	Oxford-type (low heeled lace-up shoe and 7 modified pairs of shoes with	Walking velocity, cadence, step length, double support time, step width, toe clearance	Increased walking velocity in tread and soft soles. Increased double support in elevated	p<0.05	2

differing
features:
elevated heel,
soft sole, hard
sole flared sole,
bevelled heel,
high collar and
tread sole

and hard soles.
Increased step
length in tread soles.

Menant, J[24]	Within subject RCT.	Australia	15 (47), 73.7 (4.2)	Oxford-style laced shoe with modifications: soft, hard and tread sole, elevated heel, high collar	Step length, step width, walking velocity and double support time	Elevated heels had reduced walking velocity and increased toe clearance and double support time and flared sole, beveled heel and tread sole increased step width compared with Oxford lace up.	p<0.05	2
Menz, H [25]	Within subject RCT	Australia	30, (100), 74.4 (5.6)	Enclosed slippers with Velcro® fastening, firm heel counter. Backless slipper with no dorsal fixation	Walking speed, cadence and step length, step width	Reduced walking speed in backless slippers than enclosed slippers. Step length reduced in backless slippers than enclosed slippers.	p<0.05	2

* RCT – Randomised controlled trial

MFC – Minimum foot clearance

The risk of bias within the included studies was assessed across multiple domains (Table 4). There was a universal lack of blinding of participants, therapists and assessors with all included studies.

3.6.1 Footwear features of the included studies

Three studies included multiple footwear types (Table 3). The remaining three studies reported outcomes based on modified footwear features from a single footwear type (Oxford, lace-up). Footwear naming conventions were matched from the description and pictures in the included articles. Footwear styles included Oxford/lace-up footwear, slippers (enclosed and backless) and high-heeled footwear. The features of footwear investigated included dorsal fixation (laces/Velcro® fastening over the dorsum of the foot), varying heel heights with varying base of heel surface contact with the ground, presence or absence of heel counter, heel collar and outsoles including soft, hard, flared and tread (textured) sole.

Four studies described the heel height of the footwear. Heel height was described as elevation of at base of the heel area of the shoe within three studies [23, 24]. The remaining study described high heels as a minimum of 3.5cm, as the participants were tested in their own high heeled footwear [21]. The elevated heels in three studies [22-24] were all within a similar footwear type that of an elevated heel with the same contact area with the ground as Oxford/lace up footwear. However all studies described different elevation for the footwear style and one study [22] advised that subjects had habitually worn this type of footwear with varying heel elevations. Only one study described heel height as being 3.5cm or above with no further description of the heel height features [21]. This study also had participants wearing their own high heels. No maximum or mean heel height, surface area of the base of the heel or heel “type”, such as stiletto, were articulated [21].

Table 4 Assessment of the risk of bias and methodological quality of the studies included using the PEDro scale

Study (First Author)	Eligibility criteria specified	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assess or blinding	<15% dropouts	All subjects received condition	Between- groups difference reported	Point estimate and variability reported	Total Score /11
Davis[20]	✓	✓	✗	✓	✗	✗	✗	✓	✓	✓	✓	7
De Metteling[21]	✓	✓	✗	✓	✗	✗	✗	✓	✓	✓	✓	7
Lindemann[22]	✓	✓	✗	✓	✗	✗	✗	✗	✓	✓	✓	6
Menant[23]	✓	✓	✗	✓	✗	✗	✗	✓	✓	✓	✓	7
Menant[24]	✗	✓	✗	✓	✗	✗	✗	✓	✓	✓	✓	6
Menz[25]	✓	✓	✗	✓	✗	✗	✗	✓	✓	✓	✓	7

Three studies [20, 21, 25] included the footwear styles of Oxford and slippers. The Oxford footwear style was well described with picture in all three studies, however only two of the three studies described the slippers in detail. The slippers were described as enclosed [20, 25], backless [25] or open [21].

Heel collar was investigated in two studies however, in one study [23] heel collar was described as high and low in the other [24], therefore a comparison was not possible. Three studies included footwear outsoles in regard to soft and hardness. Even though the measure of soft or hardness of the outsole was well defined [23-25] all studies had footwear styles with differing soft and hardness measures.

3.6.2 Gait parameters of the included studies

All studies included one or more of the comparative gait parameters [20-25]. Four studies included cadence, step length, step width and double support [21, 23-25] and two studies included minimum foot clearance, step velocity and stride length [20, 21, 23]. The six included studies provided information regarding footwear features and/or styles in regard to balance and falls in simulated laboratory situations [20-25].

3.6.3 Gait outcomes relating to footwear features

An increase in walking speed and step length was reported in three included studies with the footwear features of heel counter, dorsal fixation and firm sole [20, 21, 25]. One of these studies [21] also reported increased cadence and stride length attributed to these footwear features. Two included studies [21, 25] described adverse effects on step length, cadence and stride length with backless footwear (absence of a heel counter).

The heel elevation reported in three studies had variable effects on gait. One study reported an increased double support and step width [24]. One study also reported heel elevation to reduce walking velocity, and increased minimum foot clearance [23]. However, another other study found no difference in the gait between footwear usually worn and footwear with the elevated heel [22].

Two studies described the effects of different outsole density and tread on step length, step width and double support [23, 24]. One reported that tread soles increased step length, whereas hard soles resulted in an increased double support and reduced step width [23]. Another reported greater step width with tread soles compared to standard footwear [24]. This same study also reported greater step width for flared and soft soles. Both studies concluded that soft soles should not be recommended for older adults with no basis for this recommendation [23, 24].

No studies allowed for pooling of results, as the methodologies used were not comparable. Therefore the remaining studies were analysed with narrative synthesis rather than a meta-analytic approach. None of the included studies provided data on falls outcomes and no direct causal relationship between any footwear style/feature and falls could be inferred.

3.7 Discussion

Footwear features that effect falls-related gait parameters were dorsal fixation (laces and Velcro®), heel counter and medium outsole hardness. These footwear features collectively represent what is considered to be 'optimal' footwear in falls management guidelines. Alternatively, footwear features that may have an adverse effect on falls related parameters of gait were elevated heel height, absence of heel counter and soft outsoles. Footwear features that adversely affect gait can cause mechanical and neurophysiological adaptation that may alter the body's postural stability and increase

the risk of a fall [26]. Several studies have investigated footwear styles in relation to falls, however, isolating the effects of specific footwear features on falls has proven challenging. Studies have attempted to investigate specific footwear features, such as outsoles and heel height, and their relationship to gait stability [27-29] however, these studies are laboratory based and may not be relatable to real-life conditions. Falls management guidelines describe an optimal footwear style such as Oxford or athletic style footwear [14]. However, there are no evidence-based guidelines for particular footwear features in regard to falls management and recommendation.

Heel counters have been reported to be an important footwear feature in relation to falls management [25]. The heel counter secures the foot and stabilises the body as the heel hits the ground during the contact phase of gait. Footwear with a firm heel counter is recommended in falls guidelines [14, 30]. Backless footwear or footwear without a heel counter may result in the foot moving excessively during gait, placing increased cognitive demand on the body to maintain equilibrium [25]. Slippers have been implicated as a falls risk in several studies [31-33] and are the most common footwear worn by older adults indoors [10, 32]. Many slipper styles have no heel counter, which makes them easy to don and doff by the wearer. Slippers are often made of soft, conformable materials therefore if the slipper has a heel counter, it can be easily deformed and may not offer adequate support if compressed. However, Oxford style slippers perform better in falls related gait parameters [25], as their features are similar to optimal, recommended footwear.

Dorsal fixation such as Velcro® and laces, has been reported as an important footwear feature in gait stability [34]. Dorsal fixation reduces the vertical movement of the foot out of the footwear, at the toe-off phase of gait. As the heel elevates during the heel-off phase of gait, dorsal fixation such as Velcro® or laces, offer a barrier to stop the foot levering out of the footwear [20].

Elevated heel height has been extensively reported to cause adverse gait changes and imposts on the body's motor control systems [8, 35]. High heels have caused reduced step length, step width, stride length, gait speed [36, 37] and increase lateral instability [38] which could increase falls risk. However, the reporting of a definitive definition or range of what is considered to be a high heel is inconsistent. One study [39] described gait alterations with a 7cm high heel whereas another study [38] describes 7cm as a medium heel and 10cm as a high heel. The surface area and width of the outsole of high heels has also been variably reported. A thin, spike or stiletto type heel can cause postural instability and detrimental effects on gait, increasing falls risk [34]. A large surface area of the heel is considered favourable as it distributes body weight and aids the heel contact phase of gait [32, 40]. Elevated heels in this review included a large surface area base with elevations added to create a high heel as a feature of Oxford/walking style footwear. Older women who regularly wore high heels displayed habituation effects of wearing this type of footwear [38]. There is reported to be reduced firing action of tibialis anterior action to stabilise the ankle joint in experienced high heel wearers as compared to those new to wearing of high heels [36].

There is inconclusive evidence from any of the included studies for recommendation of an optimal outsole density or tread design [41]. Trip-related falls were attributed to slippery outsoles of footwear. Authors have proposed that a tread outsole is therefore recommended to reduce trip or slip related falls [9] which has been used to inform best practice guidelines for falls in community dwelling older adults in Australia [42]. There were no studies for support of this recommendation found during this review. Normal wear and exposure to surfaces over time naturally causes deterioration to the footwear's outsole [43-45]. It would be difficult to establish an ideal tread design or slip-resistant outsole for older adults in relation to falls in all real life situations.

3.8 Conclusion

There is nebulous evidence supporting footwear features as a distinct part of falls prevention strategies. Health practitioners are advised to understand footwear features that collectively make up optimal footwear styles. This understanding would support practical advice to healthy older adults about appropriate footwear styles and features, in order to reduce falls.

3.9 References

1. Terrier, P and Reynard, F. *Effect of age on the variability and stability of gait: a cross-sectional treadmill study in healthy individuals between 20 and 69 years of age*. Gait Posture, 2015. **41**(1): p. 170-4.
2. Mortaza, N. Abu Osman N.A. and Mehdikhani, N. *Are the spatio-temporal parameters of gait capable of distinguishing a faller from a non-faller elderly?* Eur J Phys Rehabil Med, 2014. **50**(6): p. 677-91.
3. Makino, K. et al. *Fear of falling and gait parameters in older adults with and without fall history*. Geriatr Gerontol Int, 2017.
4. Hirsch, T. et al. *Subjective Gait Stability in the Elderly*. Z Gerontol Geriatr, 2017.
5. Killeen, T. et al. *Minimum toe clearance: probing the neural control of locomotion*. Sci Rep, 2017. **7**(1): p. 1922.
6. Hollman, J.H. McDade, E.M. and Petersen, R.C. *Normative Spatiotemporal Gait Parameters in Older Adults*. Gait & posture, 2011. **34**(1): p. 111-118.
7. Sherrington, C. and Menz, H B. *An evaluation of footwear worn at the time of fall-related hip fracture*. Age & Ageing, 2003. **32**(3): p. 310-4.
8. Gabell, A. Simons, M A. and Nayak, U L S. *Falls in the healthy elderly: Predisposing causes*. Ergonomics, 1985. **28**(7): p. 965-975.
9. Menant, J.C. et al. *Optimizing footwear for older people at risk of falls*. Journal of Rehabilitation Research and Development, 2008. **45**(8): p. 1167-1182.
10. Munro, B.J. and Steele, J.R. *Household-shoe wearing and purchasing habits. A survey of people aged 65 years and older*. J Am Podiatr Med Assoc, 1999. **89**(10): p. 506-14.
11. Lord, S.R. and Bashford, G.M. *Shoe characteristics and balance in older women*. Journal of the American Geriatrics Society, 1996. **44**(4): p. 429-433.
12. Tencer, A.F. et al. *Biomechanical properties of shoes and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(11): p. 1840-6.
13. Björnstig, U. Björnstig, J. and Dahlgren, A. *Slipping on ice and snow—elderly women and young men are typical victims*. Accident Analysis & Prevention, 1997. **29**(2): p. 211-215.
14. Department of Health. *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Hospitals*, Australian Commission on Safety and Quality. Editor 2009: Australia.
15. Huang, X. Lin, J. and Demner-Fushman, D. *Evaluation of PICO as a Knowledge Representation for Clinical Questions*. AMIA Annual Symposium Proceedings, 2006. **2006**: p. 359-363.
16. Barak, Y. et al. *Gait Characteristics of Elderly People With a History of Falls: A Dynamic Approach*. Physical Therapy, 2006. **86**(11): p. 1501-1510.
17. World Health Organisation, *WHO Global Report on Falls Prevention in Older age*, 2007, World Health Organisation: France.
18. Buckley, S. et al. *The educational effects of portfolios on undergraduate student learning: a Best Evidence Medical Education (BEME) systematic review*. BEME Guide No. 11. Medical teacher, 2009. **31**(4): p. 282-298.
19. Howick, J. et al. *The Oxford 2011 Table of Evidence*. Oxford Centre of Evidence Based Medicine. 2016 [cited 2016 10/01/2016]; Available from: <http://www.cebm.net/ocebm-levels-of-evidence/>.
20. Davis, A.M. et al. *Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women*. Gait and Posture, 2016. **44**: p. 43-47.

21. de Mettelinge, T.R. et al. *Does Footwear Matter When Performing Spatiotemporal Gait Analysis Among Older Women?* Journal of Geriatric Physical Therapy, 2015. **38**(4): p. 155-161.
22. Lindemann, U. et al. *Elevated heels and adaptation to new shoes in frail elderly women.* Zeitschrift fur Gerontologie und Geriatrie, 2003. **36**(1): p. 29-34.
23. Menant, J.C. et al. *Effects of Shoe Characteristics on Dynamic Stability When Walking on Even and Uneven Surfaces in Young and Older People.* Archives of Physical Medicine and Rehabilitation, 2008. **89**(10): p. 1970-1976.
24. Menant, J.C. et al. *Effects of walking surfaces and footwear on temporo-spatial gait parameters in young and older people.* Gait and Posture, 2009. **29**(3): p. 392-397.
25. Menz, H.B. Auhl, M and Munteanu, S.E. *Effects of Indoor Footwear on Balance and Gait Patterns in Community-Dwelling Older Women.* Gerontology, 2017. **63**(2): p. 129-136.
26. Sousa, A.S.P and Tavares, J.M.R.S. *The role of unstable shoe constructions for the improvement of postural control,* in *Posture: Types, Exercises and Health Effects.* 2014, Nova Science Publishers, Inc. p. 125-136.
27. Arnadottir, S.A. and Mercer, V.S. *Effects of footwear on measurements of balance and gait in women between the ages of 65 and 93 years.* Physical Therapy, 2000. **80**(1): p. 17-27.
28. Robbins, S. Gouw, G.J. and McClaran, J. *SHOE SOLE THICKNESS AND HARDNESS INFLUENCE BALANCE IN OLDER MEN.* Journal of the American Geriatrics Society, 1992. **40**(11): p. 1089-1094.
29. Robbins, S. et al. *Foot position awareness in younger and older men: The influence of footwear sole properties.* Journal of the American Geriatrics Society, 1997. **45**(1): p. 61-66.
30. *Summary of the Updated American Geriatrics Society/British Geriatrics Society Clinical Practice Guideline for Prevention of Falls in Older Persons.* Journal of the American Geriatrics Society, 2011. **59**(1): p. 148-157.
31. Karlsson, M.K. et al. *Prevention of falls in old people-a review.* Reviews in Clinical Gerontology, 2013. **23**(3): p. 206-222.
32. Kelsey, J.L. et al. *Footwear and falls in the home among older individuals in the MOBILIZE Boston study.* Footwear Science, 2010. **2**(3): p. 123-129.
33. Koepsell, T.D. et al. *Footwear style and risk of falls in older adults.* Journal of the american geriatrics society, 2004. **52**(9): p. 1495-1501.
34. Nag, P. et al. *Influence of footwear on stabilometric dimensions and muscle activity.* Footwear Science, 2011. **3**(3): p. 179-188.
35. Cronin, N.J. *The effects of high heeled shoes on female gait: A review.* Journal of Electromyography and Kinesiology, 2014. **24**(2): p. 258-263.
36. Hapsari, V.D. and Xiong, S. *Effects of high heeled shoes wearing experience and heel height on human standing balance and functional mobility.* Ergonomics, 2016. **59**(2): p. 249-264.
37. Merrifield, H. *Female gait patterns in shoes with different heel heights.* Ergonomics, 1971. **14**(3): p. 411-417.
38. Opila-Correia, K. *Kinematics of high-heeled gait with consideration for age and experience of wearers.* Archives of physical medicine and rehabilitation, 1990. **71**(11): p. 905-909.
39. Gerber, S.B. et al. *Interference of high-heeled shoes in static balance among young women.* Human Movement Science, 2012. **31**(5): p. 1247-1252.
40. Keegan, T.H.M. et al. *Characteristics of Fallers Who Fracture at the Foot, Distal Forearm, Proximal Humerus, Pelvis, and Shaft of the Tibia/Fibula Compared with Fallers Who Do Not Fracture.* American Journal of Epidemiology, 2004. **159**(2): p. 192-203.

41. Thies, S.B. et al. *Effects of shoe sole geometry on toe clearance and walking stability in older adults*. *Gait & Posture*, 2015. **42**(2): p. 105-9.
42. Department of Health, *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Community Care*, Australian Commission on Safety and Quality in Healthcare, Editor 2009: Canberra, Australian Capital Territory, Australia.
43. Chen, S. Jin, J. and Lou, E. *Toward slip and fall prevention: Exploring the guidance and challenges of anti-slip footwear*. in *2012 International Symposium on Safety Science and Engineering in China, ISSSE 2012*. 2012. Beijing.
44. Kim, I.J. *Wear observation of shoe surfaces: Application for slip and fall safety assessments*. *Tribology Transactions*, 2015. **58**(3): p. 407-417.
45. Kim, I.J. and Nagata, H. *Nature of the shoe wear: Its uniqueness, complexity and effects on slip resistance properties*. in *Annual Conference of the Ergonomics Society on Contemporary Ergonomics 2008*. 2008. Nottingham.

Chapter 4 – Aims and Methodology

4.1 Preamble

This chapter sets the scene for subsequent chapters. It outlines the aims and methodology of the three studies contained within this thesis. Included in this chapter, are more detailed provision of participant characteristics, recruitment strategies used for each study, together with the design, measurement and analysis for each study. These studies are published or under submission and make up the next three chapters.

Chapter 5 is titled: Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women. The aim of this study was to examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking. A secondary aim of this study was to compare spatiotemporal characteristics of gait when wearing slippers, well-fitted footwear and walking bare foot.

Chapter 6 is titled: “Good for older ladies, not me”: how elderly women choose their shoes. This aim of this study was to identify factors that drive footwear selection and use amongst older community-dwelling women, aged 60 to 80 years who had no previous history of falls.

Chapter 7 is titled: Older adults consideration of safety in footwear choices in relation to falls. The aim of this study was to examine the relationship between footwear preferences and whether people fell or not during the preceding 12-month period.

4.2 Participants and recruitment strategy

The participant cohort for this thesis was older adults, aged 60 and above. The 60 and above age range was chosen as it aligns with the United Nations chronological age definition of the older person. However, the age definition of the older adult is arbitrary and in many developed countries, often relates to the age at which a person receives pension entitlements. According to the World Health Organisation (WHO), the majority of developed countries have defined the 'older' person/adult as the age of 65 years [1]. Footwear and falls are an issue for both genders; however, there was particular focus on older women within this thesis as women are reported to make more precarious footwear choices than men [2, 3].

Participants in the studies forming Chapters 5 and 6 were the same 30 healthy older women, between 60 and 80 years, from the south-eastern suburbs of Melbourne, Victoria, Australia. The communication strategy to recruit participants included contact with local public and private podiatry services, staff and patients at the Kingston Centre sub-acute and rehabilitation service, previous Kingston Gait laboratory research participants and the general public. All participants self-selected to be part of the studies and were then screened to assess for the inclusion/exclusion criteria of the studies. The same participant cohort for Chapter 5 was recruited for Chapter 6 for internal consistency.

Participants within the study reported in Chapter 7 were older men and women, aged 70 and above. The age range of participants is different to previous chapters as this study was nested within a larger project [4]. These 245 participants were recruited by a survey research company, from the 2006 electronic Victorian residential phone listings, using random digit dialling.

4.3 Study Designs

The design for Chapter 5 was a within subject randomised control trial for the three footwear interventions, bare feet, lace-up footwear and slippers. Randomisation between footwear conditions was conducted by permuted block. Power estimates were calculated from the effects of footwear on walking speed and confirmed that 30 participants would provide sufficient statistical power ($\alpha = .05$, $1 - \beta > 0.8$) for this study [5]. The design used for this study has been used previously in other related research for its reliability and accuracy [6-8].

The design for Chapter 6 was a cross-sectional survey using a structured, open-ended questionnaire. Data were collected through telephone interview. The questions were formulated from consultation with the Southern Health (now Monash Health) podiatry team and from literature investigating footwear choice [2, 9]. The telephone interview included questions about the footwear that was tested within the study reported within Chapter 6. Additional questions were added to better understand the drivers of participant's footwear selection.

The design for Chapter 7 was a prospective cohort study, undertaken with approximately 12 months between the baseline and follow-up telephone surveys. This study was nested within a larger study, investigating the implementation of evidence-based strategies to prevent falls in community dwelling adults [4]. The questions asked of the women participants (Chapter 6) were repeated with a larger and mixed gender cohort. This aimed to determine if there was replicability of themes regarding footwear choices. Participants were also asked about risk of falls in the survey tool. As the survey was telephone based, an information pack containing pictures of footwear styles were mailed to the participant prior to contact (Figure 1).

Figure 1 - Footwear options (Participant information)



Walking Shoes



Thongs



High Heel



Slipper (Backless)



Slipper (Enclosed)



Ugg Boot



Sandal



Boot



Moccasin



Stockings only



Low heeled Court Shoes

4.4 Interventions

The interventions of interest used in Chapter 5 were footwear conditions. These were bare feet, Propet® branded low-heeled lace up, well-fitted footwear (Figure 2) and Grosby® branded slippers (Figure 2). These particular footwear styles were chosen as low-heeled lace-up, well-fitted footwear is considered 'optimal' footwear. It is often the recommended footwear of choice by health practitioners in falls management [10, 11]. Slippers were chosen as they are often implicated in falls and as a falls risk [11-13]. Bare feet were tested as a convenience and for comparison.

Figure 2 –Chapter 5 study footwear conditions: A) Grosby® Slipper; B) Propet low-heeled lace up, well fitted footwear



4.5 Measurement

The measurements for Chapter 5 included minimum foot clearance and heel slippage. These were determined using the Vicon 612 motion analysis system sampling at 100Hz (Vicon Peak, Oxford, UK). Spatiotemporal gait characteristics were calculated using the instrumented GaitRITE® walkway. A 3D Model of the foot was formulated by placing reflective markers on the first and fifth meta-tarsal phalangeal joints, and on the distal, dorsal aspect of the large toe. The position of the plantar, distal aspect of the phalanx was measured relative to the three forefoot markers during quiet standing and its position calculated as a virtual marker during the gait trials during post

processing (Figure 3). The minimum foot clearance was measured from a virtual marker calculated from three forefoot markers in 3D space. This modelling was consistent with 3D modelling used at the time of the study.

Figure 3 - Placement of markers on footwear



Participants walked along a 10-metre walkway five times for each condition; bare feet, low-heeled lace up well-fitted footwear and slippers (four gait cycles per trial). Participants were allowed to rest between each change of footwear condition to avoid fatigue.

The Chapter 6 study involved survey questions asked during a telephone interview. The survey questions are presented in Table 1.

Table 1 Telephone interview questions

Survey Questions:
<i>Can you tell me, when buying footwear what is your main consideration?</i> Prompts - Price, Aesthetics, Comfort, Safety, Brand, Access, Other please explain
<i>Approximately how many pairs of shoes do you own?</i>
<i>Of these, how many do you wear on a regular basis (more than twice a week)?</i>
<i>What footwear (if any) do you wear most often indoors & why?</i> Prompts - Aesthetics, Activity, comfort, safety, other please explain
<i>What footwear (if any) do you wear most often outdoors & why?</i> Prompts - Aesthetics, Activity, Comfort, Safety , Other please explain
<i>In the previous research study, you were given some lace-up shoes to keep.</i> i. <i>Do you still have them? If not, why not?</i> ii. <i>Do you still wear them? If so, how many times a week? When do you wear them?</i>

-
- iii. Did participating in the previous study influence how you choose your shoes now?*
 - iv. Have you purchased similar shoes since?*
 - v. Is there anything that makes you want to wear them?*
 - vi. Is there anything that puts you off wearing them?*
-
- Is there anything further about choosing footwear that you would like to tell me?*
-

In Chapter 7, participants were asked to answer survey questions about footwear from the Chapter 6 study, in addition to questions about their falls history over the preceding year. The survey tool was adapted from previously developed questionnaires used to examine perceived risk of falling and perceptions toward participation in interventions to prevent falls [14]. A pilot of the survey questions was tested prior to the implementation of the final survey. The specific questions for this study, were:

- i. Using these pictures (Figure 2, provided prior to survey), can you describe the type of footwear you normally wear indoors?*
- ii. What is the main reason you choose to wear this footwear?*
- iii. Can you describe the type of footwear you normally wear outdoors?*
- iv. What is the main reason you choose to wear this footwear?*
- x. How many falls have you had in the past 12 months (a fall where you inadvertently come to rest on the ground or floor or other lower level)?*

4.6 Analysis

The data analysis for Chapter 5 included the average minimum foot clearance; this was calculated as the distance between the lowest point of the toe with/without footwear and the floor through the swing phase of gait. Slippage of the heel was assessed by measuring the difference between the position of the superior and inferior markers on the heel at mid-stance and at toe-off phases of gait. This distance

was averaged to determine heel slippage, which is the distance the heel travels vertically out of the footwear.

Walking speed, cadence, step length, base of support and double support time were measured and the average value of the five trials in each condition was used for analysis. Data from five trials was used to calculate the mean for each spatiotemporal variable using GaitRITE® with a mean of 54 steps per person per footwear condition. Maximum heel slippage and minimum foot clearance was measured using VICON with a mean of 18 steps per person per condition. The means and within-subject standard deviation for each participant were used to calculate the group means, standard deviations and 95% confidence intervals for each condition.

The normality of each dependent variable's underlying distribution was examined and considered normally distributed if they had skewness between -2 and 2, and kurtosis of between -2 and 2. Skewness and kurtosis were within the normal range for all variables and all footwear conditions. Analysis of variance and pairwise comparisons for maximum heel slippage were checked against the corresponding non-parametric tests (Friedman's test and Wilcoxin signed-rank tests). Similar results were found and so the non-parametric test results were not reported.

The analysis for Chapter 6 involved review of interview transcripts and application of codes. The codes were grouped into themes and the frequency of these themes were summarised. These themes were discussed with the research group to ensure trustworthiness and rigor of data and to check for content accuracy and consistency of coding. The analysis employed in Chapter 6 was quantification of all open-ended questions under a qualitative description paradigm, using descriptive phenomenology.

In Chapter 7, the participants' open-ended responses to questions were transcribed verbatim and coded into like groupings and frequency of themes. Similar to Chapter 6,

a thematic analysis approach was applied to all qualitative responses by the first researcher. The responses were initially grouped into like categories, then interpretation of the overarching themes [15]. A second co-author undertook an independent qualitative analysis to ensure reliability of the final results. A third researcher was consulted to settle any disputes and maximize the fidelity of data interpretation. Themes were presented quantitatively. Negative binomial regression was used to understand the relationship between falls and commonly worn footwear.

Ethical Principles are particularly relevant to this research involving human subjects: the principles of respect of persons, beneficence, maleficence, coercion, informed consent and access of participants to results of the studies they participated in.

Respect for persons incorporates at least two ethical convictions: first, that individuals should be treated as autonomous agents, and second, that persons with diminished autonomy are entitled to protection. In research involving human subjects, respect for persons demands that participants enter into the research voluntarily and with appropriate and adequate information. To respect autonomy is to respect a persons' considered opinions and choices while refraining from obstructing their actions unless they are clearly detrimental to others.

Beneficence within the research sphere requires that persons are treated in an ethical manner not only by respecting their decisions and protecting them from harm, but also by making efforts to secure their well-being. Two general rules have been formulated as complementary expressions of beneficent actions in this sense: (1) do not harm and (2) maximize possible benefits and minimize possible harms. As with all hard cases, Maleficence and coercion describes conduct that is inherently wrong or unlawful or where a researcher has failed to perform duties required of them as determined by human research ethics committee.

As described earlier, all participants within the studies of this thesis consented to participation. They were given information regarding the study they participated in, along with a contact person on and outside of the research team to answer questions and allay concerns if they arose. Participants were given the opportunity to opt out at any time without any effect on therapy provision or contact with the service in future.

It was impossible to separate out footwear features as part of the causative factors that lead to falls or as preventative strategies. In fact it is hard to separate out footwear as a single contributor to falls unless the research is carried out as an experimental lab based study where many of the variables can be controlled.

4.7 References

1. World Health Organisation, *WHO Global Report on Falls Prevention in Older age*, 2007, World Health Organisation: France.
2. Dunne, R.G. et al. *Elderly persons' attitudes towards footwear - A factor in preventing falls*. Public Health Reports, 1993. **108**(2): p. 245-248.
3. Frey, C. et al. *American Orthopaedic Foot and Ankle Society women's shoe survey*. Foot & Ankle International, 1993. **14**(2): p. 78-81.
4. Day, L. et al. *A protocol for evidence-based targeting and evaluation of statewide strategies for preventing falls among community-dwelling older people in Victoria, Australia*. Injury Prevention, 2011. **17**(2): p. e3.
5. Cohen, J. *Statistical power analysis for the behavioural sciences*. 1988, New Jersey: Lawrence Erlbaum.
6. Menant, J.C. et al. *Effects of walking surfaces and footwear on temporo-spatial gait parameters in young and older people*. Gait and Posture, 2009. **29**(3): p. 392-397.
7. Menant, J.C. et al. *Effects of Shoe Characteristics on Dynamic Stability When Walking on Even and Uneven Surfaces in Young and Older People*. Archives of Physical Medicine and Rehabilitation, 2008. **89**(10): p. 1970-1976.
8. Menz, H.B. Auhl, M. and Munteanu, S.E. *Effects of Indoor Footwear on Balance and Gait Patterns in Community-Dwelling Older Women*. Gerontology, 2017. **63**(2): p. 129-136.
9. Davis, A. Murphy, A. and Haines, T.P. *"Good for older ladies, not me": How elderly women choose their shoes*. Journal of the American Podiatric Medical Association, 2013. **103**(6): p. 465-470.
10. Menz, H.B. Morris, M.E. and Lord, S.R. *Footwear characteristics and risk of indoor and outdoor falls in older people*. Gerontology, 2006. **52**(3): p. 174-80.
11. Kelsey, J.L. et al. *Footwear and falls in the home among older individuals in the MOBILIZE Boston study*. Footwear Science, 2010. **2**(3): p. 123-129.
12. Koepsell, T.D. et al. *Footwear style and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(9): p. 1495-1501.
13. Sherrington, C and Menz, H B. *An evaluation of footwear worn at the time of fall-related hip fracture*. Age & Ageing, 2003. **32**(3): p. 310-4.
14. Hill, A.-M. et al. *Factors Associated With Older Patients' Engagement in Exercise After Hospital Discharge*. Archives of Physical Medicine and Rehabilitation, 2011. **92**(9): p. 1395-1403.
15. Braun, V and Clarke, V. *Using thematic analysis in psychology*. Qualitative Research in Psychology, 2006. **3**(2): p. 77-101.

Chapter 5 – Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women

5.1 Preamble

There are particular gait parameters linked to falls in older adults. This chapter investigates the effect of lace up footwear, slippers and bare feet on minimum foot clearance, heel slippage and other falls-related spatiotemporal variables of gait in community dwelling older women. Foot clearance decreases with age as muscle strength reduces, therefore increasing the risk of a toe-trip related fall. A toe trip may result in an injurious fall as compared to a heel slip initiated fall, as the body's centre of gravity is moving forward and is less likely to rebalance its equilibrium. Footwear upper materials such as canvas or leather may also be a confounding variable and further analysis would be required to determine their effects.

The effect of footwear, on heel slippage and minimum foot clearance during level-ground walking was investigated with thirty healthy older women participating in a gait laboratory assessment. Spatiotemporal characteristics of gait were assessed comparing slippers, well-fitted footwear and walking bare foot. This chapter examines the relationship between gait parameters and footwear styles commonly worn by older adults. This knowledge will improve understanding of the key features of slippers and lace up footwear and its potential impact on the mechanics of falls.

This study was published in *Gait and Posture* in 2016 (Appendix 2) and relates to aim one and two of the thesis which are firstly, to examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking; and secondly, to compare spatiotemporal parameters of gait when wearing slippers, well-fitted footwear and walking bare foot.

5.2 Abstract

Footwear has been implicated as a factor in falls, which is a major issue affecting the health of older adults. This study investigated the effect of footwear with dorsal fixation, slippers and bare feet on minimum foot clearance, heel slippage and spatiotemporal variables of gait in community dwelling older women. Thirty women participated (mean age (SD) 69.1 (5.1) years) in a gait assessment using the GaitRITE® and Vicon 612 motion analysis system. Conditions included footwear with dorsal fixation, slippers or bare feet. Footwear with dorsal fixation resulted in improved minimum foot clearance compared to the slippers and bare feet conditions and less heel slippage than slippers and an increase in double support. These features lend weight to the argument that older women should be supported to make footwear choices with optimal fitting features including dorsal fixation. Recommendations of particular styles and features of footwear may assist during falls prevention education to reduce the incidence of foot trips and falls.

5.3 Introduction

Falls are a major health issue and burden on the public health system. A significant number of reported falls in the older population are related to tripping, which have been attributed to inadequate foot clearance during the swing phase of gait [1]. Footwear has also been identified as playing an important role in the prevention of falls in older adults [2]. Yet older women are reluctant to make changes into footwear that have established fit and features associated with increased stability [3].

Footwear encompassed many different styles, heel heights and features. The features thought to increase the stability of footwear are; dorsal fixation (laces, Velcro® straps) however there is limited evidence to support this theory. There is an evidence deficit in the how dorsal fixation may impact falls yet it is a common recommendation in falls prevention education. Heel height [4, 5] has been the primary shoe feature linked with falls in the older. Walking barefoot, in slippers or socks has been correlated with a higher likelihood of falls (Odds ratio 13.7) [6] yet many older adults, women in particular, wear slippers in their home [7]. In addition, slippers were the most commonly worn footwear at the time of a fall-related hip fracture in a study of 95 older people [2] and while 16 of these people also were wearing walking shoes, 12 of these people were also in footwear with at least one theoretically sub-optimal feature such as lack of dorsal fixation and flexible heel counter. Whether the fall was initiated by a footwear related trip however was not recorded.

Slippers often lack many key features that secure the shoe to the foot and reduce trips and slips. Poor fit (too long or too wide) have been noted as common in rehabilitation settings [8] and retirement villages [9] with older people, primarily for comfort and to accommodate foot deformities. Many slippers do not contain dorsal fixtures or have any form of stabilisation around the heel or sole area. These key structural footwear features may help prevent the foot from slipping and may reduce the risk of falls [8-

10]. It has not been previously reported in the literature if the fit of the slipper is a contributing factor to falls and how this may compare to dorsally secured footwear.

Inadequate foot clearance during gait may also predispose a person to tripping and falling. Older men have demonstrated variable foot clearance [11] and this variability has been directly related to aging and trips [12]. While these studies have been conducted primarily within bare feet or in a shoe with dorsal fixtures, there has been no established impact of wearing slippers on minimum foot clearance, particularly in older women. Similarly, there is unknown what impact wearing slippers have on the spatiotemporal features of gait (i.e. cadence, time in double support, step length).

Due to the lack of evidence supporting any of the key features in commonly worn footwear impacting on falls, the aim of this study was to examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking. It was hypothesised that walking in well-fitted footwear with dorsal fixation would result in less heel slippage and a higher minimum foot clearance compared to walking in slippers. A secondary aim of this study was to compare spatiotemporal characteristics of gait when wearing slippers, well-fitted footwear and walking bare foot. It was hypothesised that participants would walk faster, with an increase step length and reduced double limb support in well-fitted footwear compared to walking in slippers or bare feet. This knowledge will improve understanding of the key features of commonly worn footwear and its potential impact on the mechanics of falls.

5.4 Method

5.4.1 Study Design

This study design was a within subject randomised control trial for the three footwear conditions. Permuted block randomisation between footwear conditions was conducted.

5.4.2 Participants and setting

Thirty community dwelling females aged between 60 and 80 years were recruited to participate in the study. Power estimates were calculated from the effects of footwear on walking speed and confirmed that 30 participants would provide sufficient statistical power ($\alpha = .05$, $1 - \beta > 0.8$) for this study [13]. Inclusion criteria required that participants were able to ambulate unaided, have no cardiothoracic, orthopaedic or neurological symptoms, or medication that had potential to affect their gait and no history of injurious falls. Participants were also excluded if they were diagnosed with severe dysphasia that interfered with communication; or if they presented with significant cognitive impairment affecting their gait or ability to participate in testing.

5.4.3 Footwear

The primary investigator fitted the “prescribed” footwear and slippers based on the size that the participant usually wore and by ensuring length of 1-2cm from the longest toe, and minimal medial and lateral movement within the shoe. The “prescribed” footwear was chosen based the common features of footwear articulated within falls prevention management. Slipper choice was made by observing the most common accessible, cost effective slipper in local stores at the time of data collection. Participants were asked if they were comfortable in the shoe and if the shoe felt that it was appropriately fitted to ensure correct fitting. The size of the shoe was recorded within the demographic data.

Participants were fitted with both the:

1. Slippers (Figure 1A): Synthetic material upper, flat rubber sole, no dorsal fixation, weight, 127g.
2. Prescribed footwear (Figure 1B): Low heeled (2.5cm heel height and 2.0cm toe pitch), leather upper, laced fixations with five eyelet points, EVA midsole and rubber outsole, 128g.

Figure 1 – Footwear used within the study: A) Slipper; B) Propet brand Well-fitted footwear.

A) Grosby Slipper



B) Propet brand Well fitted footwear



Participants were required to wear both the slipper and the prescribed footwear for approximately two weeks as part of their normal daily activity, to familiarize themselves with the footwear. Following this, the participants attended a single appointment for three-dimensional gait assessment. At this appointment, demographic data was collected including: age, height and weight.

5.4.4 Gait Assessment

Participants walked five times along a 10m walkway at their preferred pace for each condition: bare feet; well-fitted footwear; and slippers. For all conditions the participants were requested to look straight ahead and started their walk at least two metres before an 8.3m instrumented walkway (GaitRITE®, CIR Systems Inc, Havertown, Pennsylvania, USA) walkway and were asked to continue walking at least two metres beyond the end of the walkway to avoid accelerating or slowing down during data capture on the mat. Participants were required to rest between each change in footwear for five minutes to minimise fatigue. Minimum foot clearance and heel slippage were determined using the Vicon 612 motion analysis system sampling at 100Hz (Vicon Peak, Oxford, UK). Spatiotemporal gait characteristics were calculated from data collected using the instrumented GaitRITE® walkway.

5.4.5 Minimum foot clearance

Minimum foot clearance was defined as the minimum distance between the plantar, distal aspect of the phalanx and the ground during the mid-swing phase of gait [14]. This measure (mm) was determined by placement of ten reflective markers attached to specific landmarks on the feet/footwear and lower limbs as previously described [15]. Briefly, reflective markers were placed on the first and fifth meta-tarsal phalangeal joints, and on the distal, dorsal aspect of the large toe. The position of the plantar, distal aspect of the phalanx was measured relative to the three forefoot markers during quiet standing and its position calculated as a virtual marker during the gait trials during post processing. The minimum foot clearance was measured from a virtual marker calculated from three forefoot markers in 3D space. The gait laboratory equipment is maintained regularly ensuring the capture zone has less than a 1mm (3/64 inch) of measurement error therefore system error is very small and highly reliability in measuring dynamic marker position.

5.4.6 Heel Slippage

Heel slippage was measured by placing reflective markers on the heel counter of the footwear (well-fitted footwear or slipper conditions) or calcaneus (bare foot condition), and another marker placed on the muscular-tendonous junction of the Achilles tendon (calf marker) (Figure 2). The distance between the heel and calf markers was measured using an eight camera Vicon motion analysis system. Maximum heel slippage (mm) was defined as the difference between maximum distance of the heel and calf markers during bare foot walking (where there is no foot slippage) and the maximum distance between the heel and calf markers when walking in either slippers or prescribed footwear.

Figure 2 Placement of markers on footwear



5.4.7 Spatiotemporal gait characteristics

Spatiotemporal gait characteristics derived using proprietary software (GaitRITE®) included: step length (m), step duration (s), single limb support duration (s), double limb support duration (s), step velocity (m/s) and step width (mm).

5.4.8 Data Analysis

Maximum heel slippage and minimum foot clearance were determined from a mean of 18 steps per participant per condition. Spatiotemporal characteristics were calculated from a mean of 54 steps per condition, consistent with average mean steps of a standard 10 metre GaitRITE® walkway. The variability of minimum foot clearance and heel slippage was calculated as the within-person standard deviation of gait characteristics using established methods to avoid the potential confounding of asymmetry [15].

Visual inspection of the data revealed that distributions conformed to a normal distribution, therefore a repeated-measures ANOVA was used to test for main effects of footwear. Planned comparisons using a series of two-way paired t-tests were made between the three footwear conditions. A threshold of $p < .05$ was used to guide statistical interpretation.

The Human Research Ethics Committee of Monash Health (Formerly Southern Health) approved this research.

5.5 Results

We tested 30 female participants; the mean (SD) age was 69.1 (5.1) years, mean height (SD) was 157.2 (.74) cm and the mean body mass (SD) was 69.8 (7.1kg). The mean issued shoe size was a Ladies American size 8. Each participant completed all three conditions.

Results of the gait assessment are summarised in Table 1 and corresponding ANOVA statistics are reported in Table 2. Participants walked with a 4mm higher minimum foot clearance when wearing the well-fitted footwear compared to bare feet and slippers, however there was no difference between barefoot walking and wearing slippers.

Table 1 Summary of foot slippage, foot clearance and spatiotemporal gait outcomes.

Variable		Barefoot Mean (SD)	Well-fitted footwear Mean (SD)	Slippers Mean (SD)
Mean gait characteristics	Minimum Foot Clearance (mm)	15.7 (4.7) ^w	19.7 (3.8) ^{bs}	15.7 (3.6) ^w
	Maximum Heel Slippage (mm)	-	13.1 (7.4) ^s	15.5 (5.36) ^w
	Step Velocity (m/s)	1.26 (0.08) ^{ws}	1.35 (0.08) ^{bs}	1.31 (0.08) ^{bw}
	Step Length (m)	0.602 (0.03) _{ws}	0.652 (0.03) ^{bs}	0.640 (0.03) _{bw}
	Step Duration (s)	0.483 (0.02) _s	0.487 (0.02) ^s	0.492 (0.02) _{bw}
	Double limb support (s)	0.094 (0.01) _{ws}	0.115 (0.01) ^{bs}	0.103 (0.01) _{bw}
	Step Width (mm)	93.1 (12)	89.2 (15)	94.7 (10)
Within-person variability (sd) of gait characteristics	Minimum Foot Clearance (mm)	3.549 (1.865)	3.062 (0.973)	3.637 (1.033)
	Maximum Heel Slippage (mm)	-	2.681 (0.889) ^s	4.018 (1.550) _w

Superscript letters indicate a statistically significant difference ($p < .05$) between two types of footwear: w = well-fitted footwear, b = barefoot and s = slippers.

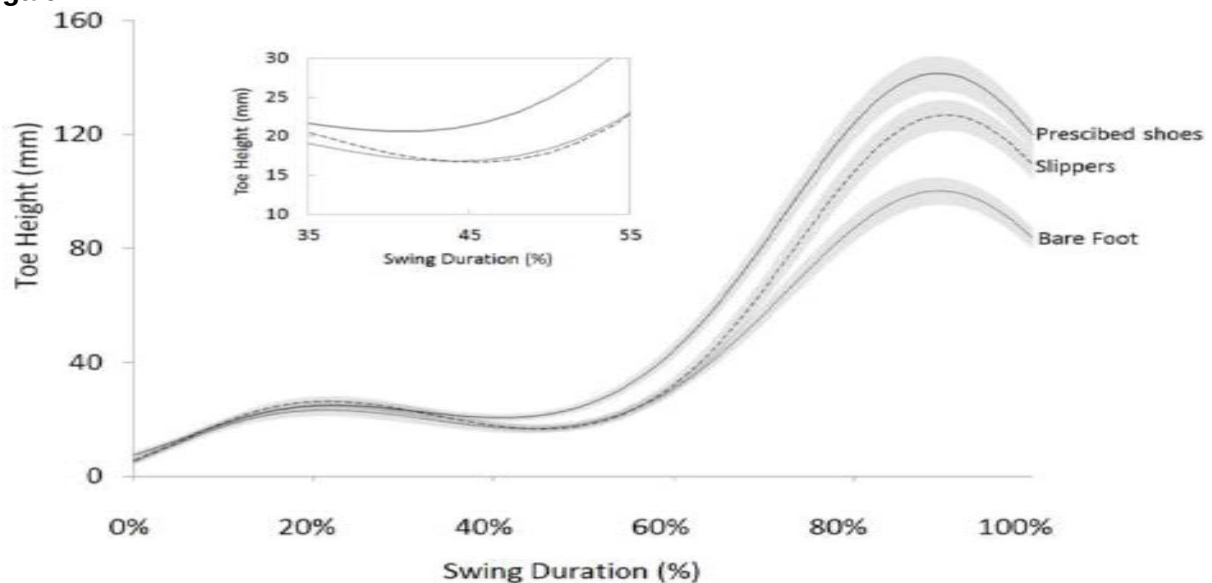
Table 2 Summary of statistics from repeated measure analysis of variance to assess differences between the means of barefoot (BF), well-fitted footwear (PS), and slippers (SL) footwear conditions.

Variable		F	p
Mean gait characteristics	Minimum Foot Clearance	13.17	<.001*
	Maximum Heel Slippage	5.78	.023*
	Step Velocity	38.54	<.001*
	Step Length	106.48	<.001*
	Step Duration	8.77	<.001*
	Double limb support	1.33	.273
	Step Width	2.57	.085
Within-person variability (sd) of gait characteristics	Minimum Foot Clearance	2.36	.103
	Maximum Heel Slippage	22.75	<.001*

* highlights a significant effect of footwear ($p < .05$)

Mean heel slippage was 19% greater and 50% more variable when participants walked in the slippers compared to the well-fitted footwear. There was greater within-subject variability of the heel slippage in the slipper compared to the well-fitted shoes that was potentially a result of the different shoe design features.

Figure 3. Mean foot height above the ground across 100% of the swing phase of gait is illustrated for each footwear condition. Grey shaded areas represent 95% confidence intervals. The insert shows foot clearance during the mid-swing phase of gait.



Footwear affected a range of spatiotemporal gait characteristics. When wearing the well-fitted footwear, participants walked faster and with a longer step length, a narrower step width, a shorter step duration and double limb support phase compared to walking barefoot or with slippers. Wearing slippers was also associated with a slightly longer step duration.

When wearing slippers as compared to walking barefoot, the participants had shorter steps, and an increased step and double limb support duration ($p < 0.05$). When walking bare foot as compared to walking in the well-fitted shoes, participants walked slower, with shorter step length and with a reduced minimum toe clearance ($p < 0.05$). There were no differences between footwear conditions for within-subject variability of minimum toe-clearance ($p > 0.05$) but greater within-subject variability for all spatiotemporal variables ($p < 0.05$) except step length when wearing slippers compared to the well-fitted shoes.

5.6 Discussion

This study has identified that the footwear older women wear when walking can significantly impact on foot trajectories (minimum foot clearance), stability of the foot within the footwear

(heel slippage) and spatiotemporal characteristics. This has implications for advice regarding the choice and development of footwear that will reduce falls risk in older women.

Participants walked with a greater minimum foot clearance when wearing the well-fitted footwear, this is footwear where the heel is secured and not slipping out of the shoe during gait. This supports the hypothesis that wearing footwear with dorsal fixation may assist in reducing the likelihood of tripping. The well-fitted footwear had a 20mm toe-pitch at the distal edge of the shoe, improving the rolling effect of the shoe during ambulation. This is also likely to contribute to a higher minimum foot clearance as, even in static stance, the toes are elevated from the supporting surface. The slippers had a totally flat sole and no toe pitch, therefore the distal edge of the slipper was in contact with the floor, this potentially contributed to the lower foot clearance.

It is important to maintain the stability of the foot within the shoe to maintain balance and guide the foot over potential trip risks when walking. In agreement with our hypothesis, maximum heel slippage was significantly greater when walking in slippers compared to well-fitted footwear. This is proposed to be directly attributed to the lack of dorsal fixation on the slipper. This deficit allows the heel to move more freely upward and out of the slipper at the heel-off phase of gait. An increase in heel slippage may result in balance instability and place greater demands on the lower limb motor control system to keep the shoe on the foot. This is also supported by the greater within-subject variability of heel slippage of the slipper compared to well-fitted footwear. Loose fitting footwear may also promote greater and more variable heel slippage, even with dorsal fixation, however we can discount this as a potential confounding factor in this study as the footwear was appropriately fitted by a podiatrist.

A secondary aim of this study was to examine the effect of footwear on the spatiotemporal characteristics of gait. The ability of the women within this study to walk faster, yet increase their period of double support when wearing the well-fitted footwear compared to the slippers,

suggests that the firm heel counter and adjustable laces of the shoe that secures the shoe onto the foot, may improve walking confidence of the wearer. It is unknown if this is a result from a decrease or change in the demand on the musculoskeletal system or change in the range of motion of the leg and foot as observed in other studies on supportive footwear in younger people [16]. Similarly, footwear has been identified as having an impact on the proprioceptive systems [17, 18] during gait therefore it is unknown if these changes in gait are a result of these impacts.

There was a key limitation within this study. While the slippers and prescribed footwear conditions were footwear that is readily available within the community, there will be variations in transferability of results. However the footwear and features used within the study were similar to many walking style shoes therefore increasing generalisability. Different brands of low-heeled lace up footwear will have varying shoe features, heel height and toe pitch. While foot deformity limiting gait was excluded, it is unknown if there were biomechanical variations between participants. Ankle flexibility and strength of the dorsi /plantar flexors of the foot and ankle have been found to reduce with age [19]. These particular foot features were not taken into consideration within this study. Future studies on foot clearance and footwear should consider range of motion and dynamometry assessment. In addition, randomised controlled trials with large cohorts are required to establish whether well-fitted footwear can indeed reduce the prevalence and frequency of falls in older women, as well as whether our findings also hold in older men.

Finally, we did not directly examine the relationship between footwear features or foot clearance with falls in our participants. It is possible that older women wearing appropriately fitted footwear with dorsal fixation may feel more secure and attempt activities that may be “riskier” than activities they may attempt while wearing footwear that they are less secure in. “Risk compensation” behaviours have previously been identified as a reason why some interventions that should theoretically reduce the risk of falls may not do so in real life [20]. Hence, experimental studies examining the effect of using different types of footwear are

warranted in order to fully understand the relationship between footwear interventions and falls.

5.7 Conclusion

The type of footwear worn by older females can influence minimum foot clearance, maximum heel slippage and spatiotemporal variables of gait and, therefore, may impact on falls risk. Footwear with dorsal fixtures was shown to improve foot clearance and many gait features making them an ideal choice for ambulant older adults.

5.8 References

1. Begg, R. et al. Minimum foot clearance during walking: strategies for the minimisation of trip-related falls. *Gait Posture*, 2007. 25(2): p. 191-8.
2. Sherrington, C and Menz, H.B. An evaluation of footwear worn at the time of fall-related hip fracture. *Age Ageing*, 2003. 32(3): p. 310-4.
3. Davis, A. Murphy, A and Haines, T.P. "Good for Older Ladies, Not Me" How Elderly Women Choose Their Shoes. *Journal of the American Podiatric Medical Association*, 2013. 103(6): p. 465-470.
4. Tencer, A.F. et al. Biomechanical properties of shoes and risk of falls in older adults. *J Am Geriatr Soc*, 2004. 52(11): p. 1840-6.
5. Gabell, A. Simons, M.A. and Nayak, U.S. Falls in the healthy elderly: predisposing causes. *Ergonomics*, 1985. 28(7): p. 965-75.
6. Menz, H.B. Morris, M.E. and Lord, S.R. Footwear characteristics and risk of indoor and outdoor falls in older people. *Gerontology*, 2006. 52(3): p. 174-80.
7. Munro, B.J and Steele, J.R. Household-shoe wearing and purchasing habits. A survey of people aged 65 years and older. *J Am Podiatr Med Assoc*, 1999. 89(10): p. 506-14.
8. Burns, S.L. Leese, G.P. and McMurdo, M.E. Older people and ill fitting shoes. *Postgrad Med J*, 2002. 78(920): p. 344-6.
9. Menz, H.B and Morris, M.E. Footwear characteristics and foot problems in older people. *Gerontology*, 2005. 51(5): p. 346-51.
10. Lord, S.R. Sherrington, C and Menz, H.B. Falls in older people - risk factors and strategies for prevention. 2001, New York: Cambridge University Press.
11. Mills, P.M. Barrett, R.S. and Morrison, S. Toe clearance variability during walking in young and elderly men. *Gait Posture*, 2008. 28(1): p. 101-7.
12. Barrett R S, Mills P M and Begg R K. A systematic review of the effect of ageing and falls history on minimum foot clearance characteristics during level walking. *Gait Posture*, 2010. 32(4): p. 429-35.
13. Cohen, J. Statistical power analysis for the behavioural sciences. 1988, New Jersey: Lawrence Erlbaum.
14. Moosabhoy, M.A. and Gard, S.A. Methodology for determining the sensitivity of swing leg toe clearance and leg length to swing leg joint angles during gait. *Gait Posture*, 2006. 24(4): p. 493-501.
15. Galna, B., Lord, S and Rochester, L. Is gait variability reliable in older adults and Parkinson's disease? Towards an optimal testing protocol. *Gait Posture*, 2013. 37(4): p. 580-5.
16. Wolf, S. et al. Foot motion in children shoes: a comparison of barefoot walking with shod walking in conventional and flexible shoes. *Gait Posture*, 2008. 27(1): p. 51-9.
17. Waddington, G.S. and R.D. Adams, The effect of a 5-week wobble-board exercise intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: a study in healthy elderly. *J Am Geriatr Soc*, 2004. 52(4): p. 573-6.
18. Robbins, S. Gouw, G.J. and McClaran, J. Shoe sole thickness and hardness influence balance in older men. *J Am Geriatr Soc*, 1992. 40(11): p. 1089-94.
19. Menz, H.B. Morris, M.E and Lord, S.R. Foot and ankle characteristics associated with impaired balance and functional ability in older people. *Journals of Gerontology Series A - Biological Sciences & Medical Sciences*, 2005. 60(12): p. 1546-52.
20. Haines, T.P. et al. Why do hospitalized older adults take risks that may lead to falls? *Health Expectations*, 2012.

Chapter 6 – “Good for older ladies, not me”: how elderly women choose their shoes

6.1 Preamble

It is important to understand the drivers of footwear selection if older women are to wear footwear that reduces their risk of falls. This chapter identifies factors that motivate footwear selection amongst older women. Older women were asked about their attitudes towards the footwear that was provided to them in the previous study reported in Chapter 5, “Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women. Older women were also chosen for this study as women have higher rates of foot pathology that may be impact their footwear selection [2].

There is a wealth of education and awareness programs and literature relating to better choices for footwear in regard to foot health and falls. However, even older adults who have fallen appear hesitant to make recommended safer footwear choices. Furthermore, adherence with safe, appropriate footwear appears to be poor. This chapter investigates the psychosocial factors that influence footwear choice for older women. Understanding the drivers of footwear selection by older women is vital to assist health practitioners when recommending footwear in regard to falls management.

There are some interesting results in relation to the participants' perceptions of their age and ageist attitude towards shoes. This may be related to living longer and the less traditional roles that older people now have or perhaps longer time in the workforce. Further research is required to fully understand this paradigm.

This study was published in the Journal of the American Podiatric Medical Association in 2013 (Appendix 3) and relates to thesis aim three, to identify factors that drive footwear selection and use amongst older community-dwelling women, aged 60 to 80 years who had no previous history of falls.

6.2 Abstract

Footwear selection is important in older adults. Little is known of factors that influence footwear selection amongst older women. If older women are to wear footwear that may reduce their risk of falls and foot abnormalities, then a better understanding of the underlying factors of footwear choice is needed. This study aims to identify factors that drive footwear selection and use amongst older community-dwelling women with no history of falls.

A cross-sectional survey using a structured, open-ended questionnaire was conducted by telephone interview. The participants were 24 women, 60 – 80 years old, with no history of falls or requirement for gait aids. The responses to open ended questions were coded and quantified under a qualitative description paradigm.

The main themes identified about footwear selection were aesthetics and comfort. Aesthetics was by far the main factor influencing footwear choice. Wearing safe footwear was not identified as a consideration when purchasing footwear. This study indicates that older women are driven primarily by aesthetics and comfort in their footwear selection. These footwear drivers have implications for health-care providers when delivering fall and foot health education.

6.3 Introduction

Footwear selection is important in older adults. Unstable and poorly fitting footwear can increase the chance of tripping and falling, leading to injury and mortality [1-5]. Poor choices with footwear selection can also contribute to foot abnormalities, including bunions, toe deformity and foot pain [6-8]. Falls are the single biggest reason for injury-related admission to hospital and presentations to hospital emergency departments for people over 65 years [1]. One in three individuals older than 65 years experience one or more falls in any given year [9] although this increases to one in two among those aged over 85 years. Common injuries resulting from a fall include hip fractures, wrist fractures and head injuries [1]. Falls may lead to other complications including a fear of falling, loss of confidence in walking and a reduction in quality of life [1].

Footwear has been identified as a risk factor in falls and falls related injury [3-6]. Particular features of footwear can increase the risk of falling, including a narrow heel, lack of or inadequate fixation, slippery sole or footwear that is poorly fitted [10-12]. Slippers and unsafe footwear are frequently identified as the footwear worn at the time of falling by community dwelling elderly adults and those in residential aged care facilities [2].

Little is known of factors that influence footwear selection amongst older women. Previous studies of elderly populations have found that slippers are the predominant indoor footwear of choice [13, 14]. The choice of outdoor footwear is varied, ranging from slippers [6] to sturdy lace-up walking shoes [15]. The most common reason cited for this choice is comfort [13, 14]. However, it has been noted that the choice of comfort does not necessarily equate to a sturdy, safe shoe with optimal features [15]. It seems from these studies that the health-care provider's perception of comfortable and safe footwear seems to be quite different to that of the elderly population [15].

There is also a psychosocial element regarding age that should be considered for this population. Footwear is intrinsically linked to the sense of self and self-worth and is an outward expression of this, even in an elderly population [16-18]. There is a key connection between loss of choice associated with retail footwear, body image and reduced self-perceived quality of life [19]. Naidoo [20] found that women between the age of 36 and 84 years (mean age, 67 years), were concerned with loss of femininity and they considered themselves to be visibly different from their peers owing to their limited choice of retail shoes, which created negative feelings and emotions about their footwear.

There are many education and awareness programs and much literature relating to better footwear choices regarding foot health and falls; however, even previous fallers are hesitant to make safer footwear selections [16-18] and compliance with safe, appropriate footwear, is also poor [19]. Safe footwear is difficult to define. Regarding contextualizing safe footwear for older women, the heel profile should be low, flat and broad [14]. The sole should be textured to improve traction, and there should be dorsal fixation, such as laces or buckles [21].

If older women are to wear footwear that reduces their risk of falls, then a better understanding of the psychosocial factors of footwear choice is needed. This study aims to identify factors that drive footwear selection and use amongst older community-dwelling women, aged 60 to 80 years who had no history of falls. The participants were also asked about their attitudes towards the footwear that was provided to them in a previously unpublished study (unpublished study, Annette Davis, BAppSc(Pod), Anna Murphy, BAppBiomech, PhD, Brook Galna BAppSc(Exercise Science & Exercise Behaviour) Barts(Psych)PhD(Biomech), 2010. Older women were chosen for this study as they have higher rates of foot disorders that may be related to

their footwear selection [7, 22] together with a higher incidence of injury after a fall due to higher rates of osteoporosis [23-25].

6.4 Method

The participants were 24 women aged between 60 to 80 years with no history of falls or requirement for gait aids. The Southern Health human research ethics committee (Cheltenham, VIC, Australia) approved this study, and all participants gave consent to participate. These participants were recruited from a previous unpublished study in which they were provided with Propet washable walker shoes (Figure 1). The Propet washable walkers, fitted by the investigator (A.D.), were provided at no cost to the participants. The participants were then allowed to keep the shoes and questions regarding these shoes form the qualitative analysis component of this study. The participants had received the Propet Washable Walkers one year before to this cross-sectional survey.

A cross-sectional survey using a structured, open-ended questionnaire was conducted by telephone interview. The questions were formulated from consultation with the Southern Health podiatric medical team and from literature investigating footwear choice [6, 13]. The telephone interview included questions about the footwear from the previous study and questions regarding drivers of footwear selection.

Before contact, participants were sent written information on the purpose of the study, consent to participate, and how their confidentiality would be managed. The primary investigator then made contact with each participant and conducted all of the interviews over the telephone during a 1 week period. Semi-structured interview questions were asked about the participant's main consideration when buying shoes, how many shoes they own, and the type of shoes worn indoors and outdoors. The survey questions are presented in Table 1. All interviews were recorded and transcribed verbatim, with each participant allocated a numerical code. During the

interview, open-ended question were asked, and prompts were used to facilitate discussion and ensure that each question was answered in detail.

Figure 1 Propet washable walker



Table 1 Telephone interview questions

Survey Questions:
<i>Can you tell me, when buying footwear what is your main consideration?</i>
Prompts - Price, Aesthetics, Comfort, Safety, Brand, Access, Other please explain
<i>Approximately how many pairs of shoes do you own?</i>
<i>Of these, how many do you wear on a regular basis (more than twice a week)?</i>
<i>What footwear (if any) do you wear most often indoors & why?</i>
Prompts - Aesthetics, Activity, comfort, safety, other please explain
<i>What footwear (if any) do you wear most often outdoors & why?</i>
Prompts - Aesthetics, Activity, Comfort, Safety , Other please explain
<i>In the previous research study, you were given some lace-up shoes to keep.</i>
<i>i. Do you still have them? If not, why not?</i>
<i>ii. Do you still wear them? If so, how many times a week? When do you wear them?</i>
<i>iii. Did participating in the previous study influence how you choose your shoes now?</i>
<i>iv. Have you purchased similar shoes since?</i>
<i>v. Is there anything that makes you want to wear them?</i>
<i>vi. Is there anything that puts you off wearing them?</i>
<i>Is there anything further about choosing footwear that you would like to tell me?</i>

The responses to open-ended questions were coded and quantified under a qualitative description paradigm using descriptive phenomenology. The primary investigator (A.D.) read through interview transcripts and applied codes. These codes were then

grouped into themes, and the frequency of these themes summarized. These themes were discussed with the research group to ensure trustworthiness and rigor of data and to check for content accuracy and consistency of coding.

6.5 Results

The mean $\pm$ SD age of the 24 participants was 67.5 ± 4.2 years. Their mean $\pm$ SD height was 161.8 ± 7.3 cm and weight was 69.8 ± 7.2 kg. The participants owned a mean of 24 (range, 2-57) pairs of shoes. All of the participants consented to the telephone interview. The main themes identified by the participants were aesthetics, comfort and safety. A subtheme of comfort was foot disorders. Participants also identified feelings of loss of autonomy and loss of decision making regarding choosing footwear.

Almost half of the participants regularly wore (more than twice a week) less than one-third of the shoes they owned. Almost half of participants (48%) most commonly wore slippers as their indoor footwear. The outdoor footwear most commonly worn by participants was lace-up walking shoes. Comfort was the main reason given for footwear worn indoors and outdoors. Participants also described the need for having shoes related to seasonal changes and working requirements, as some participants were still employed.

The theme of aesthetics was the main consideration for shoe purchase, with six participants (25%) stating this as the exclusive reason. In addition, there were other participants citing it in conjunction with comfort.

When asked whether there was anything that puts the participant off wearing the previous research shoes, 18 (75%) mentioned the aesthetics of the shoes. "They aren't very elegant" and "I can't wear them with a dress" were comments made by

participants. Aesthetics was not mentioned by any of the participants as a reason they preferred to wear the Propet washable walkers.

The theme of comfort was initially revealed when participants were asked what they consider when seeking to purchase a new pair of shoes, with 20 participants (83%) describing comfort as a key reason for purchase. The need for comfort was related to foot abnormalities for some participants, with mention of bunions, Achilles tendonitis and toe deformity: "Comfort, especially as I have bunions and my little toe is a problem". There was also mention of needing to spend more money for comfortable shoes: "Money and comfort are important but I find my budget increases to get comfort". It is unclear from the data as to the relationship between comfort and fall prevention.

Foot abnormality was also evident as a subtheme of comfort from the data collected. Foot pain or abnormality influenced shoe selection: "I have foot pain now and have to choose shoes that are more sensible". This quote shows that for this participant, comfort (pain reduction) has had to override other factors.

The theme of safety was discussed primarily in response to specific questioning regarding use of the Propet washable walkers that had been provided without cost and with education that the footwear would be safer for them to wear. There was a varied response to the receipt of this footwear and participation in this research. Some participants that it did have an effect on the footwear they chose to wear. One participant responded, "Most definitely. I always make sure I have a strap or something on top to keep them on". Whereas for others, it may have had a less dramatic impact. "Reinforced what I knew already", "Sort of made me think more about what I was buying," and "Partially. I think I had figured out over the years what was best for me" were some responses to this question.

Only half of the participants still had the Propet washable walkers, and only 6 (25%) were still wearing them. Overwhelmingly, the reason stated for not wearing them was the aesthetics of the shoes. The term *ugly* was consistently used to describe them, as

were comments describing the shoes as “good for older ladies, not me”. However, the aesthetics of a shoe were clearly a factor in a decision not to wear the research shoes. Some of the comments received revealed a potentially ageist attitude towards shoes. For example, one participant, when asked whether she would ever wear the research shoes responded, “No but recommended them to my 92-year old aunt who loves them” (participant aged 69 years), and another participant responded, “If I was 100 years old maybe” (participant aged 72 years). Clearly, some participants felt that these were the sorts of shoes that older women wore, though the average age of this sample was 67.5 years. Although the participants were considered older women by the research team, the participants themselves did not think of themselves in this way and thus, rejected the notion of wearing shoes that they associated with older women. It was also noted that slightly more than half the participants had purchased shoes of a similar style as the Propet washable walkers within the past year.

Other important themes were autonomy and loss of decision making, especially with the older participants in the study. One participant stated that her daughter makes those decisions for her now, and another stated that she only had one pair of “sensible” shoes because her other shoes had been taken away.

6.6 Discussion

The aim of the study was to investigate the drivers of footwear selection in an elderly female population. The main themes identified were aesthetics and comfort. The relative hierarchy between aesthetics and comfort is not clear from the present study. Initially, it seemed that comfort was a clear driver of footwear purchasing behaviour, with women reporting comfort as a factor as opposed to six reporting aesthetics as a factor.

Indoor shoes are primarily chosen for comfort and were commonly slippers. Slippers were often worn indoors and outdoors for comfort and convenience rather than aesthetics. The choices of outdoor shoes were primarily running or walking shoes,

which were described for their comfort. It was clear that comfort cannot be solely linked to one type of shoe. Comfort as a descriptor may be perceived differently from one individual to another. An example of this is footwear that has excessive wear to the outsole but is a favourite that the individual is reluctant to give up. This was also described as comfortable by some participants. The investigators had anticipated that the Propet washable walkers would be comfortable, yet no participants reported this to be the case (though this was not directly questioned; rather, indirect questions asking participants to report why they do or do not wear the shoes). Instead, the shoe was classified as being for “older people”, revealing that the participants possibly did not want to think of themselves as being old [26]. Greco [27] stated that when a person reached the age of 60 it does not mean they are uninterested in clothing or fashion. The large number of pairs of shoes owned by participants but not worn regularly may be related to fashion.

In an elderly female population in which fall issues and foot disorders may exist, health-care providers commonly recommend footwear for its functionality. Collaborative consultation with the woman in the decision-making process for footwear selection may be beneficial. This may also be advantageous for compliance with wearing the footwear that is recommended. Compliance with footwear recommendation in regarding fall prevention has been shown to be poor [28].

The underlying concepts of the Health Belief Model [29] could be considered by health-care practitioners when recommending footwear. The model states that a person's decision to change their behaviour is influenced by how vulnerable they perceive themselves to be to a particular health problem, the perceived seriousness, barriers to implementing the change and the possible benefits it will produce.

Williams and Nester [30] suggested that “rather than telling patients that their footwear choices are bad, we should provide positive support for the small changes that patients

may achieve and continue to promote the benefits of suitable footwear". Tools to assist health practitioners with footwear choice such as Barton's footwear assessment tool may also be useful in collaborative decision making as they give an overview of footwear styles and features [31, 32].

Safety as a theme was identified for the previous study footwear. Given that this population had no previous falls, there was no surprise that safety was not a primary consideration when purchasing shoes. However, participants may also be rejecting the notion that they are at risk of falling. Wearing safe shoes may require an inward acceptance that this population do not trust their own mobility anymore. Perhaps they do not want to inwardly accept they are at risk for falling or allow this risk to be known outwardly.

The loss or transference of footwear choice from elderly woman to other family members was a theme more prevalent in the older group. Fashion was secondary to function as a footwear selection driver, as choice was transferred to a family member who attended to this and other decisions for these participants. It was clear that there was no collaboration in the footwear selection process. The loss of independence, whether physical, mental or situational, may be the defining time for the transition of change from fashion to function in regard to footwear selection.

6.7 Limitations

Limitations of the study include a small sample size and previous history between participants and investigator from the previous research study. This could create potential pressure to be supportive of the safe footwear; however, many of the participants were willing to express the desire to never wear the previous research footwear again. The sample size in this study was dictated by the number of participants in the previous research. It is possible that if more participants had been

interviewed, a broader range of reasons for not wanting to wear the research footwear or themes underlying reasons for footwear selection may have been attained.

6.8 Conclusion

This study indicates that older women are driven primarily by aesthetics and comfort in their footwear choices. If health-care practitioners or family members want to influence this thinking so that older women wear footwear that may be considered safer, it is clear that this footwear will still have to be aesthetically pleasing and comfortable.

6.9 References

1. Department of Health, *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Hospitals*, Australian Commission on Safety and Quality, Editor 2009: Australia.
2. Sherrington C and Menz H B, *An evaluation of footwear worn at the time of fall-related hip fracture*. Age & Ageing, 2003. **32**(3): p. 310-4.
3. Berg, W.A. Mills, EM. Tong C., *Circumstances and consequences of falls in independent community-dwelling older adults*. Age and Ageing, 1997. **26**(4): p. 261-268.
4. Tinetti, M.E. *Clinical practice: preventing falls in elderly persons*. New England Journal of Medicine, 2003. **348**(1): p. 42-49.
5. Lord, S.R. and Bashford, G.M. *Shoe characteristics and balance in older women*. Journal of the American Geriatrics Society, 1996. **44**(4): p. 429-433.
6. Koepsell, T.D. et al. *Footwear style and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(9): p. 1495-1501.
7. Menz, H.B. Morris, M.E. and Lord, S.R. *Footwear characteristics and risk of indoor and outdoor falls in older people*. Gerontology, 2006. **52**(3): p. 174-80.
8. Jessup, R.L. *Foot pathology and inappropriate footwear as risk factors for falls in a subacute aged-care hospital*. Journal of the American Podiatric Medical Association, 2007. **97**(3): p. 213-7.
9. Australian Institute of Health and Welfare. *A Picture of Osteoporosis in Australia*, 2008: Canberra.
10. Gill, T. Taylor, A.W. and Pengelly, A. *A Population-Based Survey of Factors Relating to the Prevalence of Falls in Older People*. Gerontology, 2005. **51**(5): p. 340-345.
11. Barbieri, E. *Patient falls are not patient accidents*. Journal of Gerontological Nursing, 1983. **9**(3): p. 164-173.
12. Frey, C and Kubasak, M. *Faulty footwear contributes to why seniors fall*. Biomechanics, 1998. **5**: p. 45-7.
13. Munro, B.J. and Steele, J.R. *Household-shoe wearing and purchasing habits. A survey of people aged 65 years and older*. J Am Podiatr Med Assoc, 1999. **89**(10): p. 506-14.
14. White, E and Mulley, G. *Footwear worn by over 80's: a community survey*. Clin Rehab, 1989. **3**:(23).
15. Dunne, R.G. et al., *Elderly persons' attitudes towards footwear - A factor in preventing falls*. Public Health Reports, 1993. **108**(2): p. 245-248.
16. Hornbrook, MC. Wingfield, DJ. Stevens, VJ et al. *"Falls Among Older Persons: Antecedents and Consequences" in Reducing Frailty and Falls in Older Persons*. August 2008, University of Michigan USA: Thomas, 1991. 532.
17. Isaacs, B. *Clinical and Laboratory Studies of Falls in Old People: Prospects for Prevention*. Clinics in Geriatric Medicine, 1985. **1**(3): p. 513-524.
18. Frey, C. *Foot health and footwear for women*. Clinical Orthopaedics & Related Research, 2000(372): p. 32-44.
19. Williams, A.E Ravey, MI. and Nester CJ. *Rheumatoid arthritis patients' experiences of wearing therapeutic footwear - A qualitative investigation*. . BMC Musculoskelet Disorders, 2007. **8**: p. 104.
20. Naidoo, S. Mills, J. Parsons, S. Breeden, S. Bevan, E. Edwards, C and Otter, S. *"I could cry, the amount of shoes I can't get into": A qualitative exploration of the factors that influence retail footwear selection in women with rheumatoid arthritis*. Journal of Foot and Ankle Research, 2011. **4**(21).
21. Williams, A. *Footwear assessment and management*. Podiatry Now, 2006(May): p. S1.

22. Burns, S.L. Leese, G.P. and McMurdo, M.E.T. *Older people and ill fitting shoes*. Postgraduate Medical Journal, 2002. **78**(920): p. 344-346.
23. Norton, R. et al. *Circumstances of Falls Resulting in Hip Fractures Among Older People*. Journal of the American Geriatrics Society, 2015. **45**(9): p. 1108-1112.
24. Hannan, M. *Risk Factors for Longitudinal Bone Loss in Elderly Men and Women: The Framingham Osteoporosis Study*. J Bone Miner Res, 2000. **15**(4): p. 710-720.
25. Grisso, J.A. et al., *Risk Factors for Falls as a Cause of Hip Fracture in Women*. New England Journal of Medicine, 1991. **324**(19): p. 1326-1331.
26. Hockey J, Featherstone, M and Wernick A. *"Images of aging: Cultural representations of later life."* 1995, London. Taylor & Francis
27. Greco, A.J. *The fashion-conscious elderly: a viable, but neglected market segment*. J Consumer Market, 1986. **3**(4): p. 71-75.
28. Fortinsky, R.H. et al. *Fall-risk assessment and management in clinical practice: Views from healthcare providers*. Journal of the American Geriatrics Society, 2004. **52**(9): p. 1522-1526.
29. Janz NK, B.M. *The health belief model: a decade later*. Health Educ Q., 1984(11): p. 1-47.
30. Williams, A.E and Nester CJ.. *"Managing Patient Engagement. Orthoses and as a Foot Health Intervention in Footwear and Foot Orthoses: The Pocket Podiatry Guide*. 2010, London: Churchill Livingstone Elsevier.
31. Barton, C.J., Bonanno, D. and Menz, H.B. *"Barton's footwear assessment tool."* 2009. *Journal of Foot and Ankle Research*, 2(1), p.10.
32. Barton, C.J., Bonanno, D. and Menz, H.B. *Development and evaluation of a tool for the assessment of footwear characteristics*. Journal of Foot and Ankle Research, 4(3), p.26

Chapter 7 – Older adults consideration of safety in footwear choices in relation to falls

7.1 Preamble

Chapters 2 and 6 have discussed the drivers of footwear selection for older women in relation to falls. Men and women over the age of 65 years are also the group likely to have one or more falls every year, many of which result in hospitalisation. This chapter investigates the relationship between the falls history of community dwelling older adults and their indoor and outdoor footwear, as well as additional reasons behind their footwear selection.

A large scale mixed methods telephone survey of 245 older adults was used to collect responses to four footwear questions. Similar questions were used to those presented to participants in chapter 6. These questions included the preferred footwear style and the reason for footwear choice. Analysis of these questions and triangulating the responses with falls history in a larger, community dwelling cohort of both men and women allowed for broader extrapolation of resultant themes for common footwear styles and reasons for footwear choice. Slippers as a cause of falls is a presumption as there are multiple factors that cause falls. There may also be more care taken not to fall outdoor because of unfamiliar environment and terrain whereas indoors it's familiar and therefore they may be complacent. There may also potentially be a link between comfort and safety, that is, if they are uncomfortable this may lead to instability and falls.

Understanding older adults' footwear choice will aid health practitioners with more targeted information that could improve adherence to footwear recommendations in regard to falls management. This chapter examines community dwelling older adults indoor and outdoor footwear preferences, why they chose particular footwear and whether they fell or not during the preceding 12-month period.

This chapter relates to thesis aim four, to examine the relationship between footwear preferences and whether older adults (men and women) fell or not during the preceding 12-month period.

7.2 Abstract

As the population ages, falls are increasing costs for health services worldwide. Footwear has often been implicated in falls. This study investigates older people's indoor and outdoor footwear preferences, why they chose particular footwear, together with their falls history.

A two-wave, state-wide mixed methods survey of community dwelling older adults was undertaken. There were 245 participant responses to the survey. Participants reported footwear most commonly worn indoors was enclosed slippers (n=110, 45%), and outdoors was walking shoes (n=114, 47%). There was no association between slippers or any other indoor or outdoor footwear types chosen by participants and falls. Comfort was the most common reason for indoor and outdoor footwear choice. Safety was the second most reported reason for outdoor footwear choice but reported less frequently for indoor wear. For footwear to be part of falls prevention strategy in the future, comfort and safety should be considered.

7.3 Background

Falls are a major health issue for the community as the population ages and for health services worldwide [1]. Men and women over the age of 65 years are likely to have one or more falls every year, often resulting in hospitalization [1-3]. As the population ages, there is increasing pressure on health services to provide preventative measures to reduce the cost related to falls and falls injury [1].

Footwear is often implicated in falls in elderly adults [4-9] with several studies [2, 4, 10] reporting that the most commonly worn footwear at the time of fall was slippers [11]. While many falls occur in the home [12] it is unknown how many are actually attributed to footwear [8, 13, 14]. Older adults may choose other indoor footwear and non-footwear, including socks,

stockings or bare feet during indoor activities. It is unknown how variable outdoor footwear choices are for older adults.

Health professionals rely on clinical guidelines to inform evidence-based practice. The Australian Commission on Safety and Quality in Healthcare Best Practice Guidelines for Preventing Harm from Falls in Older People [15] recommend safe and optimal footwear as low-heeled lace up walking shoes. This may be suitable as outdoor footwear but is at odds with what is known to be worn indoors [8]. The reasons for older adults' indoor and outdoor footwear choices have not been sufficiently examined, in relation to individual's perception of safety and falls.

7.4 Objectives

The aim of this study was to examine the relationship between footwear preferences and whether people fell or not during the preceding 12-month period.

7.5 Methods

This study was nested within a larger project, described elsewhere [16]. The larger project investigated the implementation of evidence-based interventions for preventing falls among community-dwelling older adults in Victoria, Australia. A prospective cohort study was undertaken with approximately 12 months between the baseline and follow-up telephone surveys. The data acquired for this project was collected during the follow-up survey.

The baseline survey investigated older adult demographic variables, as well as their opinions toward a variety of specific falls interventions. These interventions included exercise programs, psychoactive medications and home modifications. This extraction of data from the larger study focussed on footwear choices and participant justification for these choices. The a priori calculation for the baseline sample size was described elsewhere [17] and was calculated using measures unrelated to this report. The sample size for follow-up was based

on convenience. Ethics approval was granted by Monash University Human Research Ethics Committee (MURHEC) No. CF11/3625-2011001912.

7.5.1 Participants

Participants were community-dwelling men and women aged 70 years and older, living in Victoria, Australia (Table 1). Participation required sufficient English language skills to confidently converse on the telephone with no cognitive impairment.

7.5.2 Survey Tool

The survey tool was adapted from previously developed questionnaires used to examine perceived risk of falling and perceptions toward participation in interventions to prevent falls [18]. Initial participant demographics and comorbidities were determined in the baseline survey. The follow-up survey updated participant demographic details, comorbidities and respondents' engagement in, and perceptions toward, various interventions for the prevention of falls (Table 1). It also included an information page with titles and pictures of different styles of footwear, such as enclosed slippers, backless slipper, sandals, boots and walking shoes (Figure 1). 'Non-footwear' choices were also included such as socks and bare feet. This information supported the survey tool footwear questions that relate to this study. Participants had the ability to include more than one answer (up to five answers) for questions relating to footwear worn indoors and outdoors.

Questions relating to risk of falls were also asked later in the follow up survey. For the purpose of this paper, we were also interested in the participant response to the survey question that asked about the number of falls the participants had experienced in the previous 12 months.

The footwear and risk of falls questions in the survey tool that related to this paper were:

- i. Using these pictures (provided prior to survey), can you describe the type of footwear you normally wear indoors?
- ii. What is the main reason you choose to wear this footwear?
- iii. Can you describe the type of footwear you normally wear outdoors?
- iv. What is the main reason you choose to wear this footwear?

v. How many falls have you had in the past 12 months (a fall where you inadvertently come to rest on the ground or floor or other lower level)?

Figure 2 Footwear options (Participant information)



Walking Shoes



Thongs



High Heel



Slipper (Backless)



Slipper (Enclosed)



Ugg Boot



Sandal



Boot



Moccasin



Stockings only



Low heeled Court Shoes

Table 1 Participant demographics

Characteristics		Participants (Total Population n=245) Mean (SD) or n(%)
Age (years)		77.5 (5.7)
Sex (Female)		148 (60%)
Marital Status,		
	Married	124 (51%)
	Widowed	80 (33%)
Country of birth		
	Australia	182 (81%)
	United Kingdom	25 (11%)
Chronic disease		
	Stroke*	20 (8%)
	Osteoporosis or osteopenia	55 (22%)
	Arthritis	145 (60%)
	Diabetes	41 (17%)
	Parkinson's disease	2 (0.8%)
	Inner ear dysfunction affecting balance	30 (12%) 55 (22%)
	Cataracts (not cataracts that have been surgically removed)	64 (26%)
	Visual impairment	45 (18%)
	Joint replacement	49 (20%)
One or more falls in the past year		94 (38.2%)

* Includes mini-strokes, aneurisms, transient-ischemic attacks.

7.6 Procedure

Participants were recruited from the 2006 electronic Victorian residential phone listings. This sampling method was chosen as it was readily available and cost-effective. Recruitment of participants was by a survey research company using random digit dialling. At the conclusion of the baseline survey, respondents were asked if they consented to being contacted again in 12 months.

Follow-up involved research assistants contacting each respondent who consented to later contact. The research assistant obtained current verbal consent from the respondent to participate, and arranged a convenient time for the follow-up survey to be administered. An information pack containing project material including pictures of footwear styles was mailed to the respondent. A second research assistant then contacted the respondent at the prearranged time to screen for cognitive impairment and conduct the survey. Cognitive

screening was performed using the 6-Item Cognitive Impairment Test (6-CIT) as it was brief, could be performed over the telephone, and correlates well with the Mini-Mental State Examination [19].

Participants for the initial baseline survey were interviewed by research assistants between December 2010 and February 2011. Follow-up took place between January and March 2012. Research assistants recorded verbatim responses to the questions, to optimize fidelity for the analysis.

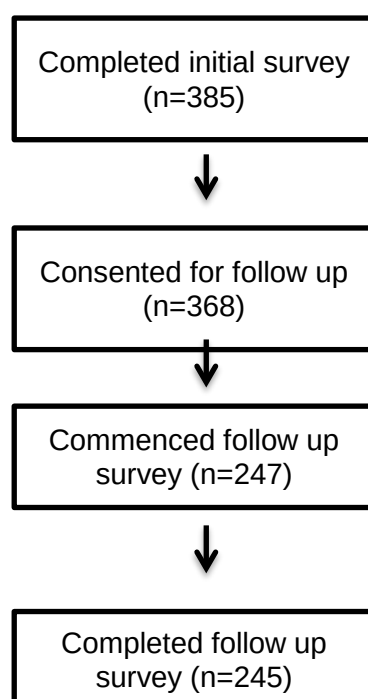
7.7 Data Analysis

Participant responses to questions were analysed using Stata 13 (College Station, TX). The number of responses that related to particular footwear types were analysed into hierarchical order of prevalence and in relation to the reported number of participant falls. Negative binomial regression was used to understand the relationship between falls and commonly worn footwear. Statistical significance was set at $p < 0.05$. A thematic analysis approach was applied to all qualitative responses by the first researcher (AD). The responses were initially grouped into like categories, then interpretation of the overarching themes [20]. A second co-author (CW) undertook an independent qualitative analysis to optimize reliability of the final results. A third researcher (TH) was consulted to settle any disputes and maximize the fidelity of data interpretation. Themes were presented quantitatively.

7.8 Results

There were 368 respondents who initially consented for the follow up survey, however, a total of 245 participants completed both waves of the survey (Figure 2).

Figure 2 Recruitment flowchart for baseline survey



There was great variation in footwear worn indoors (Table 2). The most common footwear worn indoors was enclosed slippers (n=110, 45%). Enclosed slippers represented more than double that of any other indoor footwear worn indoors. The non-footwear conditions of socks (n=49, 20%) and bare feet (n=48, 20%) respectively, were the second and third most common indoor footwear choices. No participants wore high-heeled footwear indoors.

Table 2 Footwear worn by participants, Indoor and Outdoor (n>245 as participants had more than one choice)

Footwear Type	Worn Indoor, n=245	Worn Outdoor, n=245
Slippers		
<i>Enclosed</i>	110 (45%)	0
<i>Backless</i>	42 (17%)	0
Socks	49 (20%)	0
Bare feet	48 (20%)	0
Sandals	44 (18%)	69 (28%)
Walking Shoes	40 (16%)	114 (47%)
Moccasins	24 (10%)	0
Low heeled court	20 (8%)	48 (20%)
Orthopaedic shoes	19(8%)	36 (15%)
Thongs	11(4%)	4 (2%)
Boots	5 (2%)	25 (10%)
High heeled shoes	0	7 (3%)
Other footwear types†	6 (2%)	3 (1%)

†Includes Ugg® boots, croc-style and stockings. Percentages refer to the proportion of respondents who indicated that they wear this style of footwear. As respondents could specify more than one style of footwear, these percentages add to >100%.

The most common outdoor footwear reported was walking shoes, representing 47% (n=114) of participant choice (Table 2). Sandals (n=69, 28%) and low-heeled court shoes (n=48, 20%) were the next most common footwear choices, respectively.

The reasons provided by participants as to why they wore the footwear that they chose to are presented in Table 3. The most common reason reported for indoor and outdoor footwear choices was comfort, representing more than half of all responses (indoor, n=159, 65% and outdoor, 163, 67%). The 'other' response rated as the second most commonly for reason for indoor footwear choice and included temperature issues, eg. keeping feet warm, and the next most common was habit. Indoor footwear choice for safety was reported for 6% (n=15) of participants (Table 3).

Table 3 Reasons for footwear choice, Indoor and Outdoor

Reason for choice	Indoor footwear, n=245	Outdoor footwear, n=245
Comfort	159 (65%)	163 (67%)
Other†	32 (13%)	19 (7.5%)
Ease of donning/doffing	24 (10%)	9 (4%)
Safety	15 (6%)	25 (10.2%)
Temperature related	10 (5%)	2 (1%)
Support/Balance	5 (2%)	13 (5%)
How they look	0	13 (5%)
Cost	0	1 (0.3%)

†Includes habit, health professional recommendation, self-motivated change, family influence, foot pain/pathology, convenience, cleanliness, features of footwear liked, don't like wearing footwear and only pair owned

The reason for outdoor footwear choice (Table 3) was most commonly comfort (n=163, 67%). Safety was the next most frequently reported response for outdoor footwear choice, (n=25, 10%). Examples of safety as a reason for choosing footwear by Participant #114 was "Support my ankles so I don't tip over" and Participant #209 "I feel steadier and supported in my filled in shoe." The 'other' response for outdoor footwear choice was 7.5% (n=19), with foot pain/pathology most commonly reported. Participant #95 stated, "I don't have any pain in my heels when I wear my sensible, old lady walking shoes" and Participant #71 stated, "the enclosed shoes are better because I have arthritis". The "how they look" and cost category for footwear choice was reported by respondents for outdoor footwear (n=13, 5% and n=1, 0.3%, respectively) however there were no responses for either of these categories for choice of indoor footwear (Table 3).

There were no indoor or outdoor footwear or non-footwear (stockings or barefoot) conditions associated with having one or more falls. There were two footwear conditions nearing statistical significance, wearing socks indoors (Coef, 95% CI, p=0.080) and wearing a low-heeled court shoe outdoors (Coef, 95% CI, p=0.062).

7.9 Discussion

There was no association between any footwear types and falls. Participant shoe choices were in line with other studies finding the most common footwear worn by older adults indoors were slippers [8, 13, 14]. However, this present study did not find an association between slippers (enclosed or backless) and falls. There was also no association between falls and other slipper-type footwear worn indoors, such as moccasins or Ugg® boots.

Participants within this study reported choosing footwear on a comfort basis rather than safety. Comfort was the most common reason of footwear choice for both indoor and outdoor footwear and this choice is consistent with other research [8, 14]. The term “comfort” may have variable interpretation by participants, and may well be counterproductive to safety in regard to footwear [14]. An example would be walking shoes where the outsole has worn down over a number of years of use, destabilizing the footwear. The participant may be reluctant to exchange these for new footwear, as the footwear is “worn in” and therefore comfortable [14].

Participants were less likely to report shoes chosen for safety, however, participants did report “support/balance” as the “other” responses for choice of both indoor and outdoor footwear. Participants may have been unaware or confused about the definition of “safety” of footwear and its association to falls, rather articulating, “support” as being important for choice. Support may be related to balance and therefore, falls. Safety was not considered as a primary factor for indoor footwear even though falls are more likely to occur in the home [12]. Older adults may not fully understand the importance of falls risk management within their home. It may be prudent for falls education to highlight that falls can happen indoors and outdoors [6, 12].

Socks and bare feet, rated very highly as an indoor footwear of choice and are often linked to falls in older adults in the home [3, 5, 9, 21]. Even though there was no statistical significance

for socks and falls in this study, there was a trend towards significance. Socks were the second most popular indoor footwear choice. There is a trend of “grip” on the sock sole increasing used by older people due to their use in health care [22, 23]. This is in spite of the “grip” socks having inconclusive evidence supporting it as a falls prevention strategy [22, 23].

Other footwear implicated as increasing falls risk are high-heeled footwear. None of the participants in this study wore high heels indoors, and only a small number wore high heels outdoors. There was a non-significant relationship between outdoor high heel wearing and falls. Lack of significance may be due to the small respondent number although it would appear that high heel wearing is not common in this age group [24].

Many falls prevention and management recommendations by health professions include footwear guidance. A number of participants had reported advice from health professions, particularly podiatrists and physiotherapists, about footwear. As comfort rated highly as a reason for participant footwear choice, health professionals need to consider this when making footwear recommendations. Suggesting “safe” footwear may be unclear to older adults, therefore health professional should consider explaining the relationship between the support features of footwear and safety in falls management.

Interestingly, cost and footwear aesthetics were not reported as a reason for selection of indoor footwear, and only a small number of responses for outdoor footwear. This finding is at odds with other studies reporting cost and aesthetics being an importance choice factor [14, 24]. There is the potential within this present study for response bias. Respondents may have provided obsequious responses as an effect of participating in this survey. Participating in safety-based research has been shown to change the behaviours or responses of participants [25]. As this present research primary focused on safety and preventing falls, this focus may have influenced participants answer and conflated the responses.

Type 2 error is another potential limiter in this study due to the small sample size of particular footwear types. Enclosed and backless slippers, socks, bare feet, sandals and walking shoes worn indoors, all had greater than 80% power to identify a difference in the rate of falls, with a rate difference between 25% and 50%. For all other footwear styles worn indoors, with lower frequencies of responses, there was less than 80% power to detect falls rates. While an effect this could still exist, there was insufficient data within this sample to investigate. Sandals, walking shoes and low heeled court shoes, worn outdoors, had greater than 80% power to identify a difference in the rate of falls. The other outdoor footwear styles had less than 80% power and therefore, a falls rate effect may exist however the sample size was too small to examine. Further research is needed for these indoor and outdoor footwear types to investigate whether an actual falls effect exists.

This raises an important question of how strong an effect size is needed for clinical significance for health professional footwear recommendations. For example, low-heeled court shoes were approaching statistical significance in relation to falls. Yet, low-heeled court shoes may still have an effect that could be considered clinically important. Low-heeled court shoes are often discouraged as a footwear option in regard to falls management, as they are not securely held to the foot with a strap or buckle.

7.10 Conclusion

Older adults select indoor and outdoor footwear primarily on the basis of comfort. Safety is not the primary consideration. There was no association between any footwear types chosen by participants and falls. For footwear to be part of any falls prevention strategy in the future, consideration needs to be given to comfort, safety and who recommends it rather than on a scientific basis.

7.11 References

1. Australian Commission of Safety and Quality in Healthcare. *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Hospitals*, 2009: Australia.
2. Sherrington, C and Menz, H B. *An evaluation of footwear worn at the time of fall-related hip fracture*. Age and Ageing, 2003. **32**(3): p. 310-314.
3. Tencer, A.F. et al. *Biomechanical properties of shoes and risk of falls in older adults*. Journal of the American Geriatrics Society, 2004. **52**(11): p. 1840-1846.
4. Kerse, N. et al. *Wearing slippers, falls and injury in residential care*. Australian & New Zealand Journal of Public Health, 2004. **28**(2): p. 180-7.
5. Koepsell, T.D. et al. *Footwear style and risk of falls in older adults*. Journal of the American geriatrics society, 2004. **52**(9): p. 1495-1501.
6. Menant, J.C. et al. *Optimizing footwear for older people at risk of falls*. Journal of Rehabilitation Research and Development, 2008. **45**(8): p. 1167-1182.
7. Lord, S.R. Sherrington, C and Menz, H.B. *Falls in older people - risk factors and strategies for prevention*. 2001, New York: Cambridge University Press.
8. Munro, B.J. and Steele, J.R. *Household-shoe wearing and purchasing habits. A survey of people aged 65 years and older*. J Am Podiatr Med Assoc, 1999. **89**(10): p. 506-14.
9. Horgan, N.F. et al. *The effects of usual footwear on balance amongst elderly women attending a day hospital*. Age and Ageing, 2009. **38**(1): p. 62-67.
10. Kuhirunyaratn, P. Prasomrak, P. and Jindawong, B. *Factors related to falls among community dwelling elderly*. Southeast Asian Journal of Tropical Medicine & Public Health, 2013. **44**(5): p. 906-15.
11. Sherrington, C and Menz, H B. *An evaluation of footwear worn at the time of fall-related hip fracture*. Age & Ageing, 2003. **32**(3): p. 310-4.
12. Mulley, G. *Falls in Older People*. Journal of the Royal Society of Medicine, 2001. **94**(4): p. 202-202.
13. Vass, C. et al. *What do patients wear on their feet? A service evaluation of footwear in elderly patients*. International Journal of Therapy and Rehabilitation, 2015. **22**(5): p. 225-232.
14. Davis, A. Murphy, A. and Haines, T.P. *"Good for older ladies, not me": How elderly women choose their shoes*. Journal of the American Podiatric Medical Association, 2013. **103**(6): p. 465-470.
15. Department of Health, *Preventing Falls and Harm From Falls in Older People Best Practice Guidelines for Australian Community Care*, Australian Commission on Safety and Quality in Healthcare, Editor 2009: Canberra, Australian Capital Territory, Australia.
16. Day, L. et al. *A protocol for evidence-based targeting and evaluation of statewide strategies for preventing falls among community-dwelling older people in Victoria, Australia*. Injury Prevention, 2011. **17**(2): p. e3.
17. Aboutorabi, A. et al. *A systematic review of the effect of foot orthoses and shoe characteristics on balance in healthy older subjects*. Prosthetics and Orthotics International, 2015. **40**(2): p. 170-181.
18. Hill, A.-M. et al. *Factors Associated With Older Patients' Engagement in Exercise After Hospital Discharge*. Archives of Physical Medicine and Rehabilitation, 2011. **92**(9): p. 1395-1403.
19. Folstein, M.F. Folstein, S.E. and McHugh, P.R. *Mini-mental state*. Journal of Psychiatric Research. **12**(3): p. 189-198.
20. Braun, V and Clarke, V. *Using thematic analysis in psychology*. Qualitative Research in Psychology, 2006. **3**(2): p. 77-101.

21. Menz, H.B. Morris, M.E. and Lord, S.R. *Footwear characteristics and risk of indoor and outdoor falls in older people*. Gerontology, 2006. **52**(3): p. 174-80.
22. Hartung, B and Lalonde, M. *The use of non-slip socks to prevent falls among hospitalized older adults: A literature review*. Geriatric Nursing, 2017. **38**(5): p. 412-416.
23. Chari, S. et al. *Are non-slip socks really 'non-slip'? An analysis of slip resistance*. BMC Geriatrics, 2009. **9**(1): p. 39.
24. Dunne, R.G. et al. *Elderly persons' attitudes towards footwear - A factor in preventing falls*. Public Health Reports, 1993. **108**(2): p. 245-248.
25. Den-Ching, A.L. et al. *Investigation of Older Adults' Participation in Exercises Following Completion of a State-wide Survey Targeting Evidence-based Falls Prevention Strategies*. Journal of Aging & Physical Activity, 2015. **23**(2): p. 256-263.

Chapter 8 Discussion

8.1 Chapter Summary

Falls are an increasing worldwide health issue as the population ages. Falls greatly impact individuals' quality of life and have far reaching financial implications. Footwear has been implicated as a factor in falls and falls risk. There are evidence-based guidelines regarding footwear [1] to assist health practitioners with falls management recommendations. However, these guidelines have been based on studies with limited high quality evidence, were retrospective, had limited or no falls and footwear exposure variables and limited or no validated data collection techniques or methods. This thesis offered a systematic investigation into the contributing factors associated with falls and footwear in older adults. It acknowledged the complexity between pragmatic recommendations made with limited scientific backing. This thesis systematically investigated parameters of gait in older people and footwear, the published literature on footwear styles and features and their relationships to falls and the views of older adults in regards to their footwear choices. This final chapter integrates the findings from the research contained in this thesis. It discusses how the findings may be integrated in clinical practice and falls management strategies. The clinical implications of this thesis are also discussed, as are the study limitations. It concludes with suggested directions for future research.

8.2 Summary of findings

This thesis investigated the footwear styles and features that may be a contributing factor in falls in older adults. Finally, the thesis established the most commonly worn footwear, drivers of footwear selection and perception of footwear in relation to falls and falls risk in older men and women. Chapter 2 revealed what was known about particular footwear styles, including slippers, Oxford/walking shoes, boots, sandals and high heeled footwear, in relation to falls in older

adults. There was no high quality evidence supporting any particular footwear style and a causal relationship with falls rates in older adults. There may be a general association between footwear styles and falls. There were apparent methodological concerns in many of the studies. Comparisons between footwear styles proved challenging as there were no standard footwear naming conventions. Definitions needed to be derived from the literature in an attempt to mitigate this issue. The Oxford/walking style, described as low-heeled, lace up footwear, is considered “optimal” or “safe” footwear, in falls guidelines. However, there was a dearth of quality evidence to support the recommendation that this type of footwear is safe or optimal in regard to falls.

The particular footwear style may not be as important as how accustomed the individual was to wearing that particular style of footwear. Practice effects or habituation of wearing particular footwear styles have been reported in laboratory studies. Older women who have habitually worn high-heeled footwear over a long period of time may have developed adaptive physiological and gait changes that have resulted in reduced gait parameter impacts [2, 3]. High heels as a footwear feature have also been reported to adversely affect gait parameters [4, 5]. Other footwear features may also have an effect on gait parameters and falls. This concept was explored further in Chapter 3 as particular footwear features that have been implicated in falls, were examined.

Chapter 3 investigated the relationship between specific footwear features and gait parameters that have been linked to falls. The footwear features investigated included heel height (including elevated heels), heel counter, heel collar, outsole, tread and dorsal fixation (laces, Velcro®, and buckle). The gait parameters investigated that were linked to falls are cadence, velocity, step length, stride length and foot clearance which are known to decrease with age while double support and stride time increases with age [6-10]. There may be an increase in the risk of a fall if the body's postural stability is adversely affected by footwear features manifesting in mechanical and neurophysiological modifications. As with Chapter 2,

a narrative synthesis analysis was employed rather than a meta-analytic approach as no studies had comparable methodology allowing pooling of results. There was inconsistency in the reporting of footwear features, gait parameters and an absence of falls data reported, therefore pooling of data across multiple studies was unable to be pursued. Therefore, when trying to identify any causal relationship between any footwear feature and falls, none could be concluded. Isolating specific footwear features and their effect on gait stability in relation to falls was challenging.

The footwear features that may adversely impact upon falls related gait parameters were elevated heel height, absence of heel counter and soft outsoles. Footwear features that improved falls-related gait parameters investigated were dorsal fixation (laces, Velcro[®] and buckle), heel counter and medium outsole hardness. These footwear features that could improve gait parameters and are thought to reduce the risk of falls, may represent the recommended “optimal” footwear in falls management guidelines [1]. In regard to heel height and balance, previous research has indicated that a heel above 4.5cm can result in balance issues and effects the position of the centre of pressure [2]. In addition, the position of the centre of pressure is negatively altered in heels below 0.5cm, so therefore an optimum heel height may be between 0.5cm and 4.5cm for footwear choice.

There is inconclusive evidence from any of the included studies for recommendation of an optimal outsole density or tread design. Trip-related falls were attributed to slippery outsoles of footwear. Authors have proposed that a tread outsole is therefore recommended to reduce trip or slip related falls which has been used to inform best practice guidelines for falls in community dwelling older adults in Australia. There were no studies for support of this recommendation found during this review. Normal wear and exposure to surfaces over time naturally causes deterioration to the footwear's outsole. Environment also plays a part, for example, shiny floor surfaces in shopping centres and worn floor areas as one turns to lock the door in a toilet cubicle. In both instances, smooth soled footwear would be not be ideal.

It would be difficult to establish an ideal tread design or slip-resistant outsole for older adults in relation to falls in all real life situations. It may be that rather than optimal footwear, one should consider the right footwear for the right environment and usage level.

Chapter 5 investigated footwear styles and their relationship to gait parameters thought to contribute to falls in 30 older women. Foot clearance is known to decrease with age and is often a precursor to a trip related fall in older adults. Chapter 5 reported that low heeled lace up footwear, or “optimal” footwear, had a positive effect on minimum foot clearance, improved spatiotemporal gait parameters and stability of the foot within the footwear by reducing heel slippage compared with slippers and bare feet.

The footwear feature that had the most positive effect on falls related gait parameters was dorsal fixation (laces). Dorsal fixation secured the foot into the footwear significantly reducing heel slippage and variability of gait parameters. This knowledge provides a significant contribution to the evidence as dorsal fixation, which is a standard feature on optimal footwear but frequently absent, as reported on the much-maligned slipper, may be key to stabilising the foot and reducing gait parameter variability. A study included in the Chapter 3 review showed that a slipper with dorsal fixation similar to that of optimal footwear was shown to have a positive effect on falls-related gait parameter testing [11]. As slippers are the most commonly worn footwear by older adults [12] and are often implicated in falls, a rethink in slippers design to more closely reflect optimal footwear may be prudent in relation to falls management. Healthy Footwear Guide (www.healthy-footwear-guide.com) support the need for slippers which match the criteria for a good shoe.

Chapter 6 investigated the reasons that drive footwear selection in older women. The older women who participated in the Chapter 6 study were asked a series of questions about the optimal footwear they were given in the Chapter 5 study as well as other footwear they own

and what their motivators were when purchasing new footwear. Previous studies had examined attitudes to footwear however, these studies were now quite dated, being 15- 30 years old [2, 5] and none had specifically investigated older women's footwear purchasing habits and falls. Chapter 6 provided valuable insights into the psychosocial drivers of footwear selection for older women that could assist with adherence of health practitioner's footwear recommendations.

The main themes identified in relation to footwear purchasing habits by older women were aesthetics and comfort, which was consistent with the literature for this age group. Comfort was a consideration as several of the participants had foot pain or self-reported foot pathology. Safety was the third most common consideration of footwear purchasing. However, only half of the older women still had the optimal/safe footwear given to them in the previous study and only six were still wearing them. The participants were healthy older women with no previous history of falls therefore may not have seen themselves at risk of falls. The participants regularly referenced the optimal/safe footwear from the Chapter 5 study as 'ugly' and good for older ladies but not for themselves.

8.3 Clinical implications

There appears to be a range of complex drivers of footwear choice that are related to gender, aesthetics, financial situation, ethnicity and footwear literacy of features. This means that the approach for engaging older adults in pragmatic footwear recommendations should be flexible and consumer driven. Older women who have had falls are often reluctant to make changes to footwear as there is concern about physical appearance, loss of autonomy, self-worth and self-perceived quality of life [13]. Older women primarily considered footwear in regard to fashion [13, 14]. This creates a tension between what older women want (ie. predominantly footwear that is aesthetically pleasing) and what a health professional may recommend (ie. footwear they believe is safe)[29]. Engaging with and hearing the attitudes of the client to their

condition, and discussing acceptance and expectations, in a structured consultation is crucial as well as ensuring the client actively chooses their therapeutic footwear. A critical aspect concerns presenting clinical evidence in a meaningful way and ensuring this is understood. When shared decision making tools are applied, the likelihood that therapeutic footwear will be accepted and used can be improved [29]. Consideration of the trans-theoretical model of change would be prudent to highlight the need for information at the contemplation stage, moving through to the decision stage. This is a shared decision-making process that moves clinicians away from the didactic “telling” the client what to do. Attempts by health professionals to influence the footwear selection choices of older adults may therefore require some collaborative negotiation between older adults and health practitioners and could be the subject of future research. Behaviour change strategies such as positive reinforcement for incremental changes could also be included in this work.

Work may need to be done to change the look of footwear that is considered ‘safe’ so that it also becomes aesthetically pleasing. ‘Anti-falls’ footwear already exists yet the uptake of this footwear is variable and long-term compliance is unknown [15, 16]. Perceptions that safe footwear is “ugly” has been reported as a deterrent to purchase of this footwear by older women [17]. Safe footwear may also need to be designed in a way that minimises the cost of production so that the cost to the consumer can be minimised for acceptance to be improved. Previous studies have identified that optimal footwear has been perceived by some to be more expensive than other footwear [17, 18].

The concept of safety in footwear selection and drivers of footwear choice were explored in a broader context in Chapter 7. The small cohort described in Chapter 6 elicited valuable insights into choices of footwear, however this study did not include men. Therefore, this may not be a representative sample as there was an inability to extrapolate frequencies of different perceptions to the broader population. These questions were therefore replicated in a larger study that utilised a random sampling recruitment procedure from the broader population and

was presented within Chapter 7. In Chapter 7, 65% of men and women reported that comfort was the primary consideration for indoor footwear choice and 67% for outdoor footwear choice. These findings were consistent with previous studies [12, 19]. Encouragingly, this study also found that the enclosed slipper style, that is, slippers with a heel counter, was the most common footwear worn indoors. This style was identified in Chapter 3 as having less detrimental impacts on fall-related gait parameters compared to other the slipper footwear styles. The most common outdoor footwear worn was walking style footwear, similar to the optimal footwear previously described in Chapter 5 as having minimal detrimental impacts on fall-related gait parameters.

The most common reason for both indoor and outdoor footwear choice was comfort, which reflects the findings from Chapter 6. Safety ranked as the second most common response for outdoor footwear choice, however, safety was not a consideration for indoor footwear. This finding is of great importance for falls management as older adults most commonly fall in the home [20] however safety was only a consideration for this population in outdoor footwear selection. It would be beneficial for health practitioners to convey the importance of safety in both indoor and outdoor footwear worn by older adults in falls management.

8.4 Limitations

There are several limitations of this study presented throughout the thesis.

There may be inconsistency in transferability of results in regard to the footwear styles, particularly slippers and low-heeled lace up footwear. Even though these particular footwear styles were described with accompanying pictures, nuances in footwear style design could occur altering study replicability. The chapter 5 study was also laboratory-based and therefore may not reflect real-life situations. Footwear styles were also examined without consideration of participants' lower limb joint ranges of motion and kinematics or existing podiatric pathologies that may impact gait.

Small sample size of participants and the inclusion of only women may also be an issue as participants from the Chapter 5 quantitative mechanistic study were engaged to participate in the following Chapter 6 qualitative study. A broader range of responses for drivers of footwear selection may have been elicited from a larger sample size, and may have been more diverse if the study was expanded to have included older men. However, the larger community based study described in Chapter 7 sought to address this as it included older men and women.

There may be potential bias of participant responses due to familiarity with the research team as the same participants were examined in two of the thesis studies. There was, however, candour in responses by participants particularly in regard to footwear dislikes.

The studies were primarily based in western society and therefore may not be generalisable on a global scale. Considerations of footwear choice may be dependent on cultural norms and seasonality. Slippers in western culture are soft and worn indoors however, in eastern cultures, slippers are outdoor footwear, similar to sandals, with a hard sole and strap to secure onto the foot [21]. Seasonality was noted as a factor in footwear choices in countries with differing climates. Wellington boots were reported in falls studies of cooler climate countries such as the United Kingdom and Europe [22], however were not mentioned in Australian falls and footwear studies. The Sheffield footwear toolkit may be useful as it provides a framework for influences on footwear choices [30].

8.5 Future Direction

There is a lack of clarity and tangible evidence to support a definitive footwear recommendation in regard to falls management for older adults. There are many opportunities for research in this area to inform falls management guidelines with high-level evidence.

Inconsistent footwear nomenclature was problematic throughout scientific literature which limited the replicability of footwear studies. There are few consistent naming conventions for particular footwear styles and footwear features. For example, high-heeled footwear can vary from 30mm to greater than 90mm [23-25]. Slippers may or may not have a heel counter (enclosed or backless) and have varying outsole densities and configurations [11, 26]. We sought to address this by developing footwear style definitions based on the available evidence and research team agreement in Chapter 2. Until consistency with international footwear description and naming conventions occur, it will be difficult to accurately compare outcomes of footwear studies going forward.

This thesis highlighted major methodological issues associated with falls studies. All investigated studies that included footwear variables and falls as an outcome were retrospective, using questionnaires or structured interviews, therefore relying on recall of the participants to provide falls information and circumstance. Memory recall of events and self-reporting over long periods of time, has been shown to be unreliable [27]. Real time visual observations and video recording may provide more accurate details of falls events.

Real-life situational randomised control trials are required to establish a causal link between footwear style use and falls rates in older adults. To more accurately measure the proportion of falls attributed to particular footwear styles, it would be beneficial to include a footwear exposure variable or denominator, that is, the amount of time that particular footwear is worn. The use of activity trackers and global position systems (GPS) imbedded into footwear, would assist with logging of footwear use to glean more precise falls and footwear data. As technology advances and has increasingly become more economical, trials using these features become readily accessible and feasible [28]. Laboratory study findings in combination with pragmatic, real-life situational studies would provide a complete picture for health practitioner recommendation of a footwear styles and features in relationship to falls.

Other research of note, that has occurred since publication of the Chapter 5 and 6 studies that have added to the footwear body of literature include work by Kunzler et al, [32]. *Should we consider steps with variable height for a safer stair negotiation in older adults?*, and McRitchie et al. [33]. *Footwear choices for painful feet– an observational study exploring footwear and foot problems in women*. Both of these recent studies offer insightful commentary in regard to falls management and align with the findings of the published chapter studies in this thesis.

8.6 Concluding Remarks

The research aims stated at the beginning were met from the studies and content presented in the thesis. The aims and conclusions were:

Research Aim 1. *Examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking and,*
Research Aim 2. *Compare spatiotemporal parameters of gait when wearing slippers, well-fitted footwear and walking bare foot.* Footwear with dorsal fixation resulted in improved minimum foot clearance compared to the slippers and bare foot conditions and less heel slippage than slippers and an increase in double support. These features lend weight to the argument that older women should be supported to make footwear choices with optimal fitting features including dorsal fixation (Chapter 5).

Research Aim 3. *Identify factors that drive footwear selection and use amongst older community-dwelling women, aged 60 to 80 years who had no previous history of falls.* The main themes identified about footwear selection were aesthetics and comfort. Aesthetics was by far the main factor influencing footwear choice. Wearing safe footwear was not identified as a consideration when purchasing footwear. Older women are driven primarily by aesthetics and comfort in their footwear selection. These footwear drivers have implications for health-care providers when delivering fall and foot health education (Chapter 6).

Research Aim 4. *Examine the relationship between footwear preferences and whether older adults (men and women) fell or not during the preceding 12-month period.* There was no association found between slippers or any other indoor or outdoor footwear types chosen by participants and falls. Comfort was the most common reason for indoor and outdoor footwear choice. Safety was the second most reported reason for outdoor footwear choice but reported less frequently for indoor wear. For footwear to be part of falls prevention strategy in the future, comfort and safety should be considered (Chapter 7).

As falls guidelines are based on limited evidence and do not consider motivators of footwear selection for older adults, health practitioners should be pragmatic and collaborative in their advice to older adults about footwear styles and their potential to reduce falls or falls risk.

This thesis revealed that even though health practitioners advocate for Oxford/walking style footwear for older adults in regard to falls management, there is limited evidence supporting any particular footwear style as a discrete falls prevention strategy. Specific footwear features, such as presence of a heel counter and dorsal fixation, may be of benefit in falls management however more rigorous testing in real-life situations is required to better understand their effects.

It is critical that health practitioners understand the psyche of older adult and footwear choice if we are to make headway into behavioural change in footwear selection. This thesis has provided valuable insights into the footwear styles that older adults choose and the drivers of their footwear selection. Footwear that is palatable and acceptable in style, aesthetics, cost, and function, is required for older adults to action and sustain footwear recommendation in relation to falls management. Otherwise, falls prevention footwear may well have its home in the wardrobe rather than on the feet of older adults.

8.7 References

1. *Summary of the Updated American Geriatrics Society/British Geriatrics Society Clinical Practice Guideline for Prevention of Falls in Older Persons*. Journal of the American Geriatrics Society, 2011. **59**(1): p. 148-157.
2. Menant, J.C., Steele, J.R., Menz, H.B., Munro, B.J. and Lord, S.R. *Effects of footwear features on balance and stepping in older people*. Gerontology, 2008;54(1):18-23
3. Opila-Correia, K. *Kinematics of high-heeled gait with consideration for age and experience of wearers*. Archives of physical medicine and rehabilitation, 1990. **71**(11): p. 905-909.
4. Lee, C.-M. Jeong, E.H. and Freivalds, A. *Biomechanical effects of wearing high-heeled shoes*. International journal of industrial ergonomics, 2001. **28**(6): p. 321-326.
5. Cronin, N.J. *The effects of high heeled shoes on female gait: A review*. Journal of Electromyography and Kinesiology, 2014. **24**(2): p. 258-263.
6. Merrifield, H. *Female gait patterns in shoes with different heel heights*. Ergonomics, 1971. **14**(3): p. 411-417.
7. Mortaza, N. Abu Osman, N.A. and Mehdikhani, N. *Are the spatio-temporal parameters of gait capable of distinguishing a faller from a non-faller elderly?* Eur J Phys Rehabil Med, 2014. **50**(6): p. 677-91.
8. Makino, K. et al. *Fear of falling and gait parameters in older adults with and without fall history*. Geriatr Gerontol Int, 2017.
9. Killeen, T. et al. *Minimum toe clearance: probing the neural control of locomotion*. Sci Rep, 2017. **7**(1): p. 1922.
10. Hirsch, T. et al. *Subjective Gait Stability in the Elderly*. Z Gerontol Geriatr, 2017.
11. Hollman, J.H. McDade, E.M. and Petersen, R.C. *Normative Spatiotemporal Gait Parameters in Older Adults*. Gait & posture, 2011. **34**(1): p. 111-118.
12. Menz, H.B. Auhl, M. and Munteanu, S.E. *Effects of Indoor Footwear on Balance and Gait Patterns in Community-Dwelling Older Women*. Gerontology, 2017. **63**(2): p. 129-136.
13. Munro, B.J. and Steele, J.R. *Household-shoe wearing and purchasing habits. A survey of people aged 65 years and older*. J Am Podiatr Med Assoc, 1999. **89**(10): p. 506-14.
14. Frey, C. *Foot health and footwear for women*. Clinical Orthopaedics & Related Research, 2000(372): p. 32-44.
15. Frey, C. et al. *American Orthopaedic Foot and Ankle Society women's shoe survey*. Foot & Ankle International, 1993. **14**(2): p. 78-81.
16. *B Shoes*. 2017; Available from: <http://b-shoe.com>.
17. Menz, H. for Channel 9 News Melbourne Australia. *Innovative shoes could help prevent falls in the elderly*. 2018; Available from: <https://http://www.9news.com.au/national/2017/11/22/19/41/innovative-shoes-could-help-prevent-falls-in-the-elderly>.
18. Dunne, R.G. et al. *Elderly persons' attitudes towards footwear - A factor in preventing falls*. Public Health Reports, 1993. **108**(2): p. 245-248.
19. Davis, A. Murphy, A. and Haines, T.P. *"Good for older ladies, not me": How elderly women choose their shoes*. Journal of the American Podiatric Medical Association, 2013. **103**(6): p. 465-470.
20. Jessup, R.L. *Foot pathology and inappropriate footwear as risk factors for falls in a subacute aged-care hospital*. Journal of the American Podiatric Medical Association, 2007. **97**(3): p. 213-7.
21. Mulley, G. *Falls in Older People*. Journal of the Royal Society of Medicine, 2001. **94**(4): p. 202-202.
22. Kuhirunyaratn, P. Prasomrak, P and Jindawong, B. *Factors related to falls among community dwelling elderly*. Southeast Asian Journal of Tropical Medicine & Public Health, 2013. **44**(5): p. 906-15.

23. Gabell A, Simons M A and Nayak U L S. *Falls in the healthy elderly: Predisposing causes*. Ergonomics, 1985. **28**(7): p. 965-975.
24. Gerber, S.B. et al. *Interference of high-heeled shoes in static balance among young women*. Human Movement Science, 2012. **31**(5): p. 1247-1252.
25. Hapsari, V.D. and Xiong, S. *Effects of high heeled shoes wearing experience and heel height on human standing balance and functional mobility*. Ergonomics, 2016. **59**(2): p. 249-264.
26. Hong, W.H., et al. *Effect of shoe heel height and total-contact insert on muscle loading and foot stability while walking*. Foot and Ankle International, 2013. **34**(2): p. 273-281.
27. Vass, C. et al. *What do patients wear on their feet? A service evaluation of footwear in elderly patients*. International Journal of Therapy and Rehabilitation, 2015. **22**(5): p. 225-232.
28. Stone, A.A. and Shiffman, S. *Capturing momentary, self-report data: A proposal for reporting guidelines*. Annals of Behavioral Medicine, 2002. **24**(3): p. 236-243.
29. *Engadget for Evone Smart Shoes*. 2018; Available from: <https://http://www.engadget.com/2018/01/07/e-vone-smart-shoes/>.
30. Jaap J.van Netten, Francis, A. Morphet, A. et al. *The importance of communication in therapeutic footwear provision*. Prosthetics and Orthotics International. 2016
31. Fardon et al. The Sheffield Footwear Toolkit
<https://www.sheffield.ac.uk/podiatrytoolkit>
32. Kunzler, M.R., da Rocha, E.S., Dos Santos, C.S., Ceccon, F.G., Priario, L.A. and Carpes, F.P., 2018. *Should we consider steps with variable height for a safer stair negotiation in older adults?* Work, 59(1), pp.15-21
33. McRitchie, M., Branthwaite, H. and Chockalingam, N., 2018. *Footwear choices for painful feet– an observational study exploring footwear and foot problems in women*. Journal of foot and ankle research, 11(1), p.23

Appendices

Appendix 1 Ethics approval

Southern Health

Southern Health

HUMAN RESEARCH ETHICS COMMITTEE B CERTIFICATE OF APPROVAL

DATE 27 August 2007
PROJECT NO. 07085B
PROJECT TITLE A Comparison Of Minimum Toe-Clearance In Relation To Tripping, Using Low Heeled, Lace Up Footwear And Slippers In An Elderly Female Population.
Participant Information Sheet Version No. 02 dated 23 July 2007
Consent Form Version No. 02 dated 23 July 2007

INVESTIGATOR(S) Ms Annette Davis
HREC MEETING DATE 04.06.07
APPROVAL 27.08.2007 – 27.08.2010

The Principal Investigator is required to notify the Manager of Research Directorate of:

1. Any change in protocol and the reason for that change together with an indication of ethical implications (if any)
2. Serious or unexpected adverse effects of project on subjects and steps taken to deal with them
3. Any unforeseen events that might affect continued ethical acceptability of the project
4. Any expiry of the insurance coverage provided in respect of sponsored trials
5. Discontinuation of the project before the expected date of completion, giving reasons
6. Any change in personnel involved in the research project including any study member resigning from Southern Health &/or the study team.

At the conclusion of the project or every twelve months if the project continues, the Principal Investigator is required to complete and forward an annual report to the Committee. Annual report forms will be forwarded to the researcher.

SIGNED [Redacted] **DATE** 27 August 2007
Committee Representative

Please quote Project No. and Title for all correspondence

Winner of the Premier's Award for Outstanding Metropolitan Health Service of the Year 2005

Southern Health

ABN 82 142 080 338

Dandenong Hospital
Kingston Centre
Cranbourne Integrated
Care Centre

Monash Medical Centre
Casey Hospital

Community Health
Services across the
South East

www.southernhealth.org.au

Appendix 2. Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measure of gait in old women (Publication)

Gait & Posture 44 (2016) 43–47



Contents lists available at ScienceDirect

Gait & Posture

Journal homepage: www.elsevier.com/locate/gaitpost



Full length Article

Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women



Annette M. Davis^{a,b,c,*}, Brook Galna^{d,e}, Anna T. Murphy^d, Cylie M. Williams^{b,c}, Terry P. Haines^{b,c}

^a Monash Health, Podiatry Department, Kingston Centre, 400 Warrigal Road, Cheltenham, VIC 3192, Australia

^b Monash University, Physiotherapy Department, Clayton Campus, Clayton, VIC 3168, Australia

^c Monash Health, Allied Health Clinical Research Unit, Kingston Centre, 400 Warrigal Road, Cheltenham, VIC 3192, Australia

^d Clinical Research Centre for Movement Disorders and Gait, Kingston Centre, 400 Warrigal Road, Cheltenham, VIC 3192, Australia

^e Institute of Neuroscience, Newcastle University Institute for Ageing, Newcastle University, Newcastle upon Tyne NE4 5PL United Kingdom

ARTICLE INFO

Article history:

Received 10 February 2015

Received in revised form 28 October 2015

Accepted 3 November 2015

Keywords:

Falls

Tripping

Footwear

Older

Women

ABSTRACT

Footwear has been implicated as a factor in falls, which is a major issue affecting the health of older adults. This study investigated the effect of footwear with dorsal fixation, slippers and bare feet on minimum foot clearance, heel slippage and spatiotemporal variables of gait in community dwelling older women. Thirty women participated (mean age (SD) 69.1 (5.1) years) in a gait assessment using the GaitRITE and Vicon 612 motion analysis system. Conditions included footwear with dorsal fixation, slippers or bare feet. Footwear with dorsal fixation resulted in improved minimum foot clearance compared to the slippers and bare feet conditions and less heel slippage than slippers and an increase in double support. These features lend weight to the argument that older women should be supported to make footwear choices with optimal fitting features including dorsal fixation. Recommendations of particular styles and features of footwear may assist during falls prevention education to reduce the incidence of foot trips and falls.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Falls are a major health issue and burden on the public health system. A significant number of reported falls in the older population are related to tripping, which have been attributed to inadequate foot clearance during the swing phase of gait [1]. Footwear has also been identified as playing an important role in the prevention of falls in older adults [2]. Yet older women are reluctant to make changes into footwear that have established fit and features associated with increased stability [3].

Footwear encompassed many different styles, heel heights and features. The features thought to increase the stability of footwear are; dorsal fixation (laces, velcro straps) however there is limited

evidence to support this theory. There is an evidence deficit in how dorsal fixation may impact falls yet it is a common recommendation in falls prevention education. Heel height [4,5] has been the primary shoe feature linked with falls in the older. Walking barefoot, in slippers or socks has been correlated with a higher likelihood of falls (odds ratio 13.7) [6] yet many older adults, women in particular, wear slippers in their home [7]. In addition, slippers were the most commonly worn footwear at the time of a fall-related hip fracture in a study of 95 older people [2] and while 16 of these people also were wearing walking shoes, 12 of these people were also in footwear with at least one theoretically sub-optimal feature such as lack of dorsal fixation and flexible heel counter. Whether the fall was initiated by footwear related trip however was not recorded.

Slippers often lack many key features that secure the shoe to the foot and reduce trips and slips. Poor fit (too long or too wide) have been noted as common in rehabilitation settings [8] and retirement villages [9] with older people, primarily for comfort and to accommodate foot deformities. Many slippers do not contain dorsal fixtures or have any form of stabilisation around the heel or sole area. These key structural footwear features may help

* Corresponding author at: Clinical Research Centre for Movement Disorders and Gait, Kingston Centre, 400 Warrigal Road, Cheltenham, VIC 3192, Australia. Tel.: +61 3 9265 0000; fax: +61 3 9594 6630.

E-mail addresses: Annette.davis@monashhealth.org (A.M. Davis),

brook.galna@newcastle.ac.uk (B. Galna),

Anna.Murphy@monashhealth.org (A.T. Murphy), Cylie.williams@monash.edu

(C.M. Williams), Terrence.haines@monash.edu (T.P. Haines).

<http://dx.doi.org/10.1016/j.gaitpost.2015.11.003>
0966-6362/© 2015 Elsevier B.V. All rights reserved.

prevent the foot from slipping and may reduce the risk of falls [8–10]. It has not been previously reported in the literature if the fit of the slipper is a contributing factor to falls and how this may compare to dorsally secured footwear.

Inadequate foot clearance during gait may also predispose a person to tripping and falling. Older men have demonstrated variable foot clearance [11] and this variability has been directly related to aging and trips [12]. While these studies have been conducted primarily within bare feet or in a shoe with dorsal fixtures, there has been no established impact of wearing slippers on minimum foot clearance, particularly in older women. Similarly, it is unknown what impact wearing slippers have on the spatiotemporal features of gait (i.e. cadence, time in double support, step length).

Due to the lack of evidence supporting any of the key features in commonly worn footwear impacting on falls, the aim of this study was to examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking. It was hypothesised that walking in well-fitted footwear with dorsal fixation would result in less heel slippage and a higher minimum foot clearance compared to walking in slippers. A secondary aim of this study was to compare spatiotemporal characteristics of gait when wearing slippers, well-fitted footwear and walking bare foot. It was hypothesised that participants would walk faster, with an increase step length and reduced double limb support in well-fitted footwear compared to walking in slippers or bare feet. This knowledge will improve understanding of the key features of commonly worn footwear and its potential impact on the mechanics of falls.

2. Method

2.1. Study design

This study designed was a within subject randomised control trial for the three footwear conditions. Permuted block randomisation between footwear conditions was conducted.

2.2. Participants and setting

Thirty community dwelling females aged between 60 and 80 years were recruited to participate in the study. Power estimates were calculated from the effects of footwear on walking speed and confirmed that 30 participants would provide sufficient statistical power ($\alpha = .05$, 1; $\beta > .8$) for this study [13]. Inclusion criteria required that participants were able to ambulate unaided, have no cardiothoracic, orthopaedic or neurological symptoms, or medication that had potential to affect their gait and no history of injurious falls. Participants were also excluded if they were diagnosed with severe dysphasia that interfered with communication; or if they presented with significant cognitive impairment affecting their gait or ability to participate in testing.

2.3. Footwear

The primary investigator fitted the “prescribed” footwear and slippers based on the size that the participant usually wore and by ensuring length of 1–2 cm from the longest toe, and minimal medial and lateral movement within the shoe. The “prescribed” footwear was chosen based the common features of footwear articulated within falls prevention management [3]. Slippers choice was made by observing the most common accessible, cost effective slipper in local stores at the time of data collection. Participants were asked if they were comfortable in the shoe and if the shoe felt that it was appropriately fitted to ensure correct fitting. The size of the shoe was recorded within the demographic data.

Participants were fitted with both the:

1. Slippers (Fig. 1a): Synthetic material upper, flat rubber sole, no dorsal fixation, weight, 127 g.
2. Prescribed footwear (Fig. 1b): Low heeled (2.5 cm heel height and 2.0 cm toe pitch), leather upper, laced fixations with five eyelet points, EVA midsole and rubber outsole, 128 g.

Participants were required to wear both the slipper and the prescribed footwear for approximately 2 weeks as part of their normal daily activity, to familiarize themselves with the footwear. Following this, the participants attended a single appointment for three-dimensional gait assessment. At this appointment, demographic data was collected including: age, height and weight.

2.4. Gait assessment

Participants walked five times along a 10 m walkway at their preferred pace for each condition: bare feet; well-fitted footwear; and slippers. For all conditions the participants were requested to look straight ahead and started their walk at least 2 m before an 8.3 m instrumented walkway (GaitRITE®, CIR Systems Inc, Havertown, PA, USA) walkway and were asked to continue walking at least 2 m beyond the end of the walkway to avoid accelerating or slowing down during data capture on the mat. Participants were required to rest between each change in footwear for 5 m to minimise fatigue. Minimum foot clearance and heel slippage were determined using the Vicon 612 motion analysis system sampling at 100 Hz (Vicon Peak, Oxford, UK). Spatiotemporal gait characteristics were calculated from data collected using the instrumented GaitRITE® walkway.

2.5. Minimum foot clearance

Minimum foot clearance was defined as the minimum distance between the plantar, distal aspect of the phalanx and the ground during the mid-swing phase of gait [14]. This measure (mm) was determined by placement of ten reflective markers attached to

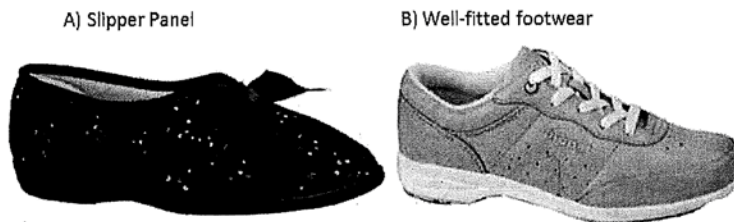


Fig. 1. Footwear used within the study: Panel (A) slipper; Panel (B) well-fitted footwear.

specific landmarks on the feet/footwear and lower limbs as previously described [15]. Briefly, reflective markers were placed on the first and fifth meta-tarsal phalangeal joints, and on the distal, dorsal aspect of the large toe. The position of the plantar, distal aspect of the phalanx was measured relative to the three forefoot markers and the ground during quiet standing and its position calculated as a virtual marker during the gait trials during post processing. The minimum foot clearance was measured from this virtual marker as per the methods illustrated by Begg et al [1]. The gait laboratory equipment is maintained regularly ensuring the capture zone has less than 1 mm (3/64 in.) of measurement error therefore system error is very small and highly reliability in measuring dynamic marker position. The measurement of foot trajectories in older women has already been shown to be highly reliable across different speeds [16].

2.6. Heel slippage

Heel slippage was measured by placing reflective markers on the heel counter of the footwear (well-fitted footwear or slipper conditions) or calcaneus (bare foot condition), and another marker placed on the muscular-tendonous junction of the Achilles tendon (calf marker) (Fig. 2b). The distance between the heel and calf markers was measured using an eight camera Vicon motion analysis system. Maximum heel slippage (mm) was defined as the difference between maximum distance of the heel and calf markers during bare foot walking (where there is no foot slippage) and the maximum distance between the heel and calf markers when walking in either slippers or prescribed footwear.

2.7. Spatiotemporal gait characteristics

Spatiotemporal gait characteristics derived using proprietary software (GaitRite®) included: step length (m), step duration (s), single limb support duration (s), double limb support duration (s), step velocity (m/s) and step width (mm).

2.8. Data analysis

Maximum heel slippage and minimum foot clearance were determined from a mean of 18 steps per participant per condition. Spatiotemporal characteristics were calculated from a mean of 54 steps per condition. The variability of minimum foot clearance and heel slippage was calculated as the within-person standard deviation of gait characteristics using established methods to avoid the potential confounding of asymmetry [15].

Visual inspection of the data revealed that distributions conformed to a normal distribution, therefore a repeated-measure ANOVA was used to test for main effects of footwear. Planned comparisons using a series of two-way paired *t*-tests were made

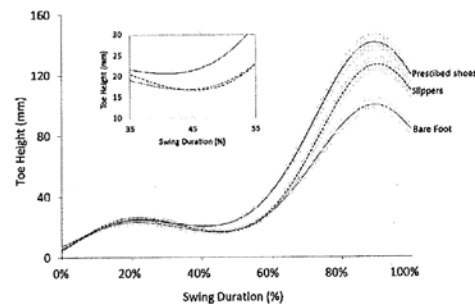


Fig. 2. Mean foot height above the ground across 100% of the swing phase of gait is illustrated for each footwear condition for aggregate group data. Grey shaded areas represent 95% confidence intervals. The insert shows foot clearance during the mid-swing phase of gait.

between the three footwear conditions. A threshold of $p < .05$ was used to guide statistical interpretation.

The Human Research Ethics Committee of Monash Health (Formerly Southern Health) approved this research.

3. Results

We tested 30 female participants; the mean (SD) age was 69.1 (5.1) years, mean height (SD) was 157.2 (.74) cm and the mean body mass (SD) was 69.8 (7.1) kg. The mean issued shoe size was a Ladies American size 8. Each participant completed all three conditions.

Results of the gait assessment are summarised in Table 1 and corresponding ANOVA statistics are reported in Table 2. Participants walked with a 4 mm higher minimum foot clearance when wearing the well-fitted footwear compared to bare feet and slippers, however there was no difference between barefoot walking and wearing slippers (Fig. 1).

Mean heel slippage was 19% greater and 50% more variable when participants walked in the slippers compared to the well-fitted footwear. There was greater within-subject variability of the heel slippage in the slipper compared to the well-fitted shoes that was potentially a result of the different shoe design features.

Footwear affected a range of spatiotemporal gait characteristics. When wearing the well-fitted footwear, participants walked faster and with a longer step length, a narrower step width, a shorter step duration and greater minimum foot clearance and less heel slippage compared to walking barefoot or with slippers. Wearing slippers was also associated with slightly longer step duration.

Table 1
Summary of foot slippage, foot clearance and spatiotemporal gait outcomes.

Variable		Barefoot Mean (SD)	Well-fitted footwear Mean (SD)	Slippers Mean (SD)
Mean gait characteristics	Minimum foot clearance (mm)	15.7 (4.7) ^w	19.7 (3.8) ^{bs}	15.7 (3.6) ^w
	Maximum heel slippage (mm)	–	13.1 (7.4) ^s	15.5 (5.36) ^w
	Step velocity (m/s)	1.26 (0.08) ^{ws}	1.35 (0.08) ^{bs}	1.31 (0.08) ^{bsw}
	Step length (m)	0.602 (0.03) ^{ws}	0.652 (0.03) ^{bs}	0.640 (0.03) ^{bsw}
	Step duration (s)	0.483 (0.02) ^s	0.487 (0.02) ^s	0.492 (0.02) ^{bsw}
	Double limb support (s)	0.094 (0.01) ^{ws}	0.115 (0.01) ^{bs}	0.103 (0.01) ^{bsw}
Within-person variability (sd) of gait characteristics	Step width (mm)	93.1 (12)	89.2 (15)	94.7 (10)
	Minimum foot clearance (mm)	3.549 (1.865)	3.062 (0.973)	3.637 (1.033)
	Maximum heel slippage (mm)	–	2.681 (0.889) ^s	4.018 (1.550) ^w

Superscript letters indicate a statistically significant difference ($p < .05$) between two types of footwear: w, well-fitted footwear; b, barefoot and s, slippers.

Table 2

Summary of statistics from repeated measure analysis of variance to assess differences among the means of barefoot (BF), well-fitted footwear (PS), and slippers (SL) footwear conditions.

Variable		F	P
Mean gait characteristics	Minimum foot clearance	13.17	<.001 [*]
	Maximum heel slippage	5.78	.023 [*]
	Step velocity	38.54	<.001 [*]
	Step length	106.48	<.001 [*]
	Step duration	8.77	<.001 [*]
	Double limb support	1.33	.273
	Step width	2.57	.085
Within-person variability (sd) of gait characteristics	Minimum foot clearance	2.36	.103
	Maximum heel slippage	22.75	<.001 [*]

^{*} Significant effect of footwear ($p < .05$).

When wearing slippers as compared to walking barefoot, the participants had longer steps, and an increased step and double limb support duration ($p < 0.05$). When walking bare foot as compared to walking in the well-fitted shoes, participants walked slower, with shorter step length and with a reduced minimum toe clearance ($p < 0.05$). There were no differences between footwear conditions for within-subject variability of minimum toe-clearance ($p > 0.05$) but greater within-subject variability for all spatiotemporal variables ($p < 0.05$) except step length when wearing slippers compared to the well-fitted shoes.

4. Discussion

This study has identified that the footwear older women wear when walking can significantly impact on foot trajectories (minimum foot clearance), stability of the foot within the footwear (heel slippage) and spatiotemporal characteristics. This has implications for advice regarding the choice and development of footwear that will reduce fall risk in older women.

Participants walked with a greater minimum foot clearance when wearing the well-fitted footwear, this is footwear where the heel is secured and not slipping out of the shoe during gait. This supports the hypothesis that wearing footwear with dorsal fixation may assist in reducing the likelihood of tripping. The well-fitted footwear has a 20 mm toe-pitch at the distal edge of the shoe, improving the rolling effect of the shoe during ambulation. This is also likely to contribute to a higher minimum foot clearance as, even in static stance, the toes are elevated from the supporting surface. The slippers had a totally flat sole and no toe pitch, therefore the distal edge of the slipper was in contact with the floor, this potentially contributed to the lower foot clearance.

It is important to maintain the stability of the foot within the shoe to maintain balance and guide the foot over potential trip risks when walking. In agreement with our hypothesis, maximum heel slippage was significantly greater when walking in slippers compared to well-fitted footwear. This is proposed to be directly attributed to the lack of dorsal fixation on the slipper. This deficit allows the heel to move more freely upward and out of the slipper at the heel-off phase of gait. An increase in heel slippage may result in balance instability and place greater demands on the lower limb motor control system to keep the shoe on the foot. This is also supported by the greater within-subject variability of heel slippage of the slipper compared to well-fitted footwear. Loose fitting footwear may also promote greater and more variable heel slippage, even with dorsal fixation, however we can discount this

as a potential confounding factor in this study as the footwear was appropriately fitted by a podiatrist.

A secondary aim of this study was to examine the effect of footwear on the spatiotemporal characteristics of gait. The ability of the women within this study to walk faster, yet increase their period of double support when wearing the well-fitted footwear compared to the slippers, suggests that the firm heel counter and adjustable laces of the shoe that secures the shoe onto the foot, may improve walking confidence of the wearer. It is unknown if this is a result from a decrease or change in the demand on the musculoskeletal system or change in the range of motion of the leg and foot as observed in other studies on supportive footwear in younger people [17]. Similarly, footwear has been identified as having an impact on the proprioceptive systems [18,19] during gait therefore it is unknown if these changes in gait are a result of these impacts.

There was a key limitation within this study. While the slippers and prescribed footwear conditions were footwear that is readily available within the community, there will be variations in transferability of results. However the footwear and features used within the study were similar to many walking style shoes therefore increasing generalizability. Different brands of low-heeled lace up footwear will have varying shoe features, heel height and toe pitch. While foot deformity limiting gait was excluded, it is unknown if there were biomechanical variations between participants. Ankle flexibility and strength of the dorsi/plantar flexors of the foot and ankle have been found to reduce with age [20]. These particular foot features were not taken into consideration within this study. Future studies on foot clearance and footwear should consider range of motion and dynamometry assessment. In addition, randomised controlled trials with large cohorts are required to establish whether well-fitted footwear can indeed reduce the prevalence and frequency of falls in older women, as well as whether our findings also hold in older men.

Finally, we did not directly examine the relationship between footwear features or foot clearance with falls in our participants. It is possible that older women wearing appropriately fitted footwear with dorsal fixation may feel more secure and attempt activities that may be "riskier" than activities they may attempt while wearing footwear that they are less secure in. "Risk compensation" behaviours have previously been identified as a reason why some interventions that should theoretically reduce the risk of falls may not do so in real life [21]. Hence, experimental studies examining the effect of using different types of footwear are warranted in order to fully understand the relationship between footwear interventions and falls.

5. Conclusion

The type of footwear worn by older females can influence minimum foot clearance, maximum heel slippage and spatiotemporal variables of gait and, therefore, may impact on falls risk. Footwear with dorsal fixtures was shown to improve foot clearance and many gait features making them an ideal choice for ambulant older adults.

Conflicts of interest

None.

Acknowledgement

Monash Health (formerly Southern Health) Research Directorate (MHRD): Emerging Researcher Fellowships. MHRD had no role in the study design, collection, analysis or interpretation of data.

References

- [1] Begg R, Best R, Dell'Oro L, et al. Minimum foot clearance during walking: strategies for the minimisation of trip-related falls. *Gait Posture* 2007;25(2):191–8.
- [2] Sherrington C, Menz HB. An evaluation of footwear worn at the time of fall-related hip fracture. *Age Ageing* 2003;32(3):310–4.
- [3] Davis A, Murphy A, Haines TP. Good for older ladies, Not Me! How elderly women choose their shoes. *J Am Podiatr Med Assoc* 2013;103(6):465–70.
- [4] Tencer AF, Koepsell TD, Wolf ME, et al. Biomechanical properties of shoes and risk of falls in older adults. *J Am Geriatr Soc* 2004;52(11):1840–6.
- [5] Gabell A, Simons MA, Nayak US. Falls in the healthy elderly: predisposing causes. *Ergonomics* 1985;28(7):965–75.
- [6] Menz HB, Morris ME, Lord SR. Footwear characteristics and risk of indoor and outdoor falls in older people. *Gerontology* 2006;52(3):174–80.
- [7] Munro BJ, Steele JR. Household-shoe wearing and purchasing habits. A survey of people aged 65 years and older. *J Am Podiatr Med Assoc* 1989;89(10):506–14.
- [8] Burns SL, Leese GP, McMurdo ME. Older people and ill fitting shoes. *Postgrad Med J* 2002;78(920):344–6.
- [9] Menz HB, Morris ME. Footwear characteristics and foot problems in older people. *Gerontology* 2005;51(5):346–51.
- [10] Lord SR, Sherrington C, Menz HB. Falls in older people—risk factors and strategies for prevention. New York: Cambridge University Press; 2001.
- [11] Mills PM, Barrett RS, Morrison S. Toe clearance variability during walking in young and elderly men. *Gait Posture* 2008;28(1):101–7.
- [12] Barrett RS, Mills PM, Begg RK. A systematic review of the effect of ageing and falls history on minimum foot clearance characteristics during level walking. *Gait Posture* 2010;32(4):429–35.
- [13] Cohen J. Statistical power analysis for the behavioural sciences. New Jersey: Lawrence Erlbaum; 1988.
- [14] Moosabhoy MA, Gard SA. Methodology for determining the sensitivity of swing leg toe clearance and leg length to swing leg joint angles during gait. *Gait Posture* 2006;24(4):493–501.
- [15] Galna B, Lord S, Rochester L. Is gait variability reliable in older adults and Parkinson's disease? Towards an optimal testing protocol. *Gait Posture* 2013;37(4):580–5.
- [16] Karst GM, Hageman PA, Jones TF, et al. Reliability of foot trajectory measures within and between testing sessions. *J Gerontol A Biol Sci Med Sci* 1999;54(7):M343–7.
- [17] Wolf S, Simon J, Patikas D, et al. Foot motion in children shoes: a comparison of barefoot walking with shod walking in conventional and flexible shoes. *Gait Posture* 2008;27(1):51–9.
- [18] Waddington GS, Adams RD. The effect of a 5-week wobble-board exercise intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: a study in healthy elderly. *J Am Geriatr Soc* 2004;52(4):573–6.
- [19] Robbins S, Gouw GJ, McClaran J. Shoe sole thickness and hardness influence balance in older men. *J Am Geriatr Soc* 1992;40(11):1089–94.
- [20] Menz HB, Morris ME, Lord SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. *J Gerontol Ser A—Biol Sci Med Sci* 2005;60(12):1546–52.
- [21] Haines TP, Lee DCA, O'Connell B, et al. Why do hospitalized older adults take risks that may lead to falls? *Health Expect* 2012.

Appendix 3. “Good for older Ladies, Not Me”. How elderly women choose their shoes. (Published)

Preventing Falls in Older People: The Role of Footwear and Lower-Extremity Interventions ORIGINAL ARTICLES

“Good for Older Ladies, Not Me” *How Elderly Women Choose Their Shoes*

Annette Davis, BAppSc(Pod)*
Anna Murphy, BAppBiomech, PhD†
Terry P. Haines, PhD‡

Background: Footwear selection is important among older adults. Little is known about factors that influence footwear selection among older women. If older women are to wear better footwear that reduces their risk of falls and foot abnormalities, then a better understanding of the factors underlying footwear choice is needed. This study aims to identify factors that drive footwear selection and use among older community-dwelling women with no history of falls.

Methods: A cross-sectional survey using a structured, open-ended questionnaire was conducted by telephone interview. The participants were 24 women, 60 to 80 years old, with no history of falls or requirement for gait aids. The responses to open-ended questions were coded and quantified under a qualitative description paradigm.

Results: The main themes identified about footwear selection were aesthetics and comfort. Aesthetics was by far the main factor influencing footwear choice. Wearing safe footwear was not identified as a consideration when purchasing footwear.

Conclusions: This study indicates that older women are driven primarily by aesthetics and comfort in their footwear selection. These footwear drivers have implications for health-care providers when delivering fall and foot health education. (J Am Podiatr Med Assoc 103(6): 465-470, 2013)

Footwear selection is important in older adults. Unstable and poorly fitting footwear can increase the chance of tripping and falling, leading to injury and mortality.¹⁻⁵ Poor choices with footwear selection can also contribute to foot abnormalities, including bunions, toe deformity, and foot pain.⁶⁻⁸ Falls are the single biggest reason for injury-related admission to the hospital and presentations to the emergency department for individuals older than 65 years.¹ One in three individuals older than 65 years experience one or more falls in a given year,⁹ although this increases to one in two among those

older than 85 years. Common injuries resulting from a fall include hip fractures, wrist fractures, and head injuries.¹ Falls may lead to other complications, including a fear of falling, loss of confidence in walking, and a reduction in quality of life.¹

Footwear has been identified as a risk factor in falls and fall-related injury.³⁻⁶ Particular features of footwear can increase the risk of falling, including a narrow heel, lack of or inadequate fixation, slippery soles, and footwear that is poorly fitted.¹⁰⁻¹² Slippers and unsafe footwear are frequently identified as the footwear worn at the time of falling by community-dwelling elderly adults and those in residential aged care facilities.²

Little is known about factors that influence footwear selection among older women. Previous studies of elderly populations have found that slippers are the predominant indoor footwear of choice.^{13,14} The choice of outdoor footwear is varied, ranging from slippers⁶ to sturdy lace-up walking shoes.¹⁵ The most common reason cited for this choice is comfort.^{13,14} However, it has been

*Podiatry Department, Southern Health, Kingston Centre, Cheltenham, VIC, Australia.

†Clinical Gait Analysis Service, Kingston Centre, Cheltenham, VIC, Australia.

‡Allied Health Clinical Research Unit, Southern Health, Cheltenham, VIC, Australia; Physiotherapy Department, Monash University, Frankston, VIC, Australia.

Corresponding author: Annette Davis, BAppSc(Pod), Podiatry Department, Southern Health, Kingston Centre, Cnr Warrigal and Kingston Rds, Cheltenham, VIC, Australia 3192. (E-mail: annette.davis@southernhealth.org.au)

noted that the choice of comfort does not necessarily equate to a sturdy, safe shoe with optimal features.¹⁵ It seems from these studies that the health-care provider's perception of comfortable and safe footwear seems to be quite different from that of the elderly population.¹⁵

There is also a psychosocial element regarding age that should be considered for this population. Footwear is intrinsically linked to the sense of self and self-worth and is an outward expression of this, even in an elderly population.¹⁶⁻¹⁸ There is a key connection between loss of choice associated with retail footwear, body image, and reduced self-perceived quality of life.¹⁹ Naidoo et al²⁰ found that women aged 36 to 84 years (mean age, 67 years) were concerned with loss of femininity, and they considered themselves to be visibly different from their peers owing to their limited choice of retail shoes, which created negative feelings and emotions about their footwear.

There are many education and awareness programs and much literature relating to better footwear choices regarding foot health and falls; however, even previous fallers are hesitant to make safer footwear selections,¹⁶⁻¹⁸ and compliance with safe, appropriate footwear, is also poor.¹⁹ Safe footwear is difficult to define. Regarding contextualizing safe footwear for older women, the heel profile should be low, flat, and broad.¹⁴ The sole should be textured to improve traction, and there should be dorsal fixation, such as laces or buckles.²¹

If older women are to wear footwear that reduces their risk of falls, then a better understanding of the psychosocial factors of footwear choice is needed. This study aims to identify factors that drive footwear selection and use among community-dwelling women aged 60 to 80 years with no history of falls. The participants were also asked about their attitudes toward the footwear that was provided to them in a previous unpublished study (unpublished study, Annette Davis, BAppSc(Pod), Anna Murphy, BAppBiomech, PhD, Brook Galna BAppSci(Exercise Science & Exercise Behaviour) BArts(Psych)PhD(Biomech), 2010). Older women were chosen for this study because they have higher rates of foot disorders that may be related to their footwear selection^{7,22} together with a higher incidence of injury after a fall due to higher rates of osteoporosis.²³⁻²⁵

Methods

The participants were 24 women aged 60 to 80 years with no history of falls or requirement for gait aids.

The Southern Health human research ethics committee (Cheltenham, VIC, Australia) approved this study, and all of the participants gave consent to participate. These participants were recruited from a previous unpublished study in which they were provided with Propét washable walker shoes (Propét USA Inc, Auburn, WA) (Fig. 1). The Propét washable walkers, fitted by the investigator (A.D.), were provided at no cost to the participants. The participants were then allowed to keep the shoes, and questions regarding these shoes form the qualitative analysis component of this study. The participants had received the Propét washable walkers 1 year before this cross-sectional survey.

A cross-sectional survey using a structured, open-ended questionnaire was conducted by telephone interview. The questions were formulated from consultation with the Southern Health podiatric medical team and from literature investigating footwear choice.^{6,13} The telephone interview included questions about the footwear from the previous study and questions regarding drivers of footwear selection.

Before contact, participants were sent written information on the purpose of the study, consent to participate, and how their confidentiality would be managed. The primary investigator then made contact with each participant and conducted all of the interviews over the telephone during 1 week. Semistructured interview questions were asked about the participant's main consideration when buying shoes, how many shoes they own, and the types of shoes worn indoors and outdoors. The survey questions are listed in Table 1.

All of the interviews were recorded and transcribed verbatim, with each participant allocated a numerical code. During the interview, open-ended questions were asked, and prompts were used to facilitate discussion and ensure that each question was answered in detail.



Figure 1. Propét washable walkers.

Table 1. Telephone Interview Questions

Can you tell me, when buying footwear, what is your main consideration?
Prompts: price, aesthetics, comfort, safety, brand, access, other please explain
Approximately how many pairs of shoes do you own?
Of these, how many do you wear on a regular basis (more than twice a week)?
What footwear (if any) do you wear most often indoors and why?
Prompts: aesthetics, activity, comfort, safety, other please explain
What footwear (if any) do you wear most often outdoors and why?
Prompts: aesthetics, activity, comfort, safety, other please explain
In the previous research study, you were given lace-up shoes to keep.
i. Do you still have them? If not, why not?
ii. Do you still wear them? If so, how many times a week? When do you wear them?
iii. Did participating in the previous study influence how you choose your shoes now?
iv. Have you purchased similar shoes since?
v. Is there anything that makes you want to wear them?
vi. Is there anything that puts you off wearing them?
Is there anything further about choosing footwear that you would like to tell me?

The responses to open-ended questions were coded and quantified under a qualitative description paradigm using descriptive phenomenology. The primary investigator (A.D.) read through interview transcripts and applied codes. These codes were then grouped into themes, and the frequency of these themes was summarized. These themes were discussed with the research group to ensure trustworthiness and rigor of data and to check for content accuracy and consistency of coding.

Results

The mean $\pm$ SD age of the 24 participants was 67.5 $\pm$ 4.2 years. Their mean $\pm$ SD height was 161.8 $\pm$ 7.3 cm and weight was 69.8 $\pm$ 7.2 kg. The participants owned a mean of 24 (range, 2–57) pairs of shoes. All of the participants consented to the telephone interview. The main themes identified by the participants were aesthetics, comfort, and safety. A subtheme of comfort was foot disorders. Participants also identified feelings of loss of

autonomy and loss of decision making regarding choosing footwear.

Almost half of the participants regularly wore (more than twice a week) less than one-third of the shoes they owned. Almost half of the participants (48%) most commonly wore slippers as their indoor footwear. The outdoor footwear most commonly worn by participants was lace-up walking shoes. Comfort was the main reason given for footwear worn indoors and outdoors. Participants also described the need for having shoes related to seasonal changes and work requirements, as some participants were still employed.

The theme of aesthetics was the main consideration for shoe purchase, with six participants (25%) stating this as the exclusive reason. In addition, there were other participants citing it in conjunction with comfort.

When asked whether there was anything that puts the participant off wearing the previous research shoes, 18 (75%) mentioned the aesthetics of the shoes. "They aren't very elegant" and "I can't wear them with a dress" were comments made by participants. Aesthetics was not mentioned by any of the participants as a reason they preferred to wear the Propét washable walkers.

The theme of comfort was initially revealed when participants were asked what they consider when seeking to purchase a new pair of shoes, with 20 participants (83%) describing comfort as a key reason for purchase. The need for comfort was related to foot abnormalities for some participants, with mention of bunions, Achilles tendonitis, and toe deformity: "Comfort, especially as I have bunions and my little toe is a problem." There was also mention of needing to spend more money for comfortable shoes: "Money and comfort are important but I find my budget increases to get comfort." It is unclear from the data as to the relationship between comfort and fall prevention.

Foot abnormality was also evident as a subtheme of comfort from the data collected. Foot pain or abnormality influenced shoe selection: "I have foot pain now and have to choose shoes that are more sensible." This quote shows that for this participant, comfort (pain reduction) has had to override other factors.

The theme of safety was discussed primarily in response to specific questioning regarding use of the Propét washable walkers that had been provided without cost and with education that the footwear would be safer for them to wear. There was a varied response to the receipt of this footwear and participation in this research. Some participants

reported that it did have an effect on the footwear they chose to wear. One participant responded, "Most definitely. I always make sure I have a strap or something on top to keep them on." Whereas for others, it may have had a less dramatic impact. "Reinforced what I knew already," "Sort of made me think more about what I was buying," and "Partially. I think I had figured out over the years what was best for me" were some responses to this question.

Only half of the participants still had the Propét washable walkers, and only 6 (25%) were still wearing them. Overwhelmingly, the reason stated for not wearing them was the aesthetics of the shoes. The term *ugly* was consistently used to describe them, as were comments describing the shoes as "good for older ladies, not me." However, the aesthetics of a shoe were clearly a factor in a decision not to wear the research shoes. Some of the comments received revealed a potentially ageist attitude toward shoes. For example, one participant, when asked whether she would ever wear the research shoes, responded, "No, but recommended them to my 92-year-old aunt who loves them" (participant aged 69 years), and another participant responded, "If I was 100 years old maybe" (participant aged 72 years). Clearly, some participants felt that these were the sorts of shoes that older women wore, although the average age of this sample was 67.5 years. Although the participants were considered older women by the research team, the participants themselves did not think of themselves in this way and, thus, rejected the notion of wearing shoes that they associated with older women. It was also noted that slightly more than half of the participants had purchased shoes of a similar style as the Propét washable walkers in the past year.

Other important themes were autonomy and loss of decision making, especially with the older participants in the study. One participant stated that her daughter makes those decisions for her now, and another stated that she only had one pair of "sensible" shoes because her other shoes had been taken away.

Discussion

The aim of the study was to investigate the drivers of footwear selection in an elderly female population. The main themes identified were aesthetics and comfort. The relative hierarchy between aesthetics and comfort is not clear from the present study. Initially, it seemed that comfort was a clear

driver of footwear purchasing behavior, with 12 women reporting comfort as a factor as opposed to six reporting aesthetics as a factor.

Indoor shoes are primarily chosen for comfort and were commonly slippers. Slippers were often worn indoors and outdoors for comfort and convenience rather than aesthetics. The choices of outdoor shoes were primarily running or walking shoes, which were described for their comfort. It was clear that comfort cannot be solely linked to one type of shoe. Comfort as a descriptor may be perceived differently from one individual to another. An example of this is footwear that has excessive wear to the outsole but is a favorite that the individual is reluctant to give up. This was also described as comfortable by some participants. The investigators had anticipated that the Propét washable walkers would be comfortable, yet no participants reported this to be the case (although this was not directly questioned; rather, indirect questions asked participants to report why they do or do not wear the shoes). Instead, the shoe was classified as being for "older people," revealing that the participants possibly did not want to think of themselves as being old. Greco²⁶ stated that when a person reaches age 60 years it does not mean they are uninterested in clothing or fashion. The large number of pairs of shoes owned by participants but not worn regularly may be related to fashion.

In an elderly female population in which fall issues and foot disorders may exist, health-care providers commonly recommend footwear for its functionality. Collaborative consultation with the woman in the decision-making process for footwear selection may be beneficial. This may also be advantageous for compliance with wearing the footwear that is recommended. Compliance with footwear recommendations regarding fall prevention has been shown to be poor.²⁷

The underlying concepts of the Health Belief Model²⁸ could be considered by health-care practitioners when recommending footwear. The model states that a person's decision to change their behavior is influenced by how vulnerable they perceive themselves to be to a particular health problem, the perceived seriousness, barriers to implementing the change, and the possible benefits it will produce.

Williams and Nester²⁹ suggested that "rather than telling patients that their footwear choices are bad, we should provide positive support for the small changes that patients may achieve and continue to promote the benefits of suitable footwear."

Safety as a theme was identified for the previous

study footwear. Given that this population had no previous falls, it was no surprise that safety was not a primary consideration when purchasing shoes. However, participants may also be rejecting the notion that they are at risk for falling. Wearing safe shoes may require an inward acceptance that this population does not trust their own mobility anymore. Perhaps they do not want to inwardly accept that they are at risk for falling or allow this risk to be known outwardly.

The loss or transference of footwear choice from the elderly woman to other family members was a theme more prevalent in the older group. Fashion was secondary to function as a footwear selection driver, as choice was transferred to a family member who attended to this and other decisions for these participants. It was clear that there was no collaboration in the footwear selection process. The loss of independence, whether physical, mental, or situational, may be the defining time for the transition of change from fashion to function regarding footwear selection.

Limitations of the study include a small sample size and a history between participants and investigators from the previous research study. This could create potential pressure to be supportive of the safe footwear; however, many of the participants were willing to express the desire to never wear the previous research footwear again. The sample size in this study was dictated by the number of participants in the previous research. It is possible that if more participants had been interviewed, a broader range of reasons for not wanting to wear the research footwear or themes underlying reasons for footwear selection may have been attained.

Conclusions

This study indicates that older women are driven primarily by aesthetics and comfort in their footwear choices. If health-care practitioners or family members want to influence this thinking so that older women wear footwear that may be considered safer, it is clear that this footwear will still have to be aesthetically pleasing and comfortable.

Financial Disclosure: None reported.

Conflict of Interest: None reported.

References

1. PREVENTING FALLS AND HARM FROM FALLS IN OLDER PEOPLE: *Best Practice Guidelines for Australian Hospitals* 2009, Australian Commission on Safety and Quality in Health Care, Darlinghurst, 2009.
2. SHERRINGTON C, MENZ HB: An evaluation of footwear worn at the time of fall-related hip fracture. *Age Ageing* **32**: 310, 2003.
3. BERG WP, ALESSIO HM, MILLS EM, ET AL: Circumstances and consequences of falls in independent community-dwelling older adults. *Age Ageing* **26**: 261, 1997.
4. TINETTI ME: Clinical practice: preventing falls in elderly persons. *N Engl J Med* **348**: 42, 2003.
5. LORD SR, BASHFORD GM: Shoe characteristics and balance in older women. *J Am Geriatr Soc* **44**: 429, 1996.
6. KOEPEL TD, WOLF ME, BUCHNER DM, ET AL: Footwear style and risk of falls in older adults. *J Am Geriatr Soc* **52**: 1495, 2004.
7. MENZ HB, MORRIS ME: Footwear characteristics and foot problems in older people. *Gerontology* **51**: 346, 2005.
8. JESSUP RL: Foot pathology and inappropriate footwear as risk factors for falls in a subacute aged-care hospital. *JAPMA* **97**: 213, 2007.
9. AUSTRALIAN INSTITUTE OF HEALTH AND WELFARE: *A Picture of Osteoporosis in Australia*, Australian Institute of Health and Welfare, Canberra, 2008.
10. GILL T, TAYLOR AW, PENGELLY A: A population-based survey of factors relating to the prevalence of falls in older people. *Gerontology* **51**: 340, 2005.
11. BARBIERI E: Patient falls are not patient accidents. *J Geront Nurs* **9**: 165, 1983.
12. FREY CC, KUBASAK M: Faulty footwear contributes to why seniors fall. *Biomechanics* **5**: 45, 1998.
13. MUNRO BJ, STEELE JR: Household-shoe wearing and purchasing habits: a survey of people aged 65 years and older. *JAPMA* **89**: 506, 1999.
14. WHITE E, MULLEY G: Footwear worn by the over 80's: a community survey. *Clin Rehab* **3**: 23, 1989.
15. DUNNE RG, BERGMAN AB, ROGERS LW, ET AL: Elderly persons' attitudes towards footwear: a factor in preventing falls. *Public Health Rep* **108**: 245, 1993.
16. HORN BROOK MC, WINGFIELD DJ, STEVENS VJ, ET AL: "Falls Among Older Persons: Antecedents and Consequences," in *Reducing Frailty and Falls in Older Persons*, edited by R Weindrich, EC Hadley, MG Ory, p 106, Charles C Thomas Publisher, Springfield, IL, 1991.
17. ISAACS B: Clinical and laboratory studies of falls in older people: prospects for prevention. *Clin Geriatr Med* **1**: 513, 1985.
18. FREY C: Foot health and footwear for women. *Clin Orthop Relat Res* **372**: 32, 2000.
19. WILLIAMS AE, NESTER CJ, RAVEY IM: Rheumatoid arthritis patients' experiences of wearing therapeutic footwear: a qualitative investigation. *BMC Musculoskelet Disord* **8**: 104, 2007.
20. NAIDOO S, ANDERSON S, MILLS J, ET AL: "I could cry, the amount of shoes I can't get into": a qualitative exploration of the factors that influence retail footwear selection in women with rheumatoid arthritis. *J Foot Ankle Res* **4**: 21, 2011.
21. WILLIAMS A: Footwear assessment and management. *Podiatry Now* **May**: S1, 2006.

22. BURNS S, LEESE G, McMURDO M: Older people and ill-fitting shoes. *J Postgrad Med* **78**: 344, 2002.
23. NORTON R, CAMPBELL AJ, LEE-JOE T, ET AL: Circumstances of falls resulting in hip fractures among older people. *J Am Geriatr Soc* **45**: 1108, 1997.
24. HANNAN MT, FELSON DT, DAWSON-HUGHES B, ET AL: Risk factors for longitudinal bone loss in elderly men and women: the Framingham Osteoporosis Study. *J Bone Miner Res* **15**: 710, 2000.
25. GRESSO JA, KEISLEY JL, STROM BL, ET AL: Risk factors for falls as a cause of hip fracture in women. *N Engl J Med* **324**: 1326, 1991.
26. GRECO AJ: The fashion-conscious elderly: a viable, but neglected market segment. *J Consumer Market* **3**: 1986.
27. FORTINSKY RH, IANNUZZI-SUCICH M, BAKER DI, ET AL: Falls: assessment and management in clinical practice: view from health care providers. *J Am Geriatr Soc* **52**: 15, 2004.
28. JANZ NK, BECKER MH: The Health Belief Model: a decade later. *Health Educ Q* **11**: 1, 1984.
29. WILLIAMS A, NESTER CJ: "Managing Patient Engagement: Orthoses and Footwear as a Foot Health Intervention" in *Footwear and Foot Orthoses: The Pocket Podiatric Guide*, edited by I Mathieson, p 138, Churchill Livingstone Elsevier, London, 2010.

Appendix 4 – Chapter 5 Background Information

Data Analysis

Number of trials analysed

Data from five trials was used to calculate the mean for each spatiotemporal variable using GAITRite with a mean of 54 steps per person per condition. Maximum heel slippage and minimum toe clearance was measured using VICON with a mean of 18 steps per person per condition. The means and within-subject standard deviation for each participant were used to calculate the group means, standard deviations and 95% confidence intervals for each condition.

Normality

The normality of each dependent variable's underlying distribution was examined and considered normally distributed if they had skewness between -2 and 2, and kurtosis of between -2 and 2. Skewness and kurtosis were within the normal range for all variables and all footwear conditions, except for heel slippage data for the own shoes conditions which violated the assumption of kurtosis. Analysis of variance and pairwise comparisons for maximum heel slippage were checked against the corresponding non-parametric tests (Friedman's test and Wilcoxin signed-rank tests). Similar results were found and so the non-parametric test results were not reported.

Summary Table

Table 3 - Means and standard deviations of spatiotemporal variables, minimum toe clearance and heel slippage for four footwear conditions. Superscript letters represent a difference of means between conditions (b = barefoot, p = prescribed shoes, s = slippers, o = own shoes).

Variable	Barefoot	Prescribed Shoes	Slippers	Own Shoes
Step Velocity (m/s)	1.26 (0.08) ^{ps}	1.35 (0.08) ^{bs}	1.31 (0.08) ^{bp}	1.29 (0.08) ^{bp}
Step Length (m)	0.602 (0.03) ^{ps}	0.652 (0.03) ^{bs}	0.640 (0.03) ^{bp}	0.640 (0.03) ^{bp}
Step Duration (s)	0.483 (0.02) ^{so}	0.487 (0.02) ^{so}	0.492 (0.02) ^{bp}	0.498 (0.03) ^{bp}
Single Limb Support (s)	0.389 (0.02) ^{po}	0.372 (0.02) ^{bs}	0.388 (0.02) ^{po}	0.383 (0.02) ^{bps}
Double limb support (s)	0.094 (0.01) ^{ps}	0.115 (0.01) ^{bs}	0.103 (0.01) ^{bpo}	0.115 (0.01) ^{bs}
Double limb Support (%)	19.4 (1.4) ^{ps}	23.7 (1.5) ^{bs}	21 (1.5) ^{bpo}	23.1 (1.6) ^{bps}
Base of Support (mm)	93.1 (12) ^o	89.2 (15) ^s	94.7 (10) ^{po}	88.2 (14) ^{bs}
Minimum Toe Clearance (mm)	15.7 (4.7) ^{po}	19.7 (3.8) ^{bs}	15.7 (3.6) ^{po}	20.1 (4.5) ^{bs}
Maximum Heel Slippage (mm)	-	13.1 (7.4) ^s	15.5 (5.36) ^p	14.2 (11.7)

ANOVA and Post-hoc statistics

Repeated-measures analysis of variance was performed on each of the dependant variables to test for main effects for footwear. A main effect was not seen for heel slippage.

Table 4 - Summary of statistics from repeated measure analysis of variance and post-hoc tests conducted to assess differences between the means of barefoot (BF), prescribed shoes (PS), slippers (SL) and own shoes (OS) footwear conditions. Degrees of freedom were adjusted using the Greenhouse-geisser correction for the analysis of variance as the assumption of sphericity was not met for most variables.

Variable	ANOVA statistics		P-value for post-hoc two-sided paired t-tests					
	F	p	BF-PS	BF-SL	BF-OS	PS-SL	PS-OS	SL-OS
Step Velocity (m/s)	18.939	<.001	<.001	<.001	<.001	<.001	.009	.828
Step Length (m)	55.347	<.001	<.001	<.001	<.001	<.001	.006	.524
Step Duration (s)	11.449	<.001	.0071	<.001	<.001	<.001	.002	.185
Single Limb Support (s)	26.402	<.001	<.001	.941	.002	<.001	<.001	.015
Double limb support (s)	66.700	<.001	<.001	<.001	<.001	<.001	.720	<.001
Double limb Support (%)	77.631	<.001	<.001	<.001	<.001	<.001	.043	<.001
Base of Support (mm)	62.054	<.001	<.001	<.001	<.001	<.001	.644	<.001
Minimum Toe Clearance (mm)	15.166	<.001	.000	.965	.000	.000	.625	.000
Maximum Heel Slippage (mm)	1.204	.295	-	-	-	.023	.475	.515

Minimum Toe Clearance

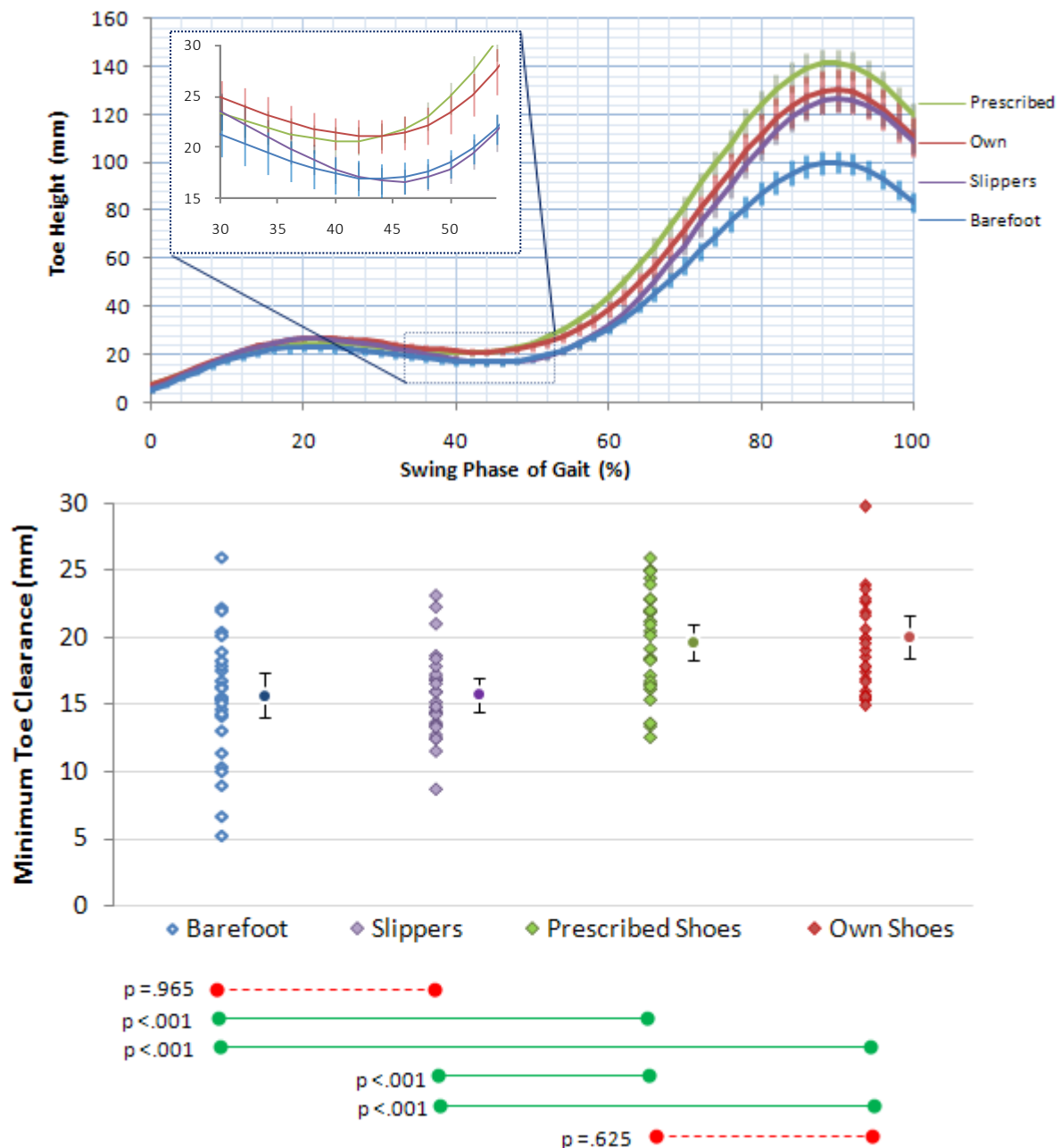


Figure 2 - Panel A) Mean toe height above the ground across 100 % of the swing phase of gait is illustrated for each footwear condition. Error bars represent 95 % confidence intervals. The insert shows foot clearance during the mid-swing phase of gait.

Panel B) Minimum toe clearance for each footwear condition. Single dots to the right of individual data represents the mean and error bars represent the 95 % confidence intervals. Results from paired t-tests are reported below the graph. Solid green lines signify p-values of post-hoc two-sided paired t-tests are statistically significant.

Heel Slippage

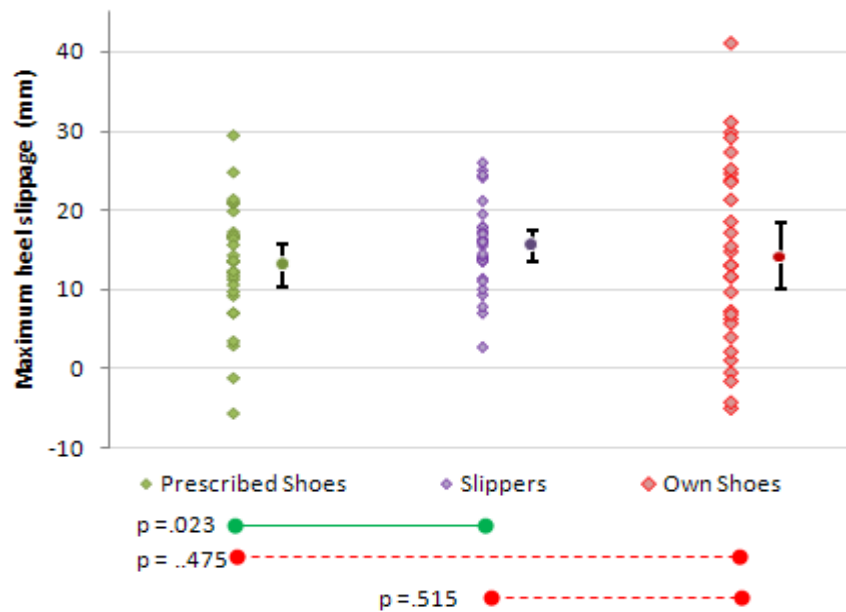


Figure 3 - Maximum heel slippage for each footwear condition. Single dots to the right of individual data represents the mean and error bars represent the 95 % confidence intervals. Results from paired t-tests are reported below the graph. Solid green lines signify p-values of post-hoc two-sided paired t-tests are statistically significant.

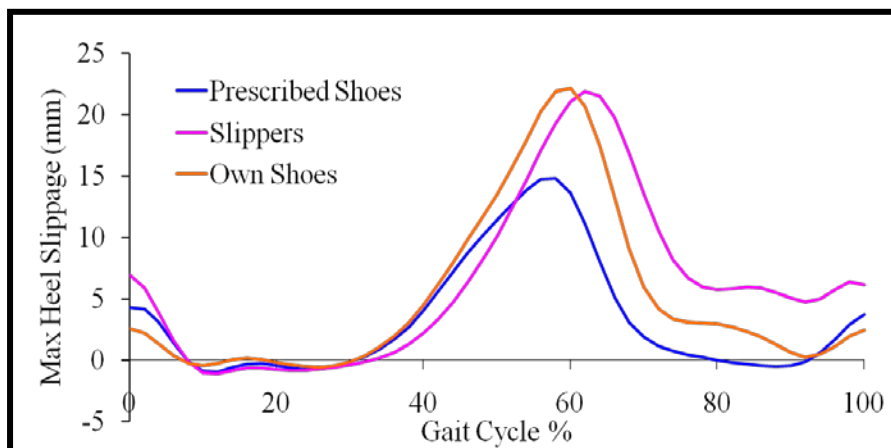


Figure 4 – Maximum heel slippage comparing footwear variables

Spatiotemporal variables

Within-subject variability

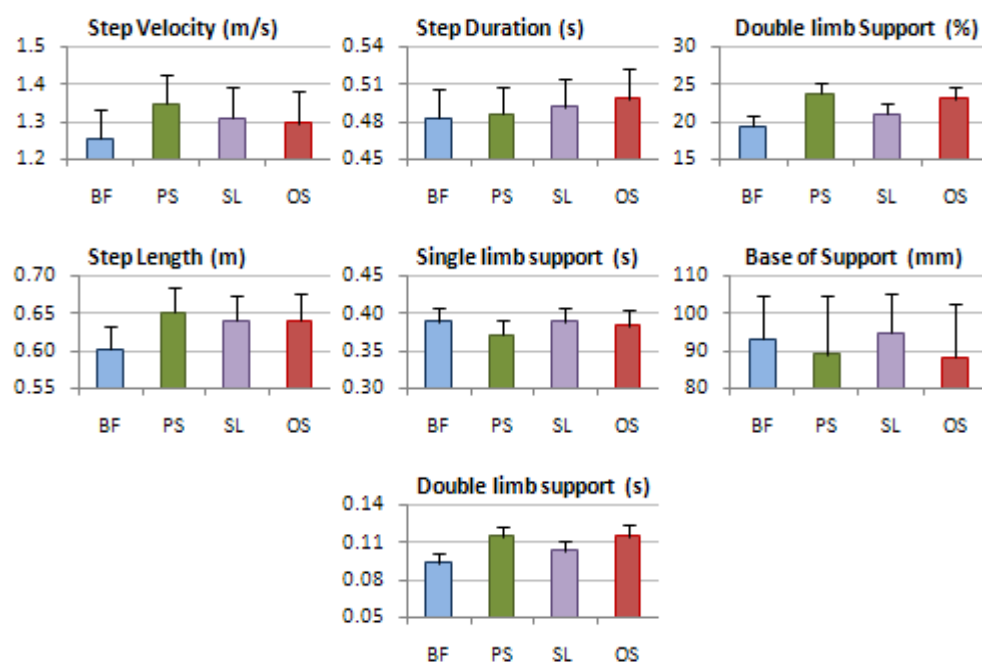


Figure 5 - Mean for spatiotemporal variables for barefoot (BF), prescribed shoes (PS), slippers (SL) and own shoes (OS) conditions. Error bars indicate 95 % confidence intervals

Table 5 - Means and standard deviations of within-subject variability for the four footwear conditions. Superscript letters represent a difference of means between conditions (b = barefoot, p = prescribed shoes, s = slippers, o = own shoes).

Variable	Barefoot	Prescribed Shoes	Slippers	Own Shoes
Step Velocity (m/s)	0.059 (1.183)	0.056 (1.455) ^{so}	0.063 (1.492) ^p	0.064 (1.631) ^p
Step Length (m)	0.021 (0.597)	0.020 (0.746)	0.021 (0.721)	0.021 (0.781)
Step Duration (s)	0.015 (0.005)	0.014 (0.004) ^{so}	0.016 (0.004) ^p	0.017 (0.009) ^p
Single Limb Support (s)	0.015 (0.004) ^s	0.014 (0.004) ^{so}	0.017 (0.003) ^{bp}	0.017 (0.006) ^p
Double limb support (s)	0.018 (0.006)	0.017 (0.004) ^{so}	0.02 (0.005) ^p	0.02 (0.007) ^p
Double limb Support (%)	0.038 (0.009) ^s	0.038 (0.007) ^s	0.043 (0.008) ^{bp}	0.041 (0.01)
Base of Support (mm)	0.15 (0.327)	0.152 (0.352)	0.165 (0.42) ^p	0.16 (0.481)
Minimum Toe Clearance (mm)	4.375 (1.907)	4.163 (1.461)	4.110 (1.172)	3.911 (1.301)
Maximum Heel Slippage (mm)	-	4.407 (2.200) ^{so}	3.551 (1.764) ^p	4.997 (2.712) ^p

ANOVA and Post-hoc statistics

Repeated-measures analysis of variance was performed on each of the dependant variables to test for main effects for footwear. Planned contrasts are presented for each of footwear condition despite several main effects not reaching $p < .05$.

Table 6 - Summary of statistics from repeated measure analysis of variance and post-hoc tests conducted to assess differences between the means of barefoot (BF), prescribed shoes (PS), slippers (SL) and own shoes (OS) footwear conditions. Degrees of freedom were adjusted using the Greenhouse-geisser correction for the analysis of variance for those variables where the assumption of sphericity was not met.

Variable	ANOVA statistics		P-value for post-hoc two-sided paired t-tests					
	F	p	BF-PS	BF-SL	BF-OS	PS-SL	PS-OS	SL-OS
Step Velocity (m/s)	2.668	.53	.324	.249	.247	.019	.006	.924
Step Length (m)	0.428	.734	.453	.794	.682	.307	.310	.974
Step Duration (s)	3.172	.058	.114	.559	.159	.003	.022	.207
Single Limb Support (s)	6.321	.002	.105	.003	.053	.000	.011	.587
Double limb support (s)	1.856	.143	.542	.152	.296	.015	.039	.952
Double limb Support (%)	2.228	.091	.893	.035	.259	.014	.194	.317
Base of Support (mm)	2.157	.099	.781	.054	.157	.023	.246	.565
Minimum Toe Clearance (mm)	0.594	.621	.871	.614	.254	.666	.289	.506
Maximum Heel Slippage (mm)	7.244	.004	-	-	-	.020	.000	.228