The Prevalence, Determinants, and Consequences of Falls in Middle-Aged Adults in Greater Manchester in 2018-2022

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PhD 2022

The Prevalence, Determinants and Consequences of Falls in Middle-Aged Adults in Greater Manchester in 2018-2022

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A thesis submitted in partial fulfilment of the requirements of Manchester Metropolitan University for the degree of Doctor of Philosophy

Department of Psychology

Manchester Metropolitan University

2022

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Abstract

Falls within older adults have been well researched for several decades, with falls in this age group remaining a significant health concern. The research that has considered falls in middle-aged adults, however, is limited despite growing evidence for falls frequency, in some cases, being similar to that of older adults. This programme of work aimed to address this unmet need by researching middle-aged fallers and contrasting them with age-match non-fallers; the profiles of both groups were considered in the context of older-aged fallers and non-fallers. In a number of the reported studies, individuals from the Greater Manchester region were recruited to four independent studies following evidence that Manchester's demographics for falls was the highest in England. Across a range of physiological, psychological, and behavioural factors, the data suggests that there are differences between fallers and non-fallers in the middle-aged population just as there are within older adults; some of these difference profiles are similar to those currently seen in only in older adults. Screening techniques used with limited success in older adults are also problematic for middle-aged fallers and presented sensitivity and validity concerns. Simple step and hopping data may be the most useful as a simple, valid field screening marker within the middle-aged fall population with middle-aged fallers displaying 29.6% shorter hop distances when compared to aged-matched non-fallers. The global pandemic was predicted to have significant implications for fallers, however, the evidence reported here suggests that falls did continue but, due to Government restrictions on movement and imposed 'lockdowns', there were fewer injurious falls outdoors and more, less severe falls indoors. The impact of increased sedentary behaviour is discussed as a future concern for middle-aged adults.

Publications and Conference Presentations Associated with this Thesis

Publications

Blodgett, J.M., **Ventre, J.P.**, Mills, R., Hardy, R. and Cooper, R. (2022) A Systematic Review of One-Legged Balance Performance and Falls Risk in Community-Dwelling Adults. *Ageing Research Reviews*, *73*, pp.1-16.

Onambele-Pearson, G., **Ventre, J.P.** and Brown, J.A., 2018. Reducing sedentary behaviour among older people. In *The Palgrave Handbook of Ageing and Physical Activity Promotion* (pp. 653-672). Palgrave Macmillan, Cham.

Conference Presentations

Ventre, J.P., Morse, C.I., Holmes, P.S., Ray, N.J., McPhee, J.S., van Schooten, K. and Craig, C.E. (2022) Should Fall-Prevention Start in Middle-Age? (Conference Abstract - International Society of Posture and Gait Research – Montreal 3rd-7th July 2022)

Ventre, J.P., Morse, C.I., Holmes, P.S., Ray, N.J., McPhee, J.S., van Schooten, K. and Craig, C.E. (2022) The Predictors of Injurious Falls Risk in a Middle-Aged Population. (Conference Abstract – EU Falls Festival - Leuven 4th-5th April 2022)

Ventre, J.P., Morse, C.I., Tomlinson, D., and Craig, C.E. (2019) An Examination of Muscle Quality, Functional Test Performance and Fall Risk in “Young-Old” Women: A Pilot Study. (Conference Abstract – International Society of Posture and Gait Research – Edinburgh 30th June-4th July 2019)

Acknowledgements

I would like to start these acknowledgements by saying thank you to the person who had the vision to make this project a reality. Dr Chesney Craig, thank you for providing me with the greatest opportunity to accomplish my dream of completing a PhD, alongside such incredible supervision for over two and half years. I feel exceptionally fortunate to have been your first ever PhD student.

Thank you to Professor Paul Holmes for continually challenging and supporting me not only during the undertaking of this thesis, but for the many years that I have spent at Manchester Metropolitan University. I am incredibly grateful to you for taking over as my Principal Supervisor with less than six months to go to submission and for continually reminding me that the completion of thesis was achievable. Without a doubt, your guidance has played a vital role in making me the interdisciplinary researcher I am today.

I cannot express my gratitude enough to Dr Christopher Morse and Dr Petra Kolic for your unwavering support and guidance right up until the final stages. Without both of your guidance, patience, and incredible support around the clock, the submission of this thesis would have not been possible.

I would personally like to thank Dr Kim van Schooten for constantly supporting me on my PhD journey all the way from the other side of the world. No call was too early or too late for you when I needed help with all things gait and accelerometery. My first international collaboration with you is one I feel very privileged to have made.

Thank you to Dr Hannah Jarvis for taking a chance on me. I will always be grateful to you for providing me with my first post-doctoral research position, even when I still had six months of my PhD remaining. Your work ethic and drive to answer the unanswered research questions in our field will always inspire me.

I would like to pay special thanks to my participants, without who, the completion of this thesis would not have been possible. Thank you for allowing me to share hours of your time and for sharing your stories with me, so that in turn I can share them with the reader. I feel honoured to share even a small part of your story.

To my family, friends and my best friend Hannah, thank you for being there since day one, for the love and the support that you have shown to me each and every day of this journey. On the days where it did not seem possible, making you all proud has spurred me on to reach the finish line. I hope that you are prouder today than on any other.

To Jack and Evie, my little people. It may be a few years yet before you open the front cover of this thesis but when you do, I want you both to know how much you have taught me about the important things in life. There are so many things to thank you both for but the main one is for being the two most perfect distractions in my life. I cannot wait to watch you both grow up and I am already so proud of how kind, caring and courageous you both are.

Last but certainly not least, to my partner Lisa. Thank you for everything that you are and for everything that you do, both for me and for our family. Your support, every second of every day means that no dream is too big or too small and that you are right by my side in accomplishing each and every one of them. Nobody motivates or grounds me like you do and for that reason, no number of words on this page could quantify how incredibly lucky I am that I get you as my best friend and my person. All that is left to say is, I owe all of this to you.

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List of Abbreviations

Abbreviation	Description
ACT	Attentional Control Theory
ADL	Activities of Daily Living
A&E	Accident and Emergency
BMI	Body Mass Index
BMD	Bone Mineral Density
BBS	Berg Balance Scale
CMP	Conscious Movement Processing
CPH	Conscious Processing Hypothesis
COVID-19	Coronavirus
DALYs	Disability-Adjusted Life Years
DEXA	Dual Energy X-ray Absorptiometry
DF	Dorsi Flexor
DHA	Defensive High Anxious
DSR	Directly Standardised Rate
ED	Emergency Department
FES-I	Fall Efficacy Scale International
FM	Fat Mass
FOF	Fear of Falling
FSST	Four Square Step Test
GM	Greater Manchester
GMCA	Greater Manchester Combined Authority
G-SAP	Gait Specific Attentional Profile
Icon-FES	Iconographical Falls Efficacy Scale
JSNA	Joint Strategic Needs Assessment
LCST	Low Contrast Sensitivity Test
LM	Lean Mass
MFT	Manchester University NHS Foundation Trust
Mini-BESTest	Mini-BESTest: Balance Evaluation Systems Test
MoCA	Montreal Cognitive Assessment
MRI	Manchester Royal Infirmary
MSRS	Movement Specific Reinvestment Scale
MVC	Maximal Voluntary Contraction
NHFD	National Hip Fracture Database
NHS	National Health Service
PHOF	Public Health Outcomes Framework
PF	Plantar Flexor
PPA	Physiological Profile Approach
QoL	Quality of Life
REC	Research Ethics Committee
STS	Five Times Sit-to-Stand Test
TIIG	Trauma and Injury Intelligence Group
TUG	Timed "Up and Go"
UK	United Kingdom
US	United States
μSv	Micro Sieverts
VAT	Vigilance Avoidance Theory
WTWA	Wythenshawe, Trafford, Withington and Altrincham

Outline of the Thesis

The original focus in the planning of the programme of PhD research was to conduct a multi- and inter-disciplinary analysis of middle-age fallers. Based on anecdotal evidence from the Greater Manchester (GM) region, there was a working hypothesis that there may need to be a review of existing screening processes currently in use for older-aged fallers and a new provision of more bespoke and sensitive tools for the middle-aged population. Some of the original thinking and reconceptualised research has been retained in this thesis. The significant constraints imposed by the global pandemic, on nearly all of United Kingdom (UK) research in the allied health professions, required a refocus of the research questions and, in most cases, a redesign of the studies and their methods. The initial pandemic restrictions began in March 2020, during the peak of research study 4 and 5 testing, requiring cessation of face-to-face research taking place in laboratories for a period of over 12-months. As a consequence of this, studies 6 and 7 had to be redesigned in a way that was permitted during the pandemic. Many of the studies featured throughout this thesis contain smaller sample sizes than originally planned for using a-priori analysis. The thesis now contains mixed methodological studies containing both quantitative and qualitative components. The change in the design of the studies featured throughout this thesis, is a direct result of conducting research that was possible during a global pandemic, however, this thesis now provides a more nuanced understanding of middle-aged falls provided by a mixed methodological approach.

Study 1 (Chapter 3) presents the findings from the examination of the prevalence of falls in populations from within the various regions of GM area and contrasts these with similar cities. The chapter explores the clinical unmet need of middle-aged falls within this geographical region and examines the prevalence of in-patient falls throughout the pandemic. **Study 2** (Chapter 4) examined some of the physiological, psychological, and environmental factors that may contribute to an increased risk of falling during the middle-stages of an adult's life. The chapter also reports on the ability of current validated clinical screening tools to discriminate between fallers and non-fallers. **Study 3** (Chapter 5) reports the use of a variety of kinematic techniques to examine ambulatory measures of trunk accelerations as part of daily-life gait quality. In the first study to examine the gait characteristics of middle-aged adults, the research investigated differences in the gait characteristics of middle-aged fallers and non-fallers and contributed to the reconceptualization of fall risk screening tools specific to middle-aged adults. **Study 4** (Chapter 6) examined the impact that the global pandemic and subsequent public health restrictions have had on fall risk factors in middle-aged adults. The chapter explored how instances of falls, physical activity engagement, physical health and mental health changed as a result of the global pandemic. **Study 5** (Chapter 7) approached the research questions with a more qualitative methodology. The aim was to understand the lived experience of fallers during the mid-stages of life. The study also provides an insight into the implications and consequences of falling during these mid-life years and how the global pandemic may have exacerbated fall risk.

Chapter 1: Introduction to the Research Programme

Falls among older adults are a persistent and well researched problem, with falls known to increase with advancing age (Fried et al., 2001). Fall-related injuries and deaths are a global concern, as the leading cause of injury-related fatality in adults aged 65+ in the USA (CDC, 2022) and the second leading cause of injury-related fatality across all age groups worldwide (WHO, 2022). Fall-related fatalities may be more prevalent in older adults due to the known link between falls and frailty, which is more prevalent in older adults (Speechley and Tinetti, 1991). Markers of frailty include age-associated declines in lean body mass, strength, balance, walking performance, and low activity (Buchner and Wagner, 1992; Campbell and Buchner, 1997), all of which are associated with greater mortality and morbidity from fall accidents. In contrast, the same age-related markers are not expected to be present in middle-aged adults. As a result, falls among middle-aged adults have, mostly, been overlooked, suggesting that the age at which an adult becomes at risk of falling may be misattributed. Therefore, a more detailed understanding of falls in adults aged 45-64 years may help to improve the ability of clinicians to identify those at risk in their later years. The identification and prioritisation of psychosocial, behavioural, and physiological factors responsible for an increased risk in falling propensity may help to direct intervention support to those whose needs to focus on falls prevention. The primary aim of this thesis was to understand the occurrence and factors associated with falls in middle-aged adults. The new knowledge generated aimed to inform the screening and prevention of falls for those at risk in this age group as they transition into older age where age-related decline predisposed them to a greater risk of fall-related injury and co-morbidity.

Chapter 2 of the thesis provides a review of the literature that has examined the prevalence and determinants of falls in both older and middle-aged adults. The chapter presents a critical and analytical discussion of the existing literature available for the older-aged population, whilst examining the economic cost and mechanisms surrounding fall occurrence. The main body of literature refers to older fallers, typically, 65+ years and the chapter includes the fall risk factors expected in those older than 65 years as well as those younger. Chapter 8 provides a more detailed discussion of all the results and considers the broader issues around middle-aged falls within the Greater Manchester region screening and prevention. The overall conclusions and future recommendations for research are presented and considered.

Falls have, typically, been investigated in older populations (65+ years) (Cigolle et al., 2015). The exploration into the prevalence of falls and associated risk factors during the middle stage of an adult's lifespan is, however, less well developed. This is surprising since, between the ages of 45-64 years, risk factors for falls are known to increase and suggest a positive directional link to an increased occurrence of falls (Peeters et al., 2018). The prevalence rates within the middle-aged population, however, remain unknown.

Targeted interventions for those aged 65+ aim to lower the risk of falling by 30% (Gillespie et al., 2012). Focused interventions such as the Otago Exercise Program (Campbell et al., 1999), Tai Chi: Moving for Better Balance (Li et al., 2005) and Stepping On (Clemson et al., 2004) have demonstrated the ability to reduce fall prevalence through the use of muscle strengthening, postural alignment and balance-retraining exercise. Despite evidence supporting these focused interventions, injury rates as a result of falling are rising (Sterling et al., 2001). An increase in fall-related injuries, along with the increasing economic cost of injuries suggests a need for new and earlier approaches to falls prevention.

Research into determining the causes of falls and their associated risk factors in older populations has been of interest for over 60 years. The pioneering research of Sheldon (1960), and more recently confirmed by Tinetti and Kumar (2010), classified falls into subtypes in an attempt to determine the role of disease and impairment in postural stability on the predisposition for falls. In addition, ageing literature attributes an increased risk of falls to multiple and interconnected factors such as impaired balance and gait, low muscle mass, increased medicinal use, visual impairment, impaired cognition and limitations to activities of daily living (Lord et al., 2003). These factors may also be influenced by the consequences of geographical socioeconomic region and the consequential health and care factors associated with inequalities and under-representation.

Developments in ageing literature have provided both researchers and clinicians with the detail to some of the causes and risk factors for falls in older adults, unfortunately, research for middle-aged adults is not yet available; younger adults may also be at risk of falling and require preventative intervention prior to reaching 65 years of age and their needs appear to have been overlooked.

The largest predictor of future falls has been suggested to be the history of previous falls (Delbaere et al., 2010d). Under current guidelines, however, individuals may risk being missed and only identified after sustaining a first fall when they are within the older life years (+64 years). This may not only be a significant health concern but also, potentially, more costly to society. It is important that research provides evidence to recognize the importance of preventative approaches in younger populations.

Younger adults at risk of falling may not present with the same risk factor profile as an adult over the age of 65 years but, to date, no study has examined risk factors for falls within those adults who ages fall only between 45 and 64 years. This makes the identification of those at risk of falls within this demographic difficult. There is limited published research able to provide population-based prevalence rates of falls in a middle-aged population and, of those that have, prevalence rates range between 11-31% (Talbot et al., 2005).

Younger, more physically active fallers will, of course, present with contrasting risk factors compared to older individuals who fall. At present, the lack of identifiable risk factors for middle-aged fallers means that evidenced-based intervention programmes are not available for this age group and are not budgeted for within the UK NHS system. This highlights a large access barrier for middle-aged adults at risk of falling. This is a concern since falls within the middle-aged demographic are known to have serious resultant injuries (Caban-Martinez et al., 2015) and also have significant impact on both family and work commitments (Lipscomb et al., 2003).

Taken together, the studies of this thesis begin the empirical and qualitative exploration of a clinical unmet need: falls within the middle-aged population of Greater Manchester. The thesis explores potential risk factors, experiences and affect that middle-aged fallers display. Using advancements in kinematic and movement technology, the work aimed to determine meaningful markers of daily-life-gait, measures of accelerometry, and how they may differ between those who fall and those who do not. Finally, the work aimed to address the additional impact of the COVID-19 pandemic on fall prevalence within a middle-aged population in Greater Manchester. This is the first work to examine the topic of middle-aged falls using these interdisciplinary methods to provide novel contributions to research.

Chapter 2: Literature Review

2.1 Introduction

The susceptibility of falling, defined as an unexpected event in which a person comes to rest on the ground, floor or lower level (Lamb et al., 2005) increases as humans age (Ambrose et al., 2013). When examining the leading cause of unintentional injury related mortality, fall incidents are the second leading cause worldwide (Stevens et al., 2006). An adult sustaining a serious fall throughout their lifespan, often results in both decreased functional independence and overall quality of life (QoL). Despite extensive research examining the prevalence of falls in older populations >65 years, very little research is indicative of the age in which a person first becomes at risk of falling. Research highlights that there is currently no model instrument to categorise those at greatest risk of falls (Jin, 2018), making the identification and intervention methods to prevent adults from falling near impossible. To date, the best-known predictor for an increased risk of falls, is a history of previous falls (Deandrea et al., 2010b). Older adults display a higher prevalence of comorbidities, age-related physiological changes and delayed functional recovery, which may explain the link between a history of falls and increased likelihood of future falls (Rubenstein and Josephson, 2002). This poses the idea that those at risk of falling are identified only upon experiencing a fall, and that then, the ability to successfully identify fall risk factors at earlier life stages are exceedingly uncommon.

2.2 Prevalence of Falls

In community dwelling adults aged 65 years and older, 30-40% fall on at least one occasion annually (Delbaere et al., 2010d). This figure rises to 50% when adults reach 80 years and above (Hausdorff et al., 2001). These statistics demonstrate that falls are a common, serious, and growing public health concern worldwide (Florence et al., 2018). Data suggest that once adults reach the age of 65 years they become more susceptible to falling (Lord et al., 1993). However, the multitude of research studies focused on this age demographic neglects those who fall and sustain serious injury during the middle stages of their lifespan. The prevalence rates of middle-aged individuals, those aged between 45-64 years, continues to demonstrate that between 15-21% fall on at least one occasion each year (Caban-Martinez et al., 2015). With previous falls presenting as the single largest predictor for future falls, the need to examine the fall risk of younger populations is imperative. Preventing falls in younger life years may directly prevent the occurrence of falling in older life years.

2.3 Economic Cost of Falls

The economic cost of treating fall-related injuries is exponential, with billions being spent each year (Whitehead et al., 2018). Within the UK, the most recent Public Health Outcomes Framework (PHOF) released figures to demonstrate that between the period of 2017/2018, the National Health Service (NHS) reported 220,160 fall-related accident and emergency hospital admissions. The same report demonstrated that fall-related injuries cost the NHS £4.4 billion each year, with injuries such as hip fractures accounting for around £2 billion of this sum. The Government also reported incurring other fall-related costs with unaddressed fall hazards in the home costing the NHS in England a further £435 million. Economic data demonstrates the extent of the major public health issue and current burden on health care costs (Mack et al., 2013). These costs are predicted to have risen during the 4-year period since the last PHOF was released. It is worth noting that economic costs are not presented based on age segregated data, making it unclear to what extent middle-aged fallers contribute to these costs.

The UK is not alone with costs related to fall occurrence and fall related injury. The United States (US) Centres for Disease Control and Prevention reported 3 million emergency department (ED) visits due to fall occurrence (Haddad et al., 2019) and of those 3 million visits, 28,000 fall related deaths (Casey et al., 2017). Falls accounted for 64% of injury related ED visits and 54% of injury related deaths in the US (Stevens et al., 2006). The result of these incidents was an annual cost of $49.5 billion (Florence et al., 2018). Given the growing age of the worldwide population and an increase in the occurrence of falls, it may be of economic benefit to identify those at greatest risk of falls earlier, alongside improving fall prevention strategies.

2.4 The Coronavirus (COVID-19) Cost on Falls

The spread of the novel COVID-19 creating a global pandemic in March 2020, saw the imposition of varied lockdown and quarantine restrictions on the worldwide population. Despite benefits of periods of quarantine reducing the overall spread of the virus, the measures have had negative consequences on the mobility of individuals, indirectly increasing sedentary behaviour and reducing physical activity (De La Camara et al., 2020). Poor physical performance in the form of balance impairment is a strong predictor of fall risk (Deandrea et al., 2010a). With inactivity also being linked strongly to increased instances of falls, previous literature has highlighted the importance of physical activity maintenance in order to prevent muscle weakness and frailty (Campbell and Buchner, 1997).

Prior to the pandemic, it has been estimated that fall-related accidents cost the NHS in excess of £4.4 billion each year and are the ninth highest cause of disability adjusted life years (DALYs) (GOV, 2022). As falls are likely to increase as a result of deconditioning during the pandemic (Pelicioni and Lord, 2020), future research will need to demonstrate how the pandemic has impacted the societal costs of falls. Other falls literature has focused specifically on older adults and findings are beginning to highlight the indirect cost of falling, in the form of loss of income both to faller and caregiver, loss of mobility, confidence, and overall loss of functional independence (Ambrose et al., 2013). The impact of the COVID-19 restrictions the lives of middle-aged adults at risk of falls remains unknown. The need for further research that determines the cost of social isolation on fall risk has been highlighted as a priority. Resultant findings from these future studies will provide information to suggest what can be done to mitigate the prolonged period of isolation and inactivity in both middle-aged and older adults.

2.5 Falls in Middle-Aged Individuals (45-64 Years)

Falls research has predominantly focused on individuals >65 years, with some evidence confirming that individuals within this age group are at greatest risk of injurious falls (Morrison et al., 2013). Emerging research into middle-aged individuals is beginning to highlight that the occurrence of falls and prevalence of associated risk factors increase during the middle-age of an adult's life (Verma et al., 2016b; Wang et al., 2021), with mounting evidence suggesting a need for examination of fall risk in a middle-aged population. Retrospective data is beginning to suggest that the rate at which middle-aged adults fall, may be similar to the rate at which older adults fall (Callisaya et al., 2011). These findings are yet to be identified in studies that use prospective methods to ascertain fall prevalence and hence forms a focus for this thesis work.

The reporting of fall incidents has been criticised due to reporting bias. In many research studies, fall prevalence and occurrence is often reported retrospectively. In those studies that have examined prevalence rates of falls in middle-aged adults, the time periods used ranged from 3 months to 2 years (Talbot et al., 2005). This method has yielded prevalence rates of between 12-25% (Caban-Martinez et al., 2015; Ablett et al., 2018). One limitation of using retrospective recall to determine falls prevalence is that there is a heavy reliance on individuals to accurately recall every fall incident over a preceding period. This method is subject to recall bias (Mackenzie et al., 2006), with a risk of underestimating prevalence of falls by as much as 32.8% (Garcia et al., 2015). This reporting bias of fall incidents is also present in the documentation of falls across various health services (Haines et al., 2008). The reporting of falls based on hospital incident reports is an accepted standard for collating falls data in clinical practice (Haines et al., 2006). However, concerns have been expressed regarding the ability of this method to measure the true number of falls taking place both in hospital and upon presentation to accident and emergency departments (Oliver, 2004). Previous research has found discrepancies in the definition of a fall used across various health services, alongside time pressures on staff causing an inconsistency in reporting and under-reporting respectively (Waring, 2005).

The large underestimation of prevalence in both research and hospital-based settings only obfuscates the growing problem of fall occurrence within this demographic. These limitations have been recognised over recent years and new guidance released by the Prevention of Falls Network Europe and Outcomes Consensus Group have recommended that the recording of falls across research studies should be conducted using prospective methods once a month for a period of 6 to 12 months. The long-term follow up of between 6 to 12 months allows for sufficient fall events to occur over a longer time period (Hauer et al., 2006), whilst the reporting of the absence or presence of a fall event each month has been documented as a short enough time period to reduce retrospective recall error into the data (Lachenbruch et al., 1991).

Many studies recognise the need for a lifespan approach to examining falls and fall related risk (Talbot et al., 2005), but limited attention, to date, has been drawn to the differences in falls that occur across the middle-aged population. It is important to consider the implications of examining falls amongst a middle-aged cohort as these adults are likely to present with altered lifestyles and activity profiles when compared to older adults. Middle-aged adults are thought to sustain a higher rate of serious injury after a fall, as a result of increased exposure to risky activities and environments. The rationale for such findings are that middle-aged adults are completing both exercise and habitual physical activity at a higher speed and force, leading to an increased risk of falling (Speechley and Tinetti, 1991; Talbot et al., 2005). The over exposure to more dynamic and risky activities should be considered when determining risk factors for falls in this age demographic. By understanding earlier fall accidents, it may be possible to reduce future falls and subsequent disability and frailty, thus improving overall life expectancy and quality of life in older age.

Research has identified that falls represent a risk for injury, however, falls are also known to impact the career, work life, income and family life of middle-aged adults, more so than any other age population (Lipscomb et al., 2003). Of the handful of studies describing falls prevalence, albeit retrospectively in the middle-aged population, there remains a lack of data describing the incidence and circumstances of these falls, or any prevalence data recorded prospectively. The interrelationship between life expectancy and fall risk as a health concern for ageing populations requires further attention.

Talbot et al. (2005) provided one of the first studies to examine falls over a lifespan, examining the perceived causes, environmental factors, and injury differences between young, middle-aged, and older community-dwelling adults. The findings of the study provided one of the first insights into different age demographics. Despite the study supporting previous literature to suggest that the highest fall prevalence rates can be observed in the older adult groups, a high frequency of falls were also observed in the middle and younger age groups (see Figure 2.1) alongside a higher proportion of fractures in middle-aged men and treated injuries in middle-aged women when compared to older adults. Prevalence rates of 21% were later corroborated in a study conducted by (Caban-Martinez et al., 2015).

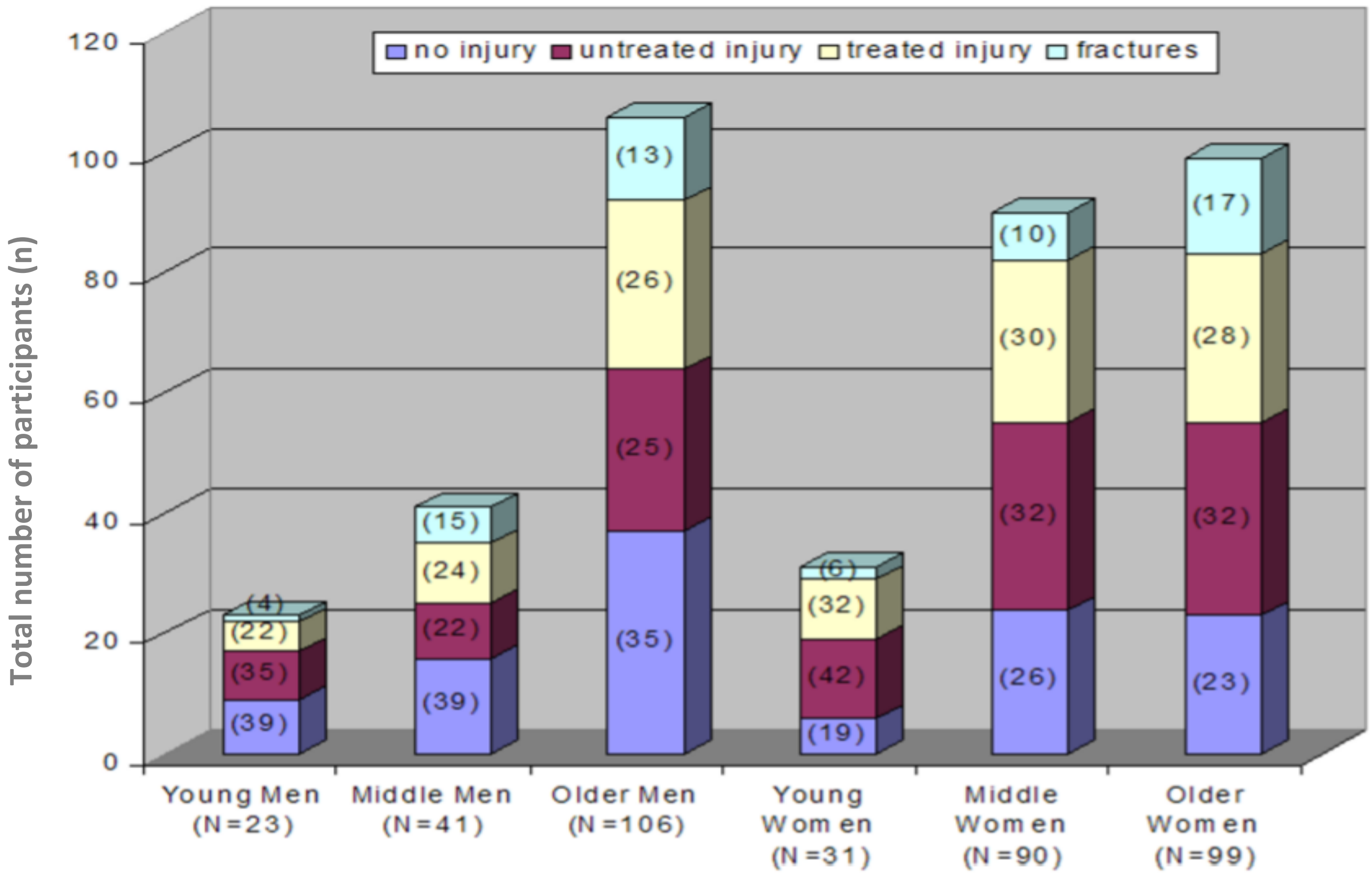

Figure 2.1. Frequency comparison of injury groups in fallers by age and sex (Talbot et al., 2005). The X-axis displays the breakdown of fallers into age and sex groups. Young men and women (20-45 years), middle-aged men and women (46-65 years) and older men and women (>65 years). Percentages of each injury type per age/sex groups are displayed in parenthesis on the graph bars.

Prevalence rates of middle-aged adults who fall range from 12-25% (Verma et al., 2016a), but the data has only been derived from retrospective methods. Recent data examining incidences of falls in women aged 41-62 years found a prevalence rate of 42% when using more prospective methods (Wang et al., 2021). This prevalence data almost doubles previous prevalence rates, confirming that retrospective recall methods of collecting fall prevalence can mask more realistic public health issues. Research has suggested that during the mid-stages of an adult's life, levels of physical activity reduce (Caban-Martinez et al., 2015) and subsequent physiological changes occur that result in increased incidences of disease and medication use (Talbot et al., 2005). These findings highlight that the events that occur between the ages of 45-64 years, may predispose individuals to a higher risk of falling in later life years.

A clearer understanding of the risk factors and characteristics associated to falls for specific age groups is required. Developments will aid the understanding of more targeted interventions and may help to reduce the medical cost of the future treatment of falls. Despite both Talbot et al. (2005) and Caban-Martinez et al. (2015) examining falls within a middle-aged population, and subsequently adding findings to a field that is currently lacking, these two studies have both adopted a population based approached. To further strengthen the field of middle-aged falls, a prospective-based approach similar to that of Wang et al. (2021) is required to investigate the epidemiology of falls in this age demographic.

Few studies to date have examined falls over the adult lifespan, comparing differences that are seen between adults who fall at younger ages <65 years, compared to older adults who fall >65 years. Many studies have examined circumstances surrounding falls; falls causation, related injuries, and identifiable risk factor determination (Gillespie et al., 2003; McClure et al., 2005b) in older adults, but the same research is now required to examine the same parameters in those aged 45-64 years.

2.6 Factors Surrounding Fall Occurrence

Falls have multiple causes and predisposing risk factors, making their diagnosis and prevention a clinical challenge (Rubenstein and Josephson, 2006). Whilst a fall may be the first indication of the presence of an acute health problem, falls may simply be a marker for the progression of an age-related decline (Ambrose et al., 2013). Falls appear to be experienced increasingly by individuals as they age, and all evidence suggests that they have multifactorial and interactive causes. To begin to understand the diversity of fall incidents within various aged populations, researchers must first understand the underpinning factors and mechanisms surrounding falls. It has been suggested that a variety of different attributes are needed to successfully predict falls in populations younger than 65 years (Peeters et al., 2018).

Amongst the ageing population, factors that have been strongly associated with falling are repeated throughout the literature; muscle weakness, altered balance and gait, previous history of falling, visual impairment, functional limitations and use of medication (Scott et al., 2007). The exploratory work into individuals younger than 65 years is beginning address risk factors that present in a younger and more active population, where the natural ageing process is less advanced. This research has been informed by findings from studies that have shown a disparity between frail and active older adults (Speechley and Tinetti, 1991).

Many research studies have consolidated evidence to identify the multifactorial causes of falls. Consistent with the aims of this thesis and the summary of (Lord et al., 2003), these factors have been further identified from an evidence base in older populations and can be seen in Figure 2.2. Consistent with the experimental chapters of the thesis, those factors with the strongest evidence base from studies investigating falls in older adults are reviewed. At present, literature has only examined the prevalence of falls in middle-aged individuals from a population-based approach, making the ability to produce a similar figure to that of Figure 2.2 in middle-aged adults almost impossible due to the lack of description of neuromuscular, psychological, vestibular or visual determinants.

Gait and balance impairments have been identified consistently as the strongest predictor for risk factor of falls (Deandrea et al., 2010a; Mancini and Horak, 2010). As adults age, gait patterns begin to alter, with older people displaying a more closed kinematic chain (freezing degrees of freedom), less co-ordinated gait and poorer postural control (Ambrose et al., 2013). In turn, those **i**ndividuals who report falls, slips and trips often display poor balance and, therefore, are unable to prevent a fall (Thorbhan and Newton, 1996).

For some time, it has been suggested that an increased body sway is a major risk factor responsible for falls in aging populations (Fernie et al., 1982). Early postural control work (Maki et al., 1994) identified that fallers demonstrate a significantly greater anteroposterior sway than non-fallers. For individuals to control postural sway when standing, torques are requires to be generated at the ankle joint (Horak et al., 1989). The ability to generate the torque needed to control postural sway declines during the aging process, altering the neuromuscular performance of the Plantar Flexor (PF) and Dorsi Flexor (DF) muscle groups (Billot et al., 2010).

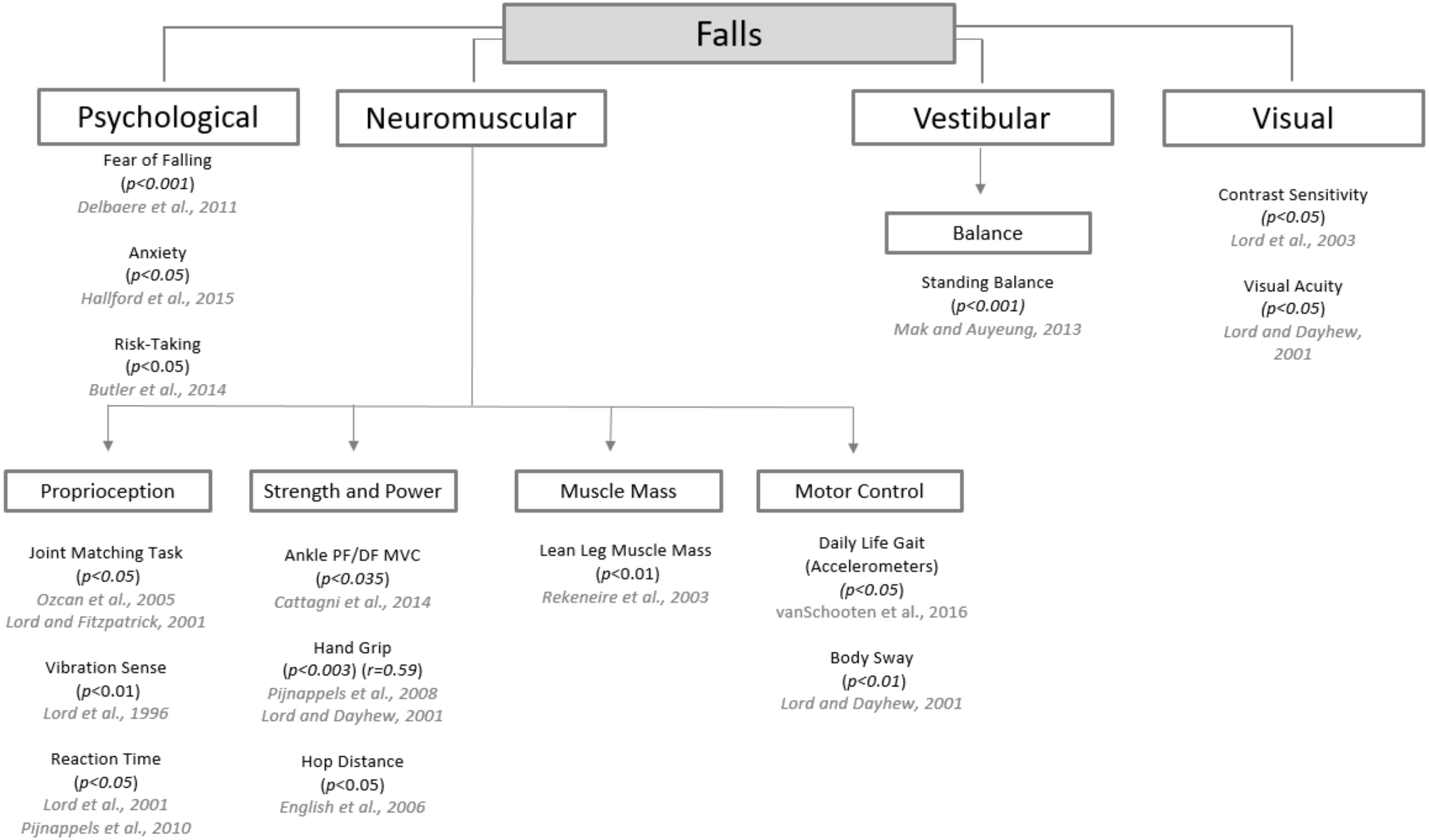

Figure 2.2. Example multifactorial intrinsic factors known to be associated with an increased risk of falling.

These findings begin to highlight the difficulties that researchers face when attempting to identify a single risk factor for future preventative interventions. To improve balance and gait, it could be argued from the evidence above, that interventions should target the strengthening of PF and DF muscle groups prior to any direct work on improving gait and balance.

Muscle weakness, quantified by low muscle mass and muscle strength, including ankle and knee maximal voluntary contraction (MVC) force has also been associated with a higher instance and risk of falls in older adults (Pijnappels et al., 2008a). Findings demonstrate that individuals with lower limb weakness are four times more likely to experience a fall (Moreland et al., 2004a), with older individuals scoring 20-40% lower MVC values than younger adults (Murray et al., 1980). Muscle weakness is often a result of periods of deconditioning, as physical activity is known to continually reduce as adults age. Studies have provided evidence to suggest the presence of sarcopenia, defined as the presence of low muscle mass and low muscle strength (Santilli et al., 2014), in individuals as young as 45 years old (Bijlsma et al., 2013). The prevalence of sarcopenia within this age group varies greatly based on different diagnostic methods (Cruz-Jentoft et al., 2010), suggesting that results should be interpreted with caution. Future studies examining the risk of sarcopenia in adults aged 45-64 years require further investigation to examine the ability of such measures to predict falls and fall related risks in this age demographic.

To detect fall risk factors in younger populations, focusing on the factors that are present in older ageing may not be sensitive enough in younger populations. Research has placed a strong emphasis on risk factors related to cognitive decline. Cognitive decline has be defined as a deficit in which one or more cognitive functions, such as memory, learning, concentration and decision making are impaired (Qiu et al., 2022). Cognition is known to decrease as adults age, and has been identified as an independent risk factor for falls (Mirelman et al., 2012). Cognitive impairment in older adults has been known to double the risk of falling (Van Doorn et al., 2003) and is thought to increase risk directly due to impaired judgement and visuospatial perception. Between 5-15% of the ageing adult population (60 years +) experience cognitive decline (Rubenstein and Josephson, 2006). It should, therefore, be noted that to-date, middle-aged adults do not appear to demonstrate levels of cognitive decline that would be likely to increase risk of falling.

Risk factors for falls often extend to external attribution such as environmental and social factors. Environmental or extrinsic factors are important contributing factors to an increased risk of falling with poor lighting and hazardous objects in the home such as upturned, loose rugs that may lead to slips and trips and result in a falls incident (Ambrose et al., 2013). These risk factors when considered in tandem with visual impairment and diminishing contrast sensitivity as adults age become problematic for the prevention of falls (Menz et al., 2003). The benefit of home hazard assessment and modification have demonstrated the possibility to reduce falls (Gillespie et al., 2003).

The association between falls and depression amongst older adults has been investigated for some time (Launey et al., 2013), suggesting that older adults who score highly on depression scales and report social isolation, loneliness and living alone were significantly associated with recurring falls in adults >60 years (Petersen et al., 2020). It is important to note that social isolation and loneliness is a widespread health problem reported among community-dwelling older adults (Nicholson, 2012). Little evidence suggests that this problem is present for middle-aged adults. However, with such a strong association to fall occurrence from the age of 60 years, this may warrant further investigation.

Future research is required to find novel multifactorial markers of fall risk that are able to identify younger individuals at risk of falling, determining both individual and external risk factors. Due to the multifactorial nature of falls, it is unlikely that researchers are able to detect a single specific factor in the causation of falls, further making preventative interventions difficult. Many risk factors studies have been conducted using an epidemiological approach and whilst these methods have determined ranked risk factors by examining the largest reported predictor (Rubenstein and Josephson, 2006), future studies should aim to adopt a free-living, prospective and experimental approach to identifying fall risk predictors in middle-aged adults.

2.7 Fall Risk Screening

As outlined throughout this review, falls are not totally random events. Research has highlighted that the occurrence of a fall is associated with multiple partially controllable risk factors. When examining fall risk within any given age population, prevention programmes attribute success to early identification of individuals at high risk of falls (Perell et al., 2001; Rubenstein and Josephson, 2006; Oliver et al., 2007). At present, screening tools have been found to be weak at differentiating fallers from non-fallers (Scott et al., 2007).

The reduction of injury from falls and the implementation of fall risk reduction programmes require specific interventions to be administered based on clinically assessed risk. Guidelines have outlined that a risk assessment carried out in any given age population should include specific tests with proven validity and reliability in the relevant setting (Mayers, 2003). Based on the recommendations by Wyatt and Altman (1995) and further emphasised by other colleagues (Oliver et al., 1997), a screening tool for the detection of fall risk should be underpinned by high values of specificity and sensitivity. It has also been suggested that screening tools should be tested within the correct study population, should include written recommendations for the correct application of the assessment and should not be time-consuming to implement (Wald and Morris, 2011). Whilst it has also been suggested that screening tools should be tested within the correct study population, no falls screening tool to date has been tested within individuals <50 years.

Fall risk screening tools have been predominantly developed to predict fall risk in individuals >65 years and are often implemented within hospitalised older adults, adults living within residential facilities and community dwelling older adults (Oliver et al., 1997; Lord et al., 2003; Matarese et al., 2015). These screening tools have been introduced into clinical practice within the UK (Gates et al., 2008), with the main purpose of reducing falls in community-living older adults. However, as many individuals are first screened post-fall or not until after the age of 65 years, it can be assumed that current tests administered within clinical practice lack sensitivity and show poor discriminative accuracy (Fabre et al., 2010). Given such findings, few of the current tools have been tested widely for diagnostic accuracy within various age populations, casting doubt on their ability to be utilised more broadly in clinical practice throughout the lifespan and to be utilised to inform early preventative interventions prior to an injurious fall occurring.

Due to the deficit in preventing falls, several clinical assessments to assess balance have been created in order to screen individuals for fall risk (Yamada and Ichihashi, 2010). More commonly used clinical screening tools are the Berg Balance Scale (BBS) and the Timed Up and Go (TUG) (James, 2007). The clinical assessments are, however, known to have limitations, such as ceiling effects in high functioning older adults (Berg et al., 1989). It is hypothesised that these tests would, therefore, not be predictive of fall risk in younger, more active populations, limiting any intervention strategies. A more recent balance assessment, the Mini-BESTest, has been developed to identify 14 tasks related to balance control systems in order to identify underlying balance impairments (Franchignoni et al., 2009). The Mini-BESTest has been successful in indicating fall risk with 86.4% accuracy (Mack et al., 2013). These figures, however, were observed in older adults and individuals with other neurological conditions such as Parkinson's Disease. Previously created clinical screenings tools still require validation in middle-aged populations.

With current screening tools lacking validity and failing to identify younger fallers, many factors underlying fall risk are required to be assessed more objectively. These methods include the assessment of posturography, gait, and strength. Significant advances in technology have allowed novel ways to examine posturography and gait impairment. Immerging evidence suggests the use of wearable sensors to predict fall risk based on daily-life gait quality (van Schooten et al., 2016). As the predictive accuracy of questionnaires and physical tests to examine fall risk continue to be questioned (Gates et al., 2008), recent insights suggest that new technologies to measure gait impairment may help to improve predictions (Rispens et al., 2015b; van Schooten et al., 2015). Alongside this, wearable sensors are able to provide tri-axial measurements during clinical functional assessments in order to provide both the scaled balance score, alongside participant specific postural sway data. Recent research has demonstrated that quality of daily-life gait, based on gait stability, variability, symmetry and smoothness appear to be sensitive markers of the intrinsic factors underlying balance ability (van Schooten et al., 2016). Wearable sensors are now able to monitor quality of daily-life gait during exposure to balance threats in everyday situations, unlike laboratory-based fall risk assessments.

Many earlier studies first attributed walking speed and stride frequency, derived from acceleration signals to fall risk (Weiss et al., 2013). However, studies are now investigating more sophisticated characteristics based on the temporal structure of trunk accelerations linked to fall risk, as they provide an insight into the underlying factors surrounding the increased fall risk. One week of ambulatory measurements of trunk accelerations, gait smoothness, dynamic stability and local dynamic stability per stride were identified as fall risk factor indicators in individuals aged >65 years (Rispens et al., 2015b). Later studies expanded these research findings by suggesting that gait quality in daily life, expressed by separate characteristics derived from trunk accelerations were predictive for both time to first and second falls (van Schooten et al., 2016). The model used was able to predict falls with good accuracy, enhancing the field further by allowing fall predictions to be made, which could help identify those in need of early fall prevention interventions. Studies are now required to examine the use of wearable sensors to detect and predict fall risk and time-to-fall in younger age groups. The method of capturing daily-life gait via accelerometery appears promising when attempting to increase the sensitivity and specificity of fall risk screening tools.

2.8 Injurious Falls

With falling comes resultant injury. Injurious falls are associated with functional dependence, reduced QoL, hospitalisation, disability and death (Ek et al., 2018), with fall induced injuries presenting as one of the most common causes of unintentional injury deaths in individuals aged 45-64 years (Kannus et al., 2005). For some time, data trends have highlighted the increasing burden that injuries, as a result of falling, have on hospitalisation and subsequent death (Curry et al., 2011). The Global Burden of Disease report released in 2010 marked a rise in the number of disability-adjusted life years (DALYs), demonstrating that falls resulted in 1.16 million DALYs among US adults. Of the 1.16 million figure, 422,000 (37%) DALYs were lost for those aged 45-64 years. The most recent report released in 2017, outlined the steady increase of total number of deaths and DALYs due to falls and highlighted that mortality rates due to falls had doubled since 1990 (James et al., 2020). These figures emphasise the rise of both fall related injury and death.

It is thought that the problem of fall related injuries in middle-aged populations, stems from a combination of high incidence and increasing susceptibility to trauma (Rubenstein and Josephson, 2006). Talbot et al. (2005) presented the percentage of falls that resulted in injuries such as fractures. These figures highlighted a gradual increase amongst the age groups (5.56% young, 11.5% middle-aged and 15.1% older). The gradual increase in injury rates with age is, as described earlier, to be expected. However, it is the severity and type of injury sustained that is of concern in younger age groups. It is thought that engagement in activity plays a significant role in the severity of injury sustained, with 22% of serious injuries being resultant of engagement in vigorous activity compared to only 6% in less active and able individuals (Speechley and Tinetti, 1991). These findings support the idea that middle-aged individuals are likely to be at a higher risk of sustaining serious injury, as a result of a fall, due to the increased exposure to riskier, more vigorous activities and environments. Exposure to such activities alongside the higher instances of disease, medication use, lower levels of physical activity and subsequent physiological changes that occur throughout the mid-stages of life, make injurious falls in this age demographic a topic worthy of further investigation.

At present, the recommendation for the reduction of injurious falls includes the combination of both a comprehensive fall risk assessment and a targeted intervention programme (Pengpid and Peltzer, 2018). As evidenced throughout this review, at present there is no available comprehensive fall risk assessments capable of identifying those at risk of falls <65 years old. Twinned with this, research to suggest specific factors and mechanisms surrounding middle-aged fallers is sparse, meaning that targeted intervention programmes are difficult to design. Research is required to highlight the potential risk factors and mechanisms surrounding falls within this age demographic, whilst highlighting the need for a comprehensive risk assessment, sensitive enough to identify those at risk of falling who are younger and more independent.

2.9 Conclusion

Falls remain a major health problem in need of preventative intervention. However, prior studies have primarily focused on older adults (Fried, 2000), resulting in individuals <65 years being severely under reported within this field. Whilst it may be a sensible approach to predominantly research the age group that are in highest need, the opportunity to identify early preventative interventions within younger populations, such as those who are middle aged is currently limited. Studies have reported on the circumstances surrounding falls in older adults including extensive description detailing fall causation, resultant injuries and determinants of risk factors (Cameron et al., 2018). This has directly led to the development of preventative interventions in older adults, including more screening for individuals over the age of 65 who are at risk (Gillespie et al., 2003). The same level of work is now required, to be able to support individuals who are predisposed to falling below the ages of 65 years.

Despite the cost of fall-related injuries to worldwide healthcare systems, factors and mechanisms surrounding injurious falls are yet to be investigated in younger, independent, and active populations. Many current clinical screening tools used to assess fall risk are successfully predicting falls in older adults and individuals with other neurological conditions. However, these clinical screening tools often demonstrate ceiling effects, meaning that these tests are not challenging higher functioning individuals and therefore are not sensitive enough to predict falls in younger age populations. With individuals living longer, but not necessarily healthier lives free of co-morbidities, further research is required to examine younger populations in order to detect fall risk and therefore provide interventions to prevent falls during earlier life stages. With advances in technology, research is required to screen younger individuals against current clinical assessments, whilst examining gait characteristics in real world risk environments in an attempt to create a more sensitive clinical screening tool in order to detect and predict fall risk in younger populations.

Chapter 3: Regional Falls

3.1 Introduction to Falls in Greater Manchester

Falls are a worldwide public health concern (Masud and Morris, 2001). The prevention of falls amongst the ageing population of Greater Manchester (GM) is, however, a major healthcare issue, with the city scoring poorly against national averages when examing fall-related outcomes such as hospital admissions and mortality. The most recent Manchester Joint Strategic Needs Assessment (JSNA) of adults and old people was last released in 2016. At the time of release, the GM area was already demonstrating significantly higher rates of emergency hospital admissions as a result of a fall in those aged 65+, when compared to the rest of England (see Figure 3.1). In line with previous findings, such prevelance rates of falls and subsequent hospital admissions are only expected to have risen as time has progressed (Burton et al., 2018). It is hard to quantify the scale of the problem of falls in GM, with many falls often going unreported and of those fall incidents that are reported to various services, many are coded accordingly to the injury or pre-existing condition of the adult. Further work is required to improve how fall incidence data is obtained and recorded across GM. As the data in this chapter has been derived from both open access sources available in the public domain (Joint Strategic Needs Assessment report) and data from local NHS trusts from an anonymised database, ethical approval for the presentation of the data in this chapter was not necessary.

Similar to many areas of fall related research, emergency hospital admissions and fall-related mortality rates for middle-aged invividuals (<65 years) are not present throughout the GM JSNA report. The prevelance of falls in middle-aged adults are known to be lower than those in adults over the age of 65 years, this data was highlighted in Chapter 2, section 2.5. It is likely, however, that fall related hospital admissions in middle-aged adults are also higher in GM than in other regions within the North of England, given the relative data displayed in Figure 3.1. To what extent falls in middle-aged adults in GM compare to other regions in England is currently unknown.

One likely contributor to the increased falls prevalence reported in GM is the higher number of hip fracture admissions also witnessed in GM residents. As discussed in Section 2.5, many falls are only reported following admission to accident and emergency. Similarly to emergency hospital addmissions, hip fractures of GM residents also remain above the national average. Data available for the period of 2010 to 2016 suggests that older adults living in GM are particularly vulnerable to injuries suffered as a result of an accidental fall. It is possible that underlying health issues, for example poor bone health, could be a contributing factor of higher than average hip fracture emergency hospital admissions across the city. Hip fractures continue to be a national health concern, with the most recent 2021 National Hip Fracture Database (NHFD) outlining that 63,284 adults presented at 173 hospitals across England and Wales following a hip fracture during the year 2020. Hip fractures alone account for 1.8 million hospital bed days and £1.1 billion in hospital costs every year, excluding the high cost of social care (GOV, 2022), alongside being one of the most serious consequences of falling, resulting in two out of three fallers unable to return to their former levels of independance.

The latest Greater Manchester Combined Authority (GMCA) report released in 2018 suggested that by 2038, 1.1 million people in GM will be over 50 years of age, accounting for approximetely 37% of the city-region population. This increase in the mean age of the population is likely to have a direct relationship with the number of falls documented in older adults in GM. Given the suggested increase in age of the GM population and the higher rates of fall-related hospital admissions when compared to other regions, it is expected the middle-aged adults in GM will follow the same trajectory as the current older adults who currently display a higher number of fall related hospital admissions.

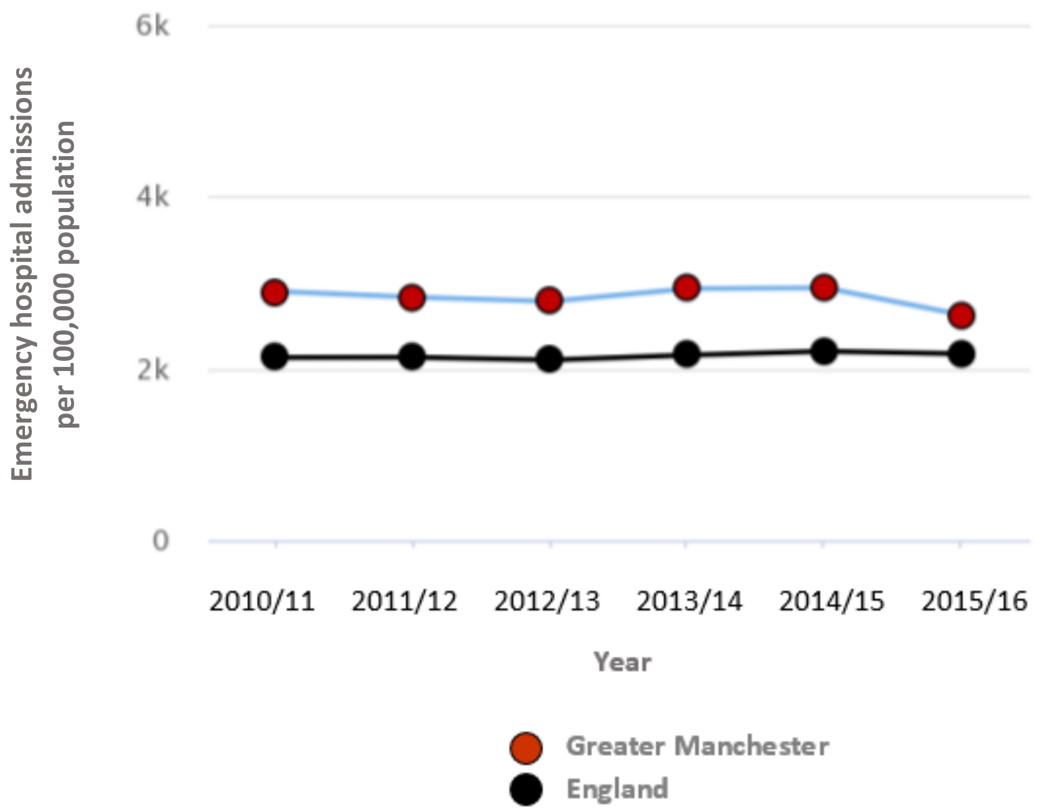

Figure 3.1. Emergency hospital admissions due to falls in individuals aged >65 years within the Greater Manchester area as presented in the Manchester Joint Strategic Needs Assessment report 2016.

Mortality rates as a result of accidental falls are also higher in GM when compared to other cities in the UK. In a JSNA report released by Liverpool City Council, GM was found to have higher mortality rates as a result of falling, in individuals older than 65 years, between the years of 2012 and 2014 (see Figure 3.2). Both hospital admissions and mortality rates as a result of falling were higher than the national averages for England until 2016.

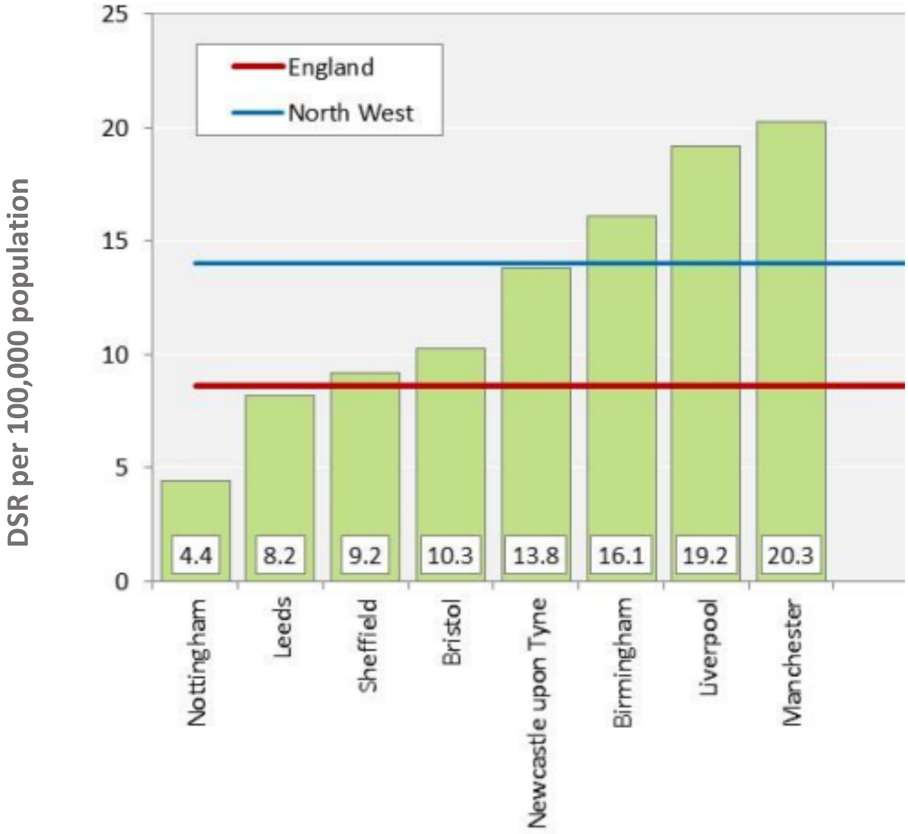

Figure 3.2. Mortality rates from accidental falls in adults 65 years and older, based on data from 8 cities in England between 2012-2014. Data presented as directly standardised rate (DSR) per 100,000 patients.

The reasons behind why individuals fall, sustain greater injury and resultant mortality more so in GM than other city regions requires further investigation. However, there are several possible interacting factors that place older GM residents at risk of injurious falls. These risk factors are likely to be both intrinsic and extrinsic in nature with healthcare infrastructure, the health of the individual and deprivation being key determinants.

National data on falls and deprivation indicate that older people in more deprived areas of GM were more likely to attend A&E departments as a result of a fall when compared to less deprived areas (Figure 3.3). People living in more deprived areas of the city experienced greater incidence of injuries due to falls, although, at present, there is no data available at ward level to evidence this. Residents of more deprived areas are likely to experience a greater number of factors that contribute to increased incidence of falls, such as poor health, poor nutrition, poor housing alongside other social and environmental issues. Future research is required to obtain up-to-date deprivation and falls data to examine how GM compares in 2022 to national averages.

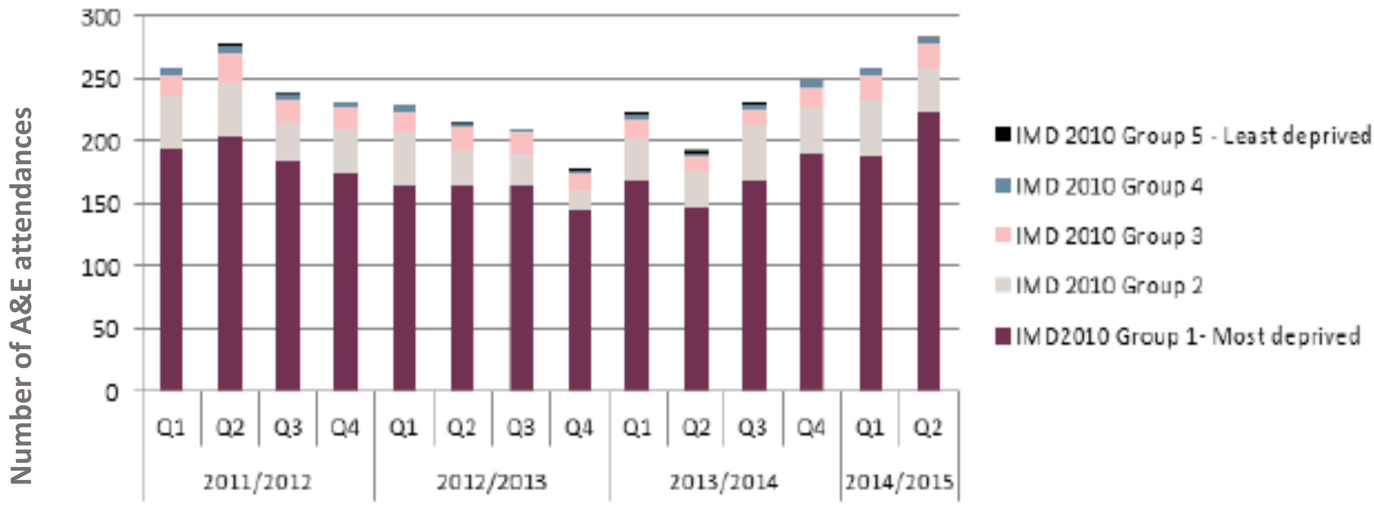

Figure 3.3. The number of older adults (65+ years) attending A&E departments in GM as a result of falling between 2011 and 2015.

At the time of the report, the available data suggested that older people in Manchester were particularly vulnerable to injuries subsequent to falling, due to the number of admissions to accident and emergency (A&E) departments. Data collected by the Trauma and Injury Intelligence Group (TIIG), in the six month period between April 2016 and March 2017, identified 2,966 A&E admissions related to falls in the GM area. Despite these prevelance rates being available within the report, further work is required to obtain accurate and up-to-date data regarding the prevelance of falls in GM. Falls are not considered a diagnosis independently, making the collection of fall data related to incidence and type of fall difficult. Clinical staff are likely to record injury type upon admission to A&E rather than what caused the injury, which makes obtaining a definitive picture of the true problem of falls in the GM area difficult.

The GM JSNA report highlighted that in 2016, falls presented themselves as a serious public health challenge for older adults residing in GM, a problem that is expected to increase. The report highlighted concerns regarding the length of waiting list times and the causes of falls and stated, "if we consider the causes of falls in term of accumulated health inequalities and depravation, we cannot expect this trend to diminish". The report, however, is 6 years old and the presence of a global pandemic may have exacerbated the issues of health inequalities, depravation and waiting list times for treatment. The impact of the global pandemic on fall-related risk factors will be discussed later in Chapters 6 and 7 of this thesis.

The priorties outlined in the JSNA report demonstrated a need to move beyond looking just at what happened and/or what affected the person at the time of the fall and moving more towards developing a programme which focused on helping people to live healthier, strong, active and more confident lives; a method that is reliant upon the development of early prevention strategies. Report evidence suggested that the best methods to reduce instances of falls would be to concentrate on the causes of falls from the age of 50. Since this time, the most recent overview for the prevention of falls has begun to recognise the need for fall risk screening in those aged 50+ years. With this report being the last to be released since 2016, a new report is required to be released by Manchester City Council to determine if there has been any movement towards the targetted priorities outlined above.

3.2 Falls in Greater Manchester

The extent to which falls have been a public health concern across GM is not evident in the data provided by GM City Council alone. To date, there has been no data released to suggest the prevalence rates of falls in the GM area between 2016 and 2022. Alongside a high prevalence of falls in the GM area, in-patient falls continues to be the most frequently reported patient safety incident in acute hospitals. Working as a member of the Manchester University NHS Foundation Trust (MFT) GM Fall Collaborative group throughout the duration of this PhD, has allowed the problem of in-patient falls in GM to be observed more closely, and with direct clinical staff dealing directly with the individual fallers. Anonymised in-patient and bed occupancy data has been provided by the following NHS MFT hospitals: North Manchester General Hospital, Manchester Royal Infirmary (MRI), Royal Manchester Children's Hospital, St Marys Hospital, Wythenshawe, Trafford, Withington and Altrincham (WTWA) Hospitals and Manchester Dental and Eye Hospitals. For the period between September 2020 and December 2021, 4,793 in-patient falls were recorded in MFT hospitals (Figure 3.4).

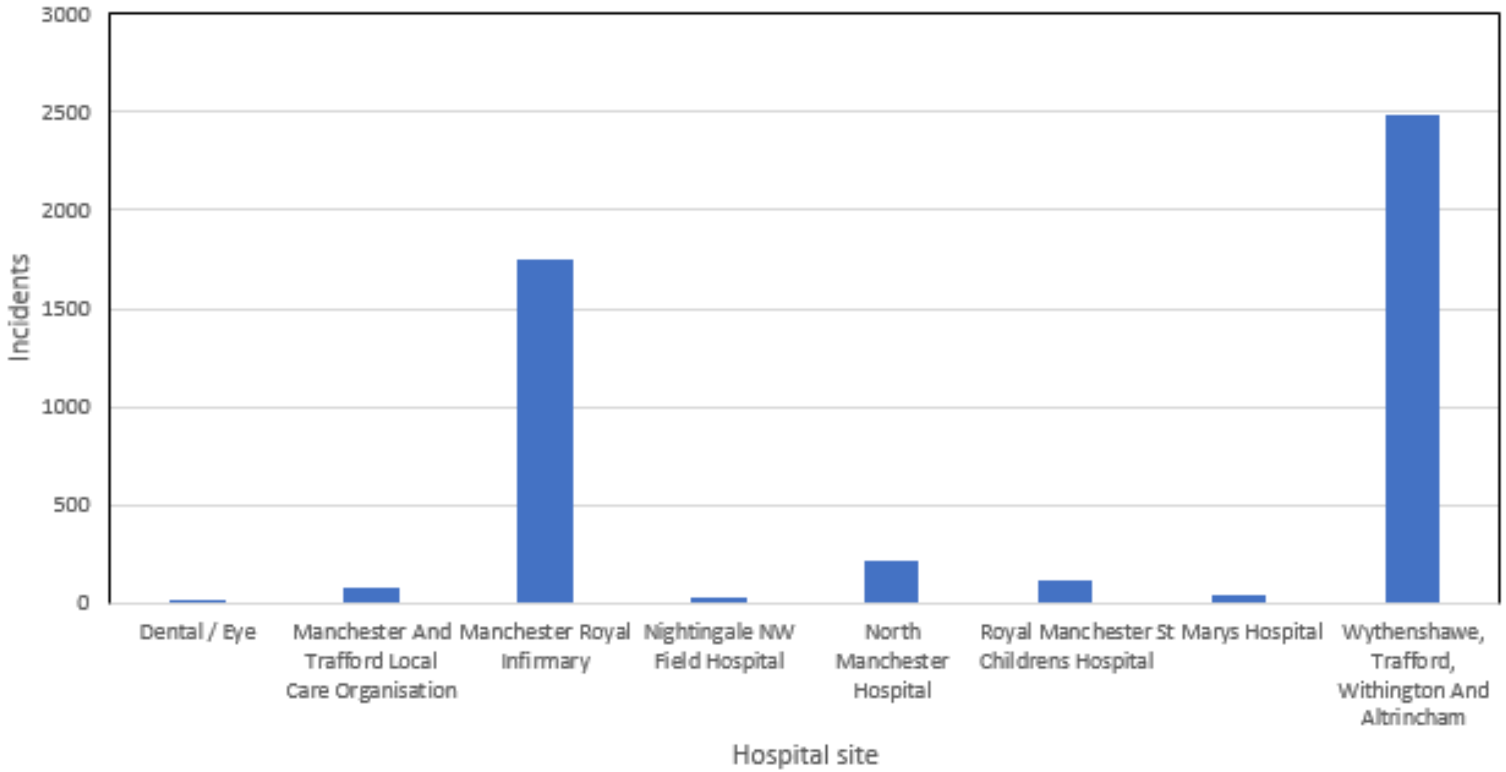

Figure 3.4. Total number of in-patient falls across all MFT hospital sites between September 2020 and December 2021.

Data has also been obtained to outline in-patient fall incidence based on age group (Figure 3.5). The highest proportion of in-patient falls can be seen within both the 61-80 and 81-100 age groups. This supports present literature suggesting older adults >65 years being at the highest risk of falls (Ambrose et al., 2013). Middle-aged fallers accounted for 16.2% (777/4,793) of all in-patient falls. These prevalence rates are in line with those found in middle-aged studies conducted by Talbot et al. (2005) and Caban-Martinez et al. (2015).

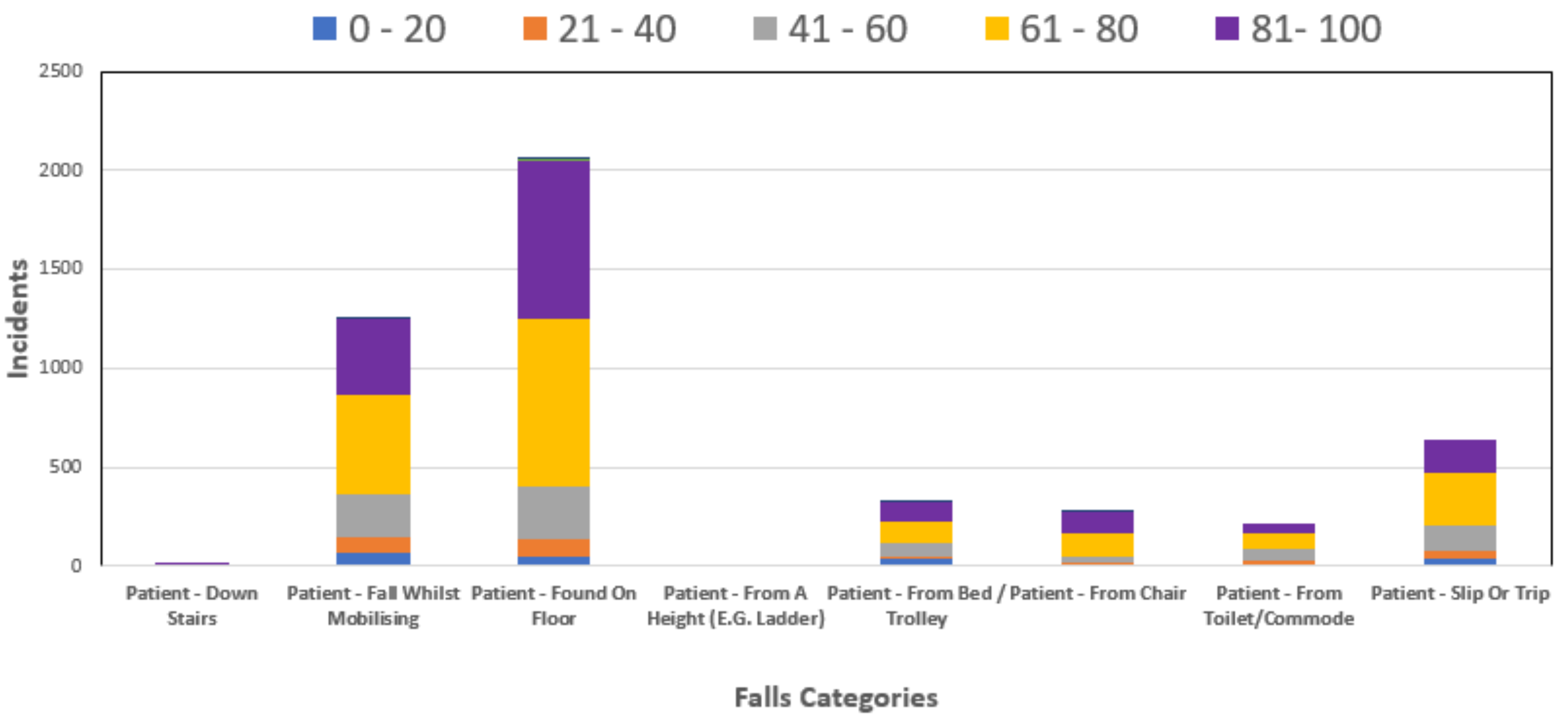

Figure 3.5. Total number of MFT in-patient falls separated into five age groups (0-20 years, 21-40 years, 41-60 years, 61-80 years and 81-100 years) based on eight fall categories between September 2020 and December 2021.

3.3 Manchester Foundation Trust Falls During the Coronavirus Pandemic

The true multifactorial extent of how the COVID-19 pandemic has impacted fall prevalence in the GM area remains unknown. A report provided to the GM Falls Collaborative group created by WTWA hospitals was able to outline numbers of falls between the period of April 2019 and February 2021. Hospital fall data is often reported based on bed occupancy percentage and falls per 1000 bed days. The number of reported fall incidents across the two hospital sites is variable throughout the duration of the pandemic. Lower bed occupancy is likely to have played a role in the number of fall incidents documented. During the COVID-19 response, WTWA had significantly lower bed occupancy rates when compared to previous months (Figure 3.6 and Figure 3.7). There is a notable drop in bed occupancy from March 2020 onwards across both hospital sites, with occupancy dropping as low as 49% at Wythenshawe Hospital in April 2020 and 56% at Trafford General Hospital. A lower average bed occupancy helps to explain why documented fall rates throughout the pandemic were lower when compared to the months preceding the pandemic, where bed occupancy was much higher.

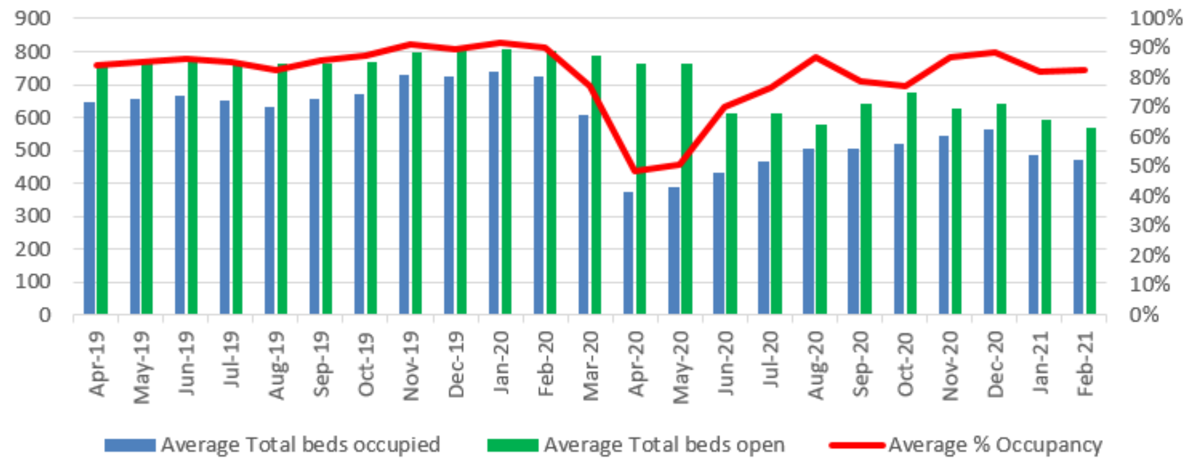

Figure 3.6. Wythenshawe bed occupancy data represented between April 2019 and February 2021.

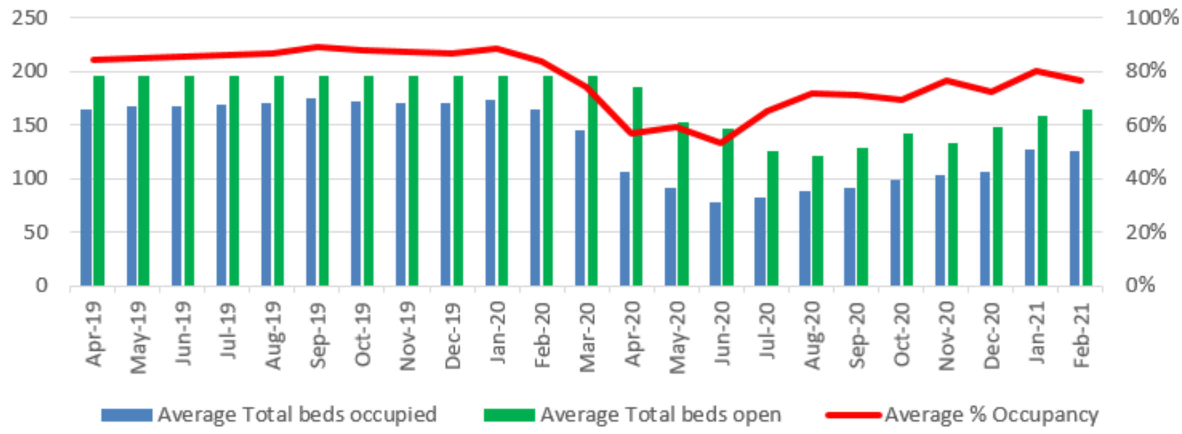

Figure 3.7. Trafford bed occupancy data represented between April 2019 and February 2021.

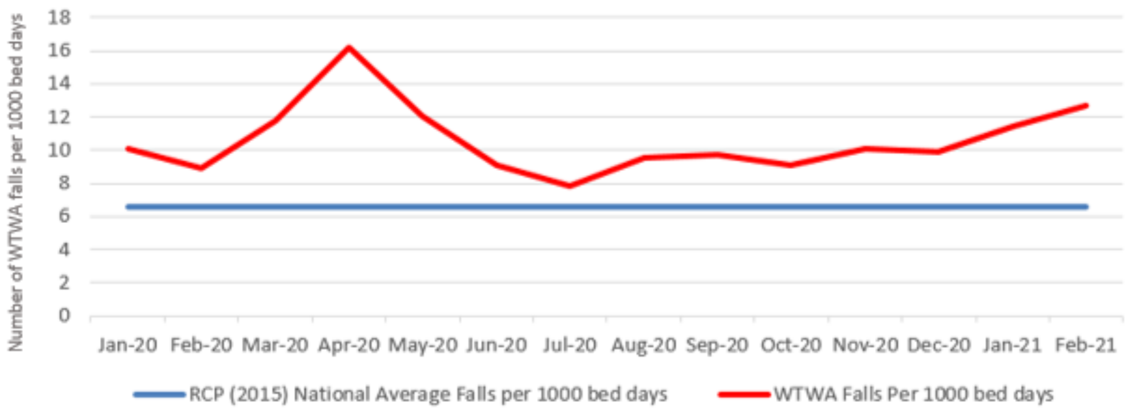

Figure 3.8. Wythenshawe, Trafford, Withington and Altrincham hospital fall data per 1000 bed days.

There are instances where a greater number of falls occurred despite bed occupancy being reduced. The month with the highest falls per 1000 bed days was April 2020 (Figure 3.8), with an average fall rate of 16.2% per 1000 bed days. These data may be partially explained by the onset of the pandemic in the UK on the 26th of March 2020. The report released by WTWA attributed an increase in falls to several factors. Staff sickness, new government advice to shield, ward moves or transitions into COVID-19 wards meaning lack of fall specific support equipment being available and the redeployment of staff meaning that fall specific staff were supporting other departments during the worst of the COVID-19 outbreak. All of these factors were somewhat unavoidable due to the extensive pressures on the NHS during a global pandemic. Despite the above factors being potentially present, it is the factors increasing an individual's risk of falling due to the COVID-19 pandemic that require further investigation. Falls are also predicted to increase due to the impact of the pandemic. The incremental increase in fall prevalence by year can be observed in MFT hospital data (Figure 3.9). The impact that the extended period of isolation and physical inactivity will have on the risk factors and prevalence of both middle-age and older adults post-pandemic is still to be determined (Pelicioni and Lord, 2020).

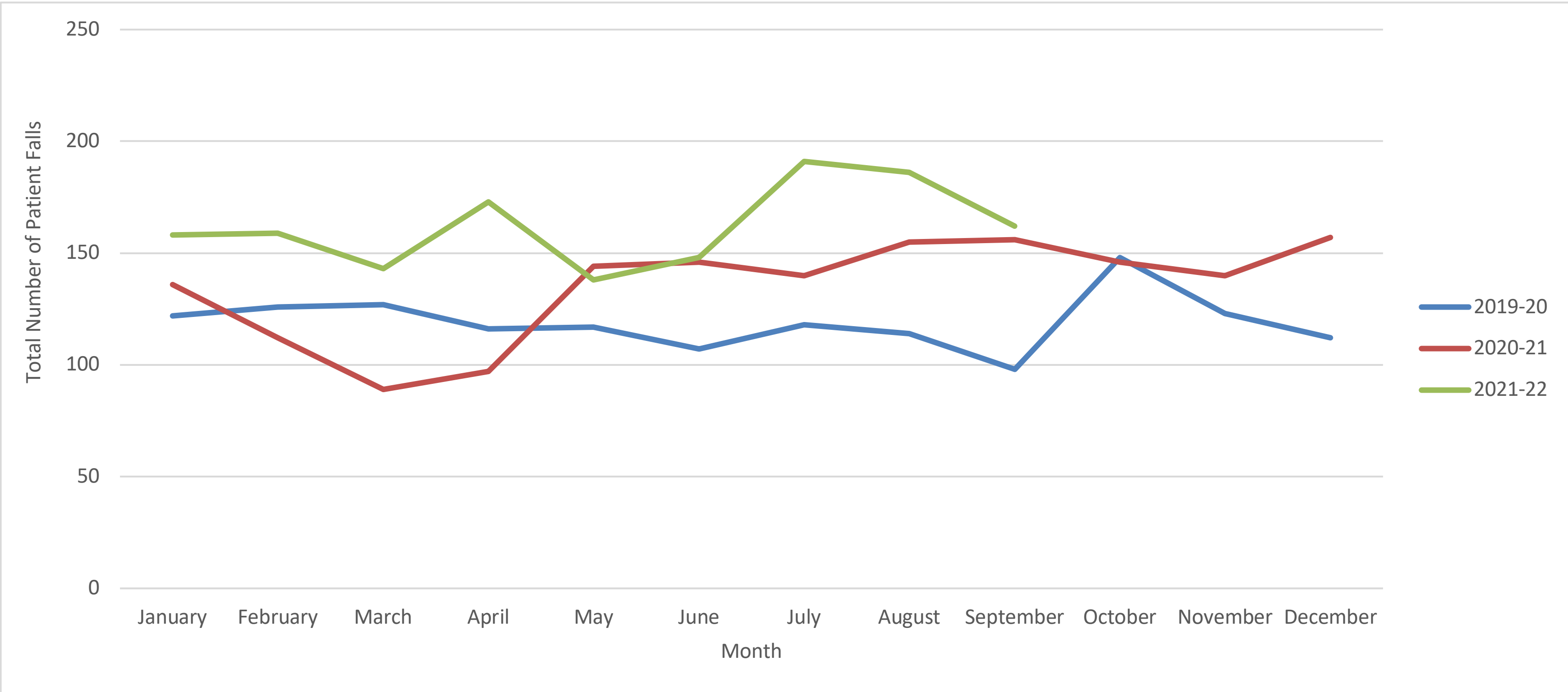

Figure 3.9. Total number of patient falls per month from April to March for years 2019-2020, 2020-2021 and 2021-2022. Data for patient falls for months January-March 2022 were unavailable when obtaining the above findings.

It can be suggested that in-patient falls may have different predisposing risk factors to community falls. These may include physical illness, mental health, increased medication usage and environmental factors (Morgan et al., 1985). Increased likelihood of falling when discharged from hospital is also more likely in these patient groups; with patients often only being screened for fall risk upon admission to hospital. Inpatient fall status provides vital information to suggest the risk of a patient falling after being discharged from hospital.

3.5 Conclusion

The data above outlines that fall prevalence is increasing in all age populations since the MJSNA report was released in 2016, and whilst this may be due to the impact of a global pandemic, future work is required to understand both the risk and instances of falls both in hospital and home settings. GM appears to be demonstrating a public health problem when examining fall rates of ageing individuals living in and around the area of Manchester. These data provide a strong rationale for both the increased need for developments in screening and prevention of falls in middle-aged and older adults in the GM area. A further challenge is that the GM data is a composite of the 10 boroughs of GM. It is probable that each presents a different profile for falls due to the differences in socioeconomic factors present across the boroughs. Some of these proposals seem evident from the hospital fall data (see Figure 3.4).

Chapter 4: Neuromuscular and Psychological Factors Contributing to Falls in Middle-Aged Adults

4.1 Introduction

Fall rates in older people are increasing, directly leading to higher injury rates, a subsequent burden on health care systems and a higher proportion of government budgets being spent on fall related costs (Bird et al., 2013). The impact that falls have on the personal lives of those at greatest risk, far outweigh the economic cost, with a reduction in functional activity, deconditioning and subsequent increased risk of falling occurring post fall (Zijlstra et al., 2007). Individuals who fall show signs of decline in: balance, gait, muscle strength and size, functional ability, and postural control when compared to their non-falling counterparts (Rubenstein and Josephson, 2006). It is not surprising, therefore, that a considerable amount of both clinical and research time has been spent trying to reduce falls by improving these factors. Intervention for these factors may reduce the fall risk of adults >65 years (Andresen et al., 2006). It cannot be assumed that individuals <65 years would display the same risk factor profile and, therefore, benefit from the same intervention strategies.

There may be many predisposing reasons as to why an individual may fall, often the most important are the physical attributes of the faller. An impairment in balance ability and a reduction in strength are both associated with the ageing process (Bird et al., 2013). Weakness of the lower limbs is a significant fall risk factor, with a reduction in muscle strength increasing an individual's odds ratio of falling by 1.76 (96% CI 1.31 – 2.37), with this value increasing if combined with the presence of lower limb weakness 3.06 (95% CI 1.86-5.04) (Moreland et al., 2004b). Changes in body composition and function, more specifically decreased appendicular skeletal muscle (ASM) mass as a result of sarcopenia have been linked to falls (Rosenberg, 1997). Decreased muscle mass was added to the definition of sarcopenia in 2012 (Cruz-Jentoft et al., 2010) to ensure that a diagnosis of sarcopenia was based on the evaluation of muscle strength, not just muscle mass (Cruz-Jentoft et al., 2019). Both muscle strength and mass need to be considered within middle-aged populations. Muscle strength is known to decrease at a faster rate during earlier stages of life compared to the reduction of muscle mass as a result of ageing (Goodpaster et al., 2006). In addition, lower limb muscle strength has been outlined as a successful predictor of negative health consequences such as falls and reduced quality of life (Schaap et al., 2018).

Increased body mass index (BMI) and high adiposity are both linked to falls in older people and often occur as a result of falling due to a deconditioning period (Peeters and Backholer, 2012). Associations of increased BMI and musculoskeletal outcomes are required to be interpreted with caution, as often a higher BMI is associated with greater bone and muscle mass (Newman et al., 2003). Muscle quality, widely defined as the force produced per unit of muscle mass (Gadelha et al., 2018), is compromised when high levels of adiposity are present. Adiposity is known to directly increase the likelihood of sarcopenia, resulting in a loss of muscle strength (Scott et al., 2020). Despite BMI increasing with age, older adults have been seen to display a high adiposity but otherwise normal BMI (Okorodudu et al., 2010). These findings suggest that middle-aged individuals at risk may not demonstrate a higher overall body mass. Examining body composition by examining lean mass, muscle quality and fat mass independently, may provide a more appropriate measure than BMI when trying to discriminate fallers from non-faller counterparts, particularly using more stringent measures such as Dual Energy X-ray Absorptiometry (DEXA). Examining segmental measures of body composition (both lean and fat mass) in relation to fall risk in a middle-aged population requires further investigation.

Another area for fall risk investigation is postural control. Age related deterioration in the mechanisms required to control balance become impaired during later life years (Melzer et al., 2010). Increased postural sway during quiet standing, in particular mediolateral sway, and a narrow base stance have been attributed to older individuals who report reoccurring falls (Melzer et al., 2004). Clinical screening tools such as the Mini-BESTest have been found to successfully detect fall risk in older adults with a decline in postural control (Yingyongyudha et al., 2016), however, these tests may lack sensitivity when examining middle aged participants due to the ceiling effects observed in the 28 point scoring system. The decrease in the sensitivity of older adults' postural control systems may never present as an identifiable falls risk factor for younger adults due to lack of age-related decline. With many fall risk factors being attributed to age related decline, researchers may be required to determine novel markers of fall risk factors that have increased sensitivity when discriminating between middle-aged who are at risk and those who are not.

Increased fall-related anxiety has been linked to postural control and locomotor changes (Adkin and Carpenter, 2018), demonstrated in the form of a reduction in knee, hip and ankle movement and an increase in muscle co-contraction (Staab et al., 2013). It has been suggested that anxiety related outcomes are due to individuals displaying a more conscious processing of walking movements (Young and Williams, 2015). Research into this area has been primarily investigated in relation to both older adults and those with neurological disorders (Hadjistavropoulos et al., 2011). However, the measurement of conscious movement processing (CMP) may identify as a sensitive risk factor for younger populations and especially for those with high trait anxious or catastrophising profiles.

The Movement Specific Reinvestment Scale (MSRS) (Masters et al., 2005) has been used to examine how anxiety related shifts towards CMP have influenced individuals' performance during motor tasks. Recent research has suggested the MSRS lacks sensitivity when measuring CMP during gait-specific tasks (Young and Williams, 2015) due to differences examined in how individuals with high anxiety profiles engage in CMP. Due to such findings, the Gait-Specific Attentional Profile (G-SAP) was created in order to reliably measure self-reported levels of CMP during gait (Young et al., 2020). This measure may now be sensitive when discriminating fallers from non-fallers when examining self-reported levels of CMP during gait.

Older adults who have fallen often report a greater fear of falling (FOF) (Cumming et al., 2000), often identified by higher scores on questionnaires such as the Falls Efficacy Scale-International (FES-I) (Yardley et al., 2005). The FES-I has been a well-used tool for assessing FOF in older populations, but developments to the FES-I have been required for some time to further examine FOF in more demanding balance related activities for those individuals who may be younger or older and more active (Delbaere et al., 2010b). The development of the Iconographical Falls Efficacy Scale (Icon-FES) has successfully provided an increased level of sensitivity to the area of FOF scales (Delbaere et al., 2011). By introducing more demanding balance related activity questions, through the use of example pictures and simple text, the Icon-FES is the first scale able to identify a level of FOF based on a range of daily activities set within specific environmental contexts. Increased sensitivity such as this, is required in younger populations to determine FOF.

Due to a lack of research experimentally identifying both physiological and psychological risk factors for falls in a middle-aged population, it is important to gain an understanding of the fall risk profile that an adult aged between 45-64 years displays. The identification of risk factors could help the development of fall prevention strategies that could then be adopted, similar to those older populations that have experienced falls (McClure et al., 2005a). The aims of the following study were to: 1) use experimental laboratory-based techniques to determine potential risk factors for falls within a middle-aged sample of both fallers and healthy non-fallers; 2) distinguish which of the outcome measures investigated contribute towards falls; and 3) explore the ability of current clinical screening tools to successfully distinguish between fallers and non-fallers.

4.2 Methods

4.2.1 Participants

32 community dwelling middle-aged adults, aged between 45 and 64 years were recruited to the study. Anthropometric data of participants are reported in Table 5.2. Falls participants (n=13) (n=8 female, n=5 male) reported as having at least one fall during the 12-months preceding the study. Control non-faller participants (n=19) (n=13 female, n=6 male) self-reported as having no known musculoskeletal disorder and no instances of falls in the 12-months preceding the study. All experimental procedures were approved by the Ethics Committee of Manchester Metropolitan University and the North-West Preston Research Ethics Committee (REC) (260217) (Appendix 4.1). All participants provided written informed consent prior to involvement within the study.

4.2.2 Protocol

All participants underwent cross-sectional experimental testing, conducted within the laboratories at Manchester Metropolitan University. Participants were asked to attend the University for a single 3-hour experimental testing session, in which measures were conducted to examine participants physical function, balance, muscle function and body composition (Figure 4.1). Data collection took place from December 2019 to September 2021[1].

[1] Data collection procedures began in December 2019 in line with the arrival of the global pandemic. During the 22 months between December 2019 and September 2021, governmental restrictions due to the spread of COVID-19 considerably impacted both study recruitment and in-person laboratory-based testing of participants.

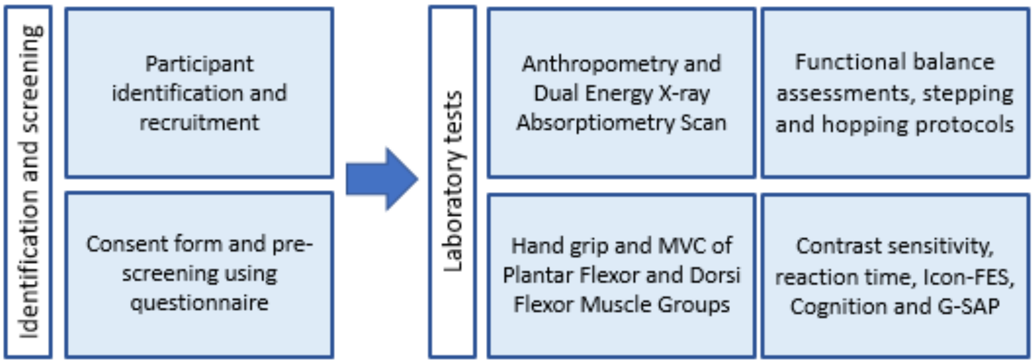

Figure 4.1. An overview of the experimental procedures completed by 32 study participants.

4.2.3 Procedure

All participants were screened for eligibility via email prior to being accepted into the study. All aspects of testing sessions including the researcher, equipment and order of data collection remained consistent throughout the duration of the study. Time of day of testing differed between participants due to participant age range and subsequent work commitments but avoided early mornings (<09’00h) and later evenings (>18’00h) to mitigate any circadian effect. Participants attended the laboratories at Manchester Metropolitan University for a total of 3 hours. Participants were asked to arrive at the laboratories in a two-hour fasted state (Bartoli et al., 2011). All anthropometric measurements were taken upon arrival to the laboratory, subsequently followed by measurement of body composition.

4.2.4 Anthropometry

Stature (m) was measured in a standing position using a stadiometer (Seca 213, Hamburg, Germany). Body mass (kg) was measured using digital scales (Seca, Hamburg, Germany). Participants were taken into a private room and instructed to change into a cotton wraparound gown in preparation for both anthropometry and body composition measurements. The dominant limb of the participant was determined via self-report. For examine, participants were asked the following question: “Which leg would you use if you had to kick a ball?” (Greenberger and Paterno, 1995).

4.2.5 Dual X-Ray Absorptiometry (DEXA)

Participants completed a 6-minute whole body scanning procedure (0.4 *μSv)* (microSievert) on the DEXA scanner (GE Lunar Prodigy Advance, UK). Participants were asked to lie in a supine position in the centre of the bed, ensuring contact between the trunk and appendicular mass was avoided. Participants were positioned with their arms by their sides with their hands positioned flat onto the bed, palms down with fingers spread apart (Appendix 1.2). Both hips of the participant were internally rotated, ensuring that the toes pointed inward (Tomlinson et al., 2014). Care was taken to ensure that sufficient spaces were left between both the arms and the torso and between the legs to improve the accuracy of the subsequent analysis. To aid comfort and to minimise participant movement, medical tape (Transpore™ Medical Tape, 3M™, USA) was placed around both feet to ensure that the hips remained internally rotated. All participants were positioned as described above with time from supine to start of scan taking between 3-5 mins.

The DEXA scan was conducted in order to obtain high-resolution contrast images of different body tissues, through measuring the attenuation of photon energy, as it passed through the different soft tissues of the body (Okasora et al., 1999). In doing so, the method provides a stable and accurate estimation of variables such as fat mass (FM), bone mineral density (BMD) and lean mass (LM) (Mazess et al., 1990). ASM calculated as total lean muscle mass of limb (kg) divided by the square of height (m^2) (Malmstrom et al., 2013). DEXA is considered a highly valid assessment tool for obtaining measurements of whole-body composition (Aragon et al., 2017).

4.2.6 Physical Function and Balance Assessments

Five clinical functional performance tests alongside a hopping and risk-taking stepping protocol were utilised to assess the balance and gait of the study population. The Mini-BESTest including Timed Up and Go (TUG) and TUG dual task, Five-Times-Sit-to-Stand Test (STS) and the Four Square Step Test (FSST) were conducted as measures of gait, sit to stand ability, balance and lower extremity strength (Rockwood et al., 2000; Sumway-Cook et al., 2000).

(1) Participants were asked to complete the Mini-BESTest. The test is a 14-item scaled functional test, in which physical performance is assessed on a rating scale. The tests items are grouped into 4 sub-systems of dynamic balance: anticipatory postural adjustment, postural responses, sensory orientation, and balance during gait. All items featured in the test are scored on an ordinal scale where 0 represents severe, indicating the inability of the participant to complete the task, 1 indicates the moderate ability of the individual to complete the task and 2 indicates normal performance (Haakonsen, 2013). For item 3 (stand on one leg) and item 6 (lateral compensatory stepping-lateral) only the worst performance score time (s) was used when calculating the total score. Each participant was

asked to complete items from 1-14 and were provided with a score that totalled up to a maximum of 28 points (Appendix 4.3). The equipment used for the Mini-BESTest was Temper® foam (T-foamTM 4 inches thick, medium density T41 firmness rating), a chair without arm rests or wheels, an inclined ramp, a stopwatch, a box (9" high) and a 3m distance measured out and marked on the floor with tape from the positioned chair. The Mini-BESTest has been found to be successfully determine history of falls with post-test accuracy of 85%, sensitivity 85% and specificity 75% (Yingyongyudha et al., 2016).

(2) Participants were required to complete the TUG test outlined within the Mini-BESTest. The task assessed the ability of the participants to perform a sequential motor task that is known to be related to walking and turning. The test provided a timed score (s) of how long it took all participants to stand from an armchair, walk at a comfortable pace for 3m, turn at the 3m distance point, walk back to the armchair and to sit down again (Sumway-Cook et al., 2000).

(3) The TUG dual test required participants to count backwards by three starting from a number between 90-100 whilst performing the TUG motor task described above. Participants were instructed to begin counting backwards by three and the time was started when the researcher said 'Go'. The time was stopped when the participant returned to a seated position in the chair. If gait speed time was >10% during the dual task condition a point was deducted from the score.

(4) Participants were asked to perform the STS test in order to examine sit-to-stand ability. Participants were asked to be seated with their back against a chair (measuring 43cm height, 47.5cm depth) with their arms folded across their chest (Whitney et al., 2015). Participants were provided with the following instructions

in order to carry out the task. “When I say go, I want you to stand up and sit down 5 times as quickly as you can”. The timing stopped when the participant sat down in the chair for the fifth time. Each participant was instructed to stand up fully between each repetition and also not to touch the back of the chair during each repetition. Lord et al. (2002) conducted the STS using the same protocol and reported an intraclass correlation coefficient of .89 for reliability on community dwelling adults.

(5) The FSST was conducted and involved all participants stepping over four canes that were laid on the ground at 90◦ angles to each other. All four canes were 90cm in length, a method previously described by Dite and Temple (2002) (Appendix 4.4). Participants were asked to stand in square 1, facing forward. Participants would then move into squares 2, 3 and 4 in a clockwise direction ensuring that all participants moved forward, to the left, backwards and to the right. After the clockwise movements, participants then moved in an anti-clockwise direction from square 4 into squares 3, 2 and 1. Participants were instructed that both feet had to touch in all four squares in order to complete the sequence. Each participant had one practice trial and 2 timed trials (s). If the participant touched the middle canes, lost his/her balance or did not touch both feet in each square the participant was asked to repeat the test. The quickest time that the participant took to perform the FSST was taken and used for subsequent analysis. The FSST has been reported to be a valid tool for measuring dynamic balance and fall risk (Moore and Barker, 2017).

(6) A single leg hop protocol was implemented as an indirect measure of lower extremity strength and balance (English et al., 2006) and subsequently participants

were asked to perform a single leg hop test. Hop distance was examined on both dominant and non-dominant legs. Participants were instructed to allow arms to move freely whilst performing the hopping task and upon landing, maintain balance for 3 seconds. Chalk was applied to the bottom of the participant's shoe for measurement accuracy upon landing. The chalk was erased from the floor after each trial to minimize visual cues. The participants performed three maximum effort trails on each leg with 30 seconds rest in-between trials to prevent fatigue. The peak of the three hop distances for each leg was recorded and used for analysis.

(7) A risk-taking stepping protocol was implemented to examine perceived vs actual stepping ability. To first obtain actual stepping ability, participants were asked to take the longest step possible on the floor without losing their balance. Each participant was required to stand with his or her heels at 0 cm on a tape measure secured to the floor and take one step with the dominant leg and remain balanced, one foot in front of the other for 3 seconds. The dominant heel of the participant was chalked to assist with measurement accuracy upon landing. An average of 3 stepping trials was recorded. Perceived stepping ability was then obtained by asking each participant to self-select the distance that they would be happy to step from one raised block to another. Participants stood on a raised wooden block (12" high) placed at 0 cm on the measuring tape and watch as the researcher progressively moved the second block further away from them. Participants were instructed to inform the researcher when the maximum distance that they believe they could comfortably step unaided had been reached. Prior to the participant making the step they were informed that they did not need to make the step, the

trial was used to examine perceived stepping ability. The distance from the heel of the stepping foot to the edge of the moved box was recorded as the perceived step distance. The actual stepping ability measure was then be subtracted from the perceived stepping ability distance to provide a measure of discrepancy between perceived and actual stepping ability.

4.2.7 Muscle Function Assessment

Plantar Flexor and Dorsi Flexor Maximal Voluntary Contractions

Isometric and isokinetic PF and DF MVCs of the ankle are known to limit stability, with a direct link to falls in ageing adults (Melzer et al., 2008), however little is known about the middle-aged population. Therefore, isometric and isokinetic maximum voluntary contractions (MVC) were performed using an isokinetic dynamometer (Cybex Norm, Cybex International, New York, NY, USA). All muscle function assessments involving the isokinetic dynamometer were interfaced with an analogue-to-digital converter (Biopac Systems Inc, Santa Barbara, USA) sampled at 2,000 Hz and displayed on a computer monitor using LabChart software (v8.1.20, AD Instruments Ltd, Oxford, UK). MVC torque of the ankle PF and DF muscle groups were assessed in both the dominant and non-dominant limbs. Participants were seated with a hip angle of 85° and their leg fully extended. The lateral malleolus of the foot was aligned with the centre of rotation and secured to the footplate using non-extensible straps. To minimise non-essential movement, participants were strapped at the hip, distal thigh and chest using non-extensible straps. Offline analysis of all muscle function assessments were performed using LabChart software (v8.1.20, AD Instruments Ltd, Oxford, UK).

Participants completed a series of 10 preparatory PF and DF contractions. Isometric MVC torque was measured with the ankle positioned anatomically at 0° (the foot at right angles to the lower leg) and a further five subsequent angles (-5°, +5°, +10°, +15° and +20°). The angles were measured in a randomised order to eliminate learning effects and to examine the torque-angle relationship of the PF DF muscle groups. Three trials of each angle were completed. 60s rest was given to each participant between trails in order to prevent fatigue. In the event that a MVC attempt exceeded >10% difference, the assessment of the angle was repeated once to ensure that a true MVC value was obtained. Subsequent analysis was performed on the highest recorded PF and DF MVC at each angle. Verbal encouragement was provided during each maximal effort, alongside visual biofeedback in the form of graphs on the computer monitor.

Hand-Grip Strength

Hand grip dynamometry is both a reliable and valid measure of strength in ageing adults (Bohannon, 2008). Hand grip strength of all participants was assessed using a handgrip dynamometer (Takei Hand Grip Dynamometer, Takei Scientific Instruments, Niigata, Japan). Participants were asked to take a seated position with the dynamometer in one hand. Participants were instructed to raise the dynamometer out straight in front of the body, holding the dynamometer in the sagittal plane. The participant was instructed to squeeze the handle as hard as possible for 3s and the reading was recorded. Three trials of both the dominant and non-dominant hands were recorded. 60s rest was provided to each participant to minimise fatigue. Hand grip strength measurements were taken in a randomised order to prevent learning effects and reduce fatigue of the dominant or non-dominant hand. The peak of the three trials was taken for subsequent analysis.

4.2.8 Questionnaire and Peripheral Assessments

Iconographical Falls Efficacy Scale

The Icon-FES (NeuRA, Sydney, Australia) app-based assessment was conducted in order to assess participant FOF (Delbaere et al., 2011). The test assesses an individual's level of concern about falls for a range of activities, such as reaching into cupboards, using steps and stepping in/out of the bath/shower. The Icon-FES provided images to aid imagination of each task. Participants were instructed to "look at each picture carefully and try to imagine performing the activity". If the participant has engaged in the activity, they were instructed to answer as if they did do the activity. The items were scored on a 4-point scale with 1 = not at all concerned to 4 = very concerned, along with facial expression icons for each of the four numbered responses. During administration, the pictures were presented to participants in a random order. At the end of the assessment, each participant was provided with a FES score.

The relationship between an increased FOF and falls has been reported for older adults (Tinetti et al., 1994). This relationship has been described as cyclical in nature, with a fear of falling associated with future falls and these subsequent falls associated with heightened fear. This cycle is moderated by activity curtailment, reducing engagement in activities that adults perceive to put them at a high risk of falling. A reduction in activity then leads to functional decline and an overall loss of independence, all of which are independent risk factors for increased falls (Friedman et al., 2002). The assessment of FOF was conducted to examine whether middle-aged fallers displayed a high FOF, similar to those of older adults based on scored from the Icon-FES.

Contrast Sensitivity

Contrast sensitivity was assessed using the Low Contrast Sensitivity Test (LCST) (NeuRA, Sydney, Australia). The LCST forms a key part of the Physiological Profile Approach (PPA) conducted previously (Lord et al., 2003). The test stimulus consists of a single luminance profile in four different orientations: horizontal, vertical, 45° left and 45° right. Participants were asked to observe the stimulus and indicate the orientation of the stimulus. Where participants failed to correctly indicate the orientation, the test was completed, and the score recorded. All scores were recorded out of a maximum 1.0.

Response Time

Response time was assessed using a computer program (Human Benchmark) by asking participants to click the mouse to turn the coloured box from blue to red to begin the test. When the coloured box on the computer screen turned from red to green participants were instructed to click the mouse as fast as possible. Five attempts at the response time test were conducted and the shortest response time score was recorded in milliseconds (ms) for final analysis.

Gait Specific Attentional Profile

Self-reported CMP during gait activities was assessed using the G-SAP (Young et al., 2020) (Appendix 4.5). Participants were instructed to answer 11 scaled questions in relation to four areas of anxiety, CMP, task-irrelevant thoughts, and processing inefficiencies. Participants were asked to answer statements such as "I am concerned about what people think about my movements" and mark from the scaled answers 1 = not at all, 5 = very much so, based on how they felt about this statement when walking. A total score was provided to each participant upon totalling the scores for each of the 11 questions. The G-SAP has been found to successfully predict several gait characteristics related to falls such as velocity (p=.033), step length (p=.032), and double-limb support (p=.015) (Appendix 4.7).

Montreal Cognitive Assessment

Cognitive function was assessed using the Montreal Cognitive Assessment (MoCA) (Julayanont and Nasreddine, 2017) (Appendix 4.6). The MoCA examined cognition using eight categories: visuospatial/executive, naming, memory, attention, language, abstraction, delayed recall and orientation. Participants were asked to complete tasks such as drawing a clock that stated the time ten past eleven and to recall a set of five words. Upon completion of all of the tasks in the eight categories, participants were provided with a maximum score of 30. A score of 26-30 points is classified as normal cognitive function. A score of <26 points indicates mild cognitive impairment (Nasreddine et al., 2005). Lower scores in the MoCA have been attributed to risk of falling in older adults (Samuelsson et al., 2019), with a decline in cognitive function known to affect concentration, memory and decision making (Qiu et al., 2022).

State-Trait Anxiety Inventory

The State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1971) was used to identify general (trait) and current (state) anxiety symptoms. Participants were required to rate the application of 30 statements from 1-4, 1 = 'not at all' 4 = 'very much'. Example statements include, 'I feel nervous and restless' and 'I am happy'. State and trait anxiety scores range between 20 and 80, with higher scores indicative of greater anxiety (Kvaal et al., 2005). Both state and trait anxiety measures were conducted at baseline, whilst only state was measured at the 6-month follow up due to trait anxiety being a stable measure (Saviola et al., 2020). The relationship between increased anxiety and increased risk of future falls has been previously established in older adults (Serrano-Checa et al., 2020). Anxiety is known to contribute to reduced degrees of freedom in joint movements, altered postural control, impaired gait, reduced head movement and altered visual search strategies increasing the likelihood of falling (Honaker, 2018). To what extent anxiety levels contribute to falls risk in middle-aged adults is yet to be determined.

4.2.9 Statistical Analysis

An *a priori* power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) to determine the minimum sample size required for the study, based on data from (English et al., 2006; Cattagni et al., 2014; Cebolla et al., 2015). Three studies were used to conduct the power analysis as no study to date had examined both physiological and psychological risk factors for falls in a middle-aged population. Resulted indicated the required sample size to detect a medium effect size, at a significance level of $\alpha = .05$ and power = .80 was n = 108, 54 in each of the faller and non-faller groups. As only 32 participants were recruited to the study, it is likely that a Type II error may be present in the results due to an underpowered sample size.

All quantitative analyses were performed using IBM SPSS Statistics software (27.0, SPSS Inc., Chicago, IL, USA). Where appropriate, parametric assumptions of normal distribution were confirmed using a Shapiro-Wilk test ($p<0.05$) for all dependant variables. Group comparisons of fallers and non-fallers were conducted using two-way ANOVA with equal variance using Levene's test ($p>0.05$) for all dependant variables. Further comparisons of both faller and non-faller groups were conducted using planned contrast t-tests. To assess whether there was a threshold of dominant leg hop distance and falling, a receiver operator curve analysis was conducted. All data are reported as means ± standard deviation (SD). Statistically significant differences were accepted at a confidence interval of 95% with α set to $p<0.05$.

4.3 Results

4.3.1 Population Comparisons for Fallers and Non-Fallers

The faller group (n=13) had 27.3% higher BF% ($p=0.003$) and a 11.1% lower ASM ($p=0.033$) than the non-faller group (n=19) (Table 4.1). There were no group differences in stature, mass, and BMI ($p>0.05$). Pearson's correlations showed that age was not associated with any other outcome measure ($p>0.05$) and as such, did not need to be adjusted as a covariate in follow-up analysis.

Table 4.1. Anthropometric data for fallers and healthy non-fallers.

	Fallers	**Non-Fallers**	***p***
Age (yrs)	56.0±6.9	54.8±5.6	0.598
Stature (m)	1.6±0.08	1.70±0.1	0.062
Mass (kg)	77.5±13.6	76.5±10.7	0.821
BMI ($kg \cdot m^{-2}$)	28.5±4.3	26.3±3.5	0.126
BF%	42.4±8.2	33.0±7.9	0.003*
ASM (kg/m^2)	6.61±0.6	7.34±1.2	0.033*

Reported as mean ±SD and *p* values; BMI; Body Mass Index, BF%; body fat percentage; ASM; Appendicular skeletal muscle mass. **Denotes significant difference between groups (p<0.05).*

The faller group had 13.1% lower LM within the dominant lower limb ($p=0.047$), 48.5% higher FM within the dominant lower limb ($p=0.009$) and 48.8% higher FM within the non-dominant lower limb (p=0.007) when compared to the non-faller group (Table 4.2.). There were no group differences in total BMD, BMD in the dominant and non-dominant legs and LM within the non-dominant leg (p>0.05) (Table 4.2).

Table 4.2. Body compositional data for fallers and healthy non-fallers derived from whole body DEXA scan.

	Fallers	**Non-Fallers**	***p***
Total BMD (g/cm^2)	1.15±0.09	1.18±0.05	0.169
Body Fat (%)	42.4±8.2	33.0±7.9	0.003*
BMD Dominant Leg (g/cm^2)	1.23±0.14	1.30±0.12	0.154
BMD Non-Dominant Leg (g/cm^2)	1.21±0.15	1.28±0.11	0.137
LM Dominant Leg (g)	6875±998	7910±1599	0.047*
LM Non-Dominant Leg (g)	6842±1059	7864±1672	0.061
FM Dominant (g)	5801±2352	3906±1463	0.009*
FM Non-Dominant (g)	5753±2271	3864±1438	0.007*

Reported as mean ±SD and *p* values; Total BMD, total bone mineral density; BMD Dominant, bone mineral density dominant lower limb; BMD Non-Dominant, bone mineral density non-dominant lower limb; LM Dominant, lean muscle mass dominant lower limb; LM Non-Dominant, lean muscle mass non-dominant lower limb; FM Dominant, fat mass dominant lower limb; FM Non-Dominant, fat mass non-dominant lower limb. **Denotes significant difference between groups (p<0.05).*

The faller group had a 3.7% lower functional test score on the Mini-BEST (p=0.028), 11.7% shorter SD ability (p=0.008), 21.6% slower RT (p=0.001), 27.6% weaker dominant HG strength (p=0.001), 28.2% weaker non-dominant HG strength (p=0.003), 29.6% shorter hop distance on the dominant leg (p=0.002) and a 24.4% shorter hop distance on the non-dominant leg (p=0.030) (Table 5.3). No group differences were observed between the TUG, TUG dual task, STS, FSST, perceived SD, step difference and CS (p>0.05) (Table 4.3).

Table 4.3. Functional and strength test performance outcomes in fallers and healthy non-fallers.

	Fallers	**Non-Fallers**	***p***
Mini-BEST	26.7±1.5	27.7±0.9	0.028*
TUG (s)	7.8±2.1	7.4±2.0	0.590
TUG Dual Task (s)	9.3±2.7	8.5±3.2	0.443
STS (s)	11.6±1.7	10.1±2.8	0.101
FSST (s)	9.2±1.8	8.3±2.0	0.211
SD (cm)	86.5±10.0	97.9±12.1	0.008*
Perceived SD (cm)	78.7±17.2	86.5±10.0	0.066
Step Difference (cm)	20.1±15.7	19.2±15.1	0.876
Contrast Sensitivity	0.91±0.06	0.92±0.08	0.766
Response Time (s)	0.37±0.07	0.29±0.04	0.001*
HG Dominant Strength (kg)	26.9±5.6	37.2±9.4	0.001*
HG Non-Dominant Strength (kg)	24.6±6.1	34.2±9.4	0.003*
Hop Distance Dominant (cm)	54.3±18.2	77.3±19.5	0.002*
Hop Distance Non-Dominant (cm)	54.4±16.3	71.9±24.2	0.030*

Reported as mean ±SD and *p* values; TUG, timed up and go test; TUG Dual Task, timed up and go test with dual task; STS, sit-to-stand; FSST, four square step test; SD, stepping distance; Perceived SD, perceived stepping distance; Step Difference, difference in distance between actual and perceived stepping distance; HG Dominant Strength, hand grip dominant hand strength; HG Non-Dominant Strength, hand grip non-dominant hand strength; Hop Distance Dominant, hop distance dominant leg; Hop Distance Non-Dominant, hop distance non-dominant leg. **Denotes significant difference between groups ($p<0.05$).*

Results from ROC analyses are shown in Figure 5.2. Dominant leg hop distance was found to be moderately accurate (p=0.004, 95% CI=0.65-0.95) at classifying participants with and without a history of falls (AUC 0.806). The dominant single leg hop test demonstrated a high sensitivity (0.846) and a moderate specificity (0.474) as well as a high post-test accuracy (0.75) using the selected cut off score 70.5cm.

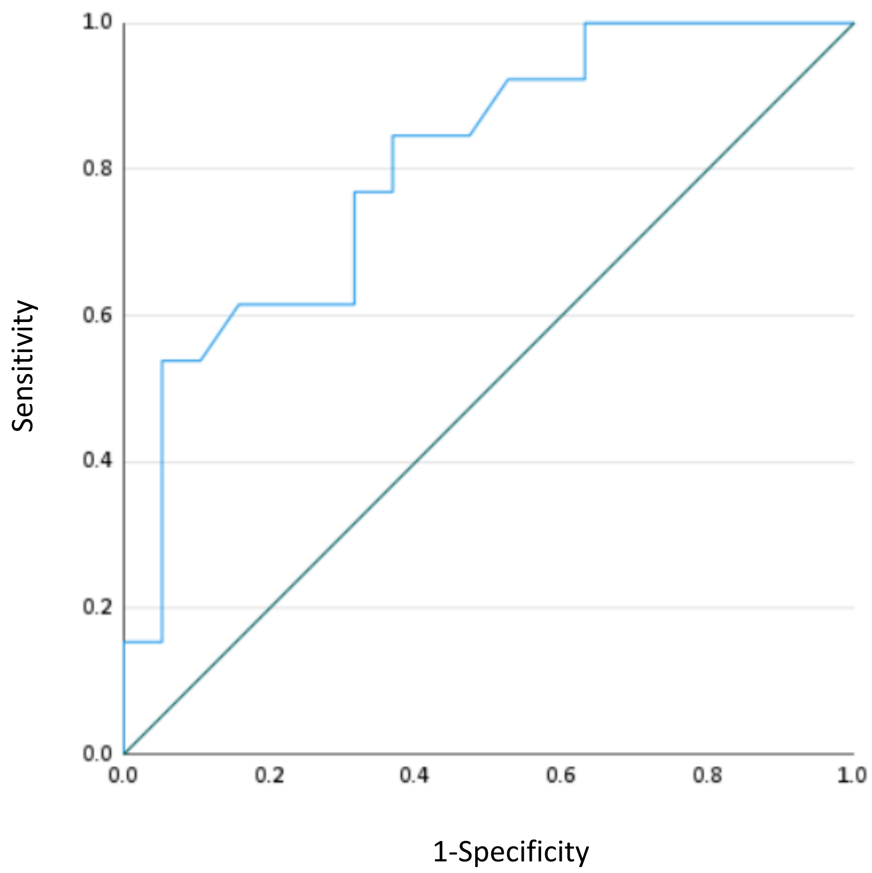

Figure 4.2. Receiver operator curve (ROC) for identifying participants with a history of falls using scores from dominant single leg hop test.

A 2-way analysis revealed a significant group effect on PF MVC, with a planned contrast t-test showing the faller group to be significantly weaker than the non-fallers at angles -5° (*p*=0.024), 0° (*p*=0.026), 10° (*p*=0.035) and 15° (*p*=0.046) in the dominant leg (Figure 4.3). There was no interaction effect of group on ankle angle. The average PF MVC across all angles was 39.3% less in the fallers when compared to the non-fallers (*p*<0.05). There was no difference in PF

MVC in the non-dominant leg across any angle (*p*>0.05, Figure 4.4). There was no difference between fallers and non-fallers for DF MVC torque at any angle in either the dominant or non-dominant legs (*p*>0.05, Figure 4.4 and Figure 4.6).

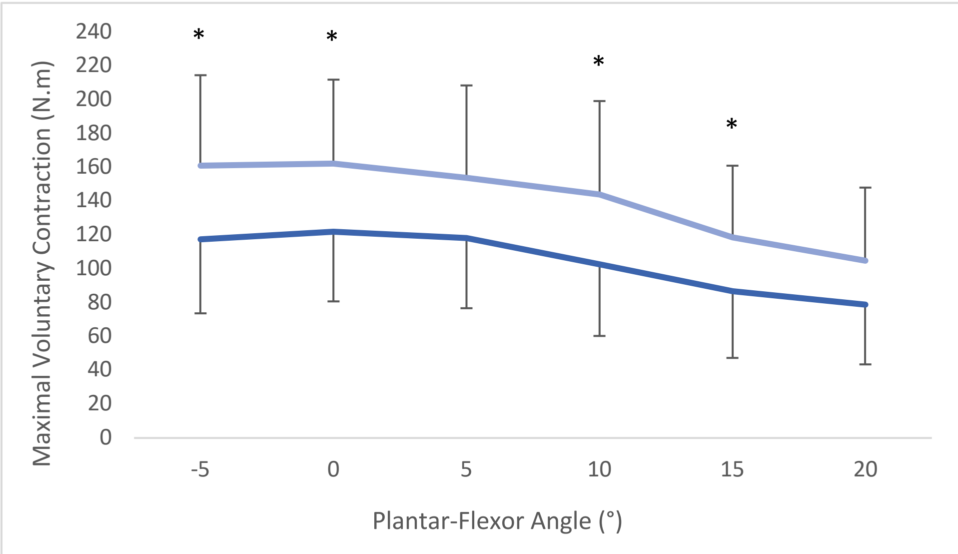

Figure 4.3. PF MVC torque (N.m) for fallers (dark blue) and non-fallers (light blue) over six ankle joint angles (-5°,0°,5°,10°,15°,20°) in the dominant leg. **Denotes significant difference between groups (p<0.05).*

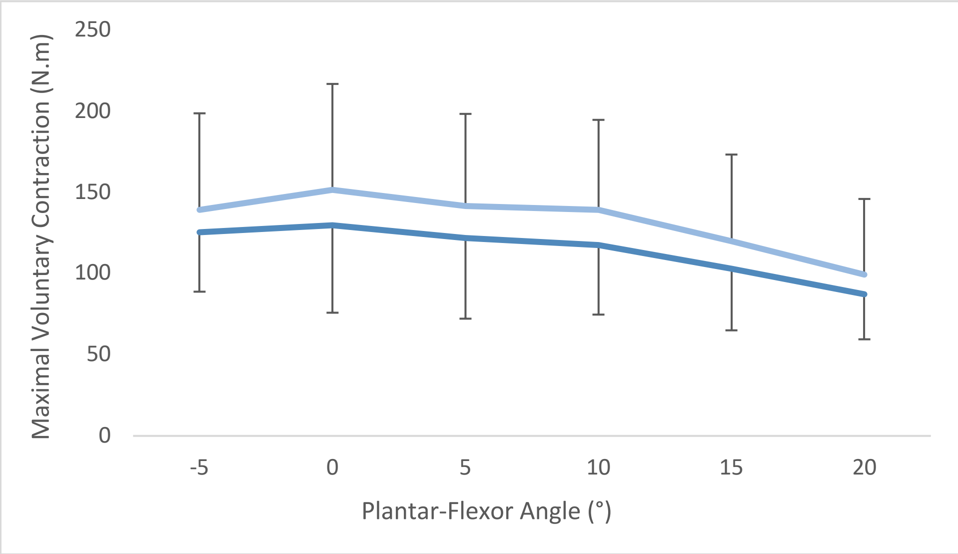

Figure 4.4. PF MVC torque (N.m) for fallers (dark blue) and non-fallers (light blue) over six ankle joint angles (-5°,0°,5°,10°,15°,20°) in the non-dominant leg.

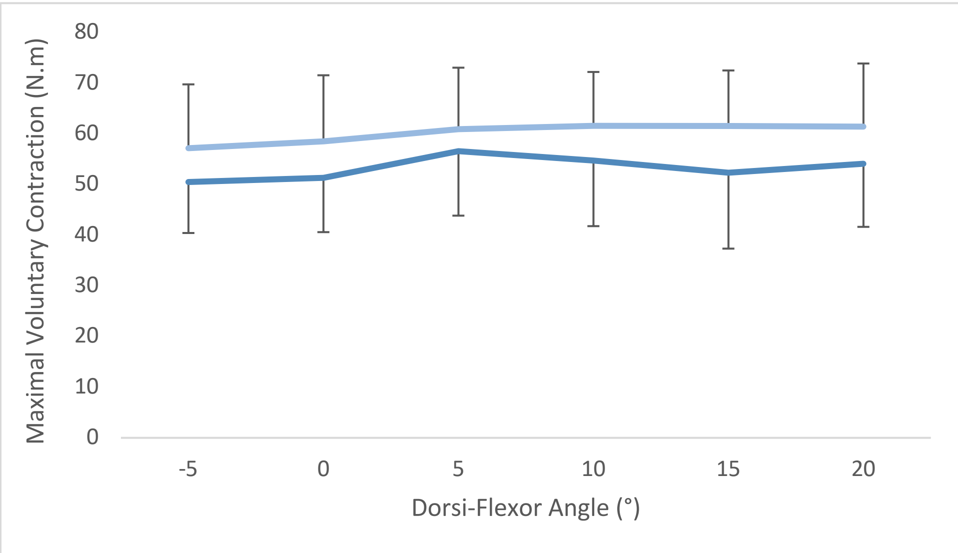

Figure 4.5. DF MVC torque (N.m) for fallers (dark blue) and non-fallers (light blue) over six ankle joint angles (-5°,0°,5°,10°,15°,20°) in the dominant leg.

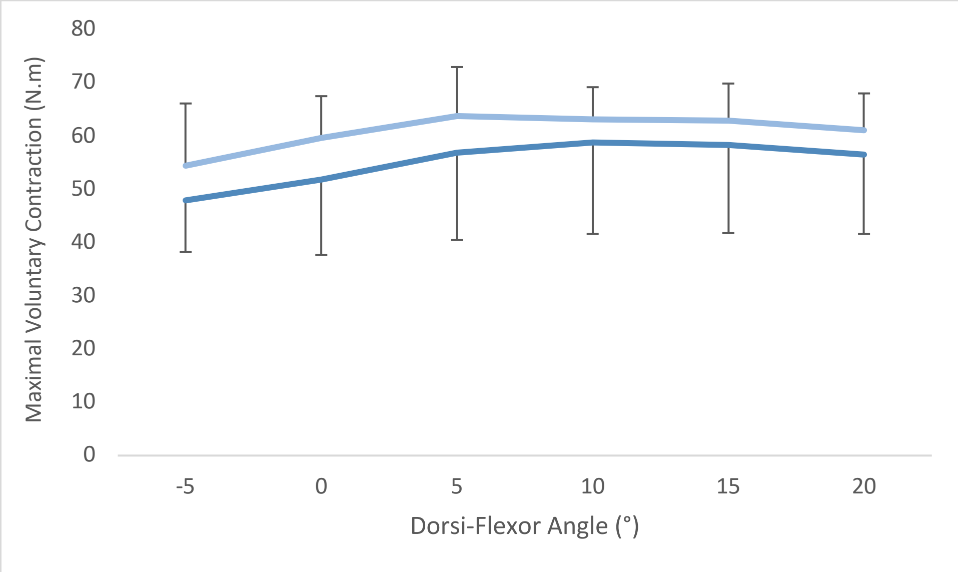

Figure 4.6. DF MVC torque (N.m) for fallers (dark blue) and non-fallers (light blue) over six ankle joint angles (-5°,0°,5°,10°,15°,20°) in the non-dominant leg.

The faller group had 26.0% higher FOF scores (*p*=0.000) on the Icon-FES when compared to the non-faller group. No further group differences were observed between faller and non-faller groups in questionnaire responses to the SAI, TAI, G-SAP and MoCA (*p*>0.05, Table 4.4).

Table 4.4. Questionnaire response data for fallers and healthy non-fallers.

	Fallers	**Non-Fallers**	***p***
SAI	29.7±8.6	27.3±6.3	0.386
TAI	35.2±8.7	29.7±7.3	0.065
G-SAP	21.2±10.3	16.7±9.1	0.204
Icon-FES	47.3±6.6	35.0±6.3	0.000*
MoCA	24.7±2.3	25.7±1.5	0.167

Reported as mean ±SD and *p* values; SAI, state anxiety; TAI, trait anxiety; G-SAP, gait specific attentional profile; Icon-FES, iconographical falls efficacy scale; MoCA, Montreal cognitive assessment. **Denotes significant difference between groups (p<0.05).*

4.4 Discussion

The aims of the study were to: 1) use experimental laboratory-based techniques to determine potential risk factors for falls within a middle-aged sample of both fallers and healthy non-fallers; 2) distinguish which of the outcome measures investigated contribute towards the falls profile and 3) explore the ability of current clinical screening tools to distinguish successfully between fallers and non-fallers. Of the study population that presented as fallers, risk factors for falls were found to be present in both physiological and psychological factors which may inform intervention designs to prevent future falls.

4.4.1 Physiological Factors and Falls

The fallers from the current study had on average 39.3% weaker PF MVC when compared to non-fallers over a variety of ankle joint angles, in line with similar magnitudes seen in older fallers and non-fallers (Pijnappels et al., 2008b). Reduced lower limb muscle strength, has been recognised as one of the most significant risk factors for falls (Lord et al., 2003; Moreland et al., 2004b). When tripping over an obstacle, which accounts for more than half of all fall incidents (Roudsari et al., 2005), high rates of moment generation around the ankle joint are required during the push-off phase in order to regain balance (Pijnappels et al., 2005). When examining the relationship between muscle strength and the outcome of a trip, in the individuals who fell and failed to regain their balance, low muscle strength measures were present (Pavol et al., 2002). Despite the majority of research being conducted in older adults, the present study findings suggest that ankle strength may also be a limiting factor in preventing a fall during middle-age.

Alongside weaker PF muscles, the fallers demonstrated a 13.1% lower LM and a 48.5% higher FM in the dominant lower limbs. Despite ageing being associated with significant changes in body composition, often resulting in a reduction in both muscle mass and function (Balogun et al., 2017). The rates at which both muscle mass and strength decline are thought to differ significantly. The present study confirms previous findings that suggest that percentage decreases in strength are far greater than percentage decreases in lean muscle (Goodpaster et al., 2006). With a 39.3% reduction in strength and only a 13.1% reduction in lean muscle, the present findings confirm that the rate in which strength decreases is thought to be accelerated when compared to loss of muscle mass. Middle-age fallers are likely to demonstrate different reductions in both muscle mass and strength as a result of being younger in life years. This is in line with the study identifying a 48.5% higher FM in the dominant lower limbs of fallers, suggesting it is important to consider adiposity and fat infiltration, as it directly affects muscle quality when examining body compositional risk factors for falls (Peeters and Backholer, 2012).

4.4.2 Psychological Factors and Falls

When examining psychological risk factors, FOF was found to be higher in fallers when compared to non-falling counterparts based on Icon-FES scores. Despite these findings being in line with previous literature (Delbaere et al., 2010b) and being attributed to an increased awareness of mobility and falling, differences between groups were not observed in G-SAP scores, a questionnaire that examines anxiety, CMP, task-irrelevant thoughts, and processing inefficiencies specifically whilst thinking about gait related activity.

Research has highlighted that fall incidents directly increase FOF (Jamison et al., 2003), however, investigations into how fearful middle-aged individuals are of falling is a largely underrepresented research area. With previous injuries sustained from a fall also being directly linked to an increased FOF and anxiety (Larson and Bergmann, 2008), it is possible that experiences of falls and subsequent injuries sustained may play a greater role in the level of fear and anxiety displayed in middle-aged adults when compared to other age groups.

FOF is known to have a detrimental effect on the balance performance of older adults (Young and Williams, 2015) and has been examined by investigating the behavioural responses to perceived threat (Staab et al., 2013). Older adults have been shown to adopt a 'stiffening strategy' in situations where threat is perceived to be high (Adkin et al., 2000). This stiffening strategy causes individuals to display a reduced range of motion caused by the co-contraction of several muscle groups (Carpenter et al., 1999), which can impede adaptive responses to external perturbations. These conservative behaviours can also be seen during walking tasks, whereby, anxious individuals reduce range of motion, subsequently reducing joint angular velocities, resulting in shorter stride lengths and reduced gait speeds (Staab et al., 2013). It is possible to assume that both middle-aged and older adults experience similar everyday task demands, that require the negotiation of complex environments, such as walking on uneven terrain. Stiffening strategies as observed in older adults, may also be present in middle-aged adults. It is important for research to determine whether increased perceived threat also reduces the ability of middle-aged adults to respond to external perturbations, leading to an increased number of slips, trips, and falls.

Anxiety has been shown to alter the allocation of attention in both young and old adults (Lee and Knight, 2009; Staab, 2014) and attentional control theory (Eysenck et al., 2007) has been used as a theoretical framework to describe how anxiety may alter this allocation of attention. It is suggested that task performance is often compromised in anxious individuals due to an inability to ignore task-irrelevant stimuli. This hypervigilance to threatening stimuli is likely to be present for middle-aged adults given the findings in both younger and older age groups.

There is a clear need for theories such as attentional control theory to be investigated in middle-aged adults to describe behaviours during functionally relevant tasks. Work by Delbaere et al. (2010b) is beginning to demonstrate how using picture representation of a range of daily activities, set within a variety of environmental contexts may be able to determine an individual's level of concern about falling. Understanding FOF in multiple circumstances related to an individual's fall risk will aid the prescription of targeted intervention strategies working towards the prevention of falls (Delbaere et al., 2020).

4.4.3 Clinical Screening Tools and Falls

The early identification of specific fall risk factors are required to detect early change in order to provide a preventative approach to fall management. However, the ability of many clinical screening tools to detect such changes are limited or have only been investigated in older populations (Brauer et al., 2000). Of the five clinical screening tools used in the present study, only the Mini-BESTest was able to discriminate fallers from non-fallers based on an overall 3.7% lower test score between the groups. These findings are in line with previous literature that suggests that the Mini-BESTest demonstrates excellent sensitivity (0.85) and specificity (0.75) in determining individuals with a history of falls (Yingyongyudha et al., 2016) when compared to screening tools such as the Berg Balance Scale (BBS) and the TUG tests.

The test was able to discriminate between groups, however, the data should be interpreted with caution. Clinical screening tools such as the Mini-BESTest are known to have ceiling effects and whilst the ceiling effects of the Mini-BESTest may be smaller than tests such as the BBS (King et al., 2012), when searching for a responsive ceiling effect within the study data, defined as the number of participant scores within 10% of the score maximum of 28. 61.5% of fallers and 94.7% of non-fallers final Mini-BESTest scores were within 10% of the score maximum. Clinical tests can provide efficient and cost-effective ways to test balance function, but they are often limited in their ability to detect small incremental change. Research is, therefore, required to determine whether clinical screening tools such as the Mini-BESTest are the most appropriate method of detecting clinically meaningful change at stages early enough to prevent falls.

The differences in strength and body composition between the fallers and non-fallers, combined with the limited discriminatory data of the established Mini-BESTest in the middle-aged participants, suggests the need for a more sensitive discriminatory tool that could be used to identify middle-aged individuals at risk of a falling. The present data identified a 30% shorter hop distances in fallers, a measure of lower extremity function that has been effective in determining function, power and neuromuscular control of younger adults (English et al., 2006). A test as simple as single leg hop distance, could provide a cost-effective and efficient method to screen middle-aged individuals at risk of falls. Researchers are encouraged to design methods to allow clinicians to indirectly determine neuromuscular function without the need for the implementation of both costly and time-consuming methods and this may be a valid example. In middle aged participants the ability to hop over 75cm showed good discriminatory capacity for identifying fallers, however future research is needed in larger participant groups to validate this as a meaningful and fully valid technique.

Comparative studies examining the best clinical screening tool have to date only been conducted in older adults (Lima et al., 2018). Future research requires a large sample size validation study to examine the ability of all clinical screening tools to identify a history of falls in younger populations. With previous falls being the single largest predictor of future falls (Delbaere et al., 2010c), the main aim of future research is, therefore, to determine the most sensitive fall risk predictors in an attempt to identify those at risk of falls prior to their first fall.

4.4.4 Strengths and Limitations

The present study provides one of the first experimental investigations into the potential risk factors for falls in a study population aged 45-64 years. Whilst the participant sample was relatively small for an experimental study such as this, the findings provide an indication into what fall risk predictors may be present in middle-aged fallers. To date, very little research has been conducted into this age demographic of fall population, making evidence-based intervention strategies difficult to implement. The restrictions imposed by the pandemic meant that study recruitment from the NHS and available time to conduct face-to-face testing within the laboratory was restricted during the study months. A larger sample of both fallers, recruited from NHS pathways, alongside control participants would provide greater confidence in the results and allow researchers to test these possible risk factors for falls in middle-aged adults.

4.5 Conclusion

The aim of the study was to assess and describe differences in both neuromuscular and psychological outcomes when determining risk factors for falls in adults aged 45-64 years, classed as middle-aged. The current study demonstrated that when exploring the body composition of middle-aged adults, FM and LM of the dominant legs were likely to contribute to falls incidence. A reduction in PF MVC at four angles and hand-grip also demonstrated strength differences between the faller and non-faller groups. The Mini-BESTest was able to distinguish fallers from non-falling individuals with a reduction in scores, alongside significant differences in response time and FOF. Step distance and single leg hop distance provided a quick and efficient method to examine functional ability between faller and non-faller groups. Despite research primarily focusing on those who fall who are >65 years, future research should investigate younger age demographics in an attempt to prevent falls in the younger age group. Further investigation into fall risk predictors and subsequent preventative interventions for middle-aged adults should take place in larger study samples to identify appropriate prevention strategies for this study population.

Chapter 5: Characteristics of Daily-Life Gait in Middle-Aged Fallers and Non-Fallers

5.1 Introduction

A progressive decline in mobility is a common issue for older adults (Ferrucci et al., 2016), and is linked to a reduction in quality of life (QoL) (Trombetti et al., 2016). The aetiology of a reduction in mobility and subsequent decline in gait ability, have been linked to a progressive loss of skeletal muscle mass and strength (Dam et al., 2014). In older adults who fall, many demonstrate a slower walking speed, reductions in mobility and declines in gait ability (Isaacs, 1985). The examination of gait to determine the exact mobility of older adults has been repeated (Buchner et al., 1996), and studies have confirmed the presence of age-related decline in the gait profiles of older adults (Kovacs, 2005). These gait profiles are known to differ to those adults who are middle-aged (Kozakai et al., 2000). To what degree age related changes in gait occur, and how they may increase the risk factor for falls in middle-aged adults is currently unknown. The examination of gait should, therefore, form part of the assessment when aiming to evaluate and prevent future falls in middle-aged adults.

As discussed previously in Chapter 4, section 4.4.3, fall-risk assessments have become reliant on questionnaires and functional tests (Tromp et al., 2001) to identify many of the fall related risk factors identified above. The ability of these clinical screening tools to detect risk of falling in middle-aged populations have been questioned, with evidence suggesting that screening tools often display ceiling effects in moderately healthy populations (Balasubramanian, 2015), alongside reported bias when examining history of falls (Mackenzie et al., 2006). It has, therefore, been suggested that many screening tools would lack responsiveness and discriminative ability when examining the fall risk of middle-aged adults (Hamacher et al., 2011). Research has, therefore, demonstrated the validity of wearable sensors in improving the accuracy of these fall risk predictors (Pluijm et al., 2006).

New approaches to examining fall risk have been established over recent years, by evaluating the gait dynamics of older adults (van Schooten et al., 2016). These methods use ambulatory measurements of trunk acceleration to capture gait characteristics to predict those older individuals at risk of falling (van Schooten et al., 2015). Walking speed, stride-to-stride variability, stride frequency and entropy are now some of the gait characteristics that able to differentiate between those who fall and those who do not (Marschollek et al., 2011; Howcroft et al., 2013). It is important to note, that often the identification of fallers in these studies are obtained by methods of retrospective recall (Cummings et al., 1988). With this knowledge, gait characteristics associated with a history of falls may provide useful information on the adaptations to gait after experiencing a fall. Associations between gait characteristics and fall status obtained via prospective methods are thought to truly identify fall risk indicators (van Schooten et al., 2015).

Advances in technology have allowed wearable sensors to monitor ambulatory markers of human behaviour in everyday life (Weiss et al., 2013), providing a real-world insight into the habitual behaviours of adults prone to falling. These methods allow for sophisticated characteristics of trunk accelerations to be captured within a variety of environments outside the laboratory, providing an insight into underlying factors that increase risk of falls. Characteristics that examine gait symmetry, smoothness and complexity, also described as harmonic ratio, index of harmonicity, logarithmic rate and divergence and sample entropy have previously been associated with fall risk in older adults (Rispens et al., 2015b).

Gait quality is often assessed in laboratory settings, which only provide data to suggest how an individual walks at a given speed, under controlled conditions (Toebes et al., 2012). The examination of gait characteristics that are influenced by both behavioural and environmental factors, and subsequently, how an individual walks when negotiating obstacles, provides for a more meaningful and valid testing environment. The development of new approaches demonstrates the potential for wearable technology to make a significant contribution to the improvement of fall-risk assessments for younger fall populations, when compared to previously adopted methods (Pluijm et al., 2006). The extent to which these methods can identify middle-aged adults at risk of falling is still to be determined.

The main aim of fall prevention research is to reduce the overall occurrence of falls; therefore, researchers are continually working towards new methods to identify those at greatest risk. To detect fall risk indicators in middle-aged adults, body-worn sensors were trialled in adults between 45-64 years. The aim of the present study was to explore the potential of trunk acceleration measurements, collected using wearable sensors during daily life, to examine gait characteristics in fallers and non-fallers.

5.2 Materials and Methods

5.2.1 Participants

28 community dwelling middle-aged adults aged between 45 and 64 years were recruited to the study. Anthropometric data of participants are reported in Table 5.1. All participants provided written informed consent prior to involvement in the study. Falls participants (n=11, n=6 female, n=5 male) reported having at least one fall during the 12-months preceding the study. Control non-faller participants (n=17, n=11 female, n=6 male) self-reported as having

no known musculoskeletal disorder and no instances of falls in the 12-months preceding the study. All experimental procedures were approved by the Ethics Committee of Manchester Metropolitan University and the North-West Preston Research Ethics Committee (REC) (260217).

5.2.2 Anthropometric and Strength Measurement

Participants completed a 6-minute whole body scanning procedure (0.4 *µSv)* (microSievert) on the DEXA scanner (GE Lunar Prodigy Advance, UK), as per the protocol described previously in Chapter 4, section 4.2.5. From this whole-body scan, the body fat percentage for each participant was calculated and taken forward for subsequent analysis. Maximal voluntary contraction (MVC) torques of the dominant ankle Plantar Flexor (PF) muscle groups were obtained using an isokinetic dynamometer (Cybex Norm, Cybex International, New York, NY, USA), as per the protocol described previously in chapter 4, section 4.2.7. Dominant MVC PF values measured at 0°, a neutral ankle angle, were taken forward for subsequent analysis.

5.2.3 Data Acquisition

Participants were instructed to wear a Triaxial Accelerometer (43.0 mm x 40.0 mm x 16.0 g) (GENEACTIV, Activ insights Ltd, Kimbolton, UK) in order to obtain individual quality of daily-life gait. The accelerometer had a sampling frequency of 100Hz and a range of -6g to +6g. All characteristics were recorded in three directions of acceleration, vertical (V), anterior posterior (AP) and medial lateral (ML). Participants were instructed to wear the accelerometer for 7 consecutive days. The accelerometer was placed dorsally on the trunk of the participant's spine, at the L5 vertebrae (van Schooten et al., 2015) and worn by the participant using an elastic belt (GENEACTIV, Activinsights Ltd, Kimbolton, UK).

Participants were instructed to wear the accelerometer at all times, except for water activities such as showering and swimming to avoid any damage occurring to the device. Participants were also instructed to remove the equipment whilst sleeping. Participants were provided with a 7-day paper diary and were instructed to document the take-off and put-on times for when the accelerometer was removed and re-applied. These documented time periods were removed from the raw data during the analysis. The first and last 6 hours recorded on the first and last day of data collection were omitted from the analysis to discard any possible artifacts caused by transportation of the accelerometer to and from the university (van Schooten et al., 2016). Physical (in)activity was derived from the raw accelerometery data using a pre-existing algorithm to examine periods of non-wearing, locomotion, sitting, lying and standing (Dijkstra et al., 2010).

5.2.4 Gait Characteristics

Daily-life gait characteristics were analysed using MATLAB (MathWorks, Natick, MA). In order to determine locomotion episodes, an activity classification algorithm was used (McRoberts, The Hague, Netherlands) following methods previously described in earlier studies (Rispens et al., 2015b). Using this algorithm, locomotion bouts of >10 seconds were selected in order to avoid both possible bias in sample size and the effects of differences in the length of any data sequences (Bruijn et al., 2009; van Schooten et al., 2014). Prior to examining gait characteristics, the raw accelerations of these 10-second epochs were aligned to the anatomical axes of the accelerometers orientation in order to correct for any misalignments with respect to gravity (Moe-Nilssen, 1998).

The gait characteristics chosen for analysis in the present study have been found to be associated with fall risk in older adults (Howcroft et al., 2013). A total of 6 gait characteristics were estimated for every 10-second epoch window of locomotion. The present study estimated gait characteristics consisting of walking speed, which was calculated using a method previously described by (Zijlstra and Hof, 2003). This method assumes compass gait with a circular trajectory of the accelerometer during each support phase and determines step lengths by trigonometry from the peak-to-peak height differences obtained by double integration of high-pass filtered accelerations. To calculate walking speed, leg length was measured from the anterior superior iliac spine to the medial malleolus. This was recorded during the participant's lab visit prior to accelerometer attachment.

Stride frequency was estimated as the median of the model frequency for ML directions and half of the modal frequencies for the V and AP directions as determined from the power spectrum (Zijlstra et al., 2007). Harmonic ratio was measured to describe gait symmetry and rhythm of acceleration patterns. In line with Menz et al. (2003), this was calculated by examining the components of the acceleration signal that were classed as an "in phase", meaning the even harmonics, and comparing these to the components classed as an "out of phase", meaning odd harmonics. The final calculation of harmonic ratio is then calculated as the sum of the amplitudes of the odd harmonics divided by the sum of the amplitudes of the even harmonics. Index of harmonicity measured to describe gait smoothness (Lamoth et al., 2002), was calculated as the individual time series of the pelvic and thoracic rotations using spectral analysis to assess the contribution of the oscillating components to the observed coordination patterns (Lamoth et al., 2002). Mean logarithmic rate of divergence per stride and sample entropy measured to describe gait complexity was based on 10-samples delayed embedding in seven dimensions using Wolf's method (Wolf et al., 1985; Richman and

Moorman, 2000). Data are presented based on the average occurrence of these gait outcomes over the 7-continuous days.

5.2.5 Statistical Analysis

An a priori power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) to determine the minimum sample size required for the study, based on data from van Schooten et al. (2016). Results indicated the required sample size to detect a medium effect size, at a significance level of α = .05 and power = .80 was n = 158, 79 in each of the faller and non-faller groups. As only 28 participants were recruited to the study, it is likely that a type II error may be present in the results.

All statistical analyses were performed using IBM SPSS Statistics software (27.0, SPSS Inc.,Chicago, IL, USA). Where appropriate, parametric assumptions of normal distribution were confirmed using a Shapiro-Wilk test ($p<0.05$) for all dependant variables. Group comparisons of fallers and non-fallers were conducted using two-way ANOVA with equal variance using Levene's test ($p>0.05$) in all dependant variables. Further comparisons of both faller and non-faller groups were conducted using planned contrast t-tests. All data are reported as means ± standard deviation (SD). Statistically significant differences were accepted at a confidence interval of 95% with α set to $p<0.05$.

5.3 Results

5.3.1 Population Comparisons for Fallers and Non-Fallers

The fallers had a 19.4% higher BF% (p=0.018) and had 21.8% weaker dominant PF strength**,** when compared to the non-fallers (Table 5.1). There was no group difference in stature, mass, and BMI ($p>0.05$, Table 5.1). Pearson's correlations showed that age was not associated with any other outcome measure (p>0.05) and as such, did not need to be adjusted as a covariate in follow-up analysis.

Table 5.1. Anthropometric and strength data for fallers and non-fallers.

	Fallers	**Non-Fallers**	***p***
Age (yrs)	56.3±5.8	56.1±5.2	0.665
Stature (m)	1.61±0.08	1.63±0.07	0.690
Body Mass (kg)	78.8±13.7	77.3±10.2	0.617
BMI ($kg \cdot m^{-2}$)	28.7±4.4	26.8±3.1	0.106
%BF	41.8±8.1	33.7±8.7	0.018*
PFD 0°	123±46	156±51	0.031*

Reported as mean ±SD and *p* values; BMI; Body Mass Index, BF%; body fat percentage, PFD 0°; plantarflexion strength of dominant leg at 0° angle. **Denotes significant difference between groups (p<0.05).*

5.3.2 Gait Characteristics

There was no difference in the gait characteristics between middle-aged fallers and non-fallers when examined in any of the VT, ML or AP directions (*p*>0.05, Table 5.2).

Table 5.2. Gait characteristics (mean ± SD) for fallers and non-fallers.

Gait Characteristics	Fallers	Non-Fallers	*p*
Walking Speed Mean (m/s)	1.14±0.10	1.22±0.15	0.184
Stride Frequency (Hz)	0.92±0.03	0.98±0.10	0.060
Sample Entropy VT	0.31±0.05	0.30±0.05	0.956
Sample Entropy ML	0.37±0.04	0.40±0.06	0.260
Sample Entropy AP	0.31±0.05	0.30±0.07	0.995
Harmonic Ratio VT	2.64±0.44	2.78±0.42	0.338
Harmonic Ratio ML	2.03±0.25	2.03±0.65	0.996
Harmonic Ratio AP	2.44±0.23	2.49±0.31	0.408
Index of Harmonicity VT	0.63±0.13	0.71±0.07	0.065
Index of Harmonicity ML	0.26±0.04	0.28±0.09	0.571
Index of Harmonicity AP	0.72±0.06	0.71±0.07	0.695
Logarithmic Rate of Divergence (stride) VT	1.77±0.21	1.61±0.25	0.115
Logarithmic Rate of Divergence (stride) ML	1.96±0.12	1.94±0.21	0.809
Logarithmic Rate of Divergence (stride) AP	1.81±0.17	1.73±0.20	0.280

Reported as mean ±SD and *p* values; VT, vertical direction; ML, mediolateral direction; AP, anterior posterior direction.

5.4 Discussion

The aim of this chapter was to examine daily-life-gait characteristics, measured using trunk accelerometry, to discriminate between fallers and non-fallers in middle-aged participants. The chapter compared the quality of daily-life-gait characteristics over 7 free-living days, to explore the ability of gait characteristics to discriminate between fallers and non-fallers. The main findings showed that there were no differences in free-living gait parameters between the middle-aged fallers and non-fallers.

5.4.1 Gait and Physiological Characteristics

To the authors knowledge, the data presented in this chapter provides the first free living gait characteristics of middle-aged fallers and non-fallers, utilising methods previously described in older adults Rispens et al. (2015b). In contrast to free living gait data in older fallers (van Schooten et al., 2015), the gait characteristics of middle-aged fallers in this chapter, did not differ significantly from their non-falling counterparts.

The absence of differences witnessed within the gait characteristics of the fall population, may be due to a lack of age-related decline. As adults age, walking speed is known to decrease (Buchner et al., 1996), and a reduction in walking speed has been significantly associated with an increased risk of falling in adults older than 65 years (Espy et al., 2010). In studies that used the same methods to determine walking speed as in the present chapter (van Schooten et al., 2015; van Schooten et al., 2016), older adults achieved maximal walking speeds of 0.83-0.87 m/s. Middle-aged adults in the present study achieved maximal walking speeds of 1.1-1.2 m/s. In studies that have examined the walking speed of older adults, and compared this to those who are middle-aged, found that walking speed declines significantly for every 10 years of advancing age (Kozakai et al., 2000). The ability of middle-aged adults to walk faster, irrespective of fall status, suggests that walking speed may not be a useful predictor of fall risk in adults younger than 65 years.

Beyond the measurement of free-living walking speed within older people, gait quality measures derived from accelerometry have shown declines in older fallers compared to non-fallers (Rispens et al., 2015a). Previous data shows that older fallers have gait patterns that are less symmetrical (harmonic ratio), less smooth and more variable in VT, ML, AP (index of harmonicity) (Weiss et al., 2013; van Schooten et al., 2015). As with walking speed, the middle-aged fallers in the present study showed no differences in any of these accelerometer measures when compared to non-fallers. Thus, indicating that walking speed and measures of gait perturbations may not be useful predictions of fall risk in middle-aged adults.

In the present study, middle-aged fallers had 21.8% weaker dominant PF muscles, compared to their non-falling counterparts. A reduction in PF strength, however, did not alter gait characteristics. Older adult fallers display weaker PF MVC values (50 N.m) (Cattagni et al., 2018) when compared to the middle-aged fallers in the present study (122 N.m). A reduction in PF strength in older adults has been linked to increased fall risk, increased postural sway and gait disorders (Melzer et al., 2008; Pijnappels et al., 2008b). It is likely, therefore, that the present middle-aged fallers are not weaker than the strength thresholds previously identified to correspond to walking decrements in older adults, despite falling below strength thresholds required to prevent trips from becoming falls (Tiedemann et al., 2005). It is unlikely that reductions in lower extremity strength witnessed in middle-aged adults, would significantly alter gait characteristics during middle-age. The threshold, at which, PF muscle weakness increases the likelihood of falling, thereby altering gait, remains unknown.

5.4.2 Strengths and Limitations

The present study aimed to be the first to investigate the ability of trunk acceleration measurements of daily-life gait to discriminate between middle-aged fallers and non-fallers. The study obtained gait characteristics from accelerations recorded in free-living environments outside of the laboratory, to examine the walking ability of middle-aged fallers when subjected to external behavioral and environmental factors. Previous studies have suggested that daily-life-gait measurement are not necessarily a superior method when examining gait related fall risk. Free-living gait capture methods appear to produce a greater variability in gait characteristics, when compared to the examination of gait in the laboratory (Rispens et al., 2016). Future studies are required to capture the gait characteristics of middle-aged fallers in both laboratory and free-living environments, to compare and determine the ability of gait characteristics to predict fall risk in this demographic.

Similar to the present study, research has also obtained fall status via self-reported retrospective recall methods (Rispens et al., 2015b). Retrospective recall methods are known to be exposed to recall bias (Cummings et al., 1988) and are thought to only be able to provide information related to alterations in gait characteristics post-fall. New methods of obtaining fall status now include the use of prospective methods, to determine the predictive ability of gait characteristics to determine fall risk (van Schooten et al., 2016). Research to examine the ability of use of perspective methods to record occurrences of falls in middle-aged adults is required.

5.5 Conclusion

This study provided the first evidence to suggest that daily-life-gait characteristics of middle-aged fallers do not significantly differ from non-falling counterparts and that alterations in gait metrics are unlikely to be witnessed until later life years. A significant difference in PF strength and BF% was observed between fallers and non-fallers. However, these measures do not appear to yield the same consequences in gait alterations for middle-aged fallers when compared to older fallers. A reduction in PF strength is likely to be a useful clinical measure of fall risk that can be observed in middle-aged adults, supported by data to suggest that both middle-aged and older fallers display a 20% reduced PF strength compared to both non-falling middle-aged and older adults. For gait characteristics and physiological measures to predict fall risk, future studies examining middle-aged fallers require the use of prospective measures when recording fall incidents.

Chapter 6: Impact of the Covid-19 Pandemic on Falls

6.1 Introduction

On 12th March 2020, the novel coronavirus (COVID-19) was classified as a global pandemic by the World Health Organisation (WHO). At this time, it was advised that pre-emptive measures should be taken by all countries to mitigate the spread of the virus. In accordance with the guidance from WHO, the UK implemented a number of public health measures on 26th March 2020 (see Figure 6.1). These measures involved putting all citizens into a nationwide lockdown to mitigate community-based transmission, meaning that all UK citizens were advised to 'stay at home' as much as possible. Despite the advice, emerging evidence describes these forms of social isolation as a two edge sword (Pelicioni and Lord, 2020), protecting individuals against contracting the virus whilst negatively impacting them with increased social isolation and reduced physical activity. A consequence of the restrictions was that COVID-19 created challenges not just in the UK but worldwide, in terms of economy, social interaction and changes to lifestyle, many of which could have an impact on falls occurrence and propensity.

With public health measures being enforced strictly, it was expected that UK citizens would be challenged with changes to their physical activity behaviours, alongside their psychological behaviour and overall dimensions of wellbeing (O'Connor et al., 2020). The closure of many recreational facilities such as gyms, parks and playgrounds required citizens to be innovative with their physical activity practices. For some, national lockdown provided additional time to be physically active, whereas for many others the unintended consequences resulted in an overall reduction of physical activity in exchange for an increase in sedentary behaviour (Ong et al., 2021).

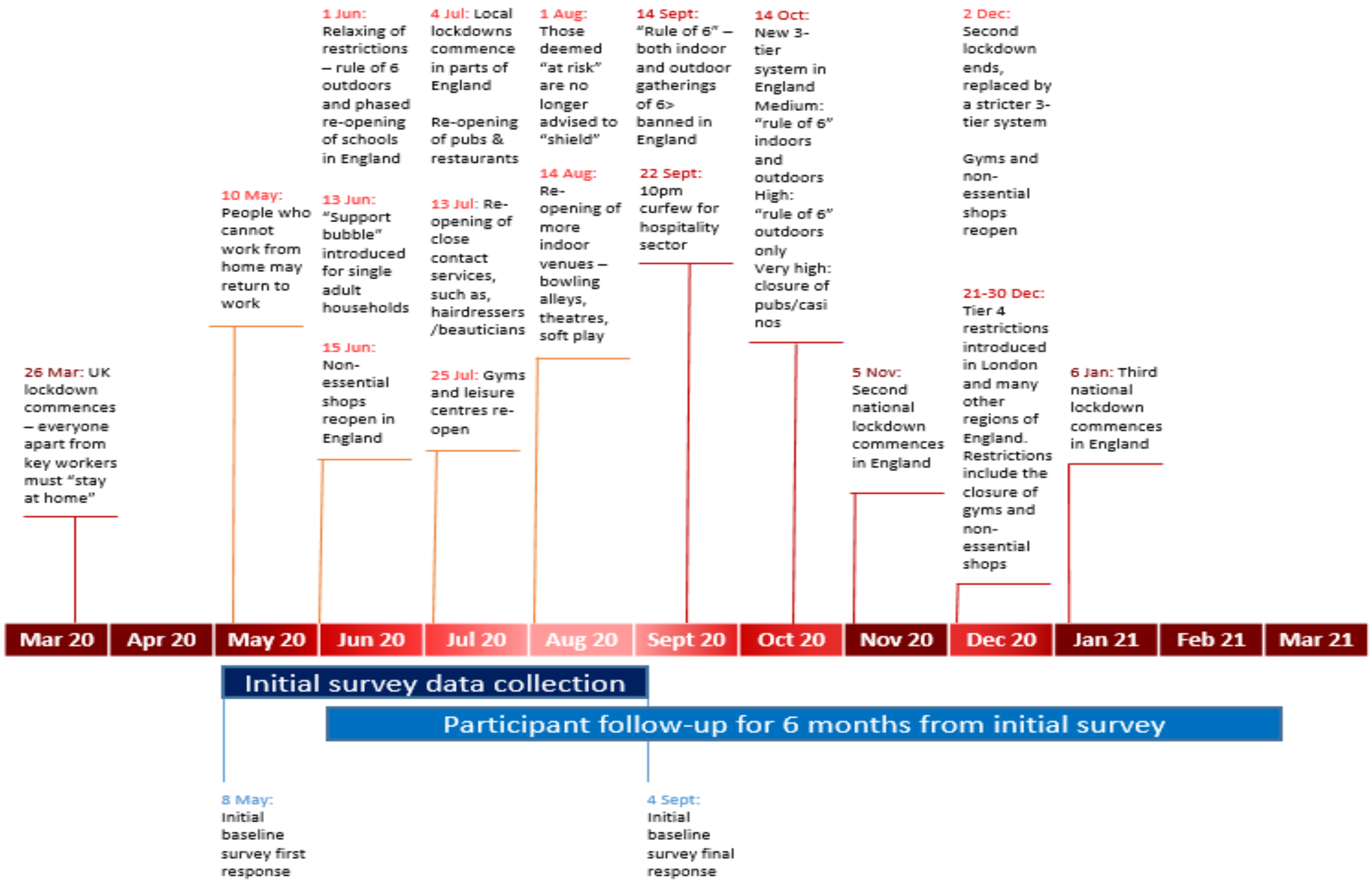

Figure 6.1. A timeline of UK governmental restrictions for the duration of the study, throughout a one-year timeframe during the coronavirus pandemic from March 2020 to March 2021.

Despite quarantine proving to be effective in containing the COVID-19 outbreak and keeping the population safe from contracting the virus, the methods used have been linked to several undesirable effects (Maugeri et al., 2020). In particular, social isolation has been linked to negative impacts on the psychological response of individuals, further leading to symptoms of confusion and anxiety (Brooks et al., 2020). Other negative consequences of social isolation include, depression (Gagnon et al., 2005), cognitive decline (van Schoor et al., 2002) and an increased fear of falling (FOF) (Gyasi et al., 2019). FOF has been recognised as an important risk factor for falls throughout the lifespan (Gazibara et al., 2017) and recent research has identified that individuals who had experienced a fall were more likely to have a FOF than individuals who had not suffered a fall (Byun et al., 2020). Previous evidence found that 37.5% of adults with a history of falls with a moderate to severe score for FOF also had a concurrent depressive mood disorder (Gagnon et al., 2005). With findings in Chapter 4 suggesting that middle-aged adults display an increased FOF, there is now a need to address the combined effects of depression, anxiety and FOF much earlier in order to prevent falls in middle-age as well as older adults. When considering these factors alongside the additional challenges imposed by the pandemic restrictions and their impact on falls propensity, it is clear that together the outcomes may be ever more problematic for those individuals who already show age-related decline and other fall markers.

Physical responses of isolation have been linked to physical inactivity, premature ageing, obesity, cardiovascular disease and decreased aerobic capacity (Bortz, 1984); factors that are known to impact negatively on falls propensity. By staying at home, some individuals were spending significantly more time within a confined environment, and hazards in the home have been linked to increased instances of falling throughout ageing literature (Stevens et al., 2001). It could be argued that the pandemic restrictions may have increased an adult's likelihood of falling, due to an over-exposure of fall risk in the home environment. In addition, time spent outdoors was reduced. Outdoor environmental hazards have been linked to an increased risk of falling in both middle-aged and older adults (Li et al., 2006). Therefore, the extent to which falls indoor and outdoors may have changed for those at risk of falling due to the constrains on individual's daily lives.

It is possible that fall risk may have increased in both middle-aged and older adults due to a reduction in physical activity, an increase in sedentary behaviour and an increased exposure to the home environment (see Figure 6.2), however it may also be possible that instances of falls decreased due to a reduction in exposure to external environmental factors. The multidirectional relationship of exposure to both psychophysiological and environmental factors require further investigation.

	Inside the Home	**Outside the Home**
Pre-Pandemic	↓ Time spent in the home ↓ Risk of home-related hazards	↑ Time spent outdoors ↑ Exposure to environmental hazards *(Li et al., 2006)* ↑ Physical Activity *(Lesser et al., 2020)*
During Pandemic	↑ Time spent in the home *(Castañeda-Babarro et al., 2020)* ↑ Home-related hazards (individuals living in the home, pets, furniture) *(Stevens et al., 2001)* ↓ Risk of falling outdoors ↑ Sedentary behaviour *(Stockwell et al., 2021)*	↓ Time spent outdoors ↓ Exercise (permitted 1 hour per day outdoors) *(Ghozy et al., 2021)*

Figure 6.2. Associated risk factors for falls examined for both pre- and during the pandemic.

Lockdown restrictions and additional time spent at home is thought to have subjected individuals to periods of physical deconditioning, a term used to describe the negative effect that inactivity has on a person's functional ability (Gray, 2021). The term was first introduced to explain the risk for patients left in hospital beds after an acute phase of illness. However, it is now also thought to be a risk to individuals who spend significant periods of time being inactive at home. Deconditioning increases the risk of disability, frailty and falls and therefore increases the need for health and social care services. This is often due to a loss of both physical and mental health over time and may explain the strong case for exercise being prescribed by general practitioners to improve mental health. It is suggested that deconditioning periods should be followed by periods of reconditioning. Reconditioning requires people not only to be informed about the benefits to their health of engaging in physical activity, but also to receive the encouragement and enablement to take action to reverse deconditioning effects. Irrespective of whether fall incidents increased or decreased as a result of the pandemic, it may be post-pandemic that middle-age fallers present with an increased risk-factor profile as a result of being subjected to, 2-years of deconditioning.

The main aim of this study was to gain an understanding of the impact that the global pandemic and subsequent public health restrictions have had on fall risk factors in adults aged 45-64 years. The study aimed to address how both instances of falls and fall risk factors, including, physical activity engagement, physical health and mental health had changed since the COVID-19 pandemic began and for a follow-up period of 6-months in individuals with/out a history of falls. It was hypothesised that COVID-19 would negatively impact the physical activity participation, increase the number of falls and scores on both depression and anxiety scales of fallers and non-fallers. It was expected that the individuals within the falls group would spend significantly less time being physically active compared to pre-pandemic and have an increased fall incidence during the pandemic period. In addition, it was also hypothesised that fall risk factors at baseline and changes in the fall risk factors throughout the pandemic would be associated with total number of falls at the end of the 6-month follow-up.

6.2 Methods

6.2.1 Study Design

The study used a cross-sectional online questionnaire. The participants were then followed up longitudinally over a period of 6-months upon completion of the initial questionnaire and for those meeting all eligibility criteria. The online questionnaire was distributed via social media platforms (e.g. Twitter) via Manchester Metropolitan University-affiliated accounts. The initial baseline questionnaire was completed by all participants between 8th May 2020 an 4th September 2020. Upon completing the initial questionnaire, the UK was 2 months into the pandemic, however, all participants were still under a type of COVID-19 restriction; an inclusion criterion for participation. All participants taking part in the study provided their written informed consent prior to completing the questionnaire. The study was approved by the Ethics Committee at Manchester Metropolitan University (EthOS 23699).

6.2.2 Participants

In order to participate within the study, participants had to be between the ages of 45-64 years. A total of 39 UK residents volunteered for the study. Participants were excluded from the study at the beginning of the questionnaire if they met any of the following exclusion criteria: aged below 45 years old, had not experienced any restrictions due to COVID-19, had any form of dementia, Parkinson's disease, stroke, Huntington's disease, suffered from paralysis or any other neurological condition known to limit walking ability or had any musculoskeletal condition such as arthritis or osteoporosis known to severely limit walking ability. 4 volunteers stated that they had musculoskeletal conditions that affected walking ability, 1 volunteer had suffered a stroke, 1 volunteer had Parkinson's disease, 1 volunteer had not faced any COVID-19 restrictions and 2 volunteers were younger than 45 years of age. After this stage, the sample then comprised 30 participants (see Figure 6.3).

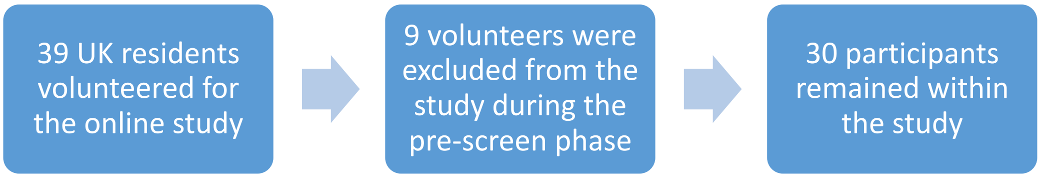

Figure 6.3. A flow diagram to demonstrate participant numbers for the study.

6.2.3 Measures

The online questionnaire was distributed to participants using a online survey software (Qualtrics®XM, USA). The questionnaire comprised 143 questions featured within 25 question blocks and took a maximum of 45 minutes to complete. Before participants were able to submit any responses, consent was taken, and the completion of the pre-screen questionnaire was conducted in order for each participant to meet the eligibility criteria. Upon both conditions being met, participants were able to begin the questionnaire. The questionnaire compromised of several blocks of questions relating to participant demographics, anthropometric and socioeconomic factors (see Table 6.1). The questionnaire also included questions examining COVID-19 living circumstances, fall status and incidents, time spent engaging within physical activity per week, mental health measures (anxiety and depression) and FOF.

6.2.4 Demographics, Socioeconomic Factors and Coronavirus Living Circumstances

Demographic characteristics included age, sex, height, weight and marital status. In addition, occupational status was captured both at the time of completing the questionnaire and the main occupation held throughout adult life. COVID-19 living circumstances including questions related to the number of people living in the household and whether any of these individuals were deemed 'at-risk'. The term 'at-risk' was defined as 'adults or children who have one or more conditions meaning that they are more likely to get severely ill from contracting COVID-19.

6.2.5 Fall History

Participants were required to recall the occurrence of one or more falls over the 12-month period preceding the study. This information was then used to categorize individuals into the correct 'faller' and non-faller' groups. Further details of their most recent fall was collected, including, when the fall occurred, was the fall indoors or outdoors, at what time of day did the fall occur and type of fall, along with any sustained injuries and medical care sought as a result of the fall. In addition, participants could openly report any additional circumstances surrounding the fall, such as the perceived cause.

6.2.6 Physical Activity Behaviour

Participants reported the amount of time, in minutes, that they spent in a typical week engaging in physical activity, for both the four weeks prior to completing the questionnaire, during the COVID-19 restrictions, and in the past year before the COVID-19 lockdown took place. Durations reported for light, moderate and vigorous physical activities were summated to provide a total activity time for all three intensity groups. In addition, participants were asked to rate how their physical activity levels had changed since before the lockdown restrictions. These questions created the opportunity to not only compare the amount of light, moderate and vigorous physical intensity exercise before and during the pandemic, but also assess the participants' perception of how their activity had changed due to the lockdown restrictions.

6.2.7 Behavioural Measures

Falls Efficacy Scale International (FES-I) was used to assess FOF (Yardley et al., 2005) (Appendix 6.1). The 16-item self-report questionnaire, asked participants to rate their level of concern about falling for a range of activities such as 'going up and down stairs' and 'walking on a slippery surface' using a four point scale (1 = not at all concerned to 4 = very concerned) (Delbaere et al., 2010a). The maximum score for the FES-I was 64 demonstrating a severe concern about falling and 16 demonstrating no concern about falling. The FES-I was assessed at baseline and then at the 6-month follow up.

The Gait Specific Attentional Profile (G-SAP) (Young et al., 2020) examined anxiety and conscious movement processing during gait-related activities in participants, as per the protocol described in Chapter 4, section 4.2.8.

A bespoke risk-taking questionnaire also assessed each participant's level of risk-taking behaviour. The questionnaire combined items from Butler et al. (2015) and the health-related domain of the Domain-Specific Risk-Taking (Adult) Scale (DOSPERT-30) (Blais and Weber, 2006). Participants were asked to provide one of four responses 'always, mostly, occasionally or never' to 18 statements. The statements included questions such as 'Do you sit down to put on your shoes and socks?' and 'Would you climb up on furniture to reach high shelves or to change a light bulb?'.

6.2.8 Mental Health

The Centre for Epidemiological Studies Depression Scale (CES-D) (Andersen et al., 1994) was used to identify depressive symptoms. Participants were asked to respond to 20 descriptive statements of depressed mood. Responses ranged on a four-point scale, starting at zero with a response of 'rarely or none of the time (less than 1 day)' to three 'most or all of the time (5-7 days)'. An example of a question that participants were asked was 'I was bothered by things that usually don't bother me'. CES-D total scores ranged from 0-60.

The State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1971) was used to identify general (trait) and current (state) anxiety symptoms as per the protocol described in Chapter 4, section 4.2.8. Both state and trait anxiety measures were conducted at baseline, whilst only state was measured at the 6-month follow up due to trait anxiety being a stable measure (Saviola et al., 2020).

6.2.9 Longitudinal Follow-Up

After providing consent at the initial questionnaire stage, participants were made aware that they would receive a 4-minute follow-up diary via email, once a month for a period of 5 months. At the 6-month period, participants completed the initial questionnaire in order to re-assess all measures after the 6-month period. The measures re-assessed at 6-months were heath and lifestyle questions, IPAQ, CES-D, FES-I, the state aspect of the STAI and the G-SAP.

6.2.10 Statistical Analysis

An *a priori* power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) to determine the minimum sample size required for the study, based on data from (Hoffman et al., 2022). Results indicated the required sample size to detect a medium effect size, at a significance level of $\alpha = .05$ and power = .80 was n = 100, 50 in each of the faller and non-faller groups. As only 30 participants were recruited to the study, the power of the study was reduced, increasing the potential for a type II error to be present in the results.

Demographic characteristics were split into faller and non-faller groups and summarised using descriptive statistics. All quantitative analyses were performed using IBM SPSS Statistics software (27.0, SPSS Inc., Chicago, IL, USA). All quantitative data was tested for parametric assumptions of normal distribution using Shapiro-Wilk's test ($p>0.05$) in all dependant variables. No dependant variables were found to be parametric. For comparison of group differences, the Mann-Whitney U test was performed. Changes in falls and activity levels over time were analysed using a Chi-Square. A Wilcoxon Signed-Rank test was used to examine changes in light, moderate and vigorous activity levels between fallers and non-fallers. Finally, a Spearman's Rho correlation was used to assess the correlation between total number of fall and post-test behavioural measures such as anxiety. All data is presented as mean ± SEM.

6.3 Results

6.3.1 General Characteristics of Study Population

Baseline characteristics of the study population are displayed in Table 6.1. Overall, the study sample (n=30) were divided into 2 groups: fallers (n=10) and non-fallers (n=20). All participants were aged between 45 years and 64 years (60.33±5.21). BMI was split into three categories: underweight (BMI ≤18.5), normal weight (BMI 18.5-24.9) and overweight (BMI ≥25.0). As shown in Table 6.1, 76.66% of participants were classified as normal weight. It is important to note the sex imbalance between males and females in this study, as participants comprised 87% females and 13% males. As only 13% of the study population was male, sex differences were unable to be determined. The highest percentage of participants were female, meaning that the results in this study should be interpreted with caution and should avoid the overgeneralisation that the results of this study apply entirely to both sex populations. Given an equal sex ratio of participants, statistical analysis would have determined any potential differences in the data collected between males and females. There was no statistical difference in age, height, body mass or BMI between fallers and non-fallers ($p<0.05$).

Table 6.1. Participant characteristics for fallers and non-fallers.

Participant Characteristics	Fallers N (%) 10(33%)	Non-Fallers N (%) 20 (66%)
Age (mean, SEM)	59.92(4.15)	60.55(5.65)
Sex		
Female	8(80%)	18(90%)
Male	2(20%)	2(10%)
Height, cm (mean, SEM)	167.91(11.04)	165.82(8.74)
Weight, kg (mean, SEM)	67.92(14.58)	66.85(11.07)
BMI		
Underweight	-	-
Normal Weight	7(70%)	16(80%)
Overweight	3(30%)	4(20%)
Risk		
No risk	6(60%)	14(70%)
At-risk individually	-	4 20%)
Living in at-risk household	2(20%)	2(10%)
At-risk individually and living in at-risk household	2(20%)	-
Fall History		
0	-	20(66%)
Yes (1 Fall)	7(70%)	-
Yes (2 Falls)	2(20%)	-
Yes (3 or more falls)	1(10%)	-
Working Situation		
Retired	6(60%)	12(60%)
Employed, working from home	3(30%)	5(25%)
Employed, working outside the home	1(10%)	2(10%)
Furloughed due to COVID-19	-	1(5%)
Marital Status		
Married	7(70%)	13(65%)
Widowed	1(10%)	3(15%)
Divorced	1(10%)	-
Co-habiting	1(10%)	2(10%)
Single	-	2(10%)

6.3.2 Fall History

Of the 30 responders at the beginning of the study, 10 participants (33%) were classified as "fallers" and 20 participants (66%) were classified as "non-fallers", based on answering 'yes' to the question 'have you fallen in the 12-months preceding this study?'.

When asked for further details regarding the incident surrounding the fall, of the 10 fallers at baseline, 7 fallers (70%) stated that their fall took place outdoors. The remaining 3 fallers (30%) stated that their fall took place indoors. The time of day that individuals fell was reported as the following: between the hours of 05:00-07:30, 2 participants (20%), 07:30-12:00, 4 participants (40%), 12:00-17:00, 3 participants (30%) and 17:00-20:00, 1 participant. When asked to describe their most recent fall, 8 fallers (80%) attributed their fall to a trip or stumble and 2 fallers (20%) attributed their fall to loss of support and balance.

Following on from the fall questions analysed, the results also explored fallers experiences of their fall. The findings revealed:

> Faller 1: '*I stopped at a junction, overbalanced and fell.'*
>
> Faller 2: *'I was going into the garden through my French windows and tripped.'*
>
> Faller 3: *'During gardening work, I tripped over a boot scrapper and fell down.'*
>
> Faller 4: *'Walking on a weekend city break and looking around me, failed to see a curb and tripped over it.'*
>
> Faller 5: *'Rushing to get downstairs to empty the washing machine and slipped on the carpet at the top of the stairs.'*

Faller 6: *'Became disorientated in total darkness [did not bother to switch light on] and fell down a step in the corridor.'*

7 participants sustained an injury as a result of their fall whilst 3 participants did not. When examining further the resultant injuries, over half of the participants experienced bruising and grazes as a result of the fall. Of the 10 fallers, 2 participants sought medical attention, 5 participants did not seek medical attention for the fall and 3 participants did not comment on whether they sought medical attention post fall.

6.3.3 Baseline Activity Levels

All participants at the time of the initial survey demonstrated engagement in at least one of the physical activity groups. There was no significant difference observed between fallers and non-fallers in light *(U*=124, *p=0.430), moderate (U*=103, *p=0.135) or vigorous (U*=108, *p=0.182)* activity before the pandemic began (see Figure 6.4).

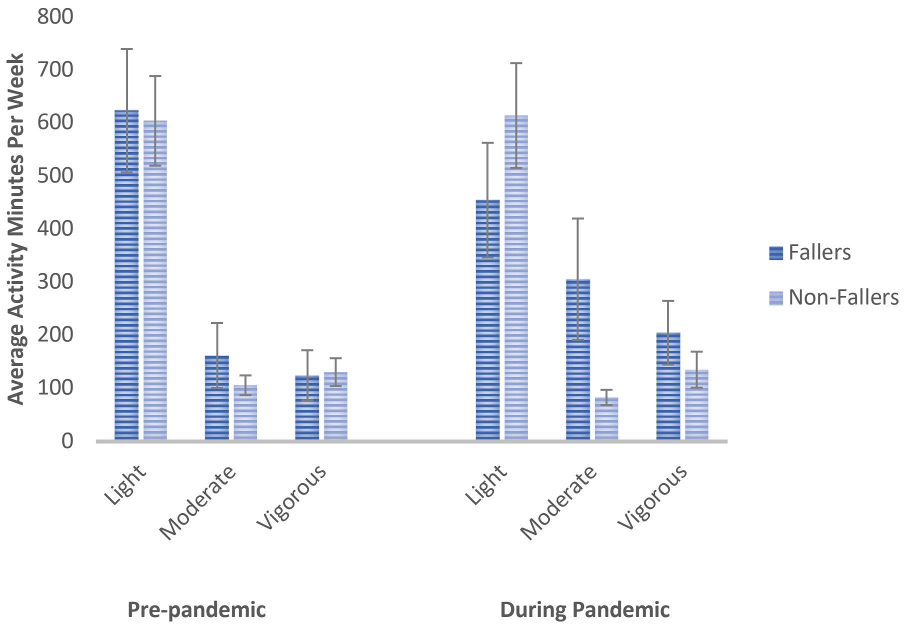

Figure 6.4. Average activity minutes per week for fallers and non-fallers both before the pandemic began and during the pandemic. Data is presented as mean ± SEM.

6.3.4 Baseline Behavioural Measures

Average scores for both fallers and non-fallers for six domains, FOF, anxiety (STAI), depression (CES-D), gait specific attentional profile (G-SAP) and risk taking are displayed in Figure 6.5. No significant differences were identified between fallers and non-fallers for any of the baseline behavioural measures (Fear of falling (FES-I): *U*=112*, p=0.245;* Trait anxiety (TAI): *U*=146*, p0.936;* state anxiety (SAI): *U*=128*, p=0.502*; depression (CES-D): *U*=100*, p=0.120;* gait specific attentional profile (G-SAP): *U*=115*, p=0.273;* risk taking behaviours: *U*=130*, p=0.551)*.

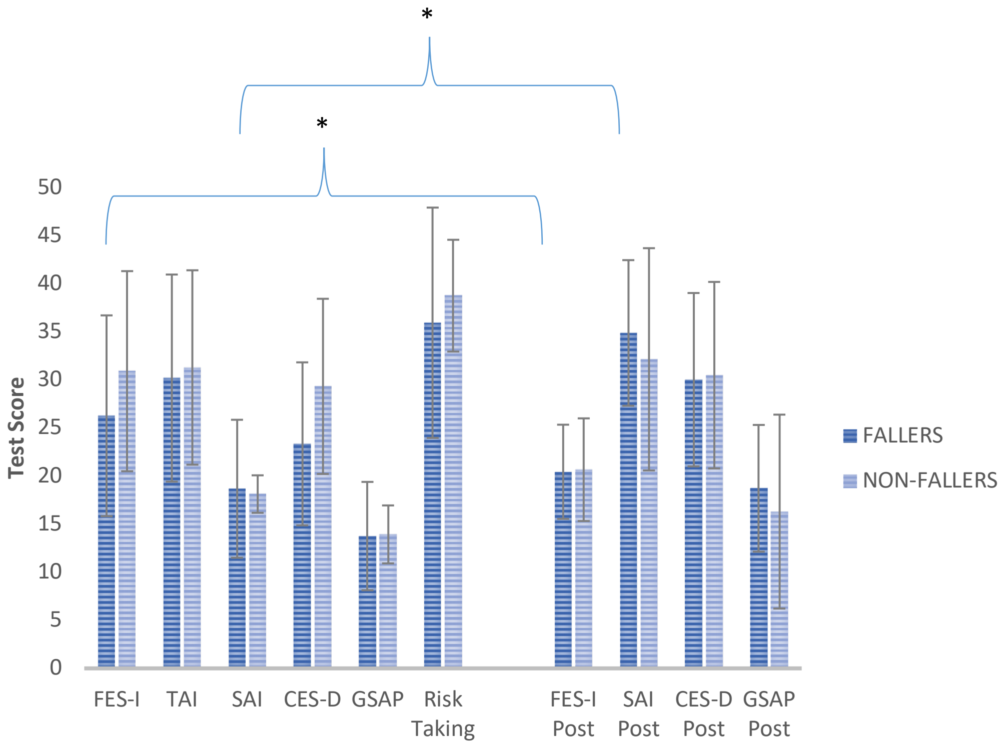

Figure 6.5. Behavioural measure differences for fallers and non-fallers, include four follow-up behavioural measures. Data is presented as mean ± SEM. **Denotes significant difference (P<0.05).*

6.3.5 Longitudinal Follow-Up

Fall Instances

Fall occurrence was measured longitudinally over a period of 6-months. The 6-month longitudinal data responses identified a further 5 fallers over this time period. Of the 30 participants at baseline, 15 participants (50%) were classified as "fallers" and 15 participants (50%) were classified as "non-fallers". Despite such findings, percentage of falls did not increase or decrease over the 6-month time period $\chi^2(5)=3.121$, p=0.681 (see Figure 6.6).

Fall Follow-Up Characteristics

Over the 6-month follow-up period, individual fall occurrences were documented. The 37 fall occurrences were spread over the 6-month period as follows: time point 1 = 6, time point 2 = 5, time point 3 = 7, time point 4 = 6, time point 5 = 5 and finally time point 6 = 8 (see Figure 6.6). When examining time of day of fall incidents, over the 6-month period 66% of falls took place indoors, whilst the remaining 33% taking place outdoors. The time of day of falls varied with the majority of falls (60%) taking place in the morning between the hours of 07:30-12:00. 4 fall incidents resulted in injuries (10.8%). Lastly, participants documented that the main cause of the fall (75%) was due to a slip or trip. The other falls were attributed to overall loss of balance (25%). When re-examining baseline data including the 5 additional fallers, no statistical significance was observed (p>0.05).

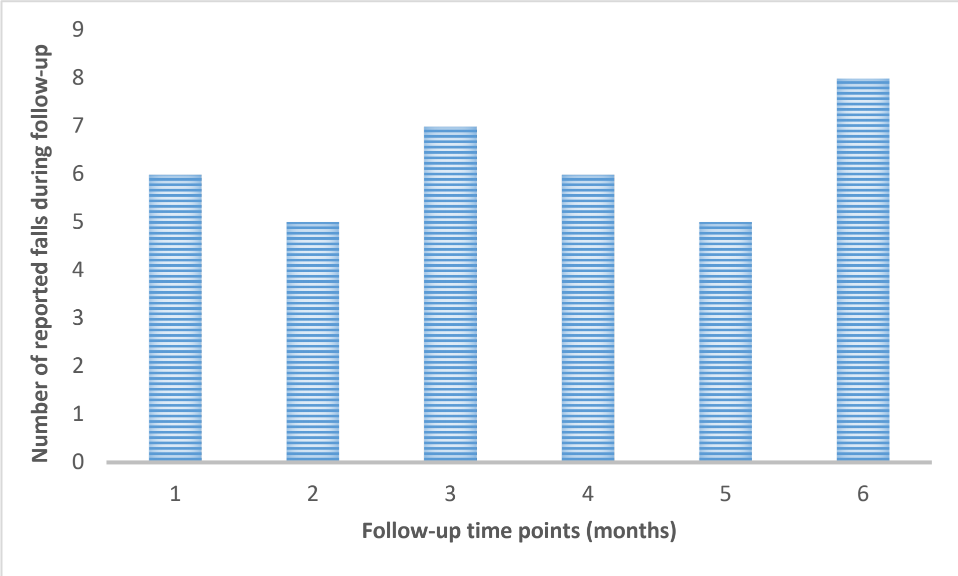

Figure 6.6. Number of falls reported by participants per follow-up month during the 6-month study.

6.3.6 Activity Levels

Physical activity behaviours and characteristics were obtained for a period of 6-month longitudinal follow-up. All participants that responded to the follow-up reminders demonstrated engagement within at least one of the physical activity groups (light, moderate or vigorous) at the six follow-up assessments. There was no significant difference observed between fallers and non-fallers in light *(Z=-1.573, p=0.116)*, moderate *(Z=-1.888, p=0.059)* or vigorous *(Z=-2.195, p=0.028)* during the pandemic (see Figure 6.7).

When examining whether individuals became more active, stayed the same or were less active due to the pandemic. No significant change was observed in average number of minutes spent engaging within light ($\chi^2(5)=3.897$, p=0.564), moderate ($\chi^2(6)=5.939$, p = 0.430), or vigorous ($\chi^2(6)=5.065$, p=0.535) physical activity before the pandemic began or any of the 6-month follow-up time points (see Figure 6.7).

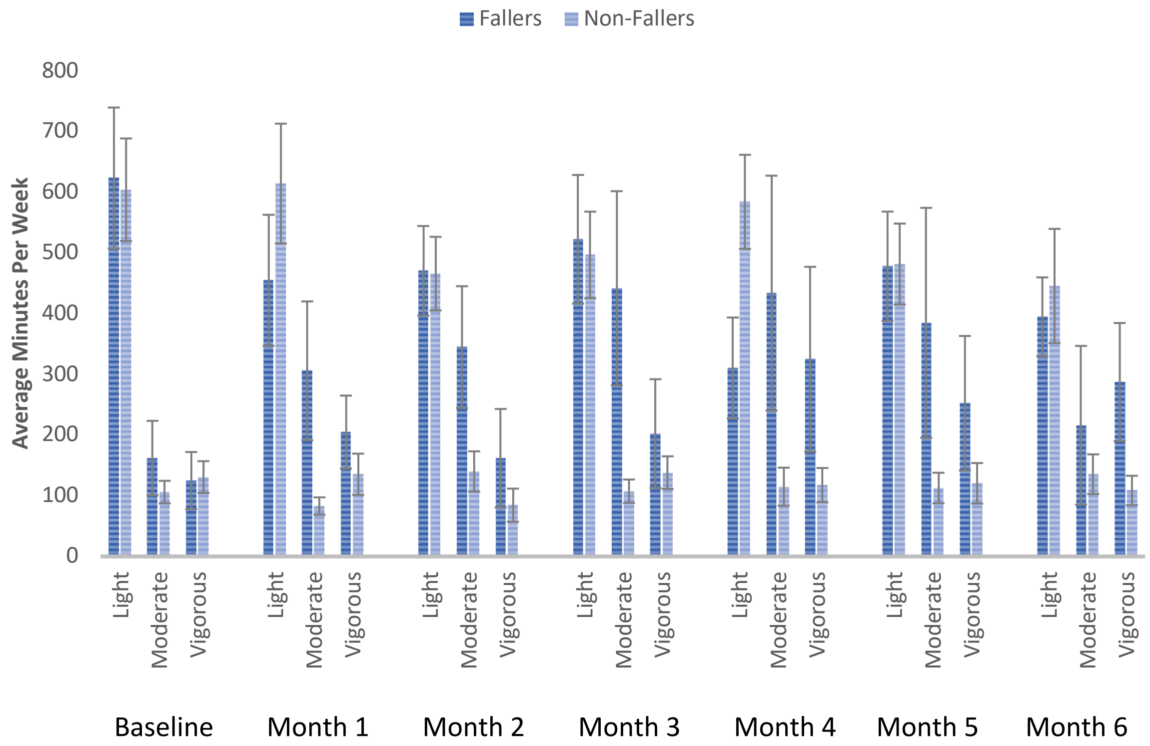

Figure 6.7. Average minutes per week of light, moderate and vigorous physical activity for fallers and non-fallers for the initial questionnaire response and 6-month longitudinal follow-up. Data is presented as mean ± SEM.

Self-reported change in physical activity was investigated between fallers and non-fallers. 73% of fallers stated that they were much less, less active or slightly less active. 13% of fallers stated that they were much more, more active or slightly more active since the pandemic restrictions were introduced, with the remaining 13% of the fall population stating no change within their physical activity time.

Whilst the largest proportion of non-fallers (53%) reported a reduction in their physical activity time, a high proportion (33%) reported an increase an increase within their physical activity time in comparison to fallers, whilst the remaining 13% of non-fallers reported no change in physical activity due to the pandemic. Larger proportions of non-faller participants demonstrated a divide when asked to report both increases and decreases in physical activity time in comparison to fallers.

Regardless of physical activity level, both fallers and non-fallers reported a change in time spent outdoors. Self-reported time spent outdoors highlighted that 60% of fallers reduced time spent outdoors by as much as two hours per week with some fallers reporting a reduction in more than two hours week. 20% of fallers reported an increase in time spent outdoors by at least one hour per week. 20% of fallers reported no change in time spent outdoors. Similarly, 53% of non-fallers also saw a reduction in time spent outdoors due to pandemic restrictions. 33% stated that they spent more time outdoors, with up to a 2 hour increase, whilst 13% highlighted no change in the time that they spent outdoors.

When asked to report on any changes in body mass. 66% of fallers reported no significant change in body mass due to the pandemic. 20% reported that they had gained weight, whilst 13% reported a weight loss as a result of the pandemic. When examining the non-faller group, the distribution of participants in relation to changes in body mass were almost evenly split. 33% of non-fallers reported no change in body mass, a further 40% reported a noticed weight gain, whilst a slightly smaller percentage (26%) observed a weight loss during the pandemic.

6.3.7 Behavioural Measures

As shown by Figure 6.5, further tests revealed no significant differences when examining post tests for behavioural measures. FES-I (U=57, p=0.665), SAI (U=61.5, p=0.878), CES-D (U=63, p=0.951), G-SAP (U=59, p=0.755). When examining the test scores at both the initial measurement and the 6-month follow up, no significant differences were observed between the two time points for CES-D (Z=-.308, p=0.758) or G-SAP (Z=-.467, p=0.640). However, when examining the pre and post test scores for FES-I (Z =-3.775, p=.000) and SAI (Z=-4.199, p=.000) both highlighted a whole group difference in scores between time points (see Figure 6.5). In fallers, FES-I scores significantly decreased from baseline to 6-month follow-up, whilst SAI significantly increased from baseline to 6-month follow up.

6.3.8 Correlations

No associations were found between the total number of falls and post scores in FES-I (r_s=.039, p=0.855), CES-D (r_s=.343, p=0.101), G-SAP(r_s=.177, p=0.407) and SAI (r_s=-.157, p=0.348). Further correlations were conducted to investigate the effects of time spent outdoors on both depression scores and total number of falls. No correlations were found between time spent outdoors and the score from the CES-D (r=.061, p=0.715) or total number of falls (r=.157, p=0.348).

6.4 Discussion

The present study reports data on how COVID-19 restrictions affected the lives of UK citizens aged 45-64 years and, more specifically, what impact such restrictions had on fall risk and incidence. Many indirect costs have been attributed to COVID-19 and the subsequent restrictions imposed. Limited research, however, has been conducted into the risks that the COVID-19 pandemic has subsequently had on falls incidence.

The projection at the onset of the pandemic was that individuals who were already predisposed to an increased risk of falling, would experience greater risk and subsequently more falls during the pandemic due to a reduction in physical activity (Ghozy et al., 2021), increased sedentary behaviour time (Stockwell et al., 2021), increased time spent in the home environment (Castañeda-Babarro et al., 2020) and increased isolation (Morrow-Howell et al., 2020) (see Figure 6.2). The onset of this extreme period of deconditioning (Pelicioni and Lord,

2020) enforced on UK citizens was thought to only bring about negative health-related consequences.

The present study did not find data to support these projections, instead identifying a pandemic paradox, in which fall occurrence in middle-aged adults did not increase during a 6-month follow up period. Of the 37 instances of reported falls, only 10.8% of these were reported as injurious falls suggesting that fall related injuries reduced during the pandemic. Hazardous outdoor environmental exposures have been recognised as a risk factor for falls (Lee, 2021) and a reduction in time spent outdoors and exposure to hazardous outdoor environments may provide a justification for these findings, as the present study found that 70% of fall incidents took place outdoors pre-pandemic in exchange for 66% of fall incidents taking place indoors during the pandemic. By utilising a prospective method to obtain fall occurrence, the present study was able to identify a further 5 participants that reported experiencing a fall during the 6-month follow up, who were otherwise classed as healthy controls during baseline data collection. The identification of these additional fallers highlights the importance of prospective measurement of fall incidence previously discussed throughout this thesis, in an attempt to reduce the potential of recall bias (Mackenzie et al., 2006).

A decline in physical activity levels have also been attributed to an increased fall risk (Karlsson et al., 2008) and many research studies identified a reduction in physical activity levels as a result of the pandemic (Puccinelli et al., 2021). These restrictions permitting individuals to engage in 1-hour of outdoor physical activity per day, may have potentially influenced physical activity behaviours and impacted fall propensity. The present study, however, did not find either a significant increase or decrease in engagement in physical activity minutes per week during the pandemic when compared to pre-pandemic. These findings may be partially explained by a small number of participants reporting a perceived increase in physical activity minutes. The increased perceived activity may be reported because of the regulations permitting short 1-hour periods of activity in any 24-hour period. This, more concentrated and formalised activity, seems to have been reported as an activity (exercise) increase but should be contrasted with the significant decrease in activity levels in the remaining 23-hours of the day. The increase in prolonged periods of sedentary behaviour is known to be a more significant issue for fall propensity (Thibaud et al., 2012). Of studies that did examine sedentary behaviour and activity in the form of step count, found that in the first 10 days of the pandemic, daily step count had reduced by 5.5%, increasing to 27.3% by day 30 (Tison et al., 2020). It can be assumed that these sudden reductions in physical activity levels are not usually witnessed in middle-aged adults, with many still completing daily activities such as the commute to work. The pandemic restrictions naturally forced middle-aged adults to adopt sedentary behaviours, otherwise not experienced until later life stages (Skelton, 2001).

Upon examining the psychological responses of participants at baseline and throughout the 6-month follow up, fall participants demonstrated a significant reduction in their FOF. These findings do not support other studies conducted throughout the pandemic that suggest that FOF increased as a result of the pandemic (Hoffman et al., 2022). A potential explanation to the contrast in these findings is that participants in the present study, compared to other studies, did not demonstrate a significant increase in number of falls or report a higher proportion of fall-related injuries, both known to directly increase FOF (Lach, 2005). A significant increase in state anxiety was observed during the pandemic in middle-aged fallers, with state anxiety scores being significantly higher at follow-up than at baseline. By this time, participants had been subjected to pandemic restrictions for some considerable time with overexposure to negative media sources, alongside worrying health prospects. It is, therefore, to be expected that this transient response to the adverse negative circumstances of the pandemic would fall in-line with the continually changing pandemic restrictions. Anxiety is, however, linked to an increased fall risk (Serrano-Checa et al., 2020) and with pandemic restrictions and implications now spanning over 2-years, to what extent middle-aged fallers still display high levels of anxiety as we begin to recover from the pandemic requires further investigation.

6.5 Limitations

The main limitation of the study was the small sample size analysed. Our original target was to gain ~100 participants, however, recruitment during the pandemic proved to be difficult. Is it thought that between group differences were not identified due to the small number of participants in both the faller and non-faller groups. In addition, the recruitment method used, an online questionnaire voluntary approach, may have resulted in selection bias. This meant that to participate, participants had to have access and knowledge of how to use technology to access the online study questionnaire. Individuals who did not have access to technological devices were unable to participate within the study. The varied seasonal transitions from spring to autumn across the UK may have impacted opportunities to engage within outdoor and social activity in accordance with the relaxing of restrictions, meaning that findings observed in the present study may have identified no differences in activity levels as a result of increased ability to exercise outdoors.

6.6 Conclusion

It is known that physical function declines incrementally as life progresses and that this physical decline is often a result of increased sedentary behaviour and periods of isolation.

These age-related risk factors have been directly linked to an increase in the number of falls that older adults experience, however, these falls risk factors are not usually experienced during the middle-stage of an adults life. The onset of the COVID-19 pandemic has subjected younger populations to a period of deconditioning and social isolation in earlier life years, potentially accelerating fall risk in this age demographic. It may have been proposed that the pandemic would bring about negative health outcomes, however, the present study findings did not align with this idea. Instead, there is a potential that middle-aged fallers fell less and when they did fall, the falls were less injurious due to the location of the falls being in the home instead of in the outdoor environment. Middle-aged fallers in the present study demonstrated a reduction in FOF as a result of the pandemic restrictions, however, state anxiety increased for these individuals. More importantly, whilst number of falls were not significantly increased, fall incidents still occurred throughout the pandemic, suggesting that falls during middle-age is still a public healthcare issue.

It is important that future studies address any deconditioning that may have occurred as a result of the pandemic in this age-group. It may be predicted that a 2-year period of alterations to both physical and social behaviour change may predispose middle-aged adults to more injurious falls in earlier life years. Future research studies should aim to follow-up middle-aged fallers in the coming years to determine whether the COVID-19 pandemic has accelerated age-related risk factors for falls. It may be sensible for clinicians to begin to propose a level of exercise intervention to offset any potential emerging risk factors. Preventative interventions will not only allow communities to be better prepared should individuals face future restrictions, but also inform adults on ways to maintain both physical and mental health to prevent increased risk of falling.

Chapter 7: The Lived Experience of Falling During Middle-Age

7.1 Introduction

Falls in older adults have been highlighted as a public health concern for some time (Lord et al., 2003) and the multifactorial nature of falls in this age demographic have been described in chapters 2 and 4 of this thesis. Given the focus on older age groups, it is, perhaps, unsurprising that the impact of falls in terms of the lived experience is well described in older people (Berlin Hallrup et al., 2009; Abrahamson et al., 2013). In contrast, however, the impact of falls on the lived experiences of the middle-aged is less well reported, despite falls in the middle-aged known to have direct consequences on both work and family commitments (Lipscomb et al., 2003).

For many older people, it is a fear of falling (FOF), rather than the physical disability from a fall that may start or accompany fear-avoidance and the associated physical and mental decline. In the middle aged, FOF becomes more apparent, but may be different to the FOF examined in older adults. Unlike older adults, middle-aged adults may not have started to accept their decline in physical function (Partington et al., 2005). In addition, they have relationship roles which are less likely to include direct care provision for their partners. They also have financial dependents and employment demands. Together these may represent unique factors for the middle-aged faller, contributing to unreported consequences of a fall and leading to depression and lower quality of life through the incongruence of psychobehavioural factors and physical decline.

Research into middle-aged fallers is, therefore, becoming of more interest (Wang et al., 2021). The global pandemic has presented a unique situation to investigate the consequences of forced lockdowns and isolation (Thomson, 2020) as factors accentuating the middle-aged decline and falls. Further, the consequences of social isolation on mental health is thought to have been intensified by the COVID-19 pandemic (Armitage and Nellums, 2020), with limited social contact known to be associated with an increased risk of falls (Bu et al., 2020). Research has established the association between these risk factors and falls and understanding how the presence of the pandemic may have accentuated feelings of social isolation (De La Camara et al., 2020) will allow researchers to explore how factors may accelerate the risk of falling in middle-aged populations.

Guidance throughout the pandemic to self-isolate helped to reduce the risk of COVID-19 transmission, protected an over-burdened health care system and directly saved the lives of those at greatest risk of COVID-19 infection (Callow et al., 2020). These restrictions, however, presented a new public health concern given the direct link between quality and quantity of human social interaction and physical health, mental health and reduced morbidity risk (Umberson and Karas Montez, 2010). It is logically intuitive that increased sedentary behaviour is a predictor of all-cause mortality (Fried et al., 1998) and is linked to depression symptoms (Mura and Carta, 2013) cognitive decline (Woodard et al., 2012), social isolation and reduced physical activity (Schrempft et al., 2019); a cycle that also appears to be a negative by-product of falls and potentially may be accentuated in the middle aged as a result of COVID-19.

Engagement in physical activity has been recognised as a way of preventing falls in older people for some time (Sherrington et al., 2008), with evidence suggesting that increased physical activity levels may reduce falls by as much as 21%, through increasing muscle mass and improving gait performance (Cameron et al., 2018). In addition, there are wider evidenced mental health benefits (Mura and Carta, 2013). Working from home was encouraged during the pandemic and many middle-aged individuals lost their only regular source of physical activity (Lachapelle et al., 2011), likely resulting in extended periods of deconditioning (Pelicioni and Lord, 2020). It could, therefore, be hypothesised that the number of falls and subsequent injuries may have increased as a result of the pandemic (De La Camara et al., 2020), with middle-aged individuals possibly being particularly effected as they are the larger part of the affected workforce.

COVID-19 regulations created an environment where middle-aged individuals experienced isolation and a loss of habitual physical activity (Callow et al., 2020). Within this population, FOF may have large implications for engaging in daily life and the perceptions of high-risk activities (Painter et al., 2012). With anxiety being linked to FOF and fall risk (Hallford et al., 2017), the pandemic may have exaggerated the role of anxiety in the middle-aged.

Within the context of qualitative studies examining lived experience of falls in older populations (Gardiner et al., 2017), there remains no broader analysis of experiences and subsequent consequences of falls or exploration into the impacts of the COVID-19 pandemic on the fall incidence of middle-aged adults. The aim of this study was therefore to (1) understand the lived experience of falls in a middle-aged population (45-64 years) and (2) explore the impact that COVID-19 had on fall instances throughout the pandemic. The research objectives of this study were, therefore, to understand how falling incidents affect FOF in middle-aged adults; examine changes in physical activity following falling incidents in middle-aged adults; and explore the impact of the COVID-19 pandemic on falling incidents in middle-aged adults.

7.2 Materials and Methods

7.2.1 Participants

Following ethical approval from Manchester Metropolitan University's Institutional Review Board (29119), advertisements for the study were posted on social media platforms (e.g. Facebook and Twitter). The aim of the project was to gain a broad understanding of the lived experience of middle-aged fallers, therefore, a purposeful recruitment strategy was adopted (Collins, 2010), as only individuals aged 45-64 years who had sustained a fall were eligible for participation. The recruitment process led to a sample of 10 participants (57.7 (4.2) years) completing the online questionnaire (see Table 7.1). Pseudonyms were used for all participants in the study. The 10 participants provided written consent to be contacted for further research participation by sharing their email address. All individuals were invited to interview which were conducted at times convenient to the participant, with all interviews taking place via Microsoft Teams due to Governmental COVID-19 restrictions not permitting face-to-face interviews.

Table 7.1. Participant characteristics and fall-related measurements taken from the study questionnaire.

Pseudonym	Sex	Age	Fall Status	FOF	SAI	TAI	Health Status
Elizabeth	Female	64	NF	21	9	12	Very good
Anna	Female	50	RF	29	9	10	Good
Eric	Male	61	RF	19	5	5	Very good
Ffion	Female	60	NF	16	5	5	Good
Vivien	Female	61	NF	20	5	6	Very good
Claire	Female	58	RF	27	12	9	Good
Lois	Female	57	RF	19	5	6	Fair
Lynn	Female	60	RF	19	5	5	Very good
Paul	Male	51	NF	17	5	6	Very good
Nicola	Female	55	RF	28	5	11	Good

FOF; Falls Efficacy Scale – International, SAI; State Anxiety, TAI; Trait Anxiety, NF; New Faller, RF; Reoccurring Faller.

7.2.2 Questionnaire

For the purposes of providing quantifiable demographics and falls data, participants completed an online questionnaire prior to being invited to follow-up interview (Qualtrics®XM, USA). It should be noted that these data were descriptive only, with the qualitative data the focus of this chapter. Participants completed questionnaire selections for age (years), height and body mass. Participants were able to provide height in centimetres and feet and inches, and for body mass in kilograms and stones and pounds.

Participants were classified as reoccurring fallers based on answering 'yes' to two questions: 1) 'Did you experience any falls in the 12-month prior to the pandemic restrictions being put in place in March 2020?' and 2) 'Have you experienced a fall during the last 6 months?' which at the time of the study was during UK governmental lockdown restrictions. Participants were classified as new fallers based on answering 'no' to experiencing any falls prior to the pandemic and answering 'yes' to experiencing falls during the pandemic and last 6 months.

A FOF score was ascertained by asking participants to complete the FES-I (Yardley et al., 2005) as per the protocol described in Chapter 6, section 6.2.7. The maximum score for the FES-I was 64 demonstrating a severe concern about falling and 16 demonstrating no concern about falling.

The STAI (short anxiety inventory) was completed in the online questionnaire (Zsido et al., 2020). Participants were required to answer the 5-item version of both the state and trait anxiety inventory. Participants were provided with both a state and trait anxiety score, with cut off scores for state anxiety (>9.5) and trait anxiety (>13.5) to signify significant levels of anxiety.

To provide an indicator of current health status, participants were asked to self-report on current health based on five possible options (very good, good, fair, poor, very poor). This approach has been used previously as a prognostic indicator for physical and mental health problems (McGee et al., 1999).

7.2.3 Interviews

Semi-structured interviews were conducted to (1) uncover how individual and social factors shaped the experiences and interpretations of middle-aged fall populations, (2) to expand on data provided throughout the study questionnaires, and (3) to generate new understandings that may not have emerged from the use of quantitative methods (O'Cathain, 2010). Semi-structured interviews provided the opportunity to discuss with participants aspects important to the investigation whilst allowing the flexibility to understand participants' diverse perspectives through impromptu questions (Brinkmann and Kvale, 2018).

In this study, 10 interviews were conducted virtually using Microsoft Teams. Prior to interview, all participants were asked to provide informed consent to the audio and/or video recording of the interviews, of which 8 interviews were video recorded and 2 interviews were audio recorded. Participants provided further consent to the transcription of the video and/or audio recordings and to the use of anonymised, direct quotations in any published work as a result of the research study (e.g., published journal articles and/or conference presentations).

Interviews were informed by an interview guide, which included both example questions and topics of relevance. The interviews began by providing a summary of the purpose of the interviews and allowing time for participants to ask any remaining questions about the interview process. Interview questions and conversations then focused on understanding the experiences of falling during middle-age. All interviews were audio and/or video recorded. The audio files of these interviews were then transcribed for subsequent interpretation (Davidson, 2009).

7.2.4 Analysis

7.2.4.1 Interviews

Reflexive thematic analysis was utilised to categorise patterns of meaning across interview data (Braun and Clarke, 2013). A phased approach to thematic analysis was adopted as suggested by (Braun et al., 2016). The first phase of the analysis began with data familiarization. This stage required engagements with the data both in the form of audio recordings and transcripts. Active engagement with the data allowed for the identification of meaning and patterns. Upon becoming familiar with the data, codes were then identified that highlighted important text within the data. Analytical questions at this stage included "What does falling mean to participants?", "How do participants think and feel about factors that may impact them falling? Why do they think and feel this way?".

The research moved to developing themes, which comprised of wider patterns of meaning. Themes were allocated based on appearing frequently between participant transcripts. The four most relevant themes to this study were related to the cause of falling, the implications of falling, the impact of COVID-19 and future considerations to prevent falling. The reviewing of themes took place by allowing other independent researchers (n=3) to read the transcribed data in order to identify, reallocate, and agree themes (Braun and Clarke, 2019). Upon the completion of this stage, the final naming of themes occurred. Following the guidance of Braun and Clarke (2013), ensuring that no more than three theme levels were present theme, codes and categories (see Figure 7.1).

The format of the interviews took a semi-structured approach (appendix 7.1). The interview schedule containing questions and suggested prompts was designed by independent researchers (n=3) to avoid bias from individual researchers. Despite this process, it was predicted that the COVID-19 pandemic restrictions may have influenced physical activity levels, deconditioning, isolation, anxiety and FOF. As a result, the semi-structure questions and subsequent prompts were biased to these topics.

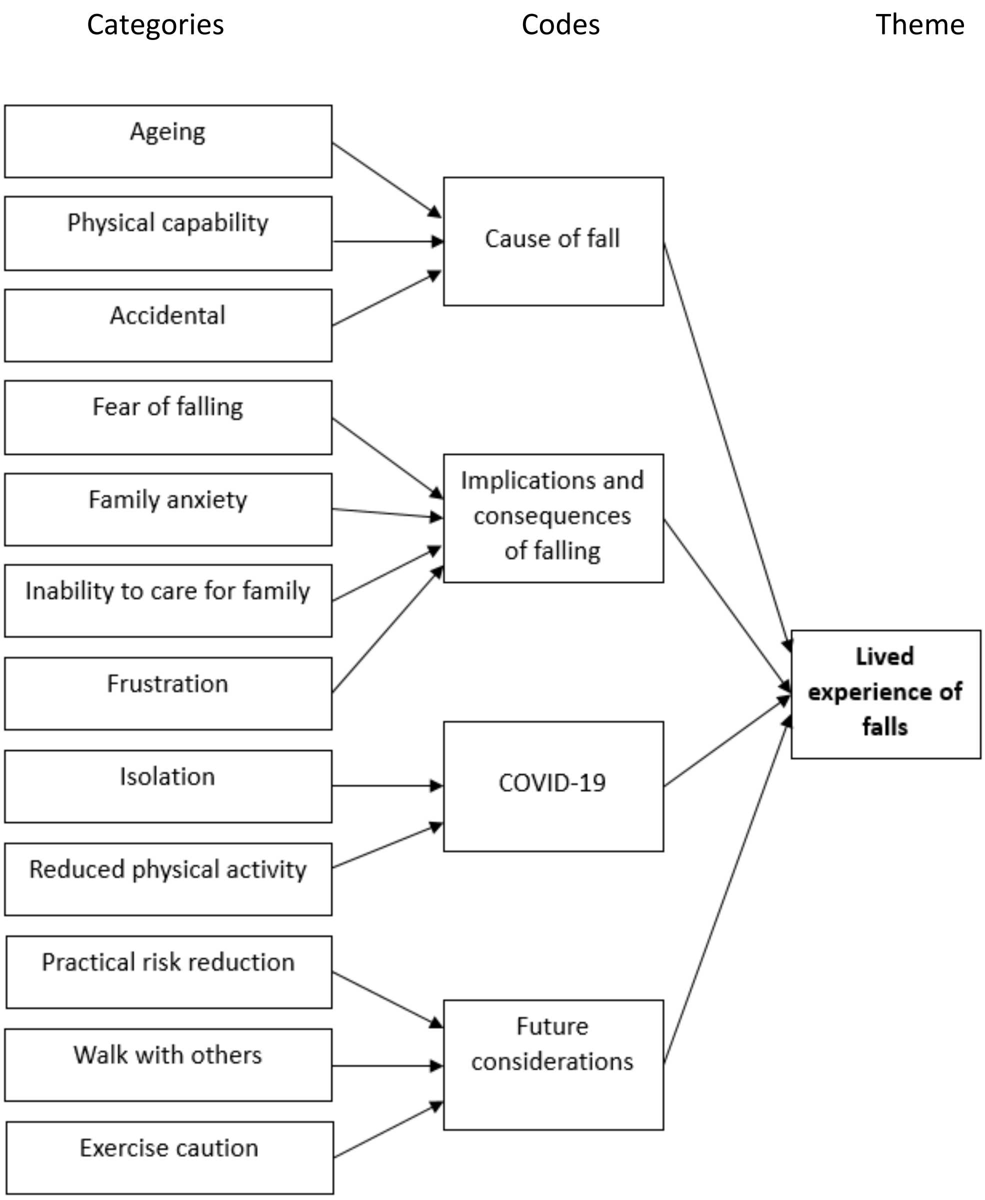

Figure 7.1. Thematic analysis framework used to develop the categories (n=12), codes (n=4) and the theme (n=1).

The writing up phase included the integration of writing originating from earlier processes and involved the editing of pre-existing analytic content. The data could then be presented in an analytical narrative in order to provide a comprehensive and interpretive account of the data (Braun et al., 2016).

7.3 Findings

The descriptive questionnaire data for participants is outlined above (see Table 7.1). Of the 10 participants, only 2 demonstrated scores that indicated a significant FOF. When examining both state and trait anxiety, only 1 participant demonstrated a significantly high state anxiety, and no participants demonstrated significantly high trait anxiety.

The results explore the lived experiences of falling during the middle stages of an adult's life; discussing the factors that affect falling and to what impact the COVID-19 pandemic has had on the personal perspective and social experiences of participants. Throughout the results section, pseudonyms were used to protect the identity of participants.

7.3.1 Cause of Falling

Ageing

The participants who took part in the interviews spoke openly about the falls that they had sustained and shared their personal experiences. Some of the participants outlined that they had only experienced a single fall preceding the study and, therefore, were not classified as reoccurring fallers. They appeared to accept falling as a consequence of natural ageing. For instance, Lois, Nicola and Vivien explained, when asked about reasons why they may fall:

> *So, I just think it is one of those age things, so you get up and get on you know you just wake up in the morning and get on with it is the way it is isn't it.* (Lois, 57 years old, NF)

> *I think it's just an age thing really.* (Nicola, 55 years old, NF)

> *Now that I'm getting older it takes me much longer to recover from falls and injuries.* (Vivien, 61 years old, NF)

Physical Capability

Participants in some circumstances attributed falls or an increased risk of falling to physical inabilities, weakness or issues with health. Elizabeth looked at her own health and ability when examining her risk of falling. She demonstrated instances of comparing herself to others and examining her own strength, which she then transferred as reasoning for reductions in muscle strength. These strategies of adopting responsibility when discussing deteriorations in personal health or physical capabilities have been identified throughout ageing literature (Dollard et al., 2012) and appear to also be present here in responses from Elizabeth, Lois and Ffion:

> *I'm not as fit as other people but I'm not too bad. I think, it's always been because my knees. I can go up hills fairly ok, but as soon as I start to come down everything is painful, and your legs are painful. I've always thought that 'you're not fit enough are you'. I think my risk of falling is me being strong enough.* (Elizabeth, 64 years old, NF)

> *I think because I wasn't doing as much exercise [compared to before the pandemic] my leg muscles weren't as strong. So, I think my quads weren't as strong so getting up was a bit more erm vulnerable um and my arthritis in my neck got a little bit worse so that makes me dizzy.* (Lois, 57 years old, RF)

> *Not really, because my falls were due to having two frozen shoulder*s. (Ffion, 60 years old, NF)

Accidental

Not only did participants attribute natural ageing and physical inability as reasons as to why they fell, participants directed reason away from their person and attributed causation to bad luck and external accidental events. These findings are in line with the Attribution Theory

(Weiner, 1985). By attributing causes to chance, participants minimised the perception that they were the type of person who would be at risk of falling (Gardiner et al., 2017), and maintaining identity as an independent, low risk person. For example, Anna, Lois, Nicola and Elizabeth described their accidental falls:

> *A couple of years ago I walked into the shower and fell for example, and I broke my foot. So, I am very aware that things can happen out of the blue* (Anna, 50 years old, RF)

> *Um, I have fallen off a stool and off a Segway. I just, I have fallen outside so I think it is just one of those things. I just fall sometimes.* (Lois, 57 years old, RF)

> *You know I've fallen over a few times. It makes me sound like I do it all the time. Uh, the first time was probably about eight years ago, so I have had a couple of accidental falls. But I don't really feel as though I feel any more vulnerable.* (Nicola, 55 years old, RF)

> *I think it was one of those things, I tripped over a root. I keep taking people there now to show them, this is where I fell.* (Elizabeth, 64 years old, NF)

7.3.2 Implications of Falling

Fear of Falling

Experiencing a single or a repeated number of falls is something that should not impact the everyday lives of middle-aged adults. A FOF is known to be more present in older populations, causing a reduction in quality of life (Tischler and Hobson, 2005). Interview participants recalled a variety of factors that presented themselves as both direct and indirect implications of falling. The suggestions broadly related to an increased fear and/or caution about falling again, the impact that falling had on the immediate support system of the faller and the reduction in independence. The following data extracts are examples of the indirect consequence of fear and caution on future falls described by interview participants:

> *I had two falls in the last two months, and both were not really my fault. Afterwards I do believe that you still relive that moment of falling down and I have found myself really scared over the last few weeks to walk again. So, it has created some fear for me. I am now conscious wherever I go when I am walking not to get my foot stuck in the ground again.* (Anna, 50 years old, RF)

> *It is a continuum that I am on. As I age, I feel that my concerns get greater and greater. I felt as if I was ageing gradually but now, I feel that I have additional concerns which have added to the normal progression. …I think it's a psychological fear. I think it's the fact that you don't bounce like you used to. You know, I'm definitely very aware of it now that I ought to be more careful, because if I do fall the implications are much greater than they used to be.* (Lynn, 60 years old, RF)

> *Oh, I'm quite apprehensive now about having a fall. I wasn't previously. Of course. And it's had quite a big traumatic effect, both mentally and physically, yeah. it's not that I'm consciously preoccupied. Or consciously fearful. But I'm much more cautious.* (Eric, 61 years old, RF)

> *Yeah, I've always had the, the fear. The worry. So, it's always on my mind and I want to walk faster but I can't because I think my knees ache and I can't walk fast because I am fearful and I think, go slow, go slow.* (Elizabeth, 64 years old, NF)

Family Anxiety

Some participants did not provide accounts to suggest an increased FOF but falling had evidently impacted the immediate support system of several participants. With the impact of falling in middle-age thought to be significantly more detrimental to both family and work commitments than in any other age demographic (Lipscomb et al., 2003), the family members of the interview participants appeared to be affected in several ways with some family members demonstrating worry and anxiety:

> *You know I will do some river walking, um so if it's slippery my husband will go 'watch out, watch out' and it gets on my nerves a bit.* (Lois, 57 years old, RF)

> *My children told me off severely, saying 'you have to realise you are this age now mum, you shouldn't be doing this kind of stuff'.* (Lynn, 60 years old, RF)

> *I can absolutely understand how it would bring an anxious state about because my husband said 'now you're gonna do this, do you need to think about anything beforehand?' Oh yes, OK, I do, because I'm somebody who in the past has just gone and done. But yeah, you have to recognize your kind of limitations. And I like swimming. I was going to go off and go swimming. He went 'just a minute, can you get a swimming costume off by yourself?' and I mean OK, I'll try it at home and I said, oh god I didn't realise how difficult this is. He said, I'm not being difficult, but if you fall in this room there's nothing I can do about it because we have a separate, you know things [changing rooms]. I miss swimming.* (Ffion, 60 years old, NF)

Inability to Care for Family

Alternative to family members expressing concern, both Lynn and Claire expressed concern about their own personal ability to be able to care for their husbands, should they fall and injure themselves:

> *Yeah, there's a fear if you have to go into hospital and my goodness sake, you know my husband's older... and more frail than I am. Less fit than I am. Who would look after him and that sort of thing, so it's there's that.* (Lynn, 60 years old, RF)

> *And so, my first concern when I fell was, I can't be laid up because I've got to look after him [Claire's husband]* (Claire, 58 years old, NF)

Frustration

Similarly, Paul, Eric and Elizabeth demonstrated a level of frustration about their reduced ability to support life at home and the practical impact that falling had on their immediate families:

> *But now it's just fact they couldn't really do anything. I couldn't do my jobs around the house as well, so my wife had to take on more. My share of the housework, so that was a bit frustrating as well.* (Paul, 51 years old, NF)

> *It has had and still has a big impact on my family 'cause they're, for example, having to look after me and having to do all the driving that I'm not allowed to do now.* (Eric, 61 years old, RF)

> *Yes. Obviously, the impacts for the family because ... my sisters we're relying on me to do it because they couldn't. [Referring to being the individual who purchases shopping items on behalf of her elderly relatives who are unable to visit the shops].* (Elizabeth, 64 years old, NF)

7.3.3 COVID-19

Isolation

Social isolation is a negative by-product of falling, resulting in a restriction of normal daily activities that ultimately result in increased frustration and anxiety (Roe et al., 2009). Research has suggested that social interaction is imperative to a balanced and healthy quality of life (Walker et al., 2011), by conducting the interviews with participants during a time of governmental restrictions, participants spoke freely about their experiences of the pandemic restrictions and to what extent they thought that they may have impacted their risk of falling.

A common consensus was increased isolation. As an example, Paul, Lynn and Eric described how they felt the isolation throughout the restrictions:

> *So, there's a level of frustration and sort of isolation. Because of that, you know. So, in 18 months, all I've done is come into my study to work so that that sort of does get you down a bit at times I must admit.* (Paul, 51 years old, NF)

> *It has probably become more severe because you are more isolated and you don't, well we live in a close and we know the neighbours well but we don't see them as much anymore. We used to pop next door and things, but I feel you are more isolated now due to the restrictions. I suppose I am more worried about it now than I was before.* (Lynn, 60 years old, RF)

> *We couldn't physically contact our children or their families. And indeed my frail mother is not exactly in the nursing home, but she's in a retirement development. The main thing that I missed, I know I surprised myself, because I didn't think I was that sociable a person. I missed spending time with friends.* (Eric, 61 years old, RF)

Nicola also shared how isolation affected her as she lived alone. She spoke about how the restrictions encouraged her to engage in exercise whilst she left her home once a day:

> *Well, because we were, we were allowed out to exercise once a day. So, I did it religiously, because otherwise you didn't see anybody at all. You know, I live alone, so it was a chance to actually see other human beings and to be able to not be restricted by the regulations. People say they like staying in, staying at home all day, if that's what you choose to do, but when you've been told to do it, you tend to rail against it a little bit, don't you?* (Nicola, 55 years old, NF)

Reduced Physical Activity

Restriction of physical activity and ability to leave the home to engage within physical activity for more then 1-hour per day during the height of the restrictions are thought to have had negative impacts on mental health (Violant-Holz et al., 2020). Participants spoke freely about how the restrictions had a direct impact on physical activity, whilst equally expressing the value of physical activity as a coping mechanism prior to the pandemic. For example, Nicola, Lynn, Eric and Vivien explained their feelings:

> *Yoga classes were stopped you know. Everything else that I did that was a physical activity was stopped and the only thing that I was actually able to do during that time was actually walk my dog. I was very fed up that I could not take part in all of my activities but, um, I wouldn't say that we were climbing the walls or anything like that. We have managed.* (Nicola, 55 years old, RF)

> *I've found I can get rid of any tension if I exercise and things like that and I wasn't being able to do that, so I was probably more stressed than I normally am at home. And just because life had changed, I wasn't seeing people, and I wasn't exercising as much as I used to.* (Lynn, 60 years old, RF)

> *And quite a large part of my physical activity. In terms of keep fit type things well, is doing Tai Chi classes indoors. So, the fact we couldn't do that, it was very frustrating.* (Eric, 61 years old, RF)

> *Well, because we could not go out. We weren't able to play badminton anymore as the leisure centres were closed.* (Vivien, 61 years old, NF)

7.3.4 Practical Considerations

Caution

In consideration of the approach to future fall risk, participants provided responses to suggest that they demonstrated a greater conscious processing of movement that aligned with the conscious processing hypothesis (CPH) (Masters, 1992). In these, hypotheses, it is claimed that individuals, during conditions of increased anxiety, shift away from more automatic movement control to a more conscious control of movement. Anna and Paul both spoke openly about how they adopt an inward focus of attention to prevent falling, stating that they plan to be 'more conscious' and 'more vigilant' about their movements and how they move around:

> *The thing is, my fall has brought me to reality of how at risk I am of falling and I will be more conscious moving forward about how I walk and move around. I don't want to fall again but accidents happen. I feel that I ought to be more vigilant about how I move around. And make sure that I don't do things and take too many chances basically.* (Anna, 50 years old, RF)

> *I guess I I'll approach the puddles and mud round them more carefully in future. Having done that, so not be so blasé about it. It's just you know it's just a bit more conscious of what you're doing perhaps. But then saying that, in six months' time I probably forget about anyway and do the same thing.* (Paul, 51 years old, NF)

Similarly, to Anna and Paul, Claire also spoke about the need for 'concentration' on movements to prevent falling. Claire also described being reluctant to 'look around' whilst out walking with her husband, due to being hyperattentive to where her feet were when walking. These findings align with attentional control theory (ACT) (Eysenck et al., 2007), whereby, anxiety manifests in impaired attentional control, reducing the ability of an individual to minimise interference from task irrelevant stimuli, in order to focus on task-relevant stimuli.

> *And the other thing is that when you're doing that, if then something distracts you and you just carry-on walking as normal you suddenly think, oh my goodness, I wasn't concentrating on that. Let's concentrate so it's that sort of thing. And even when I'm walking with my husband and he points something out and he'll say, you know, look at that house or whatever. I'm reluctant to kind of look around because I'm too conscious of where my feet are.* (Claire, 58 years old, NF)

Walking with Others

Beyond the conscious processing of movement comes the practical considerations in which participants demonstrate when they think about engaging within activities that may increase their risk of falling. Participants expressed the need to walk with others to reduce their FOF, however, dependency on others is positively associated with a reduction in independence (Yardley et al., 2006) and is not frequently displayed by middle-aged adults. Despite these findings being predominantly present in older populations, Anna and Ffion explained how they now prefer to walk with somebody to reduce their FOF:

> *I am very scared. I now only walk with somebody.* (Anna, 50 years old, RF)

> *I am sufficiently concerned. Yeah, that it might happen again so well, I'm going walking tomorrow and I'm back walking quite a long way. So, 15 miles tomorrow. But I wouldn't do that without my husband because I'm still not completely steady, So yeah, and you don't want to be reliant on other people hence so ever since I've gone back to walking, my husband always come with me because if I did fall, at least he can pick me up.* (Ffion, 60 years old, NF)

Whilst Claire did not express the need to walk with somebody, she demonstrated that she would exercise 'caution' in the following ways and found herself adjusting situations when out walking to reduce her risk of falls:

> *Well, I suppose it makes you initially, makes you more reluctant to go out on your own, which is you know, horrendous for me, and ice. So, I suppose there was a temptation to take the car. …The other thing I've noticed because I tend to because we live reasonably close to the town centre here, so a lot of the walking is along town streets. There's usually a wall or something at the side, and if I'm walking along a road where there is, there are railings, or there's a wall. I've actually found myself gravitating to that side of the pavement.* (Claire, 58 years old, NF)

Practical risk reduction

For Lynn, she also expressed her own practical methods to reduce her risk of falling:

> *And just being aware of things in there like I said, like, not turning down the back of your slippers. You know making sure you've got shoes that fit. Uh, uh, looking at rugs and things like that so it's just bring to the front of your mind because it happens so gradually, you get old so gradually that you don't. There isn't the thing saying you'll be fine up until you know March the 31st. But after that my goodness you've got to take care of yourself.* (Lynn, 60 years old, RF)

7.4 Summary of Main Findings

This study used semi-structured interviews to explore the lived experiences of falling during middle-age and explored to what extent the pandemic had an impact on instances of falls. The discussion draws together the questionnaire and interview results to provide an interpretation of the data (O'Cathain, 2010). In the present study, of the 10 participants who completed the questionnaire and subsequent interviews, 6 participants were categorised as reoccurring fallers, whilst 4 were categorised as new fallers. Differences in fall experience provided an overview of falling during middle-age.

In the present study, interview data revealed differences in perceived causes of falling. 30% of participants attributed the cause of their fall to ageing and, in turn, appeared to accept that falling over is simply a by-product of the ageing process. These findings are novel in this age-demographic as the process of age acceptance, defined as engaging with negative emotions and physical outcomes (Segal et al., 2018) is witnessed only in older age groups (Shallcross et al., 2013). There has been little evidence to suggest that middle-aged adults interact with the process of age acceptance (Partington et al., 2005), partly due to the understanding that cognitive control functions, control emotion regulation more successfully in younger adults

(Ochsner and Gross, 2005). Consistent with the knowledge that physical declines also increase level of ageing acceptance (Frenkel-Brunswik, 1968), a further 30% of participants providing a reduction in physical ability, such as a reduction in muscle strength as reasoning for falling. The impact of the pandemic on physical activity reduction and subsequent deconditioning phases may have accelerated the rate of age acceptance, previously not thought to be present within middle-aged adults.

Participants spoke openly about the consequences and concerns that they experienced as a result of falling. The single, largest cost to the lives of middle-aged fallers was the impact on the lives of their immediate family members. Participants expressed strong concerns regarding their inability to care for their partners, alongside their inability to perform household chores, especially for female participants who expressed their concerns about being able to care for their husbands after experiencing a fall. These gendered marital primary caregiving roles have previously been documented for older women (Warner and Adams, 2016), but here, we see that changing marital roles may occur in earlier life years for fallers.

Falls are thought to impact the family life and work commitments of middle-aged adults greater than in any other age demographic (Lipscomb et al., 2003). Interviews were important in exploring this issue which has previously been unreported within a middle-aged demographic. Participants spoke openly about how immediate family members such as husbands, wives, and children expressed concerns for the faller's safety and how recovering from a fall, increased the demands of family life for their partner. Participants reported that family members began to point out potential hazards whilst out walking or gave advice as to what activities the faller should or should not do after a fall had occurred. Previous research has suggested that this shift of attention to threatening stimuli may act as a protective adaptation to behaviour (Ellmers et al., 2022), however, little is known about the benefits of adaptations to behaviour if the worrisome thoughts originate from family members instead of the faller. The focus of attention on threatening stimulus may in fact alter the behaviour of the middle-aged faller, indirectly reducing engagement in activities associated with a high risk of falling. It is also possible that family anxiety could impact participant's self-perceptions of age-related decline. This could lead to further activity reduction in those reserved to the effects of ageing or alternatively motivate others who are not as accepting of the ageing process to prevent such decline.

More recent research has examined mental health through the life course, specifically examining how support and strain from relationships influence trajectories of depression and subsequently affect health (Rook, 2014). When compared to both younger and older adults, middle-aged individuals presented as the only age group to experience significantly more strain and depressive symptoms resulting from relationships with their spouse and children (Thomas, 2016). There is a new need for research to acknowledge the specific demands placed on middle-aged individuals who fall that are not currently known to be present in younger or older populations. The interview data highlighted that not only do middle-aged individuals fall, but they were also subject to additional stressors as a result of a fall, which have also been linked to an overall reduction in quality of life (Steptoe and Marmot, 2003).

Our qualitative findings demonstrated an increased FOF in middle-aged adults. Despite only 20% of the study population scoring highly enough (>23) (Delbaere et al., 2010b) to demonstrate an increased FOF score in the study questionnaire, interview responses provided detailed accounts of participants fear about falling. FOF is known to be present in older populations (Tischler and Hobson, 2005), however, interview responses from the present study demonstrated that middle-aged individuals were also fearful about future falls, findings also identified in Chapter 4 of this thesis.

Participants described how they planned to exercise 'caution' in order to reduce future falls, providing accounts to suggest that they had an increased conscious processing of movement (Masters, 1992). When anxious, participants displayed increased stimulus-driven attention to threat related stimuli (e.g., worry about outcomes of a fall, negative self-talk about walking ability, visual attention on feet and next step rather than the goal or intention of the movement, steepness of steps and imagery of previous or future fall outcomes). The full extent of the psychology of cognitive anxiety and falls within middle-aged adults is outside the scope of this thesis, however, it is clearly an important factor within the multifarious understanding of the complexity of falls. Taken together with personality research that has identified the inter-relationship of trait anxiety and defensiveness, the extreme cognitive biases in defensive high anxious (DHA) individuals (high anxiety and high defensiveness) presents a sub-section of society that tends to catastrophise situations and over emphasis expectations of failure. Individuals with DHA, for example, are significantly overrepresented (compared to their representation in society) in chronic pain clinics (Lewis et al., 2012). In contrast within vigilance–avoidance theory, the repressive coping style (low trait anxiety and high defensiveness) individuals who show low self-reported anxiety and high behavioural and physiological indicators of anxiety have an initial rapid vigilant response that triggers the behavioural and physiological responses, that may make them more fall prone, as well as attentional and interpretive biases to self-relevant threat stimuli. This theoretical model aligns well with some of the quotations above linked to falls behaviour. Avoidance of the threatening stimuli follows to inhibit the conscious experience of anxiety, and this may be more evident in middle-aged adults who have incongruent afferent feedback from their less strong limbs contrasted with a motor representational memory with limited fall experience. Future research should examine these personality styles and how each is associated with fear of falls, falls propensity, and falls avoidance.

There may be a similar explanation for all fallers. The reduction in the automaticity of the movement of fallers, with less reliance on proprioceptive feedback may, indirectly, contribute to future falls by disrupting the skill. In addition, taken together with the neurophysiological data presented in Chapter 4 (reductions in strength and muscle mass), it may be that the alterations in afferent feedback to a central representation of the more autonomic, coordinated movement contribute to the change in attentional style as the efferent copy does not match the movement feedback; the significant changes to peripheral physiology are not congruent with the motor neural network controlling the movement.

Methods to reduce stress and improve overall wellbeing have been documented for some time (Berkman et al., 2000), with social connections and close social relations being identified as methods of improving health (Antonucci, 2001). Engagement within social activities are thought to decrease in later life stages, often a consequence of age-related decline (Huxhold et al., 2013). Social isolation presents as a risk factor for falls in older age groups, however, middle-aged adults are known to perform significantly more social activities (Huxhold et al., 2014), often offsetting feelings of isolation and loneliness. The same findings were not observed throughout the present study. Participants reported feeling isolated due to the pandemic restrictions, which lead to increased levels of frustration as a result of being unable to physically see family and friends. These findings are thought to have had negative consequences on both the mental health and risk factors for falling in this age-group (Cohen and Janicki-Deverts, 2009).

In the present study, participants who lived alone expressed how they made significant efforts to engage within physical activity outdoors as a method of reducing isolation. During the tightest lockdown restrictions, individuals were permitted to leave their homes on one occasion each day for a period of one hour to exercise outdoors. These restrictions are thought to have significantly altered the habitual physical activity of individuals. Several participants reported a significant reduction in physical activity due to the closure of classes and gym facilities. Participants highlighted above the negative impacts experienced as a result of a reduction in physical activity, with several participants reporting feeling unhappy and more stressed than usual. Physical activity is known to decrease in older adults (Milanović et al., 2013), directly increasing the risk of falling (Tiedemann et al., 2015), therefore, these periods of deconditioning as a result of the pandemic restrictions are likely to increase the risk of falling for middle-aged individuals over the coming months and years.

7.4 Conclusion

In conclusion, the present study suggests that falls are complex events, that often leave middle-aged fallers with a series of fall-related implications. Some of these implications are in line with risk factors witnessed in older populations, such as a reduction in physical activity (Sherrington et al., 2008), social engagements (Huxhold et al., 2014), a greater acceptance of ageing (Partington et al., 2005) and an increased FOF (Tischler and Hobson, 2005). The present study highlighted implications that are not usually witnessed in middle-aged individuals until later in the life-course, potentially meaning that many of the implications experienced by participants are likely to have been accelerated by the pandemic and may indirectly increase an individual's likelihood of falling in the future. To what extent a study conducted outside of a global pandemic would see such results in a middle-aged demographic remain unknown.

Other implications infrequently documented throughout literature differ between middle-aged and older populations, such as the impact of falling on family life. The impact to family life during middle-age is likely to have a direct consequential link to depression symptoms as a result of relationships with spouses and children (Thomas, 2016).

Participants in this study provided accounts to suggest adaptations that they will make to prevent future falls. It is worth noting that many of these adaptations are reliant on the support of immediate family members, an adaptation not usually identified until an adult reaches older age. The present study provides an insight into the multifactorial causes and implications of falling during middle-age, and demonstrates the increasing need for research to support individuals who have fallen during these life stages. Future preventative interventions are important in order to reduce fall occurrence for those aged 45 years and above. The study highlighted that middle-aged individuals often had young families and dependants, alongside work commitments and that they appear to be a generation who do worry about falling. Furthering efforts in academia could contribute to furthering establishing the concerns and lived experiences of falling during middle-age, whilst establishing the accentuated effects of the COVID-19 pandemic on future fall risk.

Chapter 8: Discussion, Conclusion and Future Directions for Research

8.1 Main Findings

The research reported within this thesis aimed to further the understanding of the prevalence, determinants, and consequences of falling during middle-age within the Greater Manchester area. No previous research studies had investigated the psychosocial and physiological factors that could contribute to an increased risk of falling during middle-age experimentally. The new knowledge developed should be used to help improve both the screening for, and prevention of, falls in adults aged 45 to 64 years. The main conclusions of this thesis are discussed and relate to the aims outlined in each of the research chapters.

8.2 The prevalence of falls and in-patient falls in both middle and older age adults in the Greater Manchester area.

The data provided an insight into the clinical unmet need of falls within the various regions of the Greater Manchester area in both middle-aged and older adults. These data were examined and contrasted with data for fall prevalence observed in other UK cities. Data released from the Manchester Joint Strategic Needs Assessment highlighted that hospital admissions as a result of falls were significantly higher in Greater Manchester when compared to the rest of England. Fall-related mortality rates were also higher in Manchester when compared to eight other city regions. The data outlined within the various Joint Strategic Needs Assessments covered a 6-year period from 2010 to 2016 and suggest a need for an updated report to address the current burden of fall-related hospital admissions and mortality rates for the period leading up to 2022.

The in-patient fall data for older adults, those aged 65 years and above, were higher than those aged between 45 to 64 years. These findings were to be expected, as prevalence rates of falls increase as adults age. The occurrence of middle-age in-patient falls across the several Manchester Foundation Hospital Trusts appeared to be consistent with previously reported prevalence rates for this age group. The impact of the global pandemic may have exacerbated the propensity for falls, possibly more so in Greater Manchester and in both middle-aged and older adults due to extensive periods of deconditioning. The socicio-economic factors influencing the elivated falls profiles in Greater Manchester remain a complex area of concern and may be exacerbated if the middle-age falls profile for this region follows a similar trend for the future older adults. When considered alongside some of the physiological data, discused below, the compound and interacting elements may place adults in the Greater Manchester region at an even greatest risk of middle-age and old-age falls within the UK.

8.3 Potential risk factors for falls within a middle-aged sample of fallers and non-fallers. The ability of current clinical screening tools to successfully distingush between fallers and non-fallers.

This experimental study provided an insight into some of the physiological and psychological factors in middle-aged adults from the Greater Manchester region that may contribute to falls or predispose them to fall. The fall participants in this study demonstrated alterations to body composition; increased fat mass and a reduced lean muscle mass and showed weaker dominant plantar flexor muscle force and weaker hand-grip strength scores. These markers may have contributed to the lower scores on the Mini-BESTest that examined functional ability; they were unable to achieve the stepping and single-leg hopping distances of their non-falling counterparts. A reduced response time, alongside an increased FOF, was also observed in fall participants. The results from this chapter provide indicators of physiological and psychological differences that may be observed between fallers and non-fallers. These differences may be useful in informing the design of fall risk clinical screening tools and preventative interventions. The step and single leg hop markers may be particularly useful as a valid, cheap, and effective field-based test and would be recommended for further research and the development of a large data set to produce norm charts. These data may also contribute to the growing evidence that supports not only the temporal variability in age-related profiles but also be sensitive to UK regional differences as described above.

8.4 Trunk acceleration measurements, collected using wearable sensors during daily life, provide gait characteristics that may differ between middle-aged fallers and non-fallers.

Prior to the studies of this thesis, differences in the daily-life-gait of middle-aged fallers and non-fallers have not been reported. Here, the data provided evidence to suggest that, unlike older adult profiles, adaptations to gait are not present after falling in middle-aged adults. Trunk accelerometry-derived gait characteristics therefore did not provide evidence for possible risk-factors for falling. However, the data presented in this chapter, further highlighted the physiological differences in weaker plantar flexor muscles and an increased body fat percentage in fallers compared to their non-falling counterparts. The findings suggested that although fallers may differ from non-fallers in some physiological markers linked to falls in older adults, reductions in muscle strength and increased body fat seem not to alter gait characteristics until later life years. Whilst the measurement of daily-life-gait characteristics are able to discriminate between older fallers and non-fallers, at present, middle-aged adults do not appear to show the same reductions in ability when performing gait related tasks. Taken together with the findings from study 2, the results from this chapter reinforce the complexity of trying to identify meaningful markers of fall propensity in middle-aged adults and that markers typically seen in adults over the age of 65 are likely to be moderated in middle-aged adults by multifarious lifestyle factors. The important finding, however, was that daily-life-gait may not be a useful fall screening tool in middle-aged populations when compared to simple stepping and hopping differences.

8.5 The impact of the global pandemic and public health restrictions on fall risk factors in adults aged 45-64 years. Changes in falls and fall risk factors, including, physical activity engagement, physical health and mental health throughout the COVID-19 pandemic.

The global pandemic provided an opportunity to investigate the impact that Government-imposed restrictions had on the lives of middle-aged fallers in the Greater Manchester region. The data suggested that the fall-related lives of middle-aged fallers did not appear to significantly differ from before the pandemic restrictions were introduced. Despite between group differences not being observed, data that examined indoor and outdoor fall occurrence did appear to change. Prior to the pandemic, most fallers reported their fall incidents related to outdoor activities which, when activities were restricted, were reduced during the pandemic lockdowns. During the 6-month follow-up, most documented falls were reported inside the home. Of course, this does not mean more falls occurred just that the environment where fall occurred was significantly restricted to indoors so falls could only occur here. Five participants reported experiencing a fall during the 6-month follow up period. The number of falls over the 6-month follow up period, however, did not significantly increase when compared to baseline fall data. Fall incidence did not seem to increase during the restricted periods of the pandemic since individuals were exposed to fewer environmental risks outdoors. The falls reported were different to pre-pandemic and, in nearly all cases, less injurious in the confines of their home compared to outdoors. This pandemic-falls paradox for the restricted lockdown period, whilst helpful in reducing more injurious falls needs to be considered in the context of the post-lockdown environment.

Many participants in this study reported a significant reduction in their physical activity levels overall. This imposed period of deconditioning on middle-aged adults may have induced greater risks for falls in the years to come with greater physical decline (e.g., sarcopenia) and the associated fear of falls exacerbating the effect. The lockdown period and its imposed restrictions in functional physical activity artificially created the sort of lifestyle many older adults face on a daily basis. In addition, the middle-age adults in some parts of Greater Manchester may also have had fewer physical activity opportunities than those in more rural environments. The long-term health and economic consequences of the pandemic restrictions on physical activity for fall propensity require further detailed investigation.

8.6 The lived experience of falls in a middle-aged population in Greater Manchester and the impact of the pandemic.

This was one of the first qualitative research studies to examine the lived experience of middle-age people who falling and how the pandemic affected fall risk. The findings suggested that falls are complex and debilitating events for middle-aged adults and that the implications faced by this age demographic, as a result of falling, are somewhat different to the experiences of those who fall during later life stages (i.e., >65).

In this study, individuals reported on the burden that falling had on their lifestyle and immediate family and children with whom they share their household. These findings contrasts those of older adults who tend to live alone or have one dependent in the house with them. Participants also discussed how they felt isolated and without control and autonomy after falling. They immediately had to depend on others when engaging in activities that were felt to put them at a greater risk of further injury. Taken together, some of the themes concur with themes documented within ageing literature, however, new themes emerged providing detailed accounts of what it is like to fall as a middle-aged adult and, as with the physiology and psychology data, highlighted the need to consider this younger population as a distinct falls group with specific age-related factors.

The COVID-19 pandemic is thought to have accelerated the presence of fall risk factors due to a reduction in physical activity and social engagements, leading to increased levels of isolation. The evidence from these studies is that, paradoxically, the immediate effect was to reduce severe outdoor falls but increase the number of less injurious indoor trips and falls. The reported number of falls seems to have been the same. To what extent the global pandemic will increase the risk of falls in the future for middle-aged adults due to significantly increased sedentary behaviour over an extended period currently remains unknown. Whether these future challenges for the NHS will be worse in some of the Greater Manchester regions is also an important unknown.

8.7 Clinical Practice Implications

There are several clinical practice implications which emerge from the studies in this thesis. The main finding was that there are specific issues for middle-aged adults who have a propensity to fall. They present with some of the same profile characteristics as older adults, but many are either attenuated versions of the same factors or are specific to this age group. In both cases, it is recommended that all general practitioners and front facing clinical service staff are made aware of potential early-stage risk factors to reduce the risk of falling into later life years. For clinicians to facilitate these observations, the provision of additional education would be required that would contain information on what to look for when assessing earlier stage risk factors for falling. This would enable clinicians to support middle-aged fallers.

Middle-aged adults continue to present at accident and emergency departments from fall related injuries, alongside experiencing in-patient falls across the Greater Manchester region. In some cases, this is to a greater extent than in any other city in the England. These findings suggest that falls in both middle-aged and older adults are a public health concern for the North-West that account for a large proportion of NHS costs each year, it may be advisable that falls and fall-related injuries are investigated, documented, and monitored across health care settings much earlier in the life course. By identifying and reporting fall risk factors in early middle age (45 + years), it may be possible to prevent injurious falls from reoccurring in later life years. A reduction in the rate of injurious falls would help to reduce the increased personal burden to the individual, their family, and the later subsequent costs to the NHS.

The programme of work identified physiological, psychological, and behavioural factors that provide a useful starting point for both fall screening and intervention. Middle-age fallers presented with reduced strength and muscle quality, increased body adiposity, and an increased FOF. Whilst these findings are different to those of non-falling middle-aged adults, the differences, at present, seemed not to alter immediate mobility or other predictive gait parameters. It may be that general practitioners can play a vital role in referring at-risk middle-aged adults to programmes that will support the maintenance of physical health through targeted intervention to lower body adiposity, improve specific muscle strength and reducing FOF.

Future work is required to examine whether rational emotive behaviour therapy (REBT) would be useful for individuals who display high trait anxiety and demonstrate catastrophising thoughts about falling. The action-oriented approach of REBT would allow catastrophising individuals to better manage their emotions, thoughts, and behaviours in order not to avoid activities in which they deemed to be risky. Alternatively, for individuals who are repressors and low trait anxious, it may be useful to conduct risk assessments. These individuals will typically continue engagement in risk taking behaviours and activities because of externally attributing risk of falling. This behaviour may lead repressors to fall due to more frequent engagement in riskier activities. As psychological and behavioural risk factors appear to be present in middle-aged fallers, it may be beneficial for clinicians to engage in psychological continued professional development to be able to support potential risk factors.

Previous falls are the single largest predictor of future falls and, at present, middle-aged adults who fall and are younger than 65 years old have limited access to fall prevention interventions. Future research and associated recommendations for interventions should challenge the idea that fall prevention strategies start at 65 years of age. By this age, some individuals will have already suffered multiple falls starting in middle-age that progress into falls with more severe outcomes, such as disability, frailty and/or a reduced quality of life in older age. By cascading older adult fall provision to support middle-aged fallers, the proportion of middle-aged adults who become reoccurring fallers as they transition into old age may reduce.

In the UK, individuals are typically invited to attend well-person clinics from the age of 40 years. The opportunity afforded here suggests that the implementation of simple field-based measures within these screening meetings may be able to contribute to a greater understanding of an individual's risk of falling. This early identification for fall preventative intervention in middle-aged adults may impact positively on not only the fall propensity of older adults but also the significant cost implications of delaying identification.

The implementation of a single leg hop protocol (and possibly maximal step distance protocol) has demonstrated the validity of this technique to discriminate between middle-aged fallers and non-fallers (see Figure 4.2). Poor performance in this field-based test may then trigger the required prescription of an exercise intervention such as the FaME (Falls Exercise Management) programme (Skelton et al., 2005) since there is evidence that programmes such as this can be used with lower risk younger adults with similar effect as with high-risk older adults (Gawler et al., 2016). Based on the findings from Chapter 4, this easy to administer field-based measure could then be included in each 10-year follow-up clinic. Taken together with the comprehensive health screening for wider general health factors (e.g., mental health, alcohol consumption and other lifestyle factors), fall-related screening and interventions should place equal importance on the psychological, physiological, and behavioural risk factors alongside a clear understanding of the socioeconomic, political, and environmental factors that may impact on these variables.

8.8 Limitations

Falls history was, primarily, obtained using retrospective methods. Self-reported retrospective recall is subject to recall bias (Mackenzie et al., 2006) with retrospective self-reported recall methods from time periods of 3 months to 2 years (Ablett et al., 2018). Retrospective data collection is., therefore, often subject to recall bias with studies suggesting that these methods underestimate the prevalence of falls by as much as 33% (Garcia et al., 2015). A more recent consensus is that retrospective recall methods are only able to provide information that indicates post-fall changes (Rispens et al., 2015b) and that to establish fall risk predictors, prospective methods should be adopted. All participants were asked to report history of falls that occurred within the 12-months preceding each study, to determine faller and non-faller group status. Every effort was taken to ensure that validated self-reported methods and tools that were adopted throughout the present thesis had been well documented and supported in previous fall-based studies. Findings throughout this thesis are in line with previous studies, suggesting that a history of falls provides evidence to suggest post-fall outcomes only.

The modest sample size in each of the study chapters presents limitation with regard to power of statistical data and the generalisability of the findings. Participant numbers varied between studies, with faller groups ranging from 10 to 17 participants. Sample sizes for faller and non-faller groups were often unequal, with a larger number of non-falling control participants present in studies documented in Chapters 4, 5 and 6. A *post-hoc* power analysis revealed a suggested sample size of 54 participants in each of the faller and non-faller groups for findings in Chapter 4, suggesting the study findings are significantly underpowered. Despite this findings, fall-risk themes that emerged from the studies were similar to those highlighted throughout ageing literature, providing a level of confidence in the study outcomes but it is recognised that the findings should be considered cautiously.

A further consideration is that participants recruited for the experimental studies (Chapters 4 and 5) in the thesis were derived from the geographical location of Greater Manchester. This was an important variable of interest for the focus of the research programme. However, given the profile of fallers for this region, fall prevalence and associated risk factors highlighted throughout the present thesis may not be generalizable to populations who reside in different geographical regions of the UK. Indeed, it may not now be advisable to discuss 'UK falls data' at all since the range and factors contributing to regional falls data sets may be highly regionally specific. This important finding requires further research.

Participant recruitment methods may have also led to a self-selection bias in the research chapters. Participants had to have access and knowledge of online computer programmes to answer questionnaires in English and take part in virtual interviews. This digital literacy, delivered in English, meant that individuals who could not access such methods or language were not included within the study. This is an important consideration for more digitallydeprived and less digitally-confident communities and also for fallers for whom English is not a first language.

A large proportion of this research was undertaken during a global pandemic. Again, whilst the impact of the pandemic was an important factor in the design of the research, it may be that the findings may be subject to bias because of pandemic restrictions. Physiological differences examined between fallers and non-fallers, including the lived experiences of falling were recorded during pandemic restrictions. Whilst physiological differences appear to be presented in line with research conducted not in a global pandemic, comparisons cannot be made between the lived experiences of middle-aged fallers that may be experienced outside of a global pandemic. Taken together, however, the opportunities to study fallers in these restricted conditions allowed for research with fallers that would otherwise never be able to be conducted.

8.9 Future Directions

Several directions for future research emerged from the outcomes of the thesis. The findings and outcomes may help to advance clinical screening and support for fall risk factors in those aged 45 to 64 years and provide the start of an evidence-based rationale for methods of preventative intervention. Future studies should aim to identify the prevalence of falls in the middle-aged population with large population groups and from across different socio-economic parts of the UK. To date, there are very few studies that have taken a population-based approach, when examining the prevalence rates of falls in middle-aged adults. Reported prevalence rates for this age demographic vary considerably, from 11 to 31% (Verma et al., 2016a). The conflicting prevalence rates reported in the literature mask the true understanding of the burden that falls in this age group have on healthcare systems. The prevalence rates for falls in middle-aged adults also appear to differ dependent upon worldwide and regional location (Peeters et al., 2018). Future studies should to take a population-based approach to determine the prevalence of falls in middle-aged adults. Future studies should pay particular consideration to geographical, environmental, and socioeconomic factors that have been associated with differences in the prevalence rates of older adults (Han et al., 2014). Within the UK, the falls data for Greater Manchester, for older populations, is a concern. It may be worse than reported when the middle age fall data are also factored in.

Future studies are required to examine the prevalence of falls and related risk-factors via prospective methods, to increase the possibility of capturing the occurrence of falls when they occur. Using these methods, future research may be able to also examine age-related changes in prevalence by tracking the occurrence of falls as an adult transitions from middle to older age.

To date, research has focused primarily on the screening and fall prevention of adults older than 65 years. Throughout previous literature and this thesis, it has been proposed that middle-aged fallers would display different fall risk profiles, when compared to older adults who fall. Whilst a number of psychological, physiological and behavioural factors have been identified, future studies should examine these in larger samples to have more confidence in the risk factor profiles of middle-aged adults.

The COVID-19 pandemic is thought to have created a period of deconditioning for all adults (Pelicioni and Lord, 2020). At present, restrictions remain in place in many worldwide regions. Middle-aged falls requires further investigation into the impact that such periods of deconditioning may have on future fall-risk profiles. With a reduction in physical activity, social isolation and decreased physical function is known to increase instances of falling that is not normally witnessed in middle-aged adults. To what extent the COVID-19 pandemic will have accelerated any age-related decline of middle-aged adults remains unknown.

8.10 Conclusions

This thesis is the first explorations into the prevalence, determinants, and consequences of falling in adults between the ages of 45 and 64 years in the Greater Manchester region and during a global pandemic.

It can be concluded that middle-aged falls have an additive economic cost over and above those in the 65 years+ age group. There are, importantly, significant personal costs to middle-aged fallers that are specific to this age group. These questions and have not been addressed in the current literature so the work here has addressed an unmet need and a gap in the research literature. New findings provide evidence to suggest the benefit of fall screening and prevention strategies taking place in earlier life stages, may allow clinicians to target interventions to address the psychological, physiological, and behavioural differences between fallers and non-fallers identified throughout this thesis. Advances in the field of middle-aged falls would not only directly benefit individual quality of life, but also have a significant societal impact for the wider economy.

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Appendices

Appendix 4.1 Ethical Approval

Ymchwil Iechyd a Gofal Cymru
Health and Care Research Wales

NHS
Health Research Authority

Dr Chesney Craig
Manchester Metropolitan University
Crewe Green Road
Crewe
CW15DU

Email: hra.approval@nhs.net
HCRW.approvals@wales.nhs.uk

10 September 2019

Dear Dr Craig

HRA and Health and Care Research Wales (HCRW) Approval Letter

Study title:	**The design and development of a clinical screening tool for injurious fall risk in middle-aged men and women.**
IRAS project ID:	**260217**
Protocol number:	**1**
REC reference:	**19/NW/0457**
Sponsor	**Manchester Metropolitan University**

I am pleased to confirm that HRA and Health and Care Research Wales (HCRW) Approval has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications received. You should not expect to receive anything further relating to this application.

Please now work with participating NHS organisations to confirm capacity and capability, in line with the instructions provided in the "Information to support study set up" section towards the end of this letter.

How should I work with participating NHS/HSC organisations in Northern Ireland and Scotland?
HRA and HCRW Approval does not apply to NHS/HSC organisations within Northern Ireland and Scotland.

If you indicated in your IRAS form that you do have participating organisations in either of these devolved administrations, the final document set and the study wide governance report (including this letter) have been sent to the coordinating centre of each participating nation. The relevant national coordinating function/s will contact you as appropriate.

Please see IRAS Help for information on working with NHS/HSC organisations in Northern Ireland and Scotland.

How should I work with participating non-NHS organisations?
HRA and HCRW Approval does not apply to non-NHS organisations. You should work with your non-NHS organisations to obtain local agreement in accordance with their procedures.

What are my notification responsibilities during the study?

The document "*After Ethical Review – guidance for sponsors and investigators*", issued with your REC favourable opinion, gives detailed guidance on reporting expectations for studies, including:

- Registration of research
- Notifying amendments
- Notifying the end of the study

The HRA website also provides guidance on these topics, and is updated in the light of changes in reporting expectations or procedures.

Who should I contact for further information?
Please do not hesitate to contact me for assistance with this application. My contact details are below.

Your IRAS project ID is **260217**. Please quote this on all correspondence.

Yours sincerely,

Michael Pate
Approvals specialist

Email: hra.approval@nhs.net

Copy to: *Miss Alison Lloyd – Sponsor contact.*

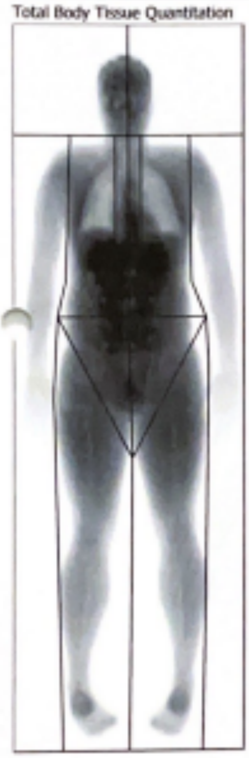
Appendix 4.2 Dual Energy X-ray Absorptiometry Example Scan

Manchester Metropolitan University

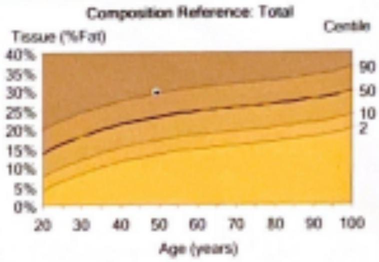
Bone Metabolism Unit

Patient ID:	[redacted]	**Facility ID:**	
Birth Date:	[redacted] 49.3 years	**Referring Physician:**	
Height / Weight:	168.5 cm 74.5 kg	**Measured:**	05/02/2020 10:14:51 (10.50)
Sex / Ethnic:	Male White	**Analyzed:**	11/02/2020 10:07:56 (10.50)

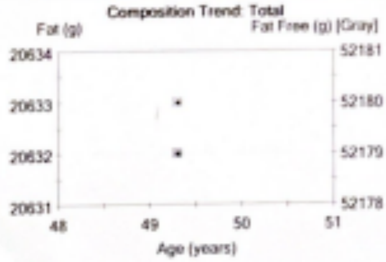
Total Body Tissue Quantitation



Composition Reference: Total



Composition Trend: Total



Trend: Total

Measured Date	Age (years)	Tissue (%Fat)	Centile[2,3]	T.Mass (kg)	Region (%Fat)	Tissue (g)	Fat (g)	Lean (g)	BMC (g)	Fat Free (g)
05/02/2020	49.3	29.5	91	72.8	28.3	69,904	20,633	49,271	2,908	52,179

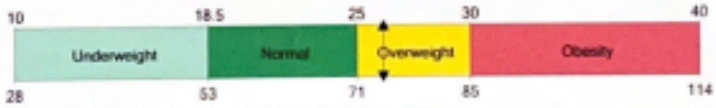
Trend: Fat Distribution

Measured Date	Age (years)	Android (%Fat)	Gynoid (%Fat)	A/G Ratio	Total Body (%Fat)
05/02/2020	49.3	42.8	32.6	1.32	29.5

COMMENTS:

World Health Organization BMI Classification

Body Mass Index (BMI) = 26.2



Weight (kg) for height = 168.5 cm

Image not for diagnosis

Printed: 11/02/2020 10:08:16 (10.50)76:0.15:153.04:31.4 0.00:-1.00 4.81x13.01
13.8:%Fat=29.5%
0.00:0.00 0.00:0.00
Filename: m7485q6fvb.dfb
Scan Mode: Standard 0.4 µGy

2 -UK Total Body Reference Population (v107)
3 -Matched for Age, Weight (males 25-100 kg), Ethnic

GE Healthcare

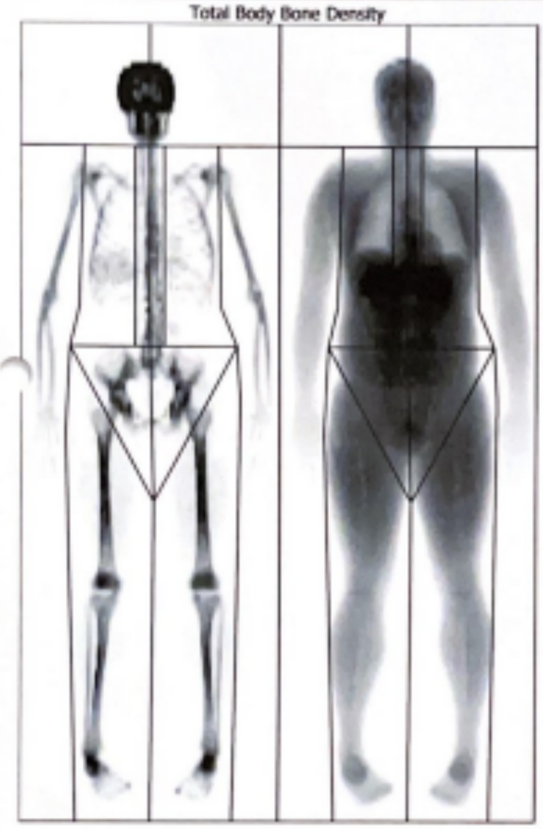
Lunar Prodigy Advance
PA+300503

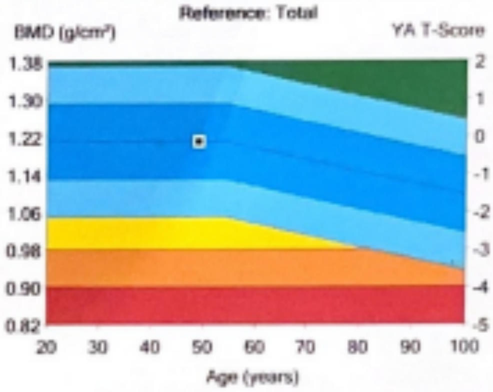
Manchester Metropolitan University

Bone Metabolism Unit

Patient ID:	[redacted]		**Facility ID:**			
Birth Date:	[redacted] 49.3 years		**Referring Physician:**			
Height / Weight:	168.5 cm	74.5 kg	**Measured:**	05/02/2020	10:14:51	(10.50)
Sex / Ethnic:	Male	White	**Analyzed:**	11/02/2020	10:07:56	(10.50)

Total Body Bone Density





Region	BMD[1] (g/cm²)	Young-Adult[2] (%)	Young-Adult[2] T-Score	Age-Matched[3] (%)	Age-Matched[3] Z-Score
Total	1.208	99	-0.1	100	0.0

COMMENTS:

Image not for diagnosis

Printed: 11/02/2020 10:08:13 (10.50)76:0.15:153.04:31.4 0.00:-1.00
4.81x13.01 13.8:%Fat=29.5%
0.00:0.00 0.00:0.00
Filename: m7485q6fvb.dfb
Scan Mode: Standard 0.4 µGy

1 - Statistically 68% of repeat scans fall within 1SD (± 0.010 g/cm² for Total Body Total)
2 - UK (ages 20-40) Total Body Reference Population (v107)
3 - Matched for Age, Weight (males 25-100 kg), Ethnic

GE Healthcare

Lunar Prodigy Advance
PA+300503

Appendix 4.3 Mini-BESTest; Balance Evaluation Systems Test

Mini-BESTest: Balance Evaluation Systems Test

ANTICIPATORY ***SUB SCORE: /6***

1. SIT TO STAND
Instruction: "Cross your arms across your chest. Try not to use your hands unless you must. Do not let your legs lean against the back of the chair when you stand. Please stand up now."
(2) Normal: Comes to stand without use of hands and stabilizes independently.
(1) Moderate: Comes to stand WITH use of hands on first attempt.
(0) Severe: Unable to stand up from chair without assistance, OR needs several attempts with use of hands.

2. RISE TO TOES
Instruction: "Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I will count out loud to 3 seconds. Try to hold this pose for at least 3 seconds. Look straight ahead. Rise now."
(2) Normal: Stable for 3 s with maximum height.
(1) Moderate: Heels up, but not full range (smaller than when holding hands), OR noticeable instability for 3 s.
(0) Severe: $\leq$ 3 s.

3. STAND ON ONE LEG
Instruction: "Look straight ahead. Keep your hands on your hips. Lift your leg off of the ground behind you without touching or resting your raised leg upon your other standing leg. Stay standing on one leg as long as you can. Look straight ahead. Lift now."

Left: *Time in Seconds Trial 1:_____ Trial 2:_____*
(2) Normal: 20 s.
(1) Moderate: < 20 s.
(0) Severe: Unable.

Right: *Time in Seconds Trial 1:_____ Trial 2:_____*
(2) Normal: 20 s.
(1) Moderate: < 20 s.
(0) Severe: Unable

To score each side separately use the trial with the longest time.
To calculate the sub-score and total score use the side [left or right] with the lowest numerical score [i.e. the worse side].

REACTIVE POSTURAL CONTROL ***SUB SCORE: /6***

4. COMPENSATORY STEPPING CORRECTION- FORWARD
Instruction: "Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall."
(2) Normal: Recovers independently with a single, large step (second realignment step is allowed).
(1) Moderate: More than one step used to recover equilibrium.
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously.

5. COMPENSATORY STEPPING CORRECTION- BACKWARD
Instruction: "Stand with your feet shoulder width apart, arms at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall."
(2) Normal: Recovers independently with a single, large step.
(1) Moderate: More than one step used to recover equilibrium.
(0) Severe: No step, OR would fall if not caught, OR falls spontaneously.

6. COMPENSATORY STEPPING CORRECTION- LATERAL
Instruction: "Stand with your feet together, arms down at your sides. Lean into my hand beyond your sideways limit. When I let go, do whatever is necessary, including taking a step, to avoid a fall."

Left
(2) Normal: Recovers independently with 1 step (crossover or lateral OK).
(1) Moderate: Several steps to recover equilibrium.
(0) Severe: Falls, or cannot step.

Right
(2) Normal: Recovers independently with 1 step (crossover or lateral OK).
(1) Moderate: Several steps to recover equilibrium.
(0) Severe: Falls, or cannot step.

Use the side with the lowest score to calculate sub-score and total score.

SENSORY ORIENTATION ***SUB SCORE: /6***

7. STANCE (FEET TOGETHER); EYES OPEN, FIRM SURFACE
Instruction: "Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Be as stable and still as possible, until I say stop."
Time in seconds:________
(2) Normal: 30 s.
(1) Moderate: < 30 s.
(0) Severe: Unable.

8. STANCE (FEET TOGETHER); EYES CLOSED, FOAM SURFACE

Instruction: "Step onto the foam. Place your hands on your hips. Place your feet together until almost touching. Be as stable and still as possible, until I say stop. I will start timing when you close your eyes."

Time in seconds:________

(2) Normal: 30 s.
(1) Moderate: < 30 s.
(0) Severe: Unable.

9. INCLINE- EYES CLOSED

Instruction: "Step onto the incline ramp. Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart and have your arms down at your sides. I will start timing when you close your eyes."

Time in seconds:________

(2) Normal: Stands independently 30 s and aligns with gravity.
(1) Moderate: Stands independently <30 s OR aligns with surface.
(0) Severe: Unable.

DYNAMIC GAIT **SUB SCORE: /10**

10. CHANGE IN GAIT SPEED

Instruction: "Begin walking at your normal speed, when I tell you 'fast', walk as fast as you can. When I say 'slow', walk very slowly."

(2) Normal: Significantly changes walking speed without imbalance.
(1) Moderate: Unable to change walking speed or signs of imbalance.
(0) Severe: Unable to achieve significant change in walking speed AND signs of imbalance.

11. WALK WITH HEAD TURNS – HORIZONTAL

Instruction: "Begin walking at your normal speed, when I say "right", turn your head and look to the right. When I say "left" turn your head and look to the left. Try to keep yourself walking in a straight line."

(2) Normal: performs head turns with no change in gait speed and good balance.
(1) Moderate: performs head turns with reduction in gait speed.
(0) Severe: performs head turns with imbalance.

12. WALK WITH PIVOT TURNS

Instruction: "Begin walking at your normal speed. When I tell you to 'turn and stop', turn as quickly as you can, face the opposite direction, and stop. After the turn, your feet should be close together."

(2) Normal: Turns with feet close FAST (≤ 3 steps) with good balance.
(1) Moderate: Turns with feet close SLOW (≥4 steps) with good balance.
(0) Severe: Cannot turn with feet close at any speed without imbalance.

13. STEP OVER OBSTACLES

Instruction: "Begin walking at your normal speed. When you get to the box, step over it, not around it and keep walking."

(2) Normal: Able to step over box with minimal change of gait speed and with good balance.
(1) Moderate: Steps over box but touches box OR displays cautious behavior by slowing gait.
(0) Severe: Unable to step over box OR steps around box.

14. TIMED UP & GO WITH DUAL TASK ***[3 METER WALK]***

Instruction TUG: "When I say 'Go', stand up from chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair."

Instruction TUG with Dual Task: "Count backwards by threes starting at ___. When I say 'Go', stand up from chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair. Continue counting backwards the entire time."

TUG: ________seconds; Dual Task TUG: ________seconds

(2) Normal: No noticeable change in sitting, standing or walking while backward counting when compared to TUG without Dual Task.
(1) Moderate: Dual Task affects either counting OR walking (>10%) when compared to the TUG without Dual Task.
(0) Severe: Stops counting while walking OR stops walking while counting.

When scoring item 14, if subject's gait speed slows more than 10% between the TUG without and with a Dual Task the score should be decreased by a point.

TOTAL SCORE: ______ /28

Mini-BESTest Instructions

Subject Conditions: Subject should be tested with flat-heeled shoes OR shoes and socks off.
Equipment: Temper® foam (also called T-foam™ 4 inches thick, medium density T41 firmness rating), chair without arm rests or wheels, incline ramp, stopwatch, a box (9" height) and a 3 meter distance measured out and marked on the floor with tape [from chair].
Scoring: The test has a maximum score of **28** points from **14 items** that are each scored from 0-2.
"0" indicates the lowest level of function and "2" the highest level of function.
If a subject must use an assistive device for an item, score that item one category lower.
If a subject requires physical assistance to perform an item, score "0" for that item.
For **Item 3** (stand on one leg) and **Item 6** (compensatory stepping-lateral) only include the score for one side (the worse score).
For **Item 3** (stand on one leg) select the best time of the 2 trials [from a given side] for the score.
For **Item 14** (timed up & go with dual task) if a person's gait slows greater than 10% between the TUG without and with a dual task then the score should be decreased by a point.

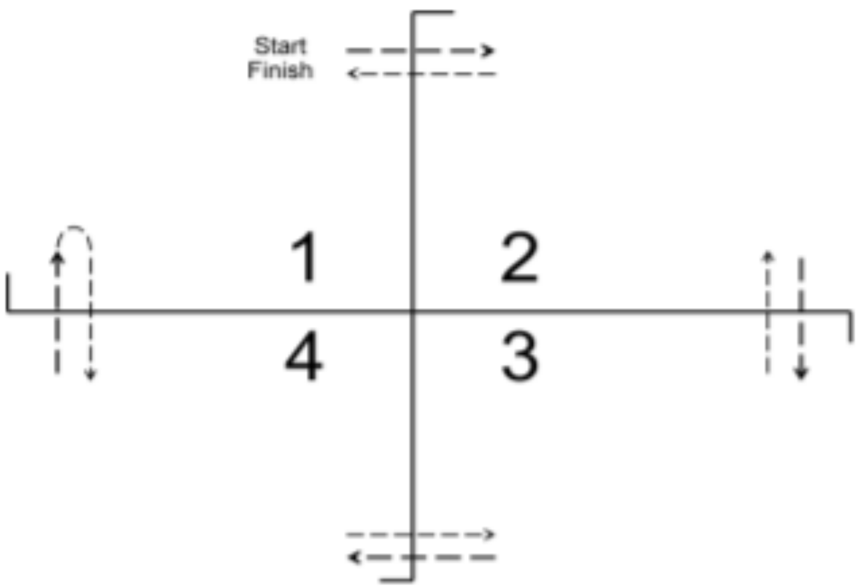
1. SIT TO STAND	Note the initiation of the movement, and the use of the subject's hands on the seat of the chair, the thighs, or the thrusting of the arms forward.
2. RISE TO TOES	Allow the subject two attempts. Score the best attempt. (If you suspect that subject is using less than full height, ask the subject to rise up while holding the examiners' hands.) Make sure the subject looks at a non-moving target 4-12 feet away.
3. STAND ON ONE LEG	Allow the subject two attempts and record the times. Record the number of seconds the subject can hold up to a maximum of 20 seconds. Stop timing when the subject moves hands off of hips or puts a foot down. Make sure the subject looks at a non-moving target 4-12 feet ahead. Repeat on other side.
4. COMPENSATORY STEPPING CORRECTION-FORWARD	Stand in front of the subject with one hand on each shoulder and ask the subject to lean forward (Make sure there is room for them to step forward). Require the subject to lean until the subject's shoulders and hips are in front of toes. After you feel the subject's body weight in your hands, very suddenly release your support. The test must elicit a step. NOTE: Be prepared to catch subject.
5. COMPENSATORY STEPPING CORRECTION - BACKWARD	Stand behind the subject with one hand on each scapula and ask the subject to lean backward (Make sure there is room for the subject to step backward.) Require the subject to lean until their shoulders and hips are in back of their heels. After you feel the subject's body weight in your hands, very suddenly release your support. Test must elicit a step. NOTE: Be prepared to catch subject.
6. COMPENSATORY STEPPING CORRECTION- LATERAL	Stand to the side of the subject, place one hand on the side of the subject's pelvis, and have the subject lean their whole body into your hands. Require the subject to lean until the midline of the pelvis is over the right (or left) foot and then suddenly release your hold. NOTE: Be prepared to catch subject.
7. STANCE (FEET TOGETHER); EYES OPEN, FIRM SURFACE	Record the time the subject was able to stand with feet together up to a maximum of 30 seconds. Make sure subject looks at a non-moving target 4-12 feet away.
8. STANCE (FEET TOGETHER); EYES CLOSED, FOAM SURFACE	Use medium density Temper® foam, 4 inches thick. Assist subject in stepping onto foam. Record the time the subject was able to stand in each condition to a maximum of 30 seconds. Have the subject step off of the foam between trials. Flip the foam over between each trial to ensure the foam has retained its shape.
9. INCLINE EYES CLOSED	Aid the subject onto the ramp. Once the subject closes eyes, begin timing and record time. Note if there is excessive sway.
10. CHANGE IN SPEED	Allow the subject to take 3-5 steps at normal speed, and then say "fast". After 3-5 fast steps, say "slow". Allow 3-5 slow steps before the subject stops walking.
11. WALK WITH HEAD TURNS-HORIZONTAL	Allow the subject to reach normal speed, and give the commands "right, left" every 3-5 steps. Score if you see a problem in either direction. If subject has severe cervical restrictions allow combined head and trunk movements.
12. WALK WITH PIVOT TURNS	Demonstrate a pivot turn. Once the subject is walking at normal speed, say "turn and stop." Count the number of steps from "turn" until the subject is stable. Imbalance may be indicated by wide stance, extra stepping or trunk motion.
13. STEP OVER OBSTACLES	Place the box (9 inches or 23 cm height) 10 feet away from where the subject will begin walking. Two shoeboxes taped together works well to create this apparatus.
14. TIMED UP & GO WITH DUAL TASK	*Use the TUG time to determine the effects of dual tasking. The subject should walk a 3 meter distance. TUG:* Have the subject sitting with the subject's back against the chair. The subject will be timed from the moment you say "Go" until the subject returns to sitting. Stop timing when the subject's buttocks hit the chair bottom and the subject's back is against the chair. The chair should be firm without arms. *TUG With Dual Task*: While sitting determine how fast and accurately the subject can count backwards by threes starting from a number between 100-90. Then, ask the subject to count from a different number and after a few numbers say "Go". Time the subject from the moment you say "Go" until the subject returns to the sitting position. Score dual task as affecting counting or walking if speed slows (>10%) from TUG and or new signs of imbalance.

Four Step Square Test Instructions

General Information:

- The patient is instructed to stand in square 1 facing square number 2 (see figure below)
- The patient is required to step as fast as possible into each square in the following sequence: 2, 3, 4, 1, 4, 3, 2, and 1
    - requires the patient to step forward, backward, and sideway to the right and left
- Equipment required for the FSST includes a stopwatch and 4 canes.

Set-up (derived from Dite and Temple 2002): A square is formed with the 4 canes by resting them flat on the floor.



Patient Instructions (derived from Dite and Temple 2002):

- "Try to complete the sequence as fast as possible without touching the sticks. Both feet must make contact with the floor in each square. If possible, face forward during the entire sequence."
- Demonstrate the sequence to the patient.
- Ask the patient to complete one practice trial to ensure the patient knows the sequence. Repeat the trial if the patient is unsuccessful

Appendix 4.5 Gait Specific Attentional Profile

Gait-Specific Attentional Profile ©

Study ID Number: ______________________________

A1. I feel strained	1	2	3	4	5
A2. I am concerned about what people think about my movements	1	2	3	4	5
A3. I think about previous occasions when I lost my balance	1	2	3	4	5
A4. I think about what would happen if I fell	1	2	3	4	5
A5. I get confused and make illogical decisions	1	2	3	4	5
A6. Worrisome thoughts about falling run through my mind	1	2	3	4	5
A7. I try to think about the way I walk/move	1	2	3	4	5
A8. I consciously try to control my movements	1	2	3	4	5
A9. I examine the way I walk/move	1	2	3	4	5
A10. I feel tense	1	2	3	4	5
A11. I find it difficult to concentrate on two things at once	1	2	3	4	5

B1. Have you fallen in the past 12 months? Yes ◻ No ◻ *(if 'No' you have finished the questionnaire)*

B2. Why did your most recent fall occur? Accident/environment ◻ Other______________

B3. Compared to before my first fall I now think about my movements much more:

Strongly disagree ◻ Disagree ◻ Agree ◻ Strongly agree ◻

B4. Compared to before my first fall worrisome thoughts about falling now run through my mind more when I walk:

Strongly disagree ◻ Disagree ◻ Agree ◻ Strongly agree ◻

B5. I take unnecessary risks with my balance (i.e., I try to do things that I am no longer able to do safely) (Circle the appropriate number)

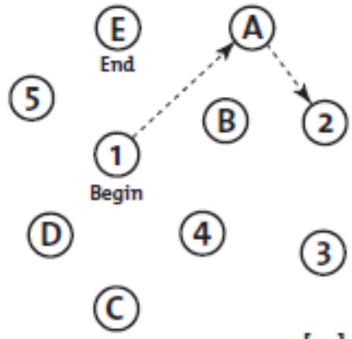
Not at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Very much

Appendix 4.6 Montreal Cognitive Assessment

MONTREAL COGNITIVE ASSESSMENT (MOCA)

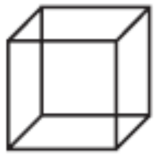
NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE



[ ]

Copy cube



[ ]

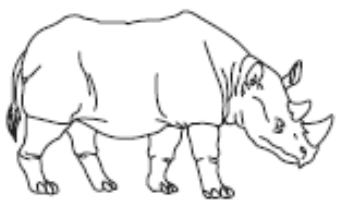
Draw CLOCK (Ten past eleven) (3 points)

[ ] Contour [ ] Numbers [ ] Hands

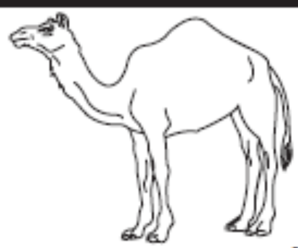
POINTS: __/5

NAMING

[ ]



[ ]



[ ]

__/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2 __/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B __/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** __/3

LANGUAGE

Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] __/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] ____ (N ≥ 11 words) __/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler __/2

DELAYED RECALL

Has to recall words	FACE	VELVET	CHURCH	DAISY	RED	Points for UNCUED recall only
WITH NO CUE	[ ]	[ ]	[ ]	[ ]	[ ]	
Optional: Category cue						
Optional: Multiple choice cue						

__/5

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City __/6

Normal ≥ 26 / 30

TOTAL __/30
Add 1 point if ≤ 12 yr edu

Appendix 4.7 State-Trait Anxiety Inventory

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1

Please provide the following information:

Name____Date______________S_____

Age__________________ Gender (*Circle*) **M** **F** T_____

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

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STAIP-AD Test Form Y
www.mindgarden.com

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name____Date__________

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

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STAIP-AD Test Form Y
www.mindgarden.com

Appendix 6.1. Falls Efficacy Scale-International (FES-I)

Falls Efficacy Scale-International (English)

I would like to ask some questions about how concerned you are about the possibility of falling. For each of the following activities, please circle the opinion closest to your own to show how concerned you are that you might fall if you did this activity. Please reply thinking about how you usually do the activity. If you currently don't do the activity (example: if someone does your shopping for you), please answer to show whether you think you would be concerned about falling IF you did the activity.

		Not at all concerned 1	Somewhat concerned 2	Fairly concerned 3	Very concerned 4
1	Cleaning the house (e.g. sweep, vacuum, dust)				
2	Getting dressed or undressed				
3	Preparing simple meals				
4	Taking a bath or shower				
5	Going to the shop				
6	Getting in or out of a chair				
7	Going up or down stairs				
8	Walking around in the neighborhood				
9	Reaching for something above your head or on the ground				
10	Going to answer the telephone before it stops ringing				
11	Walking on a slippery surface (e.g. wet or icy)				
12	Visiting a friend or relative				
13	Walking in a place with crowds				
14	Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)				
15	Walking up or down a slope				
16	Going out to a social event (e.g. religious service, family gathering, or club meeting)				
	Sub Total				
				TOTAL	**/64**

Reference: Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C., & Todd, C. (2005). Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age and Ageing, 34*(6), 614-619. doi:10.1093/ageing/afi196.

Appendix 7.1. Topic guide for participant interviews

Interview agenda

Ethos ID 29119 V1.2 Date 29/03/2021

Interview questions

This is a semi structured interview so depending on the interviewee's answers, questions may not be asked in this order and the questions are not exhaustive. This interview agenda will be tailored slightly to each participant depending on their previous survey answers and will not ask demographics as they have already been collected. A final point to mention is the prompts given are the planned prompts, informal prompts will not be noted here.

1. Could you please describe what having a fall means to you?
   Prompt- How do they make you feel? Prompt- Has this change since the lockdown restrictions began in March 2020?

2. Thinking back to your most memorable fall during the lockdown restrictions, what was your biggest concern?
   Prompt-What do you think made you feel that way?
      Sub-prompt- For example, to what extent were any of the following [pick as appropriate]; your injuries; need for hospitalisation; psychological consequences; effects on your family; the impact on your lifestyle and living circumstances; a concern for you?
   Prompt- How concerned are you about falling again?
   Prompt- Are these concerns different to before the restrictions? How?

3. [a. For previous fallers, b. for new fallers]
   a. From looking at your survey answers, I can see that you did report having a fall before the pandemic restrictions. Do you think you fall less or more now and what about lockdown (if anything) may have contributed to this?

   Prompt- To what extent has this varied throughout the pandemic?

   Prompt-What about the lockdown restrictions do you think had the biggest impact on your falls? Why might this be?

   b. From looking at your survey answers, I can see that you did not report having a fall before the pandemic restrictions. What do you think has changed since then that may have contributed to your fall(s)?

   Prompt-How do you think restrictions contributed to your fall(s)?

   Prompt- To what extent has this varied throughout the pandemic?

   Prompt-What about the restrictions do you think had the biggest impact on you fall(s)? Why might this be?

4. From looking at your survey answers, I can see that you did/did not report significant fear of falling. May I ask what you think a fear of falling feels like?

Prompt- For example, do you think this feels like a general constant fear/worry about falling or is it more feelings/physical sensations associated with certain activities or maybe both?

Prompt- What has caused this/helped you avoid this?

5. Can you tell me about how lockdown restrictions impacted your fear of falling (if at all)?
   Prompt- Did you have a fear of falling before the restrictions?
   Prompt- To what extent do you worry about falling in the future? Why might this be?

6. From looking at your survey answers, I can see that you reported feeling anxious. What makes you feel like this? [This will only be asked if relevant to the participant]
   Prompt-How have the restrictions impacted your experience of anxiety?

7. In general, how have you coped during the restrictions?
   Prompt- What do you think helped you cope/adapt during the restrictions?
   Prompt-What do you think could have helped you feel better during this time?

8. Now that we are moving out of lockdown, is there anything in particular that you feel would help reduce your risk of future falls?

9. Do you have any questions for me or anything else you may like to add?