

EFFECT OF COVID-19 LOCKDOWN ON HOME STAIR FALLS AND CONSEQUENCES FOR STAIR-NEGOTIATING BIOMECHANICS IN OLDER ADULTS

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Abstract

Falls on stairs represent a leading cause of injury, loss of independence, and mortality among older adults, yet little is known about how individual, behavioural, and environmental factors interact to shape stair fall risk in real-world home contexts. This thesis adopts a multi-method approach to investigate the biomechanics, perceptions, and experiences of stair use among older adults, with a particular focus on the unique conditions created by the COVID-19 pandemic.

Study 1 employed a survey of older adults ($n = 164$) to examine the incidence and consequences of stair falls during the UK COVID-19 lockdown. Findings indicated an increase in home stair falls and near-falls during confinement. A higher injury severity was observed in older adults of increased age and higher risk of falling for those living alone. Reduced physical activity were identified during the lockdowns and may be contributing factors to increased stair falls. Study 2 used home visits combining interviews and environmental stair assessments to explore older adults' perceptions of stair safety in relation to objective staircase conditions. A disconnect emerged between perceived and actual safety, as all stair fallers rated their stairs as safe despite 40% of staircases failing to meet British Standards for staircase rise and going. Behavioural and décor choices, such as leaving objects on steps or patterned stair coverings, were identified as modifiers of risk. Participants frequently reported reactive changes in behaviour following a fall, and strong emotional attachment to their home. Study 3 examined stepping biomechanics under different handrail use conditions in older adults with and without a history of stair falls/near-falls. No significant improvements in stability were found; instead, handrail use increased CoM acceleration variability during lowering, suggesting reduced movement consistency. Handrail benefits may depend on individual caution and real-world conditions, warranting further investigation outside of controlled settings.

In summary, the findings revealed that stair fall risk in older adults arises from a complex interplay of individual characteristics, environmental hazards, and behavioural factors, all of which were amplified during the COVID-19 pandemic due to increased exposure to home stairs, reduced physical activity, and social isolation. This thesis highlights the urgent need for multifaceted fall prevention strategies that go beyond physical impairments to address behavioural training, hazard awareness, and home adaptations. Recommendations are made for research (e.g., use of real-world wearable monitoring and larger, more diverse samples),

practice (e.g., integrating stair-specific questions into fall risk assessments, training in safe handrail use), and policy (e.g., strengthening housing regulations and investing in affordable home adaptations). Collectively, these measures are essential for supporting safe stair use, preventing falls, and enabling older adults to maintain independence in their homes.

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Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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Publications

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List of abbreviations

ABC	Activities-specific Balance Confidence Scale
A&E	Accident and Emergency
CoM	Centre of mass
CoP	Centre of pressure
FRAT	Fall Risk Assessment Tool
HES	Hospital Episode Statistics
HHSRS	housing health and safety rating system
IMD	Indices of Multiple Deprivation
MoCa	Montreal cognitive assessment
NEADL	Nottingham extended Activities of Daily Living
NHS	National Health Service
PFLCS	Proportion of foot length in contact with stair
ROM	Range of motion
SAQ	Stair Assessment Questionnaire
Short FES-I	Short Falls Efficacy Scale-International
UK	United Kingdom
VCOP	Centre of pressure velocity
WHO	World Health Organization

CHAPTER 1:

General Introduction

1.1. Incidence and consequences of stair falls

Falls on stairs are a leading causes of injury among older adults, contributing significantly to morbidity, loss of independence, and mortality ^[1,2]. In the UK alone, stair falls account for approximately 250,000 non-fatal injuries and around 700 deaths each year ^[2]. Among adults aged 65 and over, stair falls are a leading cause of hospitalisation, with over 57,000 emergency department visits annually ^[3]. However, these figures may underestimate the scale of the problem, as many minor falls go undocumented, with estimates suggesting the actual injury rates may be up to five times greater ^[4]. In addition to falls, it is crucial to recognise that even slips, trips, or stumbles on stairs that do not result in an actual fall (commonly referred to as near-falls), offer critical insight into the mechanisms that precede actual stair falls ^[5,6]. A near-fall is defined as an event, such as a trip, slip, or loss of balance, that would have led to a fall had the individual not managed to recover their balance. This recovery may involve unplanned arm movements to catch a nearby object or wall, or rapid stepping to stabilise themselves. Near-falls are often underreported but are more frequent than actual falls and can be predictors of future falls, especially when they occur repeatedly ^[5,6]. Therefore, recognising and addressing the circumstances leading to near-falls is critical for a more comprehensive understanding of stair negotiation, balance perturbation, and stair fall prevention strategies.

While stair falls research has traditionally focused on adults aged 65 and over ^[7–11], emerging evidence indicates that adults aged 50 may also face substantial risk ^[12–14]. Supporting this, NHS data reported 8,170 hospital admissions due to stair falls among adults aged 50–64 between 2023–2024 ^[15]. More broadly, stair falls not only cause physical injury, loss of independence, and fear of falling ^[16(p. 201)] but also place financial pressure on health and social care services, costing the NHS an estimated £435 million each year ^[16]. Given that the UK's older population is expected to grow by 8.6 million by 2066 ^[17] and the UK's incidence of stair falls is increasing, the demands on health services ^[18,19] and the associated economic impact will likely rise ^[20,21]. Despite the impact of stair-related falls, there is limited understanding of how older adults perceive and negotiate stairs in real-world home environments. Addressing this gap is essential for designing effective, context-specific prevention strategies.

1.2. Biomechanics of stair negotiation and mechanisms of stair falls

Stair negotiation is a complex and high-risk daily task for older adults, posing significantly greater biomechanical challenges than level-ground walking. Level-ground gait is characterised by relatively consistent step length, small vertical displacement, and a relatively stable centre of mass (CoM) trajectory [22]. Unlike level-ground gait, stair negotiation demands coordination of lower-limb strength, larger joint range of motion (RoM), precise dynamic balance control, visual processing, and confidence [22–25]. Stair ascent and descent present unique risks and understanding these phase-specific challenges is critical for identifying when and how falls are most likely to occur. Stepping strategies in both ascent and descent may be executed in step-over-step manner or one step at a time, both of which involve alternating periods of stance and swing phases.

In stair ascent, the swing phase is particularly hazardous because the trailing foot must clear two step edges, increasing the likelihood of tripping, especially if step height is misjudged [26]. The stance phase also presents risk, particularly during the push-off phase of the trail foot, as exertion is required to lift the body onto the next step. This may result in slipping if the foot loses traction and/or if only a small proportion of foot length is in contact with the stair tread. Although stair ascent involves physical exertion and risk, falls during ascent tend to be less severe than those during descent. This is due to the forward positioning of the body's CoM, which typically results in the body falling forward toward the stairs, a direction that is closer to the hands and may allow for a more protective response [26].

Although more falls occur during stair ascent, descent remains more hazardous than ascent [27–29]. Stair descent is associated with a higher rate of serious injuries as it places particularly high demands on lower-limb strength [30], coordination [31], balance control [32], and visual feedback [33,34] due to the downward trajectory of the centre of mass (CoM) and vertical displacement involved. Stair descent involves two distinct phases of CoM control: the lowering phase and the landing phase [15,18]. An increased CoM acceleration and velocity in the lowering phase may result in loss of balance and a consequent forward fall [35,36]. Additionally, inconsistent or poorly timed CoM control may result in inaccurate foot placement in the subsequent landing phase, greater impact forces upon landing, and a reduced ability to recover from small perturbations, each of which increases fall risk [35,37,38]. In the landing

phase, individuals are particularly vulnerable to over- or under-steps shortly after initial contact, as body weight is transferred to the leading leg. In over-stepping, the ball of the foot rolls off the edge of the step, potentially resulting in a forward stumble or a backwards slip [24,32,39,40]. In under-stepping, a forward stumble may arise from the heel of the leading foot contacting the riser. Collectively, these factors can make stair descent falls more severe than those during ascent, as they can result in tumbling falls down multiple steps. The compounded influence of gravity, precise dynamic balance control, and lower-limb strength needed amplifies both the likelihood and severity of injuries during descent. In summary, suboptimal trajectory and placement of the lead foot on the step is a key contributor to stair falls [26].

Several interrelated aspects may contribute to stair falls, including intrinsic, extrinsic and behavioural characteristics. These are explored below.

1.3. Individual factors and stair fall risk

Successful stair negotiation in older adults depends on an interplay of several intrinsic characteristics, including physiological, visual, and psychological factors. Physiological factors such as reduced muscle strength, joint range of movement (RoM), and balance are commonly associated with stair fall risk. Low muscle strength may limit the ability to respond effectively to perturbations [41,42], while small joint RoM, and diminishing mobility may impair safe step clearance or landing [19,41]. Similarly, poor balance reduces the ability to make postural adjustments for perturbation recovery [19]. Collectively, age-related declines across these factors and functional abilities may account for the increased stair falls in older adults. This heightened stair fall risk is particularly acute in older adults living in socio-economically disadvantaged areas, where chronic health conditions such as cardiovascular disease and Type 2 Diabetes are more prevalent [30,43], therefore understanding these factors are essential.

Visual factors are essential for accurately perceiving stair dimensions and environmental context. Impaired visual acuity, reduced contrast sensitivity, or suboptimal gaze behaviours such as failing to look at critical locations at the appropriate time can compromise step negotiation, reduce confidence, and increase fall risk [34,44]. Psychological factors, including fear of falling and anxiety, are associated with stair fall risk [45]. For example, reduced confidence and increased anxiety can change visuomotor behaviour during obstacle

negotiation, such as decreased walking speed ^[44,46] and reduced visibility ^[47]. While individual factors such as strength, vision, and psychological factors influence stair negotiation, these factors do not operate in isolation. They are shaped by their environment in which stair negotiation occurs. The following section explores how environmental factors such as stair design, lighting, and maintenance interact with individual limitations to influence stair safety and fall risk.

1.4. Environmental hazards and stair design

Older adults face a heightened risk of stair falls due to unaddressed hazards on their staircases. Such unaddressed extrinsic hazards may include poorly designed or absent handrails, stairs that are too steep and narrow, step surfaces or covering in poor condition, objects left on steps, and poor lighting ^[3]. Around 10 million people currently live in a home that poses significant risk to their health and safety, with nearly half of these occupied by individuals aged 55 or older ^[48]. Hazardous environmental features interact with age-related declines in strength, balance, and vision, making stair negotiation particularly challenging. When the environmental demands increase, such as increased riser heights or inconsistent step dimensions, the mechanical demands can increase. Even adopting a compensatory strategy can become ineffective, leading to higher CoM velocities at landing and greater fall risk. Poor lighting can reduce visibility of step edges, influencing confidence, increasing anxiety, and decreasing dynamic balance and visual guidance needed for accurate foot placement ^[49]. Additionally, these environments can overwhelm attentional capacity, slow response times and increase anxiety, further compromising stair safety ^[9–12]. For example, anxiety may cause older adults to fixate on future hazards too early, inducing an attentional bias toward environmental features perceived as more threatening ^[44,50]. This premature transferral of gaze from a stepping target such as the next step to future obstacles such as moveable items on the stairs or clutter can reduce stepping accuracy and increase foot placement variability, which could exacerbate fall risk ^[44,50].

One environmental feature designed to enhanced safety is the availability of handrails to assist stair negotiation ^[41,42,51–53]. Handrails offer mechanical support through redistributing load to reduce demands on the lower limbs ^[51,53], and can be useful for recovering balance during sudden losses of stability ^[42]. Moreover, handrails offer tactile feedback for those with visual

or mobility impairments, or in reduced visibility (e.g. poor lighting) and psychological reassurance for individuals with a fear of falling ^[51–54]. Despite their known benefits, concerns have been raised about the suitability and accessibility of handrails in the home ^[55]. For instance, the English Housing Survey ^[56] reports that only 9% of homes in England meet the basic accessibility standards set by the British Standard BS5395-1, highlighting a significant gap in housing suitability for older adults ^[57]. The Adherence to established safety guidelines, such as those outlined in British Standard BS5395-1 (see table 1.1), could reduce the risk of stair falls by up to 60% ^[55]. However, retrofitting existing staircases to comply with specifications for pitch, rise, and going presents substantial structural and financial challenges. While updating building regulations remains important for future housing developments ^[58], there is a need to better understand how current home stair conditions, such as handrail use, stair coverings, and step dimensions affect stair safety in older adults. Investigating these factors may help identify features that support improved centre of mass (CoM) control during stair negotiation.

Table 1.1. Stair safety guidelines outlined by British Standard BS5395-1.

	Rise		Going		Handrail height	
	<i>mm</i>		<i>mm</i>		<i>mm</i>	
	Min.	Max.	Min.	Max.	Min.	Max.
Private stair	150	200	250	400	900	1000
Normal-use stair	150	180	300	450	900	1000

Moreover, poor housing quality and maintenance are key determinants of overall health and safety for older adults. For example, cold, damp, or poorly maintained homes can also adversely impact physical health such as by worsening respiratory or circulatory conditions and create a more hazardous environment for stair navigation ^[58]. This is particularly prevalent in older adults living in socio-economically disadvantaged areas, where housing is often older, poorly maintained, and structurally unsafe ^[56,59], with chronic health conditions more frequent ^[30,43]. The English Housing Survey ^[56] noted that approximately 820,000 homes in England experience issues such as damp or mould, with many residents viewing these problems as more pressing than adapting the homes for stair safety or making their homes

future-proof ^[48,57]. This prioritisation reflects a broader tension between immediate health concerns and long-term fall prevention strategies. However, poor housing conditions not only affect respiratory and general health but may also indirectly increase stair fall risk ^[48] by contributing to cold, damp environments that impair mobility, balance, and confidence on stairs. Similarly, the condition and design of staircases within these homes can directly contribute to increased fall risk. For example, loose carpets, uneven steps, inadequate lighting, and lack of handrails can create hazardous stair environments ^[3]. Financial constraints remain a key barrier to implementing necessary home adaptations, leaving many older adults at continued risk ^[48,56,57]. Unfortunately, the scale of the problem is set to increase as the UK's older population continues to grow, alongside the UK possessing one of the oldest housing stocks in Europe ^[20,21]. Unlike some broader housing issues, many stair-related hazards, such as missing handrails or worn stair coverings are modifiable. Therefore, understanding the need for adaptations and improvements in the individual's staircase and surrounding environment is vital for the changing needs and abilities for older adults to live safely and independently ^[48,60]. These considerations further highlight the importance of exploring home environments to identify modifiable factors that can reduce stair fall risk and promote safer ageing in place.

1.5. Behavioural factors and stair fall risk

Beyond individual and environmental factors, behavioural and perceptual factors also play a critical role in stair safety. For example, décor choices such as, surface colour and patterned carpets can impair the ability to judge step edges, reduce confidence, and increase anxiety during stair negotiation ^[44,61]. Reduced confidence and heightened anxiety have been linked to changes in visuomotor behaviour, such as slower walking speeds ^[44,46], reduced visibility ^[47] and altered gaze strategies that impair foot placement accuracy ^[44,50]. Additionally, unsafe behaviour such as rushing, carrying items on stairs, misjudging step placement, or not using available handrails may increase stair fall risk. These issues underscore the importance of pre-emptive interventions, rather than reactive responses following a fall and support the implementation of fall prevention strategies that address both environmental and behavioural factors ^[1,62].

These individual, environmental, and behavioural risk factors are interrelated, and their complex interaction may have a greater impact on stair safety than any single factor in isolation. For instance, an older adult with impaired vision and reduced confidence may be particularly vulnerable when negotiating cluttered staircases or using staircases with non-compliant dimensions. In such situations, diminished visual cues, suboptimal postural strategies, and unsafe environmental features can increase stair fall risk. Despite growing evidence of the environmental and behavioural contributors to stair falls, there remains limited understanding of how older adults negotiate stairs and perceive their own stair safety and environment. Real world changes for maintaining the independence and quality of life for older adults requires an understanding of the connection between their perceptions of home safety, housing condition, and home stair falls. This interconnectedness highlights the importance of multifactorial fall prevention strategies that go beyond addressing physical impairments alone. Effective interventions must also consider home design, environmental modifications, and behavioural adaptations to support safe stair use and preserve independence among older adults.

1.6. Potential impact of the COVID-19 pandemic on stair fall risk

Falls on stairs represent a significant and ongoing public health concern, particularly among older adults. The unique demands of stair negotiation, such as maintaining balance, joint flexibility, and precise foot placement mean that even minor intrinsic, extrinsic and behavioural factors can increase stair fall risk. These fall risks, while remaining under normal circumstances, were likely exacerbated during the COVID-19 pandemic. The COVID-19 pandemic resulted in nationwide lockdowns across the UK on the 23rd of March 2020. This unprecedented health crisis forced individuals to self-isolate and stay at home for extended periods ^[63–65], only permitted to leave for essential purposes, such as buying food or for medical reasons. Social gatherings were banned, and vulnerable populations such as older adults were advised to "shield" to reduce exposure ^[66]. As the pandemic progressed, lockdown measures evolved through a series of restrictions, which included:

- **Lockdown 1 (March–June 2020):** The strictest measures, including closure of schools, non-essential shops, and hospitality venues. Eased in stages through summer 2020.

- **Local Restrictions (Autumn 2020):** A tiered system was introduced in England in October 2020, imposing region-specific rules based on infection rates.
- **Lockdown 2 (November 2020):** A second national lockdown lasting four weeks to control rising case numbers.
- **Lockdown 3 (January–March 2021):** Following a brief easing over Christmas, a third national lockdown was imposed due to the emergence of new variants and increased pressure on the NHS. Schools and non-essential retail closed again.

Restrictions were gradually eased from March 2021 through the government's “roadmap” for lifting lockdown, with most legal limits on social contact ending by July 2021 in England. While these measures were crucial for public health, they inadvertently created new challenges for older adults, particularly relating to falls in the home. Extended periods of home confinement during the COVID-19 pandemic may have heightened the risk of stair falls, particularly as the unprecedented health crisis forced individuals to self-isolate and spend prolonged periods at home. A systematic review of 66 studies by Stockwell et al.^[67] demonstrated that a large proportion of the studies reported a decline in physical activity and an increase in sedentary behaviour during the COVID-19 pandemic lockdown. This could raise further stair fall risk, as even short periods of home confinement (from just two days of inactivity) can rapidly impair musculoskeletal, cardiovascular, and metabolic function, including muscle loss, insulin resistance, and reduced aerobic capacity ^[63]. These effects are especially relevant to stair negotiation, which demands strength, joint flexibility, and postural control. During lockdown, the closure of gyms, walking groups, and community centres meant older adults were more likely to become sedentary ^[67], heightening their risk to stair falls due to reduced physical capacity. Home confinement has also been qualitatively linked to faster deteriorations of dementia symptoms in older adults ^[64], thereby amplifying the likelihood of individuals experiencing a stair falls in their home environment during the COVID-19 pandemic lockdown.

Social isolation and loneliness are additional factors that may contribute to an increased risk of home stair falls in older adults ^[68–70]. Feelings of loneliness are associated with emotional distress, reduced self-esteem, and symptoms of depression, all of which can negatively affect overall well-being and functional independence ^[69,70]. The experience of a stair fall may

further intensify this isolation, as physical injury resulting from a stair fall may lead to reduced mobility and independence, limiting individuals' ability to engage in social and physical activities ^[1]. This creates a cyclical risk, where reduced participation in meaningful activities exacerbates loneliness, while also weakening strength, balance, and confidence, which are critical factors in fall prevention ^[71-73]. While much of the existing evidence was gathered prior to the COVID-19 pandemic, it remains highly relevant in the context of lockdown and social distancing measures, which likely heightened feelings of loneliness and isolation among older adults ^[73]. Additionally, the suspension of in-person fall prevention programmes and community support services during the pandemic may have further amplified these risks, particularly in the home environment where stair hazards are most prevalent.

Additionally, older adults likely increased their exposure to staircases, including potentially unsafe, hazardous, or non-compliant staircases. This increased and continuous interaction with their staircases may have elevated stair fall risk, particularly in households where hazards such as poor lighting, inadequate handrails, or worn stair coverings were already present. Additionally, resource constraints during the pandemic likely delayed or prevented essential home adaptations or repairs. As a result, the lockdown not only amplified the frequency of interactions with hazardous environments but also reduced the capacity to implement preventive changes, heightening the stair fall risk posed by unsafe home stairs. Similarly, if older adults were already engaging in unsafe stair behaviours, such as rushing, not using handrails, or carrying items while negotiating the stairs, then the increase in time spent at home may have magnified their risk. These compounded factors during lockdowns likely increase the risk of stair falls and warrant further investigation ^[60]. The underlying mechanisms for a stair fall have been studied extensively, and as a result stair-specific risk factors have been identified. However, there remains limited understanding of how older adults negotiate stairs, and perceive their own stair safety and environment, particularly during periods of prolonged home confinement such as the COVID-19 pandemic. Taking actions to establish how and why stair falls in the home occurred is crucial to generate learnings for future pandemics and beyond. Designing and implementing effective targeted interventions or community-based fall prevention programmes necessitates the identification of at-risk individuals and a comprehensive understanding of the specific nature of the hazards associated with stair falls in the home environment.

1.7. Limitations of existing stair fall research.

Despite the substantial amount of biomechanical research examining stair falls, there remains a limited understanding of how older adults experience, perceive, and negotiate stairs in their everyday home environments ^[3,74]. Laboratory-based biomechanics studies provide valuable insight into mechanical demands and movement strategies ^[34,62], however, they offer limited insight into the behavioural, perceptual, and contextual factors that influence real-world stair use, particularly in private domestic settings.

Survey-based and qualitative approaches can capture in depth stair fall and near-fall events that might not result in medical attention ^[75,76], as well as changes in intrinsic, extrinsic and behavioural characteristics. Near-falls, in particular, are rarely documented despite being more frequent than falls and strong predictors of future fall risk ^[77]. Surveys provide a way to explore stair-related risk remotely, particularly during periods such as the COVID-19 pandemic. Notably, to date there is a lack of qualitative research that specifically explores stair negotiation and stair safety within older adults' home environments. This highlights a critical gap in the literature. Understanding why individuals continue to use potentially hazardous stairs, how they perceive safety, and how emotional attachment to the home influences their behaviour requires methodologies that extend beyond biomechanical research alone. Addressing this gap is essential for the development of effective fall prevention strategies.

1.8. Purpose and outline of the thesis

The overarching aim of this thesis is to investigate stair fall risk among community-dwelling older and middle aged adults (50+ years) using a multi-method approach, with a particular focus on the effects of the COVID-19 pandemic. The long-term goal is to inform fall prevention strategies for potential future pandemics or lockdowns by improving the identification of at-risk individuals and understanding the specific environmental and behavioural factors that contribute to home stair falls. Greater awareness of these risks, particularly with older adults that live in socio-economically disadvantaged areas may support efforts to implement affordable and practical home adaptations that reduce fall incidence and support ageing in place.

To address this aim, three interconnected studies were conducted, each targeting a distinct aspect of stair fall risk but designed to build progressively upon one another. These studies draw on quantitative, qualitative, and biomechanical methods to build a comprehensive understanding of how environmental, psychological, and physical factors interact during stair negotiation in older adults.

Chapter 2 presents a national survey study that examined the incidence and characteristics of home stair falls during the COVID-19 pandemic, including changes in behaviour and environmental exposure.

Chapter 3 reports a mixed-methods study that explored older adults' lived experiences and perceptions of staircase safety in their homes, providing insights into how environmental features and behavioural adaptations influence perceived risk during lockdown. Participants were recruited from the initial survey cohort in Chapter 2.

Findings from Chapter 3 revealed gap between participants recognising the safety value of handrails, their actual behaviour, and the effective use. Therefore, **chapter 4** details a laboratory-based biomechanical investigation into how self-selected handrail use affects centre of mass (CoM) control and foot placement during stair descent, assessing key parameters associated with fall risk. Participants in Chapter 4 were drawn from those who took part in the home visits in Chapter 3, allowing for a more targeted biomechanical assessment based on real-world insights.

Chapter 5 synthesises the findings from all three studies, drawing theoretical and practical conclusions about stair safety in ageing populations. This chapter also outlines implications for fall prevention practice and offers recommendations for future research and policy development.

Together, the studies in this thesis aim to contribute to a more nuanced, context-specific understanding of home stair fall risk in older adults and provide a foundation for targeted interventions in both research and public health domains.

Qualitative methods were selected to complement biomechanical analysis by enabling an in-depth exploration of how older adults perceive, interpret, and adapt to stair-related risk within

their own home environments. While quantitative approaches are well suited to identifying biomechanical risk factors, they cannot fully capture the older adults experiences, decision-making processes, and contextual influences that shape stair use in everyday life or their stair fall experience. Semi-structured interviews allow participants to articulate their lived experiences of stair negotiation, including perceptions of safety, habitual behaviours, and emotional attachment to the home, which are essential to understanding stair fall risk.

This research adopts a pragmatic, mixed-methods perspective, recognising that stair fall risk is multifactorial and cannot be adequately understood through a single methodological lens. The integration of survey, interview, and biomechanical data enables a more comprehensive understanding of stair fall risk.

CHAPTER 2:

The effect of COVID-19 lockdown on home stair falls in older adults: An exploratory survey

The information presented in this chapter has been reported in the paper:

Wharton, E., O'Brien, T., Foster, R. J., Giebel, C., Shenton, J., Akpan, A., & Maganaris, C. (2025). The effect of COVID-19 lockdown on home stair falls in older adults: An exploratory survey. *BMC Public Health (under review)*

2.1. Abstract

Stair falls in older adults can have severe consequences for the faller, their carers, and health and social care services. The COVID-19 pandemic brought about national lockdowns, which may have impacted the occurrence of and outcomes from stair falls. Therefore, this study investigated the effect of the COVID-19 pandemic on stair falls in the home environment to help be better prepared for a potential future pandemic.

An online and telephone survey was conducted with UK residents aged ≥ 50 years (July - October 2021). The survey captured rates of stair falls in the home before (June 2019 – 23 March 2020) and during (23 March 2020 – October 2021) COVID-19 lockdown. Additional outcome measures included perceived activity levels, and Indices of Multiple Deprivation (IMD) quintile. Quintile '1' indicates the most disadvantaged neighbourhoods, with quintile '5' indicating the least disadvantaged neighbourhoods.

Home stair falls increased by 25% during COVID-19 lockdown. Ninety percent of stair fallers were in IMD quintiles 3 (20%, n = 4), 4 (30%, n = 6) and 5 (40%, n = 8) and 10% were in quintiles 1 (5%, n = 1) and 2 (5%, n = 1).

The survey revealed an increase in stair falls during the first COVID-19 pandemic lockdown period. This may be attributed to the increased exposure to the participants' stairs due to prolonged home confinement resulting from the lockdowns and restrictions. Age emerged as a key contributor to stair fall risk, with older adults experiencing more severe injuries. Additionally, feelings of loneliness and social isolation were associated with increased falls, emphasising the importance of addressing these issues in fall prevention strategies. The study highlighted the need for more extensive research to inform effective interventions and policies for preventing home stair falls in older adults, especially during future pandemics.

2.2. Introduction

Stair falls in older adults can have severe consequences for the faller, their carers, and health and social care services. In the United Kingdom (UK) alone, previous reports suggest that 550 – 575 deaths and 350,000 injuries result from falls on domestic staircases per year [4,78,79]. This could be an underestimate of the actual crisis as many minor falls are not documented and it has been estimated that the real figure of injuries may be up to five times greater [4]. These injuries cause distress, pain, injury, loss of confidence, loss of independence, and mortality [1], which also greatly affect family members and carers of the fallers [16(p. 201)]. Stair falls can have profound, long-lasting effects on the quality of life for the faller and the fall itself can often be preventable. Therefore, understanding the individual's risk factors, fall experiences, and the exact nature of the environmental hazard regarding stair falls is crucial for prevention, interventions, and rehabilitation.

The COVID-19 pandemic resulted in nationwide lockdowns across the UK on the 23rd of March 2020. This unprecedented health crisis forced individuals to self-isolate and stay at home for extended periods [63–65], only permitted to leave for essential purposes only, such as buying food or for medical reasons. These extended periods of home confinement may have heightened the risk of stair falls among older adults [63–65], as this increased exposure to home stairs amplifies the risk of falls and injuries beyond the usual levels. Adding to the complexity of stair falls and the pandemic, older adults residing in socio-economically disadvantaged areas are more likely to have chronic health conditions, such as Type 2 Diabetes and cardiovascular diseases [30,43], and stair climbing is a riskier task for these individuals [80,81]. This makes them particularly vulnerable to the adverse effects of enforced inactivity regarding COVID-19 lockdown [82,83], especially in the context of home-based stair falls [59]. Moreover, homes of older adults of socio-economically disadvantaged areas are more likely to be of poorer housing conditions [59], with stair falls being the main hazard [56]. This is only going to get worse with the ageing population increasing, the ongoing effects of COVID-19, and continued impact of inflation on NHS resources and healthcare system. Consequently, older adults from socio-economically disadvantaged areas may be more likely to have suffered a home stair falls during the COVID-19 pandemic.

During lockdown, several additional factors could have increased stair fall risk. Reduced physical activity and an increase in sedentary behaviour ^[67], coupled with social isolation ^[73] are a few potential contributors. Physical inactivity can lead to significant and rapid loss of muscle mass, insulin resistance, decreased aerobic capacity, fat deposition and low-grade systemic inflammation from just two days of inactivity ^[63]. Physical inactivity has also been qualitatively linked to faster deteriorations of dementia symptoms in older adults ^[64]. Additionally, increased feelings of social isolation and loneliness in older adults due to the COVID-19 lockdown has been recognised in research ^[73] and it's likely these feelings can impact stair falls ^[68–70], thus, further amplifying the likelihood of an individual experiencing a stair fall in their home during the COVID-19 lockdown.

The aforementioned factors may have contributed to an increased occurrence of home stair falls during the COVID-19 pandemic, potentially exacerbating pre-existing health disparities in socio-economically disadvantaged areas. Gaining a deeper understanding of these effects and interactions is crucial for generating insights and valuable lessons for future pandemics. Therefore, the aim of this study was to determine whether the COVID-19 pandemic increased stair falls in the home environment for older adults. We hypothesised that there would be a greater number of home stair falls during the first UK national COVID-19 lockdown.

2.3. Methods

2.3.1 Sampling and procedures

In this exploratory retrospective study, we recruited UK residents, aged ≥ 50 years, through opportunity sampling. Participant recruitment required substantial engagement due to the constraints imposed by the COVID-19 pandemic and the reliance on remote data collection. Recruitment was conducted through multiple channels, including community organisations, older adult fora, and mailing lists. In addition, approximately 100 older adults were contacted by telephone and 100 by email, with up to three contact attempts made per individual to maximise response rates. Where no response was received after three attempts, no further contact was made. This process was repeated across recruitment waves to ensure adequate sample size and representation. We also directly contacted people who were accessing regular

services, such as older adult fora (such as The Orrell Trust, Sefton Older Persons Forum, NIHR Applied Research Collaboration North West Coast Public Advisor Forum, and Women's Club Forum) and individuals who had previously engaged with stair falls research, largely by emailing/telephoning.

2.3.2. Survey variables

The survey questions ([Appendix A: Survey questions](#)) were co-developed by the research team (E.W., T.O., R.F., and C.G.), public advisors (J.S. and A.A.), older adult networks (Sefton Older People's Fora, Liverpool, UK) and informed by previous literature.

Participants were asked about their background characteristics (including age, gender, ethnicity, postcode, living situation, health, physical activity levels and employment). Physical activity was assessed using self-reported categorical items capturing baseline activity status and perceived change during the COVID-19 pandemic (Likert scale); question wording and response options were refined through patient and public involvement and piloting to ensure clarity and comprehension. Examples of common activities (e.g. walking, gardening, household tasks) were included to aid comprehension and promote consistency in responses ([Appendix A: Survey questions](#), p.g. 141 -142). Postcode data were collected to generate an Index of Multiple Deprivation (IMD) quintile ^[84]. The IMD is an index of neighbourhood deprivation generating one deprivation score for Income (22.5%), Employment (22.5%), Health Deprivation and Disability (13.5%), Education, Skills Training (13.5%), Crime (9.3%), Barriers to Housing and Services (9.3%), and Living Environment (9.3%) ^[85]. Quintile '1' indicates the most disadvantaged neighbourhoods, with quintile '5' indicating the least disadvantaged neighbourhoods.

Home stair fall(s) or near-fall(s) were recorded by asking if the participants experienced a fall within three time periods: (1) pre COVID-19 pandemic (July 2019 - 23rd March 2020); (2) during the UK COVID-19 lockdown and restrictions (23rd March 2020 - October 2021); and (3) post the UK lockdown and restrictions (12th April 2021 – October 2021). The survey defined a fall as an event (e.g. trip/slip/stumble) that results in a person losing their balance and coming to rest inadvertently on the ground, floor, step or other level ^[24]. A near-fall (sometimes referred to as a near-miss) was defined as an event (e.g. trip/slip/stumble/loss of balance) that would have resulted in a fall if that person had not managed to recover their balance, e.g. by using

an unplanned movement of their arms to catch themselves on a nearby wall or object, or stepping to prevent a fall. The survey design did not capture the total number of stairs falls or near-falls the participants experienced in the home environment. Rather, the survey captured if the participants had experienced at least one fall/near-fall on stairs in the home environment within the three time periods and if they had fallen in more than one time period.

Participants were also asked about: Injuries resulting from stair falls/near-falls, including fractures, head injuries, and concussions. The activities they were engaged in during the fall (e.g., carrying items, talking, moving too quickly). Their perceptions of the surrounding environment during the fall (e.g., poor lighting, step colour, glare). The direction of walking during the fall (ascent and/or descent). Influential factors regarding the fall (e.g., footwear, misjudgement of step location, clutter). A description of the staircase where the fall occurred (e.g., uneven surface, steep stairs, narrow staircase, worn carpet/flooring) and the participants' perception of staircase safety. For further information about the questions and structure of the survey please see the Appendix A.

Participants were asked to complete the Short Falls Efficacy Scale-International (FES-I) ^[86] to assess an individual's level of confidence in avoiding falls in various situations and concern about falling via 7-items on a 4-point Likert Scale. Individuals who score between 7-8 on the Short FES-I are typically considered to have a low concern about falling, while scores ranging from 9-13 indicate a moderate concern. Scores of 14-28 are generally associated with a high concern about falling.

2.3.3. Data collection

The survey was completed either online, as a paper-based survey, or via telephone with a research team member who entered the participant's responses into the online survey. Data collection took place between 2nd of July 2021 and the 31st of October 2021 after obtaining ethical approval (Ref: 21/SPS/050). Consent was obtained through an implied consent process, whereby participants were informed in the participant information sheet that completing the survey was voluntary. A consent statement was provided at the start of the survey, requiring participants to confirm their agreement via a tick box; those who did not

consent were screened out. All participants provided informed consent prior to taking part in the study.

2.3.4. Data analysis

Frequency analysis was used to compare the number of people who have fallen prior to the COVID-19 pandemic and after the first COVID-19 UK lockdown restrictions. The main results were presented as percentages of studied variables.

2.3.5. Patient and Public Involvement and Engagement

Patient and Public Involvement and Engagement (PPIE) was embedded throughout the development of the survey to ensure that the research ensure relevance to older adults and that the survey was accessible, suitable, and meaningful to the target population. Two Public Health Advisors (J.S and A.A) were recruited as members of the research team and were involved at all stages of the survey development, data processing, reporting, and dissemination. Their contributions included refining the focus and scope of the study, identifying and prioritising survey questions, advising on the wording and sequencing of questions, and determining an appropriate survey length to minimise participant burden. They also provided guidance on potential barriers to completing an online survey among older adults and supported the development of strategies to enhance accessibility and response rates, such as phone calls, in-person completion of the survey, and access to fora.

Additional public involvement was facilitated through collaboration with the Sefton Older Adults Forum and the NIHR Applied Research Collaboration North West Coast (ARC NWC) Public Advisor Forum. Members of the Sefton Older Adults Forum provided insight into stair falls, near-falls, and home safety, and contributed feedback on the clarity, relevance, and acceptability of proposed survey questions. The ARC NWC Public Advisor Forum was used to obtain focused feedback on early study concepts, specific survey items requiring wider public input, overall survey design, and supported participant recruitment.

PPIE contributors were actively involved in piloting the survey. This included piloting with the two Public Health Advisors, members of Together In Dementia Everyday (TIDE), and approximately ten members of the public. Feedback from the pilot phase informed revisions

to question wording, response options, and survey flow, and helped identify technical issues related to online completion. The comments from each round of piloting were reviewed and the survey items were adapted accordingly, and confirmed comprehension of revised questions from a lay perspective.

Several survey amendments were made directly in response to PPIE feedback. For example, the wording of questions relating to housing and living arrangements was simplified to improve clarity and relevance. The response options for the question “What best describes your current living situation?” were revised from more technical terminology (e.g. “community dwelling”) to plain language options (e.g. “living on your own/independently” and “living alone in retirement housing”), reflecting participants’ preferences and everyday language use. This ensured that questions were more easily understood and reduced the risk of misclassification.

Overall, PPIE played a central role in shaping the survey design, enhancing its accessibility, and ensuring that it reflected the lived experiences and priorities of older adults. This collaborative approach strengthened the validity and relevance of the data collected and supported inclusive participation during a period when face-to-face research was not feasible.

2.4. Results

2.4.1. Demographic characteristics

A total of 180 survey responses (153 online survey, 21 via telephone, 6 paper-based survey) were received. Most participants completed the survey online (93.3%). Sixteen responses were removed from the results (13 duplicates and 3 unidentifiable postcodes), leaving 164 participants for data analysis.

The participants were predominately female (76%) and from a White ethnic background (96%), lived with other(s) (66%), and were retired (66%), with more participants living in less disadvantaged (IMD Quintiles 3, 4, and 5) neighbourhoods. A large proportion of the participants owned their homes outright (68%), had existing medical conditions or long-term illnesses (63%), and were in the age ranges of 70 – 79 years (43%). Table 2.1 shows all demographic characteristics of the participants.

Table 2.1. Demographic and health characteristics of participants by stair fall status.

	Non Home Stair Fallers (n = 84)	Home Stair Fallers (n = 20)	Near-Fallers on Home Stairs (n = 11)
<i>N(%)</i>			
Gender			
Female	60 (71%)	17 (85%)	9 (82%)
Male	24 (29%)	3 (15%)	2 (18%)
Ethnicity			
White	79 (94%)	20 (100%)	11 (100%)
People from Ethnic Minority Backgrounds	5 (6%)	0 (0%)	0 (0%)
Age			
50 – 59	12 (14%)	5 (25%)	3 (27%)
60 – 69	25 (30%)	2 (10%)	5 (45%)
70 – 79	35 (42%)	9 (45%)	3 (27%)
80 +	12 (14%)	4 (20%)	0 (0%)
IMD quintiles			
1 (most deprived)	15 (18%)	1 (5%)	2 (18%)
2	12 (14%)	1 (5%)	1 (9%)
3	21 (25%)	8 (40%)	5 (45%)
4	21 (25%)	6 (30%)	2 (18%)
5	15 (18%)	4 (20%)	1 (9%)
Living situation			
Living alone	22 (26%)	10 (50%)	2 (18%)
Living with someone	62 (74%)	10 (50%)	9 (82%)
Occupation			
Full-time	13 (15%)	3 (15%)	2 (18%)
Part-time	10 (12%)	0 (0%)	1 (9%)
Volunteer	4 (5%)	2 (10%)	1 (9%)
Retired	57 (68%)	14 (70%)	7 (64%)
Prefer not to say	0 (0%)	1 (5%)	0 (0%)
Other	0 (0%)	0 (0%)	0 (0%)

Home ownership

Owned outright	54 (64%)	14 (70%)	7 (64%)
Owned with a mortgage/loan	17 (20%)	4 (20%)	4 (36%)
Shared ownership/shared equity loan	1 (1%)	0 (0%)	0 (0%)
Family/friends home	1 (1%)	0 (0%)	0 (0%)
Rented	8 (10%)	1 (5%)	0 (0%)
Temporary accommodation	0 (0%)	0 (0%)	0 (0%)
Prefer not to say	1 (1%)	1 (5%)	0 (0%)
Other	2 (2%)	0 (0%)	0 (0%)

Existing medical conditions or long-term illnesses

51 (61%)	13 (65%)	7 (64%)
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COVID-19 Physical Activity Levels

1. Significantly less physically active	14 (17%)	1 (5%)	4 (36%)
2. Less physically active	25 (30%)	7 (35%)	2 (18%)
3. No change in my physical activity level	25 (30%)	7 (35%)	1 (9%)
4. More physically active	18 (21%)	5 (25%)	4 (36%)
5. Significantly more physically active	2 (2%)	0 (0%)	0 (0%)

Mean (SD), (range)

Short FES-I (possible range 7 - 28) 8.9 (2.5), (7 -22) 13 (4.4), (8 – 22) 9.9 (4.2), (7 – 22)

^aHigher scored on the Short FES-I indicate higher concerns about fallings (minimum 7, no concern about falling to maximum 28, severe concern about falling). IMD Quintile 1 indicates the most disadvantaged neighbourhoods and Quintile five the least disadvantaged neighbourhoods. Abbreviations: IMD (Index of Multiple Deprivation); Short FES-I (The Short Falls Efficacy Scale International)

2.4.2. Fallers and near-fallers on home stairs

The majority of all stair falls and near-falls were experienced inside the participants home (70%) such as home and apartment stairs, and garden steps. Twenty participants experienced at least one home stair fall (one positive answer in one of the three defined time periods), and 11 participants experienced at least one near-fall on home stairs.

For the three time periods studied, the survey showed a 25% increase (+3 participants) in the number of participants who experienced a fall on their home stairs since the first COVID-19 lockdown. Since the lockdown restrictions eased (post-UK lockdown) we saw a decrease of 46% (-7 participants) in home stair fallers. The survey showed no increase in the number of participants who experienced a near-fall on their home stairs since the first COVID-19 lockdown. Ninety percent of stair fallers resided in areas with IMD quintiles 3 (20%, n = 4), 4 (30%, n = 6) and 5 (40%, n = 8) and 10% were in quintiles 1 (5%, n = 1) and 2 (5%, n = 1).

As shown in Table 2.1, patterns of physical activity change during the COVID-19 lockdown differed across stair fall outcome groups. Importantly, within participants who experienced a home stair fall, 40% reported they were overall less physically active (5% 'significantly less physically active' and 35% 'less physically active'), 35% reported no change in physical activity levels, and 25% reported being overall more physically active (25% 'more physically active' and 0% significantly more physically active') during COVID-19 lockdown (23rd March – 12th April). Similarly, 55% of near-fallers on home stairs reported they were less physically active, 9% reported no change, and 36% reported being more physically active during the COVID-19 pandemic. Injury severity for home stair fallers aged 80 years above was 50% greater than home stair fallers aged 50 – 59 years, with injuries including fractures and broken bones. Additionally, half of the individuals who experienced stair falls at home reported living alone, representing a 19% increase when compared to the entire group of 164 respondents (31%).

2.4.3. Perceptions of home stair safety

Ninety percent of the stair fallers perceived their stairs at home to be safe. When asked about the description of their stairs, 25% of home stair fallers stated they struggled to fit most of their foot on their steps, 20% said their stairs were steep, and 5% had uneven step/stair surface, or worn carpet/flooring. Figure 2.1, and figure 2.2. shows there was a preponderance of home stair fallers who reported they misjudged the step/stair edge location (65%), were carrying an item (55%), and descending the stairs (65%) when inquired about the stair fall.

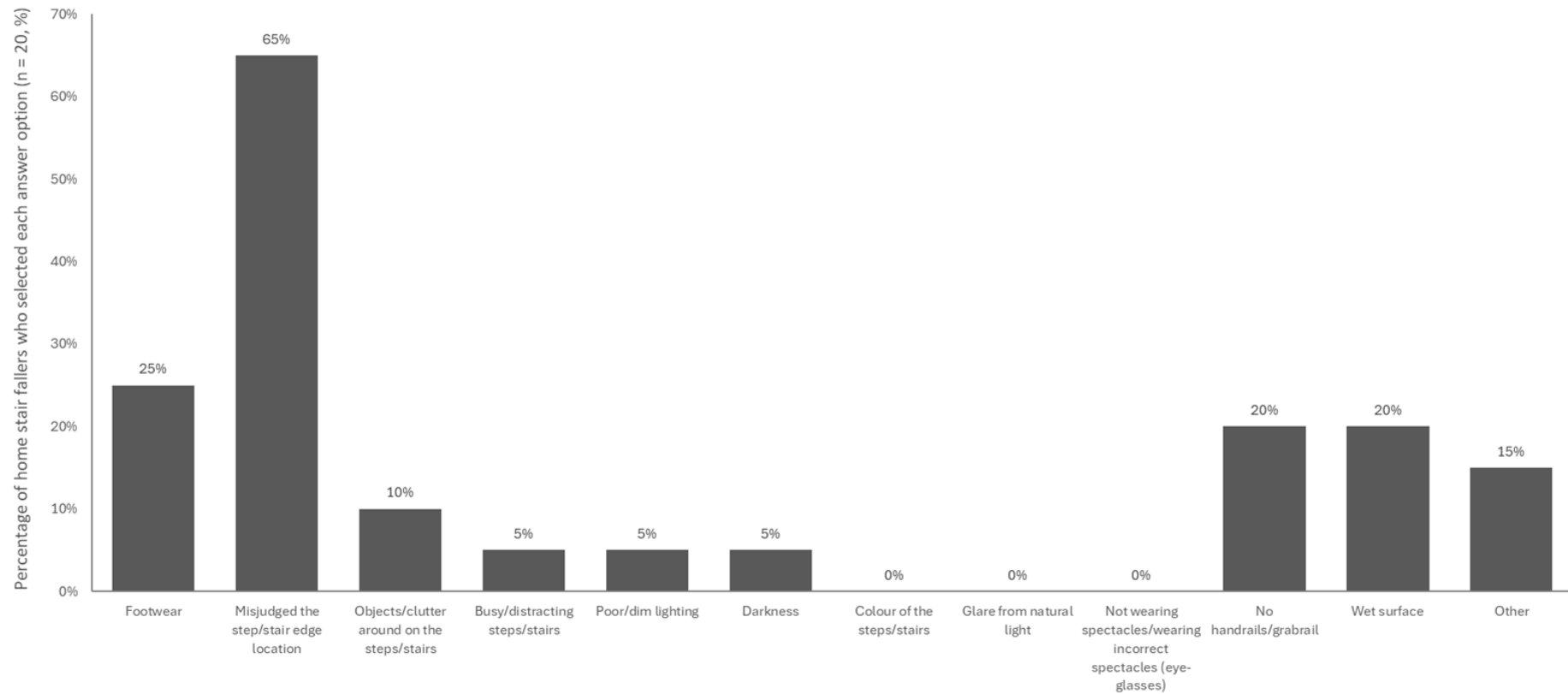


Figure 2.1. Contributing factors to home stair falls

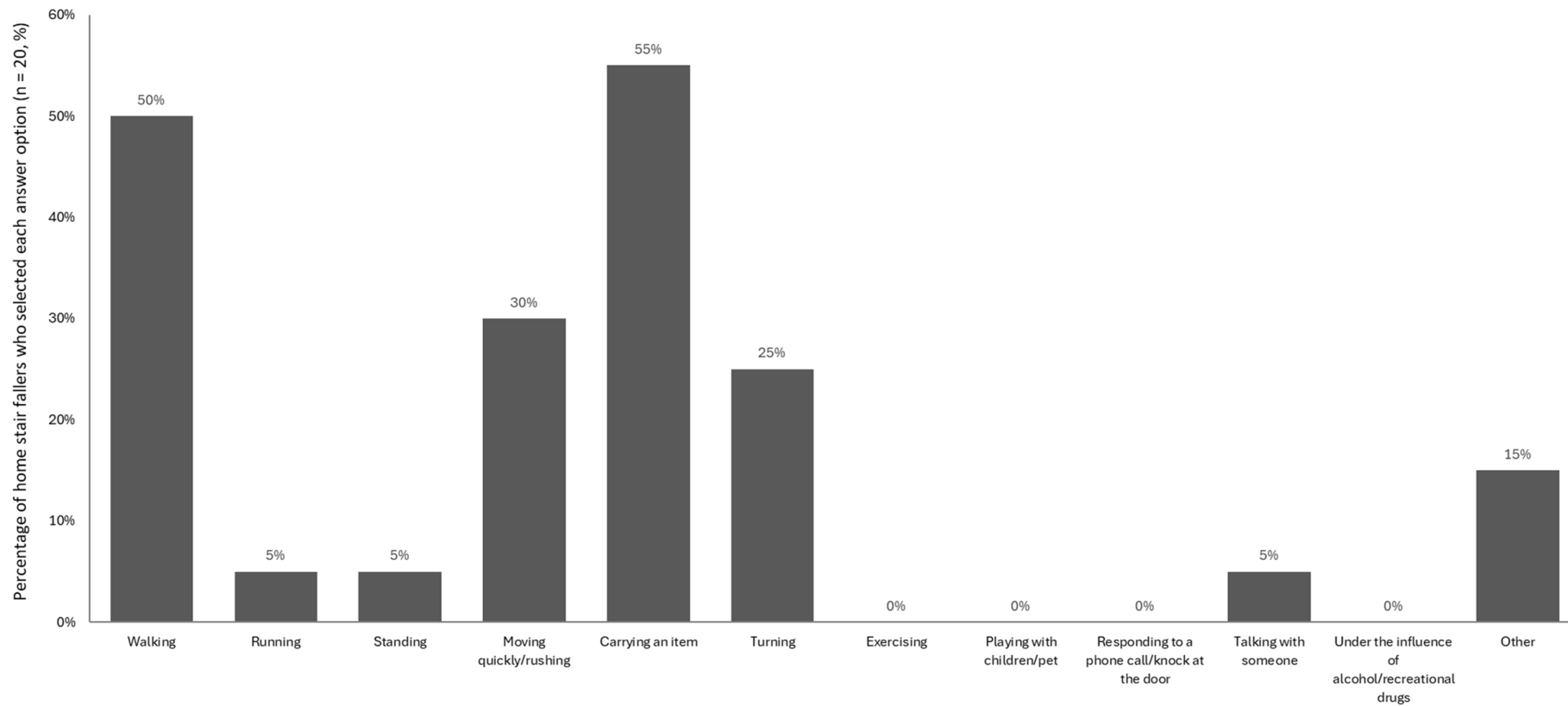


Figure 2.2 Activity/activities that were occurring during the home stair fall(s)

2.5. Discussion

This study is the first to specifically explore the extent to which the COVID-19 pandemic may have been linked to stair falls in older adults. We found an increase in home stair falls and reduced physical activity during the COVID-19 UK lockdown. Older adults living alone were more likely to experience a home stair fall, and increased age was associated with greater injury severity.

We hypothesised that there would be a greater number of older adults who experienced stair falls/near-falls in the home due to the COVID-19 pandemic. Despite the small sample size, the survey supported our hypothesis as we found an increase in home stair falls during lockdown and a decrease since the restrictions eased (post UK lockdown). This may be attributed to the increased exposure to the participants' stairs due to prolonged home confinement resulting from the lockdowns and restrictions [63–65]. An additional underlying factor may be the reduced physical activity levels during lockdown among participants who experienced home stair falls or near-falls, which is known to affect fall risk in older adults [16,30,87–89]. While over half of all the participants (53%) reported no change and an increase in physical activity during the COVID-19 period combined, reduced activity was more prevalent among participants who experienced home stair falls or near-falls when compared to increased physical activity alone (42% less physically active compared to 29% more physically active). This suggests that changes in physical activity may be a contributing factor for some individuals, rather than an overall stair fall risk across the wider population. Reduced physical activity due to COVID-19 lockdowns for several weeks to months can result in physical deconditioning and may have caused significant and rapid loss of muscle mass [63]. Functional deterioration can occur within two days of inactivity and is caused by muscle deconditioning, insulin resistance, decreased aerobic capacity, fat deposition and low-grade systemic inflammation [63]. However, we acknowledge that the present data do not directly establish a link between increased exposure to risk and a higher likelihood of a home stair fall, neither do the results confirm physical deconditioning as the singular cause for the rise in home stair falls during the lockdown. Nevertheless, older adults need to be more aware of their heightened vulnerability to such incidents during home confinement. The potential relationship should impact the need for stair fall risk awareness, alongside supporting physical activity interventions during future pandemic events to prevent stair falls in older adults [30].

Age is one of the factors that can contribute to frailty and is associated with an increased stair fall risk, which can also be affected by other factors such as chronic illnesses, cognitive impairment, and physical inactivity

[30]. Consistent with current literature, we also showed that age is one of the key factors associated with experiencing falls on stairs [30,53,90,91]. Additionally, for individuals who experienced a stair fall in their home, we found that injury severity increased with age. This finding aligns with previous research indicating that older adults face the greatest risk of death or serious injury (e.g., broken bones or concussions) from falls, a risk that escalates as they age [30,90].

Previous studies have shown that older adults who report feelings of loneliness and social exclusion are more likely to experience falls [71-73]. This may be due to several factors such as reduced physical activity, increased depression and impaired balance [71-73]. Out of the 164 survey respondents, 31% reported living on their own, and this percentage was higher among those who had experienced a stair fall in their home environment, with 50% of home stair fallers reporting living on their own. This could be the result of individuals who live on their own being more likely to feel lonely and socially isolated especially during the COVID-19 pandemic [73]. Given the evidence linking loneliness, social isolation, and fall risk, particularly due to the heightened effects of lockdown and social distancing, it is necessary to consider interventions and support systems aimed at reducing social isolation, and the occurrence and severity of stair falls among older adults [73], ultimately contributing to enhanced safety and well-being in this demographic. An additional factor that may influence stair fall risk is long-term familiarity with the home environment. Many older adults remain in the same home for extended periods and results from the survey showed majority owned their home outright, which might have promoted improved habitual stair negotiation strategies and increased perceived safety. However, duration of residence and stair familiarity were not measured in the survey and therefore could not be evaluated quantitatively. Older adults emotional attachment to the home and perceived safety of familiar staircases was further explored in Study 2. This study highlights the multifaceted nature of stair fall risks among older adults.

We explored whether socio-economically disadvantaged areas represented a higher rate of experiencing a home stair fall. However, with only 20 participants who experienced a home stair fall (12%) out of the total sample of 164, the survey did not have enough distribution across all IMD to test this association through statistical analysis. Nevertheless, the frequency analysis suggested that people living in less deprived areas experienced more home stair falls. This finding is unexpected and contradicts previous studies that indicate older adults from socio-economically disadvantaged neighbourhoods are more susceptible to general falls [30]. Stair falls are complex and difficult to predict as they are determined by multiple changing factors, including cognitive, perceptual, psychological, physical, as well as biomechanical parameters [92], therefore

may not have a strong association with IMD. In addition, it might be that behavioural aspects of stair safety outweigh the effects of stair design. For example, employing cautious stepping technique could offset reduced functional capabilities, health inequalities, and/or inadequate safety standards ^[62]. It should also be considered that, although the IMD is a valuable tool for assessing overall deprivation at a neighbourhood level, it may not capture the specific nuances of housing quality and living conditions that can compromise stair safety. Although the design of stairs will differ, they may not necessarily be safer. For example, a house with an IMD Quintile of 5, might have unaddressed fall hazards such as poorly designed or absent handrails, stairs that are too steep, objects left on steps, and/or poor lighting ^[3]. Therefore, relying on the IMD to assess housing conditions may have led to misleading links between neighbourhood deprivation and stair falls.

Nonetheless, this finding may be related to a demographic limitation of the survey, as most participants were from a White ethnic background and living in less deprived areas (IMD Quintiles 3, 4, and 5). This population sample may not accurately represent diverse communities for whom solutions may be less effective, and perpetuating health disparities. Inclusivity and representation in studies is important for understanding and addressing the needs of diverse communities and socio-economically disadvantaged areas ^[65,93]. In addition, there may have been older adults without internet access, and potentially from deprived areas, more isolated and at a higher risk for a stair fall through the COVID-19 pandemic ^[94]. Although we actively contacted those older adults via phone and in person when presenting at fora, only a few engaged over the phone. We were also limited to the number of face-to-face fora that we could attend due to COVID-19 restrictions. This suggests that there may have been home stair fallers in socio-economically disadvantaged areas who were not captured because they did not participate in the survey due to digital exclusion. Future research needs to investigate experiences of older adults from socio-economically disadvantaged areas and those from minority ethnic groups by enabling more diverse recruitment, as these are potentially one of the most impacted groups by lockdown restrictions such as those during the COVID-19 pandemic ^[65,93].

Another limitation of this study is that physical activity was assessed using self-reported Likert scale rather than objective monitoring. Although the physical activity questions were refined through patient and public involvement and piloting, interviewing or psychometric validation of the categories was not undertaken. As a result, responses reflect participants' perceived changes in activity rather than quantified changes in activity volume or intensity, and interpretations may have varied slightly between individuals. Nevertheless, the use of simple, relative categories aligned with the exploratory nature of the study and was appropriate

for remote data collection during the COVID-19 pandemic. Additionally, the survey did not capture information on informal care provision or family support related to stair safety (e.g. assistance with clearing stairs, monitoring behaviour, or environmental modifications). Although participants were asked whether they received help completing the survey, this item was intended to assess response support rather than ongoing care arrangements or fall risk mitigation. Consequently, the potential protective role of family or caregiver involvement on stair fall risk could not be examined, thus further exploration into this is needed.

Despite there being more than double the number of stair falls in the home environment compared to falls outside the home (e.g., shopping stairs, beach steps, park steps, public areas) in this study, the majority (90%) of home stair fallers perceived their home stairs as safe. When probed about the description of their stairs, home stair fallers stated that they struggled to fit most of their foot on their steps (25%), their stairs were steep (20%), they had uneven step/stair surface (5%) and worn carpet/flooring (5%). This finding suggests that individuals who experienced a home stair fall may have lacked the knowledge to identify hazards on their stairs and features that could make their staircase safer. Allowing older adults to have access to educational interventions is crucial for fall prevention ^[30]. Montero-Odasso et al. (2022) recommends the criteria for a quality home-fall hazard intervention should include increasing the faller and their carer's ability to identify functions and hazards to prioritise actions (such as removing/adapting hazards and modifying risky behaviours), with the knowledge of how to access support for these adaptations and modifications. Moreover, assessments and educational interventions should consider socio-economically disadvantaged areas and different demographics such as cultural differences as these could differ from individuals ^[30]. The cost of housing and stair adaptations could be counterbalanced by the reduction in hospital admissions and increase in the number of available hospital bed for further/other admissions ^[95]. Additionally, establishing suitable housing is expected to impact on other health, social and educational outcomes overall helping improve health inequalities ^[95].

2.6. Conclusion

This study highlights several factors which could result in an older adult experiencing a stair fall in their home environment. The survey revealed that the self-isolation and restrictions led to a rise in stair falls among older adults. However, further research is needed to address the limitations, establish the specific circumstances under which the home stair falls occurred and assess the impact of poor housing conditions, specifically stair quality on these falls. Understanding living conditions and stair fall experiences will help

further identify the individuals at risk. Additionally knowing the exact nature of the hazard will allow for implementation of effective targeted interventions or community-based fall prevention programs to prevent home stair falls in older adults for future pandemics.

2.7. Reflection of methods

Findings from Chapter 2 demonstrated the value of survey-based methods for exploring stair fall risk during the COVID-19 lockdown; however, they also revealed methodological limitations. While the survey identified patterns of stair falls, near-falls, and changes in physical activity, it was unable to capture contextual factors such as environmental management of stairs, long-term familiarity with the home environment, or how older adults perceive and adapt to stair-related risk in daily life.

These limitations directly informed the design of Chapter 3, which employed qualitative semi-structured interviews alongside objective home stair assessments to explore stair safety within real-world environments. This approach enabled a more nuanced exploration of perceived stair fall risk and actual stair safety, behavioural adaptations following falls or near-falls, and the implication of remaining in a familiar home environment. By adopting a mixed-methods design, Chapter 3 was able to address questions that could not be answered through survey data alone, thereby strengthening the interpretation of stair fall risk in older adults.

Importantly, Chapter 3 was informed by findings from Chapter 2, with survey responses used to shape and personalise interview questions. Participants were asked to reflect on their survey-reported experiences, including feelings during lockdown and home confinement (e.g. living alone or living with others), self-reported changes in physical activity (e.g. being “more physically active during lockdown”), and stair fall or near-fall experiences. For example, participants were invited to elaborate on why they believed their physical activity levels had changed during lockdown and how this may have influenced stair use and fall risk within the home. Participants were also asked to reflect on changes over time, including whether they had experienced any new stair falls or near-falls since completing the survey, and whether they perceived their risk to have increased during lockdown. Additionally, perceptions of stair safety reported in the survey (e.g. describing home stairs as “safe” or “unsafe”) were explored during interviews, with participants asked to identify specific environmental, behavioural, or individual factors that contributed to these perceptions.

CHAPTER 3:

"It was probably because of lockdown that I fell": Older adults' experiences of independent living and home stair falls during COVID-19 lockdown

The information presented in this chapter has been reported in the paper:

Wharton, E., O'Brien, T., Foster, R. J., Giebel, C., Shenton, J., Akpan, A., Mills, A., Roys, M., & Maganaris, C. (2025). "I don't know if it makes a difference to safety?" perception vs actuality: A mixed-methods study on older adults' experiences of home stair falls revealed during COVID-19 lockdown. *PLOS ONE*, 20(6), e0326850. <https://doi.org/10.1371/journal.pone.0326850>

3.1. Abstract

In the UK, stair falls in older adults' homes cause up to 575 deaths and 350,000 injuries annually, costing the NHS £435 million. The stair falls may be related to hazards such as poorly designed/absent handrails, too steep/narrow stairs, poor step surface (e.g., loose carpets), and poor lighting. Our study aimed to understand older adults' experiences of independent living and home stair falls during the first COVID-19 lockdown, and shed light on older adults' physical staircase dimensions that influence stair fall risks in relation to British Standard BS5395-1.

A mixed-methods approach was employed, conducting semi-structured interviews alongside quantitative home stair assessments with 22 participants aged ≥ 60 years. The stair assessments captured the physical dimensions (i.e., measurements of pitch, rise and goings) of their home stairs, and if they perceived their stairs safe to negotiate.

We identified four overarching themes common across older people living independently: effects of lockdown on daily living during the COVID-19 pandemic; stair-related accidents and perceived causes; fall preventative measures and safety awareness; and attitudes towards ageing and care services. Although all of the participants perceived their stairs to be safe, nearly half of participants' staircases (40%) did not meet the British Standards for pitch, rise and going.

While the COVID-19 lockdown provided a unique context for exploring fall risk and stair safety, our findings highlight broader, ongoing issues. Despite emotional attachment to their homes, many lacked staircases that meet current British Standards, highlighting a need for targeted interventions to mitigate environmental hazards. Additionally, financial constraints and education further complicate efforts to enhance home safety. Discrepancies between perceived and objective safety assessments highlight the need for comprehensive care approaches and evidence-based home design guidelines, allowing for collaborative support for ageing in place. Bridging this gap is essential for reducing home stair falls.

3.2. Introduction

In the United Kingdom, over 57,000 older adults attend hospital Accident and Emergency (A&E) departments each year due to falling on steps and stairs at home, and almost 1,000 deaths occurring as a consequence [3]. While this may not immediately seem like a crisis in a nation of 67 million and over 11 million individuals over 65 (18.6% of the total population), it becomes an important issue when considering that falls are the second leading cause of accidental death among older adults. Stair falls can lead to a loss of independence, greater isolation and depression, reduced mobility, and increased morbidity and mortality [1]. Stair falls also have social impact due to the increased healthcare costs and demands on healthcare professionals. Unaddressed fall hazards in the home environment are estimated to cost the NHS in England £435 million [1]. Such unaddressed hazards may include poorly designed or absent handrails, stairs that are too steep and narrow, step surfaces or covering in poor condition, objects left on steps, and poor lighting [3]. Therefore, housing conditions, and specifically the staircase environment, pose a significant risk for stair falls [48]. Unfortunately, the scale of the problem is set to increase as the UK's older population continues to grow, alongside the UK possessing one of the oldest housing stocks in Europe [20,21]. Therefore, understanding the need for adaptations and improvements in the individual's staircase and surrounding environment is vital for the changing needs and abilities of an older population to live safely and independently [48,60].

On March 23rd 2020, the UK Government implemented a nationwide "lockdown" in response to the COVID-19 pandemic, including a prohibition on non-essential travel and interactions with individuals outside of one's household [96]. The increased exposure to home stairs during lockdowns and restrictive measures may have amplified the risk of falls and related injuries beyond the usual levels [60]. Moreover, lockdown increased social isolation, loneliness, ageism, sedentary behaviours, delayed essential medical treatment, and increased challenges in meeting basic needs (food shopping and/or cleaning the house) [63–65,97]. Older adults primary source of social contact often occurs outside of their homes, and especially those living alone, have been disproportionately affected by these measures [98,99]. Although studies linking stair falls and social isolation primarily use pre-COVID-19 data [71–73], these findings are particularly relevant during the pandemic, as lockdown and distancing measures likely heightened risks of loneliness, isolation, and falls [73].

Real world changes for maintaining the independence and quality of life for older adults requires an understanding of the connection between their perceptions of home safety, housing condition, and home stair falls during lockdown. Therefore, this study aimed to understand older adults' experiences of independent living and home stair falls during and after the COVID-19 pandemic. Additionally, the study

aimed to shed light on their perceptions regarding the safety of their staircases and whether these perceptions align with the staircase features and design that influence stair fall risks.

3.3. Methods

3.3.1. Study design

A nested mixed-methods design was used to investigate the studies aims. The study obtained ethical approval from the Liverpool John Moores University (LJMU) Ethics Committee (Ref No: 22/SPS/037) prior to study commencement.

3.3.2. Participants and recruitment

Twenty-two participants (9 stair-fallers, 1 near faller, and 12 non-fallers) aged ≥ 60 years agreed to a home visit to carry out stair assessments and semi-structured interviews, between September 2022 and February 2023. Consent was obtained either verbally or written at the time of the home visit (semi-structured interviews and stair assessments) and recorded in the interviewer's notes. The number of participants recruited were consistent with recommendations for semi-structured interview studies that aim to identify patterns across data ^[100].

Participants were recruited from a previous survey study presented in Chapter 2. The online and telephone survey was conducted with 164 UK residents aged ≥ 50 years between June and October 2021, to understand the extent to which COVID-19 lockdowns increased home stair falls. The survey included collecting participants postcodes to generate an Index of Multiple Deprivation (IMD) quintiles for socio-economic status and collecting the participants falls/near-falls experiences before (June 2019 - 23 March 2020) and during (23 March 2020 - October 2021) COVID-19 UK lockdown. The participants agreed for their contact details to be stored for the purpose of contacting them about future studies. Participants who had either reported experiencing a stair fall in their home environment, reported experiencing a stair near-fall in their home environment, and reported not having experienced a home stair fall were recruited. Participants volunteering to participate in the study were contacted via email or telephone by the primary researcher (E.W.) to inform them about the study's purpose, risks, benefits, and informed consent.

3.3.3. Data collection

The semi-structured interviews were conducted by the E.W. either by telephone, via videoconferencing or in the person's home according to the participant's preferences. The participant then chose a suitable time

for the researcher to conduct a stair assessment in their home. The majority of participants (95%) chose to conduct the semi-structured interviews and stair assessments in one home visits.

A semi-structured topic guide (Appendix B) was developed in co-operation with two public advisors (A.A. and J.S.) and older adults from Women's Club forum. The semi-structured interviews explored the participant's fall experiences and how the COVID-19 pandemic had affected the participant's activities, socialising, care routines, and details about how the fall occurred. Interviews lasted between 20 to 60 minutes (35.18 ± 9.71) and were recorded using an encrypted digital Dictaphone.

The stair assessment was conducted after the semi-structured interviews, using a protocol (Appendix C) that identified whether the participants' staircases met existing UK building regulations and practice standards for stair pitch, rise and going ^[55,101,102]. We captured the physical dimensions (i.e. pitch, rise and going) and visual appearance (i.e. handrails and lighting) of their staircase. To assess the visual appearance, we adapted the housing health and safety rating system (HHSRS) assessment ^[102] and a previously developed Stair Assessment Questionnaire (SAQ) by researcher M.R. The stair assessment required the participants to describe their staircase dimensions (i.e. steepness, narrowness, wear and tear), record their behaviour related to stair safety, such as their use of handrails, and if they perceived their stairs safe to negotiate. Photographs of stairs were taken.

We also collected background data on participant age, gender, ethnic background and postcode.

3.3.4. Equipment and measurements

To enhance measurement precision, a custom-made ruler (acrylic sheet) measuring 400 mm x 270 mm, marked with a scale on both long sides (Figure 3.1.), was utilised.

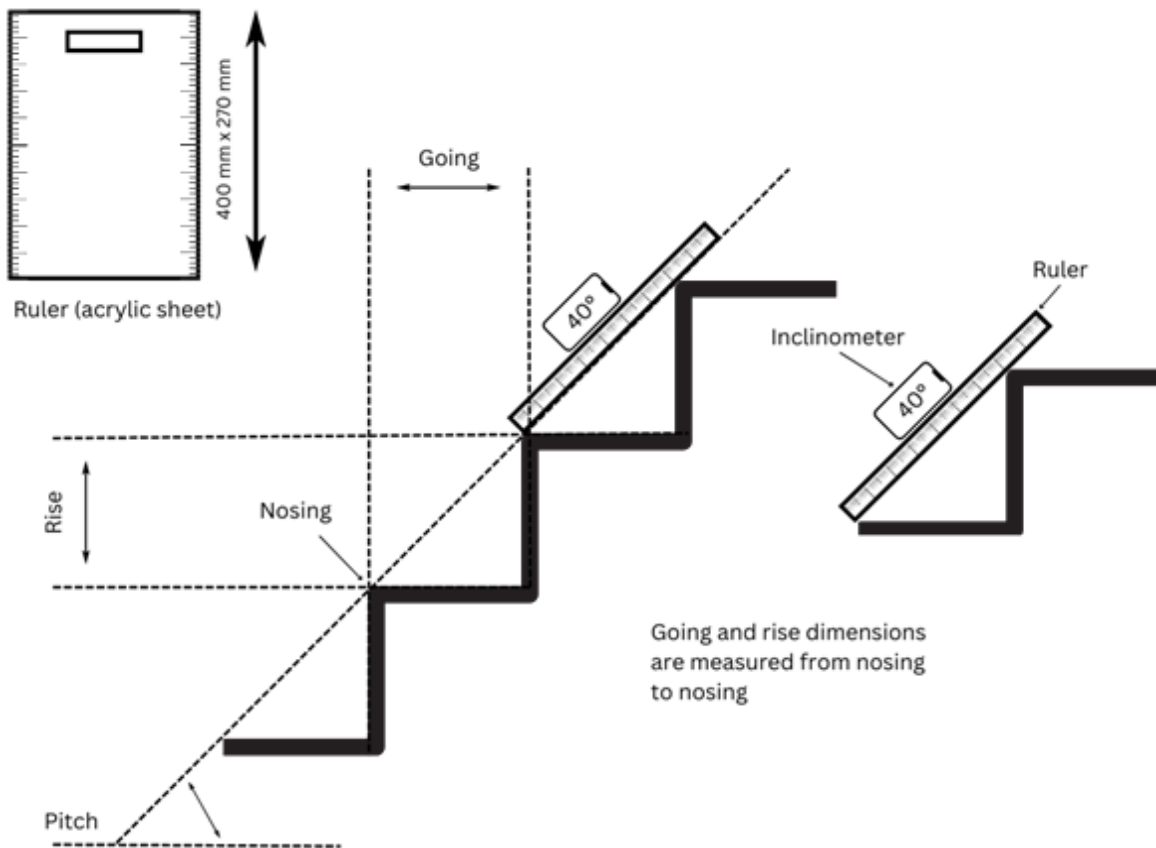


Figure 3.1. The equipment used for measuring stair dimensions. *The top left of figure 3.1. shows the custom-made ruler (acrylic sheet) that was utilised, measuring 400 mm x 270 mm, marked with a scale on both long sides. The middle part of figure 3.1. shows the rise, going, nosing, and pitch of a staircase. The right part of figure 3.1. shows the process of measuring the rise and going with the custom-made ruler.*

The bottom edge of the acrylic sheet was carefully aligned with the edge of the nosing, positioned close to the side of the step, to measure the length to the next nosing. An inclinometer was used to measure the angle of the acrylic sheet. This angle measurement provided the necessary data for determining the pitch of each step. Using the nosing-to-nosing length and inclination data the rise and going of each step was calculated using trigonometry. Table 3.1. provides example calculations for stair geometry, offering a basis for comparing against measured stair dimensions in participants' homes.

Table 3.1. Theoretical rise and going values calculated based on pitch angles and nosing-to-nosing distances.

Going (mm)						Rise (mm)					
Nosing-to-Nosing	Pitch (°)					Nosing-to-Nosing	Pitch (°)				
	40	40.5	41	41.5	42		40	40.5	41	41.5	42
280	214	213	211	210	208	280	180	182	184	186	187
285	218	217	215	213	212	285	183	185	187	189	191
290	222	221	219	217	216	290	186	188	190	192	194
295	226	224	223	221	219	295	190	192	194	195	197
300	230	228	226	225	223	300	193	195	197	199	201
305	234	232	230	228	227	305	196	198	200	202	204
310	237	236	234	232	230	310	199	201	203	205	207
315	241	240	238	236	234	315	202	205	207	209	211
320	245	243	242	240	238	320	206	208	210	212	214
325	249	247	245	243	242	325	209	211	213	215	217
330	253	251	249	247	245	330	212	214	216	219	221

3.3.5. Qualitative analysis

The semi-structured interviews were digitally audio-recorded and transcribed verbatim and imported into NVivo (QSR International Pty Ltd). The transcripts were anonymised and checked for accuracy. The data were analysed by using an inductive thematic approach ^[103] to extract meaningful insights from the interview data. The aim of this method was to explore and identify patterns, themes, and insights that emerged directly from the data, without being constrained by pre-existing theories or predetermined coding schemes.

The interview transcripts were thoroughly read to gain a comprehensive understanding of the data, immerse in the content and to identify initial impressions and ideas. After becoming familiar with the data, initial codes were generated to capture meaningful concepts, ideas, or patterns within the dataset. These codes were generated in an open-ended manner, allowing for a flexible and exploratory analysis. The initial codes were reviewed, refined, and organised into potential themes.

Throughout the coding process, E.W. engaged in regular meetings with C.G., an experienced qualitative researcher and co-author, to review and discuss the evolving codebooks. These discussions provided a valuable opportunity to validate and refine the coding scheme, ensuring the accuracy and consistency of the analysis. To ensure the trustworthiness of the analysis, a coding trial was conducted. During this trial, the data were systematically re-examined to confirm the overall representativeness of the identified

subthemes and themes. The iterative process of rereading and reviewing the data enhanced the reliability and credibility of the analysis.

The data were continuously reviewed and discussed (C.M., C.G., T.O., and R.J.F.) until a consensus was reached on the final themes and subthemes. This iterative review process facilitated the refinement and consolidation of codes, ensuring a comprehensive and coherent representation of the interview data.

3.3.6 Positionality and reflexivity

Qualitative research can be shaped by the positionality of the researcher and the relationships formed with participants. Reflexivity was therefore implemented to acknowledge how my (E.W) background, identity, and interactions with participants may have influenced data collection, interpretation, and analysis.

At the time of data collection, I had no personal experience of ageing-related care responsibilities and no lived experience of older family members, having grown up without grandparents. This position meant that I approached the participants' experiences without personal assumptions rooted in family caregiving or ageing within the home. While this lack of lived experience could be viewed as a limitation, it also supported an open and inquisitive stance, allowing participants to frame their experiences in their own terms rather than through presumed shared understanding.

I occupied a dual role during home visits: as an academic researcher conducting semi-structured interviews and objective stair assessments, and as a visitor entering a highly personal and emotionally significant space, the participant's home. This dynamic introduced potential power imbalances, particularly as I was measuring staircases and assessing compliance with British Standards, which may have been perceived as evaluative or judgmental. To mitigate this, care was taken to emphasise that the assessments were not inspections of participants' homes, but exploratory measures aimed at understanding broader environmental risk factors. Participants were reassured that no individual judgement would be made about their living arrangements or personal choices.

Data collection took place during the COVID-19 pandemic, a period marked by heightened isolation, anxiety, and bereavement among older adults. I engaged in informal conversation before and after interviews, shared cups of tea, and remained in participants' homes beyond the formal interview schedule when invited to do so. These interactions were not treated as extraneous to the research process but as part of relationship-building that helped participants feel comfortable, respected, and heard. In several instances,

participants disclosed sensitive experiences, including the loss of spouses or family members during the pandemic, discussions about mortality, and fears related to ageing and independence. These moments required emotional attentiveness and ethical sensitivity, recognising the emotional labour involved in both participation and data collection. Additionally, my position as a younger female academic may also have influenced participants' willingness to explain concepts in greater detail, particularly around long-term familiarity with stairs, adaptations made over time, and attitudes towards ageing in place. Rather than assuming shared knowledge, participants often adopted an explanatory role, which enhanced depth and clarity in the data.

While this relational approach may have encouraged richer, more reflective accounts, it also carried the risk of participants framing their responses in ways they perceived as socially desirable or protective of their homes. Reflexive notes, through voice notes were therefore maintained following each visit to document my impressions, emotional responses, and potential influences on the interaction. These voice notes were revisited during analysis to support critical reflection and to distinguish participants' accounts from the researcher's interpretations. Furthermore, the involvement of supervisors and public advisors also provided a reflective counterbalance to my involvement with participants. Having spent extended time in participants' homes and developed rapport during interviews, I remained mindful of the potential for emotional proximity to influence interpretation. Analytic discussions therefore helped to challenge assumptions and ensure that interpretations were grounded in the data. This collaborative and reflexive process strengthened the trustworthiness of the findings by ensuring transparency, methodological rigour, and interpretive balance.

Additionally, consideration to my safety during home-based data collection was given. As a young female researcher conducting interviews and environmental assessments alone in participants' homes, a formal safety protocol was required and implemented. Prior to each visit, participants were contacted to confirm the interview time and who would be present in the home. On arrival, I notified supervisors (C.M., C.G., T.O., and R.J.F.) of the visit, shared live location details, and provided an estimated departure time. Supervisors were informed once the visit had ended and I had safely left the premises. These procedures were adopted to ensure my wellbeing and to support safe and ethical conduct of the data collection, particularly during periods of reduced public contact and heightened vulnerability associated with the COVID-19 pandemic.

3.3.7. Frequency analysis

The stair assessment element of the study employed a frequency analysis to examine the occurrence and distribution patterns of the variables under investigation.

3.3.8. Public involvement

Four public advisors (A.A., J.S., A.M., and R.M) formed part of the research team, and assisted with conceptualising the study, designing the interview guide, interpreting the findings and with dissemination. This ensured that the study and the interpretation and implications of findings were grounded in the lived experiences of those affected by stair falls and COVID-19 lockdown. This collaborative approach helped ensure that the research questions, methods, and interpretations were relevant, accessible, and reflective to participants' lived realities.

Public advisors were actively involved in reviewing early drafts of the semi-structured interview schedule. Initial drafts were highly structured and focused heavily on falls incidence, physical activity levels, and stair use frequency. Feedback from public advisors highlighted the importance of first allowing participants to describe their home environment and daily routines in their own words, before discussing falls or stair safety. As a result, the final interview guide was restructured to begin with broad, open-ended questions about the home, daily life, and experiences during lockdown, before progressing to more specific questions about stair falls, near-falls, and perceptions of stair safety.

Public advisors also emphasised the emotional sensitivity of discussing falls, ageing, bereavement, and isolation during the pandemic. This led to revisions in question wording to reduce clinical language, avoid assumptions of vulnerability, and allow participants to retain control over the depth of disclosure. For example, questions were reframed from "Describe your fall" to "Reflecting on the home stair fall or near-fall that's most memorable, could you talk me through what happened?", which participants found less confronting and more conversational.

The interview guide was further refined through three pilot interviews conducted with older adults. These trial runs helped assess question clarity, flow, timing, and emotional impact. Older adults feedback on the speed of which the questions were being delivered was vital, as it allowed me to self-reflect and slow down when asking the questions and get comfortable with silence, allowing participants to reflect before answering immediately. Additional feedback from pilot participants resulted in minor simplification of

prompts, and greater flexibility for probing individual experiences. Practical issues related to conducting interviews in participants' homes and completing stair assessments were also identified and addressed during this phase. This included meetings with an experienced housing researcher, and stair safety consultant (R.M.) to ensure accurate and efficient collection of stair measurement data. Additionally, shadowing occupational therapists on two occasions allowed me to observe how they engage, communicated with older adults, and assess their home environments. This experience informed both the interview approach and the conduct of home stair assessments, highlighting the challenges of real-world housing conditions and the importance of clear, respectful communication.

Public advisors were also involved in discussions around data interpretation, particularly in relation to discrepancies between perceived and objectively assessed stair safety, emotional attachment to the home, and attitudes towards ageing in place. Their input helped contextualise findings within everyday lived experience. Public advisors were reimbursed for their time in line with NIHR guidance.

3.4. Results

3.4.1. Demographic characteristics

Participants were all from a White ethnic background (100%), and were predominately female (68%), lived with other(s) (73%), and were retired (73%), with more participants living in less disadvantaged neighbourhoods, as measured by the IMD quintiles. A large proportion of the participants were from the North West region (82%), lived in urban major conurbation areas (77%), and owned their homes outright (91%). Additionally, the majority of participants had existing medical conditions or long-term illnesses (64%), and were in the age ranges of 70 - 79 years (55%). Characteristics of all participants are presented in Table 3.2.

Table 3.2. Demographic characteristics

	Non Home Stair Fallers (n = 12)	Home Stair Fallers and Near-Fallers on Home Stairs (n = 10)
<i>N(%)</i>		
Gender		
Female	7 (58%)	8 (80%)
Male	5 (42%)	2 (20%)
Ethnicity		
White	12 (100%)	10 (100%)
People from Ethnic Minority Backgrounds	0 (0%)	0 (0%)
Age		
60 – 69	2 (17%)	4 (40%)
70 – 79	7 (58%)	5 (50%)
80 +	3 (25%)	1 (10%)
IMD quintiles		
1 (most deprived)	3 (25%)	1 (10%)
2	1 (8%)	0 (0%)
3	3 (25%)	4 (40%)
4	3 (25%)	4 (40%)
5	3 (17%)	1 (10%)
Living situation		
Living alone	3 (25%)	3 (30%)
Living with someone	9 (75%)	7 (70%)
Occupation		
Full-time	1 (8%)	0 (0%)
Part-time	1 (8%)	0 (0%)
Volunteer	3 (25%)	1 (10%)
Retired	7 (58%)	9 (90%)
Home ownership		
Owned outright	11 (92%)	9 (90%)

Owned with a mortgage/loan	1 (8%)	1 (10%)
Existing medical conditions or long-term illnesses	7 (58%)	7 (70%)
COVID-19 Physical Activity Levels		
1. Significantly less physically active	0 (0%)	3 (30%)
2. Less physically active	3 (25%)	3 (30%)
3. No change in my physical activity level	7 (58%)	3 (30%)
4. More physically active	2 (17%)	1 (10%)
5. Significantly more physically active	0 (0%)	0 (0%)

^aIMD Quintile 1 indicates the most disadvantaged neighbourhoods and Quintile five the least disadvantaged neighbourhoods.

3.4.2. Quantitative findings

During the home stair assessment, only 20% of stair fallers stated that they were struggling to fit most of their foot on the steps, and 30% acknowledged that their stairs were steep. All stair fallers perceived their stairs as entirely safe for negotiation. However, the stair dimensions and measurements showed that 45% of staircases did not meet the safety guidelines established by the British Standard BS5395-1, and 50% of these belonged to stair fallers.

Eight percent of stair fallers had turning stairs with quarter landings (90°/180° turn to a second flight), compared to 58% of non-fallers. Forty percent of stair fallers had patterned carpets compared to 25% of non-fallers, and 70% of stair fallers had a moveable item at the bottom of stairs compared to 30% of non-fallers. Additionally, 30% of stair fallers had items left on the steps compared to only 80% of non-fallers. Moreover, there was a difference in the use of handrails while descending stairs, with 55% of stair fallers stating that they do not use handrails compared to 45% of non-fallers (figure 3.2.).

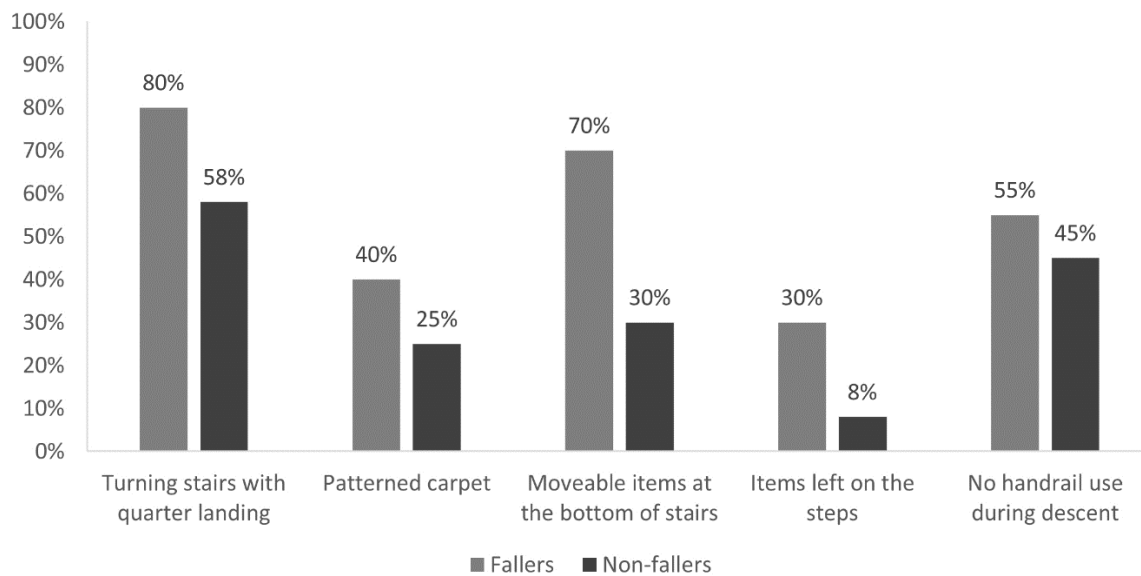


Figure 3.2. Potential staircase hazards identified during home assessments.

3.4.3. Qualitative findings

Using reflective thematic analysis, we identified four overarching themes: Effects of lockdown on daily living during the COVID-19 pandemic; Stair-related falls and perceived causes; Fall preventative measures and safety awareness; Attitudes towards ageing and care services. The main findings, including quotes from participants who had experienced a fall, a near fall on the home stairs, and who had not experienced a fall on their stairs are presented below.

Effects of lockdown on daily living during the COVID-19 pandemic

Impact of lockdown on physical activity and routine

Older adults articulated a notable shift in their daily routines during the COVID-19 lockdowns, resulting in a decline in physical activity and exercise. This transitioned towards a more sedentary lifestyle, influencing both their indoor and outdoor activities. For instance, when we asked participants to explain what activities they were doing during lockdowns, it was often met with a defeated answer as a participant expressed, they did “*Sod all.*” [Near Faller-Female5, aged 60-69], and another reported “*I felt as if I did less actual movement.*” [Stair Faller-Female10, aged 60-69]. Despite participants initial efforts to maintain outdoor physical activity, such activities diminished with the onset of adverse weather conditions and subsequent lockdowns.

“The first lockdown we were careful, we would just go out for an evening stroll when the weather was good...the winter times we just didn't go out... as I say we had our own in the house activities” [Stair Faller-Female7, aged 70-79].

Although this observation is not particularly unusual, the previous classes or activities that would get older adults out of the house during the colder and darker months were unavailable due to the lockdown restrictions. While some attempted to shift their exercise routines to online classes as a substitute, most participants faced challenges with this transition having long term affects.

“Immediately during lockdown, I was doing no exercise except for maybe an online class... COVID changed people's lifestyles, and that didn't ever get back to normal really” [Near Faller-Female5, aged 60-69].

The lack of physical activity during lockdowns contributed to overall physical well-being concerns among participants.

“I started to get symptoms of like a cystitis and I ended up having to have antibiotics. I was just having painful urinary tract infections because I was just sitting...I wasn't moving around enough” [Near Faller-Female5, aged 60 -69].

The lack of physical activity during lockdown contributed to overall physical well-being concerns among participants and while only a few participants reflected on falls, the ones who did commonly expressed uncertainty about the causes of these falls. A few participants often suggested a probable link between reduced exercise during lockdown and the occurrence of their falls.

“I've only ever had the one fall on the stairs...I've just no idea really what caused that fall. But it was probably because I have been getting less exercise in that year, because that was the year wasn't it, when people didn't do anything much” [Faller-Female19, aged 70-79].

This connection between sedentary behaviour and health concerns is an aspect of the broader challenges faced by older adults during the pandemic.

Emotional and social impact of lockdowns

With the rapid spread of the virus and limited understanding of its implications, older adults often found themselves dealing with the emotional and social repercussions of lockdowns and social distancing measures. Public transportation was regarded as a potential hotspot for virus transmission due to close quarters and shared spaces, which led to the participants' fearing leaving the house.

"During COVID, we were afraid to go anywhere, to do anything, and especially travel on public transport" [Non-faller_Female4, aged 70-79].

Furthermore, participants frequently articulated feelings of isolation, frustration, and a longing for social interactions. This frustration of the loss of social engagement due to lockdown led one participant to believe that's the reason they experienced a fall.

"It was probably because of lockdown that I fell because I was frustrated by not being able to go out and see people that I started doing a lot of projects around the house...I was manically doing things to displace discomfort and to distract myself." [Stair Faller-Female2, aged 70 -79].

This sentiment of frustration was echoed when the participants discussed how they coped with the discomfort of lockdown by immersing themselves in household projects as a distraction.

"I was trying to distract myself by doing something...I was doing things to the house, I was ordering stuff from Ikea...I bought myself a hammock for the garden because that's the other thing as well, there's two sides to it. You need to keep busy, but you might die soon, so you know I deserve a hammock" [Stair Faller-Female11, aged 60 – 69].

The emotional complexity of living through a lockdown was shown to be a challenge. Especially when the participants spoke about major life changes, such as the loss of a spouse, the absence of familiar gatherings, and the change in the dynamics of human interaction during lockdown.

"I did have patches of feeling upset and desperate. I wasn't used to being by myself because my husband had died less than a year before...So you know, it was it was quite hard." [Faller-Female2, aged 70-79]

Stair-related falls and perceived causes

Home environment hazards leading to falls

Participants identified various elements such as the presence of a stair lift, rugs on the floor, tight turns, and lighting as potential hazards contributing to incidents and falls. For instance, the lack of a continuous handrail (see figure 3.2.) and slippery surfaces were cited as factors in several falls.

"Because there's the stair lift at the bottom, and there is a turn in the stairs to the final two. There is a handrail, but it does not go around the corner. That's when it [the fall] happened." [Faller-Female2, aged 70-79].



Figure 3.2. Photograph of the location where the stair fall occurred (Faller-Female2, aged 70-79). *The image highlights the absence of a continuous handrail and the restricted corner space created by the stair lift installation, both of which may have contributed to the fall.*

"It was wet underfoot and it was a very slippery surface. I put one foot down and it went vroom, and I fell really heavily on my back. My back went onto the nose of the other steps and I got a terrible bruise there" [Faller-Male17, aged 70 – 79].

The participants' experiences underscored the importance of considering not only the visual aspects of safety features but also their tactile properties in assessing and addressing fall risks on stairs. Rugs, especially on wooden floors, were noted as trip hazards, and the tactile properties of safety features like handrails were highlighted as important for preventing accidents.

"I had two very beautiful Bokhara rugs on the wooden floor in my hall. So they were trip hazards, weren't they?... I did skate on them. If they hadn't been there, whether I would have still fallen and broke my ankle so much... and it's a tight right turn because of what I said about the very narrow hall" [Faller-Female2, aged 70-79].

"I've always had to sort of pull myself up with the banister. And I think they're a bit slippery and my right hand slid a bit." [Faller-Female19, aged 70-79].

However, most participants struggled to recall what their stairs look like or acknowledge their stairs as the reason for their falls and injuries.

"I can't even remember the type of stairs I have... I can't remember." [Faller-Female7, aged 70-79]

"Interviewer: Do you think your home stairs are safe? **Respondent:** Yes, I think I'm the element that probably isn't safe...I must stop running up and down stairs and jumping across them because you know, I can't do it anymore." [Faller-Female11, aged 60-69].

Unsafe behaviour leading to falls

Participants frequently discussed various situations where unsafe behaviours led to falls and injuries. Older adults commonly shared their experience in overestimating their abilities to carry out a task such as carrying numerous items while ascending or descending the stairs.

"I just grabbed a load of teabags and put them in my hand...My foot just slipped and I couldn't grab hold of the rail because I had teabags in it...I would've fallen anyway even if I hadn't had the teabags because I couldn't hold on to the banister with my broken hand." [Faller-Female20, aged 80+]

Additionally, participants often discussed incidents where wearing inappropriate footwear and misjudging the step edge location resulted in a stair fall.

"Oh it was slippers. Yeah, slipper and it was where you catch right on the edge of the step" [Near Faller-Female5, aged 60-69]

"I can't really tell you how it happened. I just missed it somehow. Do it every day and I tend to run up and down stairs and our stairs divide at the top, I tend to jump across. I mean it's all not recommended you know...I run up and down stairs. But there is this thing as you get older you use it or you lose it. So perhaps I should just run upstairs and not down stairs, perhaps that's... (Laughs) Mind you, I can fall upstairs as well can't I? It's like people are telling us to exercise all the time, but they don't tell us what sort of exercise, and they can't because it's very individual." [Faller-Female11, aged 60-69].

Moreover, incidents of rushing up and down stairs were commonly reported, often resulting in severe consequences. The narratives of these stair fallers reflected a mix of casual attitudes towards stair use, a lack of awareness about the risks involved, and the absence of a clear recollection of the fall adds an element of unpredictability to their behaviour.

"It was the oven timer and I thought I don't want my dinner to be scorched. I just ran down the stairs...I shot down the stairs, much to my detriment because that's when the accident happened" [Faller-Female2, aged 70-79]

These incidents illustrate how unsafe behaviours on stairs can lead to severe outcomes and underscore the importance of addressing behavioural risks to prevent stair-related accidents among older adults.

Consequences of falls and injuries on stairs

Older adults reported about the physical and emotional tolls of stair-related accidents. Participants frequently described feeling stiff, sore, and bruised after their falls, with some sustaining severe injuries such as cracked arms, bruised limbs, and haematomas.

"I did feel stiff and sore on my shoulder, and my knee that two years previously I'd had knee replacement, hurt my elbow and the side of my head...And then I managed to turn over onto my side and crawl to the bottom of the stairs and hold on to the railing to pull myself up and sat there for a while" [Faller-Female7, aged 70-79]

"I put my foot on the top step and I went up in the air and just absolutely smacked down...really cracked on my arm...And instead of landing flat on my coccyx, I landed on the one cheek really, in particular. I knew I'd really hurt myself... my backside was starting to burn and burn and burn, and swell up more and more...when I did go to hospital, to A&E, and the doctor saw me, he said, "It's a massive haematoma"" [Faller-Female21, aged 60-69]

Not only were these consequences echoed by the older adults who had experienced a stair fall, but we also found that an injury was sustained from an older adult who experienced a near fall.

"And then the next day I got bruises on my arm where I'd whacked against the banister" [Near Faller-Female5, aged 60-69]

The immediate reactions to these accidents were often marked by surprise, confusion, and fear, leading them to re-evaluate their actions and behaviours on stairs.

"Immediately after I was surprised. How has this happened? Why am I down here? Why am I on the floor? and then feeling stiff and sore. I sat there for a while and really it just surprised me." [Faller-Female7, aged 70-79]

The physical impact of these falls included mobility limitations and prolonged recovery periods, significantly affecting their daily lives and activities. In some cases, initial falls led to additional, more serious falls, resulting in extended hospital stays and further complications.

"I fell in the garden and broke my wrist...Then as my wrist was healing, as it was getting better...I slid down just backwards. I didn't fall backwards, I just slid down the stairs but I cracked my knee. I had two cracks in my fractured knee, two fractured ribs and of course I did hurt this wrist again...I was in hospital for 12 weeks waiting for this to heal, which took me right to Christmas Eve, I got home on Christmas Eve." [Faller-Female20, aged 80+]

In addition to physical consequences of falls, emotional responses were common among participants, reflecting self-blame and regret regarding the circumstances of their falls. Despite recognising the risks and emotional impact, some participants admitted to continuing unsafe behaviours after experiencing a fall, suggesting challenges in modifying behaviour.

"Just annoyed with myself, I was just angry with myself for being so stupid...I just felt angry with myself, really. I should've been a bit more careful." [Faller-Female20, aged 80+]

"I had just come up the stairs. I was trying to carry too much... I put a bag down and it obviously was the weight factor and I started falling to one side...that did actually frighten me, and it made me think, don't be stupid, you shouldn't be doing this, but it hasn't actually stopped me" [Faller-Female10, aged 60-69]

These findings present a multifaceted story of falls, injuries, emotional responses, and the lasting impact on the participant's mobility and independence.

Fall preventative measures and safety awareness

Use of handrails for stability

Participants widely reported that handrails played a pivotal role in their safety and stability when navigating stairs and often emphasised how they'd made conscious efforts in using the handrails to prevent falls. Some participants came to realise that they adapted their behaviour as they aged, becoming more inclined to use handrails for stair safety.

"I do tend to use the handrails now and I probably didn't before. But is that just a thing that you get nailed at?" [Non-faller-Female6, aged 70-79]

This observation highlights a common trend among older adults to prioritise safety measures such as handrail usage as they navigate stairs, reflecting a broader recognition of the importance of injury prevention and fall mitigation strategies with age. Additionally, the role of the handrail was not just seen as a supportive and preventative measure by older adults but actually helped them mitigate the impact of a fall.

"I slipped down two but I got hold of the banister...I always put my hand down the banister rail, just automatic run my hand down the banister rail." [Near Faller-Female5, aged 60-69]

The willingness of older adults to adapt and utilise handrails when feeling unsteady was captured by most respondents. Despite varying levels of autonomy in using handrails, participants actively sought support from them to ensure a sense of safety during stair navigation.

"Sometimes I'm aware that I don't feel safe, and I'll grab the rail or touch the wall to make sure that I'm feeling safe." [Faller-Female10, aged 60-69]

Caution and awareness for non-fallers

The majority of participants who did not experience a stair fall reported on their conscious efforts and awareness of potential risks and hazards when using the stairs, as well as their proactive measures to ensure safety.

"I've learned the two most dangerous places in the home is getting in and out of the bathtub to have a shower...and the stairs. So now I am aware of the stairs" [Non-faller-Male3, aged 70-79]

Respondents often emphasised their increased level of concern and adaptive behaviours to reduce the potential for accidents, particularly when carrying items up or down the stairs. The consistent mention of being more "cautious" among all non-faller participants indicates a shared recognition of the potential risks associated with multitasking while on the stairs.

"I be more cautious if I was carrying something down like if I'm bringing the laundry basket down" [Non-faller-Female5, aged 60-69]

Additionally, participants discussed how dim lighting affected their ability to navigate the stairs safely.

"The landing light is one of these ones an Energy Saver ones. So it's pretty dim...I find you when you put it on, you're just hanging around and you could be up there by the time it's lit up probably." [Non-faller-Male8, aged 70-79]

Physical health and fitness as factors in preventing falls on stairs

Older adults highlighted the role of physical health and fitness in preventing accidents on stairs. They often suggested that the older adults who are physically fit may find it easier to maintain balance and be more stable when using stairs, potentially reducing the risk of falls and accidents.

"I suppose because I'm fairly fit. So I was able to just grab it, we have a big banister rail... I've done Yoga and Pilates so my balance is better and I was able to just regain balance, that and my hands on the banister rail and being quite fit enough to grab hold of it" [Near Faller-Female5, aged 60-69]

Participants who engaged in regular exercise, such as yoga, Pilates, or running, reported better balance and quicker reactions to potential hazards, attributing their fitness to enhanced stability and accident prevention. This was shown by one of the older adults (Non-faller-Male12, aged 70-79) who had experienced a stair fall in his previous home several years ago.

"I fell onto the top part and rolled over, which as a runner you learn to do because you don't and a half get smacked when you hit the curb as a runner. So you start learning how to do the roll. You get scratched to death but it's saves you a lot of grief" [Non-faller-Male12, aged 70-79].

While the majority of participants highlighted the importance of physical fitness, respondents who had experienced a stair fall acknowledged the potential impact of underlying health conditions, on stair safety. The older adults who maintained good physical fitness tended to feel more confident and secure when using stairs, while those with underlying health conditions were more aware of the potential risks and took preventive measures to address them.

“I also have Type 2 Diabetes and I noticed it particularly in my feet more than anywhere... I go and have a massage every fortnight on my feet...So I am very conscious... And that makes me aware that I can fall down stairs”. [Faller-Female10, aged 60-69]

This reflects a broader awareness among older adults of the potential impact of health conditions on their safety and mobility.

Routine adaptations after a fall

Older adults who had experienced a fall reported that they adapted their routines to prioritise safety, by becoming more vigilant about potential hazards in their environment, such as uneven surfaces and steps, and adjusted their behaviour to mitigate and avoid these risks. For example, instead of navigating hazardous routes, they chose safer alternatives, such as using facilities on a single level. This change in routine highlights the reactive measures taken by older adults to prevent future falls, showcasing their heightened caution and deliberate actions after a fall.

“And although I'm being careful I have to watch how I'm walking out of the conservatory where there are two ridges. And there are two steps down from the decking to the bathroom toilet. So mostly now, I would use that downstairs toilet.” [Faller-Female7, aged 70-79]

Moreover, participants reflected on the psychological transformation they've undergone, acknowledging that they became more cautious and careful as a result of their experiences.

“Well, I'm just more cautious and more careful... I don't think I'm a cautious and careful person by nature, but I have learned to be.” [Faller-Female2, aged 70-79]

Additionally, older adults frequently delved into their specific and individualised routines that they had developed to enhance stair safety after a fall. Although older adults frequently reported on their individualised routines, it conveyed an overall responsive effort rather than proactive measure to prioritise safety and prevent a reoccurring stair fall.

“Now I do hold the rail more and every time I go up or down the stairs, I count the stairs 12 up and then one to the left. I just automatically count them all now to make sure I'm not missing any, that is not my fault that I've just forgotten I'm not at the bottom. I just do that automatically now.” [Faller-Female7, aged 70-79]

Home design and safety concerns

Respondents often expressed safety concerns regarding their living environment. They often indicated a heightened awareness of the potential dangers associated with the specific architectural features of their home, such as narrow landings and tight staircases (figure 3.3.).

“Sometimes I do think the landing isn't wide from the bathroom and I have thought you know, if you've got a bit confused or stumbled, you'd go straight down the stairs” [Non-faller-Female6, aged 70-79]



Figure 3.3. Photographs of the stair landing area reported by a non-faller (Non-faller-Female6, aged 70-79).

It was common for the respondents to discuss their narrow staircase. However, only a few participants discussed their narrow staircase in the context of the consideration and decision-making process regarding the stair lift in their home.

“I was very tempted to get rid of the stair lift because it gives you more space as you're doing the tight turn. I have tried having the stairlift at the very top of the stairs. But I think that's a tad precarious because there's another tight turn. And I suppose I don't want to get rid of it because once I could use it, it was very valuable to me.” [Faller-Female2, aged 70-79]

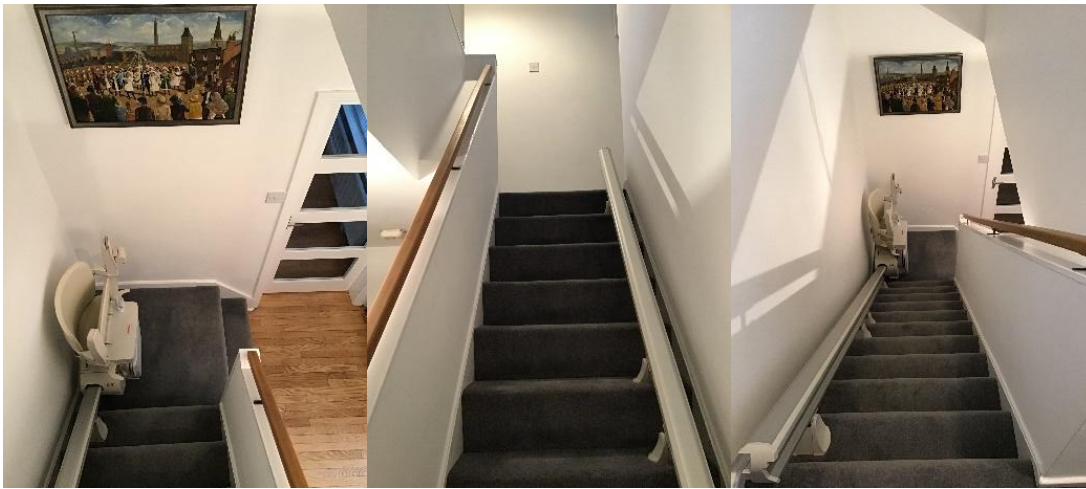


Figure 3.4. Photographs of the staircase reported by a faller (Faller-Female2, aged 70-79).

Furthermore, the idea of future-proofing their homes was mentioned by multiple respondents, indicating a shared recognition of the importance of planning ahead for ageing-related changes. Older adults often offered practical solutions, such as installing additional handrails, to enhance safety and support during stair use.

“It’s kind of future proofing to retain it...I suppose there is a possibility that another, an extension to the banister going round a corner might be useful, or even a vertical grab rail though I come to think about it.” [Faller-Female2, aged 70-79]

“We could have a handrail on the wall side as well against the wall because my partner had a new hip...and one of the things is whether he'd be able to get up the stairs.” [Near Faller-Female5, aged 60-69]

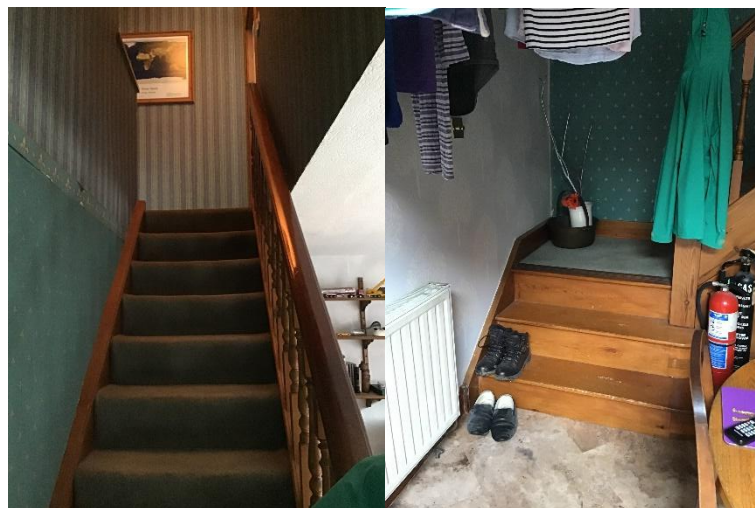


Figure 3.5. Photographs of the staircase reported by a near-faller (Near Faller-Female5, aged 60-69)

Concerns about architectural features, like steep entryway steps, were also raised, and older adults emphasised the need for more accessible designs.

"At the moment coming into the front door, there's one steep step, and then another steep climb into the front porch." [Faller-Female7, aged 70-79]

Interestingly, when discussing hazards and safety concerns in their home, only one out of the six respondents who had patterned carpet (Faller-Female19, aged 70-79) mentioned the choice of patterned carpets in their home, questioning whether aesthetic preferences impact safety.

"It's patterned. They're all out of fashion these patterned carpets, but we like them. Everybody's got plain ones now, haven't they? We were looking for a new carpet, and there was nothing we liked. They all look the same, all grey and light grey...I don't know if it makes a difference to safety" [Faller-Female19, aged 70-79]

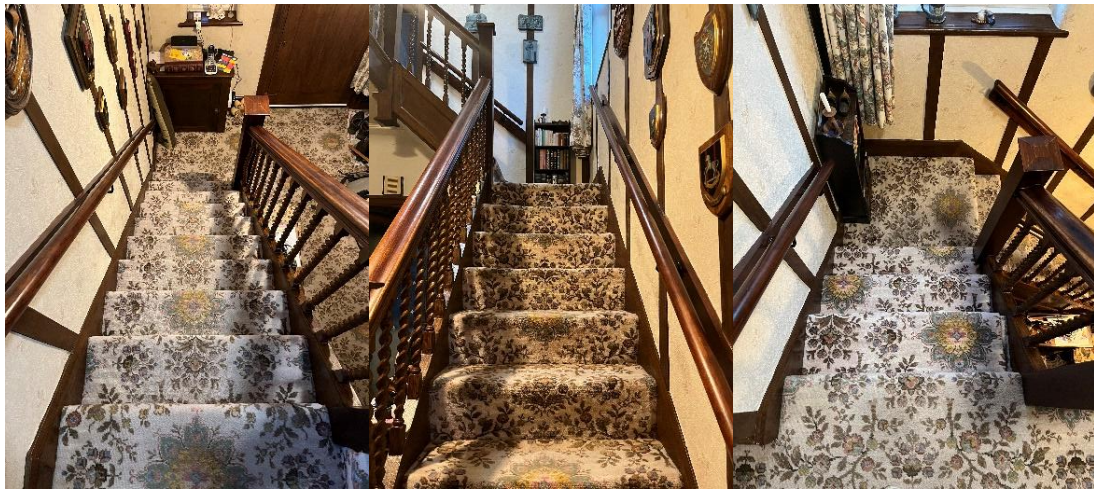


Figure 3.6. Photographs of the staircase, specifically the pattern carpet reported by a faller (Faller-Female19, aged 70-79).

When asked about the barriers to ageing in their current homes, many older adults identified stairs as a significant challenge, although not necessarily the most immediate concern. They acknowledged the inevitability of ageing which prompted evaluations of their living situations.

"Interviewer: What are those barriers to growing old in this home? Non-faller: I think it's probably the... the stairs are going to be a component of it, whether it's the first component or not, I don't know... we're not immortal. So maybe the long plan should be enjoy it while we can and then look to enjoy something that might fit in better when you're a bit older" [Non-faller-Male22, aged 60-69]

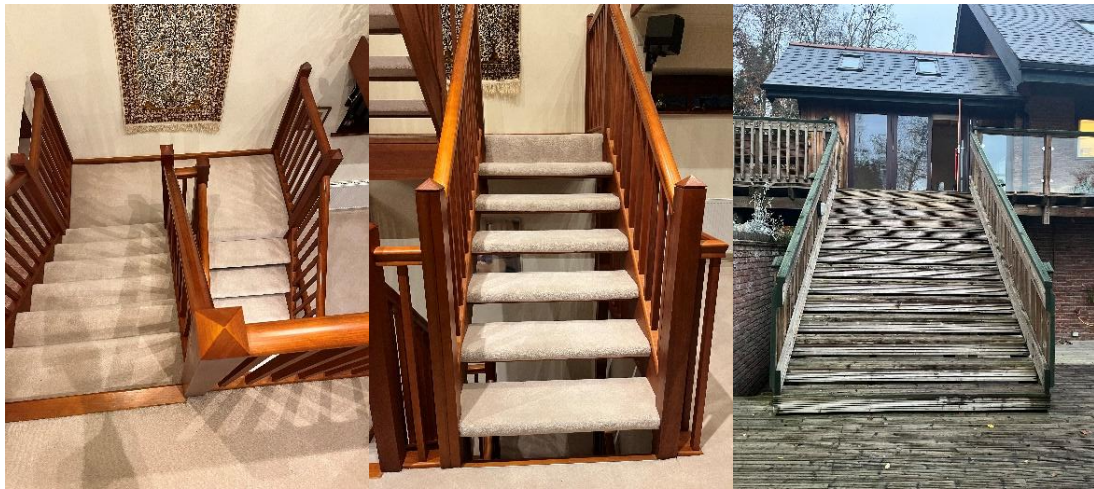


Figure 3.7. Photographs of the staircase (indoor and outdoor) reported by a non-faller (Male, aged 60–69) who is also the partner of a faller who lives with them (Faller-Female21, aged 60-69).

Attitudes towards ageing and care services

Financial considerations and concerns in ageing

Participants discussed an array of expenses linked to ageing. A focal aspect of financial consideration revolved around the expenses tied to adapting home environments for safety and accessibility.

“The only thing I thought of in that respect would be a stairlift eventually. And I think there about £6000...I think if we need really needed one then we manage it somehow other than that, it will be a downstairs toilet. Which was one of the reasons why we left the other place and moved.” [Non-faller-Male8, aged 70-79]

While some participants expressed determination to manage the financial costs, others reflected on their financial ability to upgrade their homes as they age differently. Many expressed concerns about the affordability of such upgrades when attempting to make their homes more age friendly.

“Interviewer: Do you feel you're financially able to upgrade your home as you age? Participant: It's getting harder” [Non-faller-Female9, aged 60-69]

Beyond home modifications, respondents also touched upon the financial considerations associated with potential future care needs. The prospect of residing in care homes involves significant financial planning, and often participants expressed concerns about these potential costs.

“I know there are some beautiful care homes, but then they cost beautiful amounts of money” [Faller-Female10, aged 60-69]

This sheds light on the intricate financial landscape that older adults must navigate as they contemplate their future living arrangements. Additionally, the financial considerations extended to day-to-day expenses, including energy costs. Economic challenges, such as increases in energy costs or uncertainties about income, were mentioned, highlighting the impact of broader economic factors on older adults' daily decisions and behaviours.

"We didn't know how much income we had...and with this energy crisis coming I'm paranoid about leaving lights on and turning lights on unnecessarily." [Non-faller-Female4, aged 70-79]

Moreover, respondents often expressed their emotional and practical aspects of ageing, and the desire to remain independent. Frustration and feelings of dependence on others for assistance were discussed, reflecting the challenges older adults face in overcoming sensory limitations alone.

"I'm getting frustrated because I can't see and I can't hear properly, that is getting me down a bit, that's making me feel like I have got to have somebody to help me." [Faller-Female20, aged 80+]

This tension between the desire for many older adults to maintain independence, the acknowledgment of the potential benefits of safety measures and the implementation of these safety features, was resounding.

"It's reluctance to admit, I'm beginning to get a bit older and beginning to need these things...Because older people usually hold on to both rails as they're trying to get themselves up the stairs. And I feel at the moment, I can still cope with one. But then as I say this, Falls Prevention Team have tried to persuade me that it's my own benefit to have the other one." [Faller-Female7, aged 70-79]

Many participants emphasised the importance of preserving their ability to make choices and decisions.

"You lose so much independence. They are regimented up to a point which they probably have to be but you can't do anything. I mean, we've got so many things we can do here the garden, you couldn't do that. The amount of reading that we do. I mean, I've got several hobbies as well. I couldn't do those. There would be nowhere to put anything that we use. So just the massive loss of independence from ability to do what you wanted and when you wanted." [Non-faller-Male8, aged 70-79]

"I'm just frightened of falling, because at my age, if you have a fall, I'd lose my independence because I probably wouldn't be able to stay at home." [Non-faller-Female15, aged 80+]

Seeking and receiving care services

A few participants described their experiences with the receiving care services, indicating their active engagement in efforts to mitigate the risk of accidents and falls.

"Unfortunately, I had one or two falls...that's when the Falls Prevention Team became involved with me. And they helped the assistants, they put a rail down there for me to get down the decking easier."

And a rail in the bathroom, and one by the door. So that's when that service came in. And that's how I've got those appliances “ [Faller-Female7, aged 70-79]

Likewise, receiving care services, such as accessing a guide dog increased activity levels and improved the respondents well-being.

“I've got more active with doing all the training with the dog. And so, I think it's done me good, because I was really starting to see stuff. And having problems with arthritis in my knees and feet and back and so on, and actually, having to keep moving around, I keep going every day out and I felt better in the last few weeks.” [Faller-Female19, aged 70-79]

However, access to, and seeking care during the COVID-19 pandemic was somewhat challenging for the respondents.

“I hadn't been hospital when I first did it, because of lockdown, because of the pressure on the NHS and everything, and I was like, I'll be all right” [Faller-Female21, aged 60-69]

Among the respondents who received care services during the pandemic, there was a shared sense of risk and anxiety associated with any form of external contact, due to the fear of contracting COVID-19.

"I was offered a care package. And for two days carer's did come in. But that made me feel very concerned because they would be going to lots of places...It's hard, isn't it, to remember how scared you were during the first lockdown... I think I thought if I put my nose through the front door something awful would happen" [Faller-Female2, aged 70-79].

Overall, these findings reflect a proactive approach of the participants to maintaining their health and independence by seeking and receiving different types of care and assistance as they age. It also highlights the impact of the fear of contracting COVID-19 had on respondents receiving care services, despite their potential need for assistance.

Emotional attachment to the home and reluctance to move into care homes

The emotional attachment to the home and reluctance to move into care homes were consistently reported. Many of the older adults included sentiments of comfort, security, and the significance of homeownership.

“Like a real feeling of security, I suppose. It's always a thing where or when you come home from work. It's nice to close the door and close the curtains and it's, oh, you can sort of breath out and relax.” [Near Faller-Female5, aged 60-69]

Participants often reflected on the idea that their homes are places with deep emotional and practical importance in their lives. Moreover, the respondents often expressed strong reservations and aversion to the idea of leaving their current homes to live in care homes or assisted living facilities.

“I would be extremely reluctant to do anything like that. Yeah, very, very, very reluctant” [Non-faller-Male8, aged 70-79]

The respondents' reservations about care homes stemmed from concerns about the quality of care, the potential loss of independence, and the regimented nature of such facilities.

“Well I don't think you get much care and I think once you get to certain age like people seem to think you're invisible, especially in care homes. So you know, I'd rather snuff it at home.” [Non-faller-Male12, aged 70-79]

Furthermore, participants expressed a preference for facing end-of-life issues in their familiar home environment rather than moving into care homes. This was a common response to the idea of moving into a care home.

“I would rather go to Dignitas or have something by that time, hopefully in this country where you can say right, I would just want to end it.” [Faller-Female10, aged 60-69]

"Dignitas" is an assisted dying organisation in Switzerland that helps individuals with terminal illness or unbearable suffering to end their lives with medical assistance. Older adults often expressed reluctance to consider alternatives such as moving into care homes, emphasising the importance of maintaining control over their own lives and decisions, even in matters related to the end of life.

3.5. Discussion

This mixed-methods study provides insight into older adults' experiences of independent living and home stair falls during and after the COVID-19 pandemic. Although the COVID-19 lockdown provided an opportunity to explore fall risk and stair safety, our findings extend beyond the context of the COVID-19 pandemic. They highlight a broader gap between older adults' perceptions of staircase safety and the actual risk factors present in their homes. We identified four overarching themes common across older adults' living independently: effects of lockdown on daily living during the COVID-19 pandemic; stair-related falls and perceived causes; falls preventative measures and safety awareness; and attitudes towards ageing and care services. The journey to attain and sustain older adults' independence within their homes is intricate,

requiring not only increased awareness, education, and modifications in the physical environment, but also considerations of behavioural and situational factors.

Every single stair faller perceived their stairs as safe, despite a substantial proportion (40%) of them having staircases that did not meet British Standard safety guidelines. Reinforcing these findings, the English Housing Survey Headline Report states that only 9% of homes met the basic standard of accessibility set by the British Standard BS5395-1 ^[57]. This discrepancy may be due to the UK's growing older population and the fact that the UK possesses one of the oldest housing stocks in Europe ^[20,21], making it challenging to meet modern safety standards. Interestingly, our measurements of stair dimensions failed to distinguish between those who had experienced home stair falls and those who had not, indicating that both groups equally did not meet the safety standards. This suggests that behaviour and décor choices may play a pivotal role in home stair safety. Behaviours such as leaving items on the stairs or neglecting to use handrails and décor choices such as patterned carpet were identified as influential factors in home stair safety.

However, this finding should not downplay the inherent risk, as adhering to safety standards, specifically those set by the British Standard BS5395-1, could potentially reduce the risk of falls by 60% ^[55]. Our interviews supported the importance of adhering to safety standards, especially the provision of handrails, with several instances where their use prevented more severe falls. While the structural transformation of existing stairs (pitch, rise and going) poses challenges, updating building regulations for new constructions emerges as a proactive preventive strategy ^[58]. For homes with non-compliant staircases, interventions targeting elements of safety standards, such as slip resistance, stair coverings, and the provision of handrails, can be effective ^[58,104].

Regarding stair coverings, participants recognised that loose or worn carpets could be a potential hazard. However, 90% of participants who had patterned carpet did not perceive them as a risk, indicating a lack of awareness of the increased fall risks. Surface colour and/or pattern can affect visually locating step edges or judging distances, reduce confidence and increase anxiety for stair negotiation ^[44,61]. Educational initiatives that inform older adults about the role of behaviour and décor choices in home stair safety are imperative ^[30]. Increasing the older adults and their carer's ability to identify hazards, challenge assumptions of safety with the knowledge of how to access support for home adaptations can minimise the stair fall risk and risky behaviours ^[30]. This underscores the need for targeted interventions to modify behaviour and promote safer stair practices among older adults.

Participants also reflected on unsafe behaviours that resulted in falls and injuries on stairs, such as misjudging step edges, carrying items, or rushing. These falls had considerable impact on their well-being, with consequences such as broken bones, discomfort, and increased fear when navigating their homes. This prompted a reactive response rather than preventative. Reduced confidence and increased anxiety have been linked to changes in visuomotor behaviour during obstacle negotiation, such as decreased walking speed ^[44,46] and reduced visibility ^[47]. Anxiety may cause older adults to fixate on future hazards earlier, inducing an attentional bias toward environmental features perceived as more threatening ^[44,50]. This premature transferral of gaze from a stepping target such as the next step to future obstacles such as a moveable item left on the top of the stairs has been shown to reduce stepping accuracy and increase foot placement variability, which could exacerbate fall risk ^[44,50]. Therefore, prevention strategies, such as adaptations to the home and education are needed before a fall occurs ^[1]. Addressing unsafe behaviours can effectively reduce the overall risk of stair falls among older adults ^[62].

However, our study only captured a brief understanding of the participants behaviour negotiating stairs. We understand that factors such as patterned carpet, items left on the steps or having turning stairs with quarter landings (90°/180° turn to a second flight) may also amplify fall risk. Employing cautious stepping technique might mitigate the likelihood of a stair fall, potentially compensating for reduced functional capabilities or inadequate safety standards ^[62]. Further research is required to explore the behavioural aspects of stair safety to understand additional perceptions and differences in stepping techniques between fallers and non-fallers, informing effective fall prevention interventions.

During interviews, participants discussed their safety concerns and approach to 'future proofing' their homes, emphasising the significance of handrails, lighting, and tight turns on stairs. Financial challenges were significant, as participants often could not afford home upgrades and avoided using lights and heating to reduce costs. Poor lighting can exacerbate stair fall risks, influencing confidence, anxiety, and dynamic balance ^[49]. Cold homes can also have a severe impact on both physical health (such as respiratory or circulator problems) and mental health, making negotiating stairs a challenging and riskier task ^[58]. It is clear that there is a huge and urgent need to adapt UK homes. The English Housing Survey (2021) indicates that around 820,000 homes have issues like damp or mould growth, and this is seen as a more concerning issue than adapting their homes for future use or making them more energy efficient ^[48,57]. Previous research and our findings show that that people cannot afford to make adaptations to their home to ensure their safety and prevent care needs ^[48,56,57]. Additionally, the high costs of quality care homes underscore the financial

burdens and uncertainties older adults and their families confront when contemplating future care options. It is clear that home adaptations can play a key role in supporting older adults to live independently for longer, equally, it can act as a preventive measure against the escalation of care requirements as a result of stair falls and accidents within the home ^[48].

When we factor COVID-19 lockdown into this, the risk of falls and injuries is amplified beyond the usual levels as prolonged period of home confinement during the pandemic may have heightened exposure to these potentially 'unsafe' home ^[63-65]. Lockdown measures disrupted regular exercise routines, leading to a decline in physical movement. Participants described engaging in extended periods of indoor activities, including working from home, watching TV, and virtual meetings. This coupled with reduced outdoor activities, potentially affected the muscle strength and balance necessary for safe stair negotiation ^[30,49] and contributed to deconditioning and diminished physical fitness, increasing the susceptibility to stair falls, especially for older adults ^[63]. Furthermore, access to healthcare and essential facilities encountered substantial hurdles during the pandemic ^[48,63-65], adding further layers of complexity to the endeavour of fostering safe and independent living among older adults. The long-lasting effects of the closure of organised activities and services were evident as individuals faced difficulties returning to their pre-lockdown routines. These highlight the need for implementation of effective exercise programmes for older adults especially during periods of self-isolation and home-confinement ^[30].

The COVID-19 lockdowns not only had an impact on physical wellbeing but also greatly affected older adults' mental wellbeing. Feelings of loneliness, frustration, and the absence of social interactions with friends and family during COVID-19 is recognised in research ^[65,73] and were recurrent themes throughout the interviews. The frustration caused by restricted social engagement manifested coping mechanisms such as increased engagement in domestic projects, increased exposure to risk which may have impacted fall risk and consequences ^[68-70]. Social connectedness appears to be a protective factor against falls. Hajek and König., ^[71] found that older adults who maintained regular contact with friends, family, or other important individuals were less likely to experience a fall ^[71-73]. Unfortunately, for many participants in the present study, such social contact was severely limited during lockdown. Reduced opportunities for interaction may have contributed to declines in physical activity, increased depression symptoms, and impaired balance, factors all known to increase fall risk ^[71-73]. Given the evidence linking loneliness, social isolation, and fall risk, magnified by the effects of lockdown and social distancing, it is necessary to consider interventions aimed address both physical and social dimensions of fall prevention ^[73]. This includes promoting safe

opportunities for social engagement, supporting mental wellbeing, and mitigating physical deconditioning to reduce stair fall risk in older adults.

The varied and sometimes contradictory participant narratives reflect the complex relation between perceived and actual fall risk, and the individual ways older adults respond to the risk. For example some participants actively use handrails or modify behaviour, whereas others express reluctance or overconfidence in their mobility. In addition, some acknowledge environmental hazards, while others attribute falls to personal behaviour or fitness levels. In regards to lockdown, some experienced frustration leading to risky behaviour, whereas others adapted cautiously. These differences highlight how individual experiences that are shaped by physical environment, personal attitudes and situational factors contribute to different perceptions of stair safety, risk-taking behaviours, and fall prevention strategies. This variability highlights the need for flexible, person-centred approaches to fall prevention. The implications of this study extend beyond the COVID-19 pandemic, as the environmental and behavioural factors compromising stair safety that were identified will likely remain until specific actions are taken to mitigate stair fall risk. This study revealed a previously unacknowledged issue: many older adults' homes fail to meet British Standards for stair safety, leaving staircases with numerous unaddressed hazards. While COVID-19 provided an opportunity to examine these environments due to increased time spent at home, the associated rise in loneliness and decline in physical activity among older adults ^[63–65,97] emphasises the ongoing importance of addressing home safety beyond the pandemic context. This calls for further research and educational interventions, that include in-person education, peer-led sessions, community building sessions and, home safety assessments to raise awareness of home hazards and promote fall prevention strategies.

3.5.1. Strengths and limitations

The findings of our study emphasise the importance of fall prevention teams, particularly occupational therapists (OTs) conducting ongoing objective assessments of home environments, to identify potential risks for stair falls specifically. In the UK, fall prevention teams provide assessment and rehabilitation for adults who have fallen. This multidisciplinary team, which includes physiotherapists, occupational therapists, and podiatrists, works with patients in their homes and communities to restore independence, improve confidence, and reduce hospital admissions ^[105]. The involvement of OTs usually takes place post-fall (intervention stage) due to lack of resources to assess fall risk and intervene accordingly before the occurrence of the first fall. However, given that a fall is on its own a risk factor for consequent falls ^[1], the

fall prevention team should be involved earlier, to prevent the first fall in those identified as high-risk older adults. Implementing multicomponent interventions such as community fostering, housing adaptations, and physical activity recommendations could all potentially help prevent home stair falls for older adults ^[30], and need to be addressed in future research.

We acknowledge the study has certain limitations. Firstly, we did not collect detailed information on ambulatory impairments or the use of mobility aids such as canes or walkers. The use of walking aids has been identified as a potential risk factor for future falls among older adults ^[106], which may have influenced our findings. Another limitation may have been recall bias. As individuals age, there can be variations in the accuracy and completeness of their recollections, potentially leading to recall bias ^[107]. The ability to recall specific details, especially those related to past events or experiences during the COVID-19 pandemic, may be influenced by factors such as cognitive function, health conditions, and the emotional significance of the memories ^[108–111]. Despite efforts to minimise this limitation through careful interview techniques and validation of information, it is crucial to acknowledge that differences in recall abilities among participants might have impacted the comprehensiveness and accuracy of the collected data ^[112]. While these insights provide valuable qualitative data, future research may benefit from additional methods, such as cross-referencing participant accounts with records from Hospital Episode Statistics (HES) and general practitioner data records on falls, to further enhance the robustness of data gathered from older adults ^[112]. In addition to recall bias, this study may also be subject to self-selection bias, as individuals who chose to participate might have had stronger opinions or experiences related to the topic, potentially limiting the generalisability of the findings. An additional limitation is the homogeneity of our sample, which may impact the generalisability of our findings and that the representation of diverse communities may not have been captured. The study included participants that were from a White ethnic background, living in more affluent areas (IMD Quintiles 3, 4, and 5) and mostly homeowners. This limited representation may not fully capture disparities present in other populations, including ethnic minorities and individuals from lower-income backgrounds. Inclusivity and representation in studies is vital for recognising and addressing the needs of diverse communities and socio-economically disadvantaged areas ^[65,93]. Therefore, solutions may be less effective, further continuing health disparities, and future research aiming to address this issue is needed.

Furthermore, Braun and Clarke's ^[103] framework was used for its clear, systematic guidance and widespread use in applied health research. However, their later developments place emphasis on researcher subjectivity, epistemological positioning, and the active construction of themes rather than their discovery

within data ^[113]. These were not formally implemented within the original framework. Although the analysis conducted was reflexive in practice, the epistemological positioning of the analysis may have been less transparent than would be expected under more recent reflexive thematic analysis guidance. This is acknowledged as a limitation, and future research building on this work would benefit from aligning with later reflexive thematic analysis guidance to enhance transparency and reflexive depth.

3.6. Conclusion

Our study illustrates the gap between what older adults perceive as safe staircases and the actual risk factors present in their own homes. The COVID-19 lockdown provided an opportunity to explore fall risk and stair safety, however, our findings expand beyond the context of the COVID-19 pandemic. Findings highlight the desire of wishing to remain living as independently as possible in their own home, and how stair falls can deeply affect the way older adults navigate their homes. Findings also highlights the importance of conducting objective assessments and emphasise the role behavioural factors may play in stair safety. Stair fall prevention strategies should take a multifactorial approach, with education, home adaptations, community-based interventions and allowing for collaborative support for ageing in place. Installing safety features and implementation of educational practical interventions can help minimise fall risk and enhance the safety of older adults.

3.7. Reflection of methods

While the combined use of semi-structured interviews and in-home stair assessments enabled exploration of perceived stair safety within real-world contexts, the findings revealed a disconnect between safety awareness and observed or reported behaviour. Participants frequently described handrails as essential to safe stair negotiation; however, reported use was inconsistent, and descriptions of how handrails were used varied substantially, ranging from light touch for reassurance to load-bearing support during descent. These findings highlighted the limitations of self-report and environmental assessment methods for understanding the biomechanical mechanisms underpinning stair fall risk. These insights necessitated a shift toward objective, biomechanical study. Consequently, Chapter 4 adopted an objective, laboratory-based approach to quantify the effects of handrail use on biomechanical parameters during stair descent. Importantly, participants were allowed to use the handrail in their preferred manner to preserve the behavioural variability observed in Chapter 3, while analysing biomechanical parameters.

CHAPTER 4:

Exploring the influence of handrail use on foot placement and centre-of-mass control during stair descent in older adults

The information presented in this chapter has been reported in the paper:

Wharton, E., O'Brien, T., Foster, R. J., Giebel, C., & Maganaris, C. (2025). Exploring the influence of handrail use on foot placement and centre-of-mass control during stair descent in older adults. *Gait & Posture* (under review)

4.1. Abstract

Stair descent is a major cause of falls in older adults, accounting for significant morbidity, mortality, and healthcare costs. Handrails are widely recommended for enhancing stair safety. However, little is known about the biomechanical impact of handrails when used in a self-preferred way. Additionally, when we factor in COVID-19 pandemic, older adults spent more time at home, potentially increasing both their exposure to stair use and reliance on handrails. Therefore, this study examined whether using the handrails in their preferred way during stair descent affects key biomechanical parameters associated with fall risk in older adults with and without a history of stair falls during COVID-19.

Fourteen community-dwelling older adults (mean age = 72.6 ± 6.2 years) descended an instrumented seven-step staircase in two conditions: handrail use in a self-preferred way and no handrail use. Three-dimensional motion capture and force plates were used to quantify the proportion of foot length in contact with the step (PFLCS), centre of mass (CoM) peak acceleration and velocity during landing and lowering phases, and variability across trials. Statistical analyses were performed using paired samples t-tests and Wilcoxon signed-rank tests where appropriate.

No significant differences were found between handrail and no-handrail conditions for PFLCS or CoM parameters during landing or lowering, except for CoM peak acceleration variability during the lowering phase, which was significantly greater with handrail use ($p = .012$, Cohen's $d = 0.87$).

We found that an increased variability in CoM peak acceleration during the lowering phase was the only significant change with handrail use, suggesting less consistent movement patterns, potentially due to confidence and reduced caution during the stair descent tasks. Given the controlled laboratory conditions, the task may not have been sufficiently challenging to cause stabilising effects from handrail use for these participants. Within the scope of the specific biomechanical parameters measured during unperturbed stair negotiation in our study, using the handrails in their preferred way did not offer safety advantages for older adults. Future research should assess handrail use under more demanding, real-world conditions.

4.2. Introduction

Falls are one of the leading causes of injury and death in older adults, with significant social and economic consequences for individuals, families, and healthcare systems ^[1,3]. In the UK, falls among older adults place growing demands on the National Health Service (NHS) and social care systems, while also severely affecting quality of life and independence ^[18,53]. Notably, falls on stairs account for approximately 20% of all falls and are the primary cause of accidental death among older adults ^[27,45].

Stair descent is particularly more hazardous than stair ascent ^[27–29], as it places particularly high demands on lower-limb strength ^[30], coordination ^[31], balance control ^[32], and visual feedback ^[33,34]. Research suggests that stair falls during descent can result from missteps as the leading foot contacts the step below, and/or loss of centre of mass (CoM) control between steps ^[114]. A misstep can be an over- or under-step. In over-stepping, the ball of the foot rolls off the edge of the step, potentially resulting in a forward stumble or a backwards slip if the friction between the foot and the step edge is inadequate ^[24,32,39,40]. In under-stepping, a forward stumble may arise from the heel of the leading foot striking the riser. An increased CoM acceleration and velocity between steps can result in loss of balance and a consequent forward fall ^[35,36]. Additionally, inconsistent or poorly timed CoM control results in higher likelihood of unpredictable foot placement, greater impact forces upon landing, and a reduced ability to recover from small perturbations, each of which increases fall risk ^[35,37,38].

Given the complexity and risk of stair descent, particularly among older adults, it is imperative to explore effective strategies that can enhance safety and maintain independence. One such strategy is the use of handrails, which are a key environmental feature designed to enhance safety during stair use ^[41,42,51–53]. They offer mechanical support through redistributing load to reduce demands on the lower limbs ^[51,53], and can be useful for recovering balance during sudden losses of stability ^[42]. Moreover, handrails offer tactile guidance for older adults especially for the visually impaired, or in reduced visibility (e.g., poor lighting), and to assist those with mobility issues. From a psychological perspective they offer reassurance and increase the perceived stability of stair negotiation, especially for those with a fear of falling ^[51–54].

Only a few studies have investigated the effect of handrail use on joint kinematics of stair descent ^[41,42,51]. The previous research supports the stabilising benefits of handrail use. For instance, Reeves et al. ^[41] found that using handrails during stair descent reduced CoM–CoP separation, a proxy for improved postural control. They attributed these results to the mechanical support provided by the handrail, allowing

participants to offload some of the stabilising demands typically placed on the lower limbs. Gosine et al. [42] found that with an experimentally induced perturbation during stair descent, participants demonstrated higher downward and forward COM velocity, and exerted larger forces on the handrail. They suggested that handrails offer a mechanism to aid reactive balance recovery. Reid et al. [51] reported that older adults with a fear of falling (n = 3) descended stairs with a reduced centre of pressure velocity (VCOP) when using a handrail, indicating more controlled and stable postural adjustments. VCOP describes the neuromuscular response to shifts of the body's centre of mass and serves as an indicator of stability. Though, Reid et al. [51] also reported no significant difference in cadence or VCOP between stair conditions (handrail vs. no handrail) for healthy older adults with high confidence. However, in all these studies, the handrail use has been prescribed and standardised to be gliding the non-dominant hand along the handrail without active gripping or pulling [41,42,51]. While this approach allows consistency and validity in between-task measurements, it may not be generalisable to individual real-world handrail use among older adults. Thus, it remains unclear whether using the handrails in their preferred way improves biomechanical markers of stair safety in older adults.

In the previous chapter of this thesis (chapter 3), which presents measurements taken during COVID-19 lockdown, the increased exposure to home stairs during lockdowns and restrictive measures may have amplified the risk of falls and related injuries beyond the usual levels [60]. During this time period participants consistently noted handrails as a vital strategy to their safety and stability during stair negotiation. Many described adapting their behaviour with age, becoming more reliant on handrails as a precautionary measure. For instance, some participants described actively pulling themselves up with the handrail during routine stair use, indicating a more functional, load-bearing reliance on the handrail. One participant described catching herself mid-fall using the handrail, while others reported consciously choosing to run their hand along the rail for reassurance. However, despite recognising the safety value of handrails, 55% of stair fallers in our study reported not using them during descent, compared to 45% of non-fallers. This highlights a critical discrepancy between safety awareness and actual behaviour.

Participants also expressed concerns about narrow staircases, poor lighting, and the absence of dual handrails. While some had adapted their home environments or modified behaviour to manage risk, others expressed overconfidence in their ability or noted barriers to using handrails effectively. These varied and sometimes contradictory narratives reveal the need to move beyond perceptions and explore the actual biomechanical outcomes of handrail use during stair descent in older adults.

Arising from the findings above, the purpose of the present study was to objectively evaluate whether handrails modify certain stair fall risk factors during descent when participants are allowed to use them in their preferred way. Specifically, we assess 1) changes in the proportion of foot length in contact with the stair (PFLCS), 2) changes in CoM acceleration and velocity, 3) the variability of these parameters across steps and trials.

4.3. Methods

4.3.1. Participants

Fourteen older adults (age: 72.6 ± 6.2 years; body height: 163.3 ± 7.1 cm; body mass: 69.3 ± 12.6 kg) participated in the study. Nine participants were female (5 males). Participants were recruited from a previous survey study and home-visits study presented in Chapter 2 and 3, respectively. All participants lived independently and were recruited from the UK. Participants who used any other walking aid apart from the handrail to negotiate stairs were excluded. Participants volunteering to participate in the study were contacted via email or telephone by the lead researcher to inform them about the study's purpose, risks, benefits, and informed consent. The study obtained ethics from the Liverpool John Moores University (LJMU) Ethics Committee (Ref No: 23/SPS/017).

Participants were categorised into two groups: prior history of a stair fall(s)/near stair fall(s) ($n=4$) and no prior history of a stair fall ($n=10$) all recorded in the previous chapters of this thesis (chapter 2 and 3) during the COVID-19 pandemic. Stair falls were defined as an event, such as a trip, slip, or stumble, that caused a person to lose their balance while navigating stairs and inadvertently come to rest on the stairs or on another lower level, such as the ground or floor ^[115]. This definition was adapted from the World Health Organizations (WHO) general definition of a fall ^[115]. Near stair falls were defined as an event, such as a trip, slip, stumble, or loss of balance, that would have resulted in a person falling if they had not managed to regain their balance, also adapted from the WHO framework ^[115]. This recovery may involve using unplanned movements of the arms to catch onto a nearby wall, handrail, or object, or employing unplanned stepping movements with the legs to prevent a fall. Essentially, it is an incident where a person comes close to falling on the stairs but manages to prevent it through corrective actions. Those who experienced a previous stair fall/near stair fall were categorised into one group labelled stair fallers. The non stair fallers were the remaining participants who did not experience a fall on the stairs.

In terms of habitual handrail use at home, most participants habitually use their handrails at home (n=11). One participant reported using both handrails, seven reported using the right handrail, four used the left handrail, and two reported not using a handrail at all.

4.3.2. Procedure

The participants wore tight fitting shorts and shirt and wore their own flat-soled shoes. All participants wore a five-point safety harness, which was attached to the overhead belay safety system. A trained member of the research team was in a sit harness (waist belt and two leg loops) and operated the rope by a belay system whilst making sure that there is no tension in the rope during the trials. The research team member was attached to an additional rope on the floor by the sit harness, to anchor them down.

Measurements were taken on a custom-built staircase instrumented with four individual force platforms (1080Hz, 9260AA, Kistler AG, CH) embedded in the lower four steps. Kinematics were obtained using a 26 infrared camera system (120Hz, Vicon, Oxford Metrics, UK). The staircase configuration was set up to represent a typical private home staircase in agreement with the building regulations in the UK ^[55,101,102], with the rise set at 20 cm and the going at 25 cm, resulting in a pitch of 38.7°. Handrails on both sides of the staircase were in place during all tests, with a height of 900mm and a pitch of 38.7° (Figure 4.1.). The top landing and bottom walkway were independent structures (Figure 4.1.) to the steps of the staircase. The position of the top landing was fixed and the walkway was secured on the floor to the metal framework of the different steps by bolts.

Participants were asked to descend an experimental seven-step staircase at their self-selected pace in a step-over-step (i.e. alternating limb lead on each step) manner for a maximum of 15 times over the course of 3 hours. To allow familiarisation with the experimental setup and safety harness, participants performed up to five practice trials. After familiarisation participants completed two trial conditions in a fixed order:

- 1) Five trials using the handrail(s) in their preferred way (for example using one handrail, both handrails, grabbing, gliding etc.)
- 2) Five trials without using a handrail

The participants were asked to consistently take two steps before descending the stairs, leading with the same leg for every trial. This distance marks the point at which individuals typically acquire feedforward visual information about the stair environment ^[116–118]. To minimise fatigue caused by the repeat staircase

ascents and descents, participants were given as many breaks as needed. Following the completion of stair descent trials, a battery of questionnaires and functional movement tests were performed (described below).

4.3.3. Biomechanical measurements

Full-body six-degrees of freedom model using a 15 segment (head, thorax, pelvis, upper arms, lower arms, hands, thighs, shanks, feet) defined by 74 reflective markers (diameter 14 mm; Appendix D, Figure D.1.) was obtained to gain full-body kinematics. A static calibration (anatomical pose) was captured to acquire whole body marker coordinates. To create virtual landmarks on the toe and heel-tips of participants' footwear a digitising wand (C-Motion, Germantown, MD, USA) was used in a separate trial. Landmarks for the heel-tip and toe-tip were at the anterior-inferior (toe-tip) and posterior-inferior (heel-tip) point of each shoe. A triangular cluster of markers placed over the forefoot portion of the shoe was used to track the virtual landmarks during movement trials.

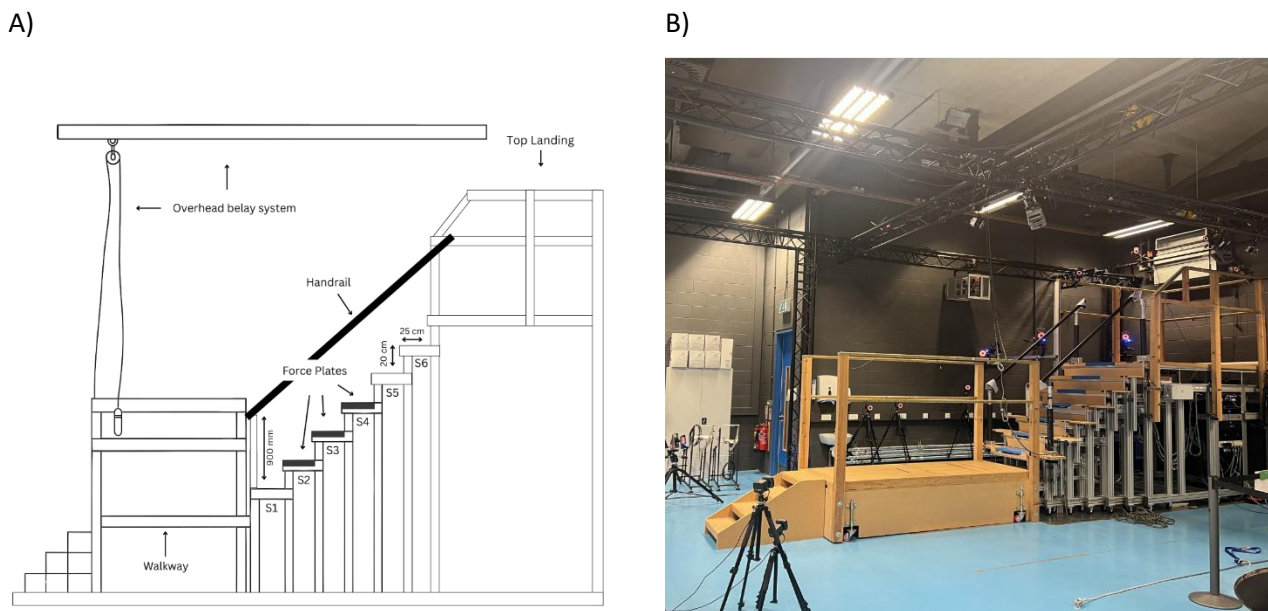


Figure 4.1. A schematic representation (A) and image (B) of the custom-built instrumented seven-step staircase. (*S1, Step 1; S2, Step 2; S3, Step 3; S4, Step 4; S5, Step 5; S6, Step 6*)

All marker data were labelled and gap filled in Vicon (Vicon Nexus 2.6, Oxford Metrics, UK), and exported as c3d files for analysis using Visual 3D (C-Motion, Germantown, MD, USA). A low-pass fourth order Butterworth filter with a cut-off frequency of 6 Hz was used to filter all kinematic data. Gait events were identified using force plate data, with a vertical ground reaction force threshold of >20 N used to define foot contact and <20 N to define toe-off. Kinematic data were analysed to determine the following outcome measures:

1. *Proportion of foot length in contact with stair (PFLCS)*. PFLCS was calculated to assess overstep/slip-induced fall risk by quantifying the anterior-posterior foot placement relative to the step edge. A lower PFLCS value indicates less of the foot is placed on the step. First, the toe-to-step edge distance was extracted as the anterior-posterior (AP) distance between the virtual toe-tip landmark and the step edge. This value was taken at the instant of peak vertical ground reaction force during foot contact, this timing was consistent across all trials and reflects maximal loading on the step. PFLCS was then computed as the percentage of the foot that was in contact with the tread using the following equation:

$$\text{PFLCS (\%)} = \frac{\text{Foot Length (AP)} - \text{Toe to Step Edge Distance}}{\text{Foot Length (AP)}} \times 100$$

where, foot Length (AP) is the horizontal distance from the virtual heel-tip to the toe-tip landmark (defined from a separate digitisation trial using a wand). The toe and heel virtual landmarks were tracked during dynamic trials using a triangular cluster of markers placed over the forefoot portion of each shoe. PFLCS was calculated for steps 2 to 4 of the descent phase and averaged across all five handrail and five no-handrail trials for each participant.

2. *COM Parameters*. These parameters reflect the body's dynamic stability during stair descent, particularly the ability to control movement while lowering the body and making contact with each step. Greater downward CoM acceleration and velocity during lowering, as well as reduced CoM acceleration upon landing, have been associated with increased risk. Whole-body CoM was calculated in Visual3D as the weighted average position of 13 body segments: the head, trunk, pelvis, bilateral upper arms, forearms, thighs, shanks, and feet. They were calculated for steps 2-4 for each participant, CoM parameters were averaged across all five trials for both handrail and no-handrail conditions. The CoM parameters were divided into the following phases:

Landing Phase: The landing phase was defined as the period from foot contact with the step below (touch-down), identified when the vertical ground reaction force surpassed a 20 N threshold, until the CoM's downward velocity reached zero (indicating the end of its upward acceleration). This phase captures weight acceptance and forward motion [23,38].

Lowering Phase: The lowering phase began at the end of the landing phase and continued until the contralateral limb made contact with the next step.

2.1. *CoM peak Acceleration-Land.* This represents the peak positive acceleration of the CoM in the downward direction during the landing phase.

2.2. *CoM peak Velocity-Lower.* This parameter represents the peak negative velocity of the CoM in the downward direction during the lowering phase.

2.3. *CoM peak Acceleration-Lower.* This represents the peak negative acceleration of the CoM in the downward direction during the lowering phase.

3. *Within steps and between trials variation.* Variation was calculated to assess ability to maintain a steady/safe movement pattern. A higher variance within steps and between trials may increase the risk for a fall [119]. For each participant, the variance of each parameter was calculated across the five trials and three analysed steps (steps 2, 3, and 4). The within steps and between trials variance values for each parameter, was used for further analysis.

4.3.4. Questionnaires and functional movement tests

A range of questionnaires and functional movement tests were completed following the staircase handrail condition trials. To account for the possible effect of fatigue caused by the staircase trials, all participants were given a break (approximately 15 minutes overall) in which they received refreshments, and the tests were started with the questionnaires that allowed the participants to be sat down and rest for another 30 minutes. None of the participants reported that fatigue had an influence on their performance on the functional movement tests.

The following questionnaires were completed: the Activities-specific Balance Confidence Scale (ABC), to assess self-perceived balance confidence while performing daily activities [120], the short Falls Efficacy Scale-International (Short-FES-I), to assess concern about falling while completing activities of daily living [121], the Montreal Cognitive Assessment (MoCA) to assess the cognitive functioning [122], the Nottingham extended

Activities of Daily Living (NEADL) index to assess the functional status ^[123] and the FRAT to determine fall risk ^[124].

The following six tests of the Fullerton Functional Fitness Test ^[125] were complete to obtain functional movement measures: 1) Chair stand, to measure functional lower body strength; 2) Arm curl, to measure functional upper body strength; 3) 2-min step test, to measure physical stamina; 4) Chair sit and reach, to measure lower body flexibility; 5) Back scratch test, to measure upper body flexibility and 6) Timed up and go, to measure speed, agility and balance ^[125].

4.3.5. Data analysis and statistics

A frequency analysis was used to compare the measured biomechanics parameters between handrail conditions (handrails and no handrails) and groups (fallers and non-fallers). The biomechanics parameters showed that fallers and non-fallers values were similar (Table 4.1.) and therefore we treated all fallers and non-fallers as one group (n=12). Therefore, a paired samples t-test was conducted to compare the effect of handrail condition (handrails and no handrails usage) on the biomechanical parameters examined. For each parameter, the average of all steps was used for the comparisons. Inspection of residual plots was performed to assess the normal distribution of data. Where data were not normally distributed, a Wilcoxon signed rank test was used.

4.4. Results

Table 4.1. Biomechanical parameters assessed during stair descent with no handrails and with use of the handrails for fallers and non-fallers.

		Faller (n = 4)	Non-fallers (n = 9)
PFLCS (%)	Handrails	82.20 (1.30)	84.14 (0.10)
	No Handrails	85.90 (5.21)	81.98 (1.20)
Var. PFLCS (%)	Handrails	1.38 (1.71)	1.18 (0.36)
	No Handrails	1.20 (8.03)	1.51 (1.51)
CoM peakAcc-land (m/s²)	Handrails	4.27 (1.30)	4.68 (1.71)

	No Handrails	4.52 (1.22)	4.28 (2.01)
Var. CoM peakAcc-land (m/s²)	Handrails	0.10 (0.10)	0.36 (0.36)
	No Handrails	0.11 (0.11)	0.28 (0.28)
CoM peakVel-lower (m/s)	Handrails	0.65 (0.07)	0.59 (0.07)
	No Handrails	0.64 (0.07)	0.61 (0.09)
Var. CoM peakVel-lower (m/s)	Handrails	0.03 (0.03)	0.01 (0.01)
	No Handrails	0.01 (0.01)	0.01 (0.01)
CoM peakAcc-lower (m/s²)	Handrails	2.41 (0.56)	2.30 (0.60)
	No Handrails	2.16 (0.60)	2.01 (0.56)
Var. CoM peakAcc-lower (m/s²)	Handrails	0.29 (0.29)	0.23 (0.23)
	No Handrails	0.09 (0.09)	0.19 (0.19)

All values are presented as means (SD).

PFLCS, Proportion of foot length in contact with step; Var., within steps and between trials variation; CoM, Centre of Mass.

For the staircase trial section of the protocol, one participant was fully excluded due to marker error. Another participant, a non-faller, was unable to descend without using a handrail and thus only completed the handrail condition. This participant's data was included in descriptive reporting for the handrail condition only but excluded from statistical comparisons across conditions. As a result, 13 participants were included in the handrail condition, while only 12 participants had usable data for both the handrail and no-handrail conditions, allowing for 12 valid comparisons. Among these, four were stair fallers and eight were non-fallers.

During the handrail condition, most participants (n = 11) used both handrails, while two used only the right handrail. Similarly, most reported habitual handrail use at home (n = 11). Participants demonstrated varied handrail engagement patterns during descent. Eight participants used both hands in a continuous glide, one participant used both hands with an intermittent grab, and one participant alternated an intermittent grab with both hands. One participant bilaterally used the left hand in a continuous glide and used the right hand in an intermittent glide. Two participants used the right hand only in a continuous glide.

Across the majority of parameters, handrail use had no significant effect (Figure 4.2.). A paired samples t-test found no significant effect between handrail and no handrail condition on PFLCS and on PFLCS variability. No significant effect of handrail conditions on CoM peak acceleration-landing and on CoM peak acceleration-landing variability was found. Similarly, no significant effect were observed of handrail condition on CoM peak velocity-lowering. A Wilcoxon signed-rank test showed no significant effect of handrail condition on CoM peak velocity-lowering variability. A paired samples t-test showed no significant effect of handrail condition on CoM peak acceleration-lowering ($t(11) = -1.945$, $p = 0.078$). However, a significant difference was found of handrail conditions on CoM peak acceleration-lowering variability ($t(11) = 3.027$, $p = 0.012$, Cohen's $d = 0.874$) (Figure 4.2.H). Handrail condition (0.57 ± 0.20) compared to the no handrail condition (0.45 ± 0.16) was significantly greater, with a large effect size (Cohen's $d = 0.874$) and the 95% confidence interval ranging from 0.189 to 1.531.

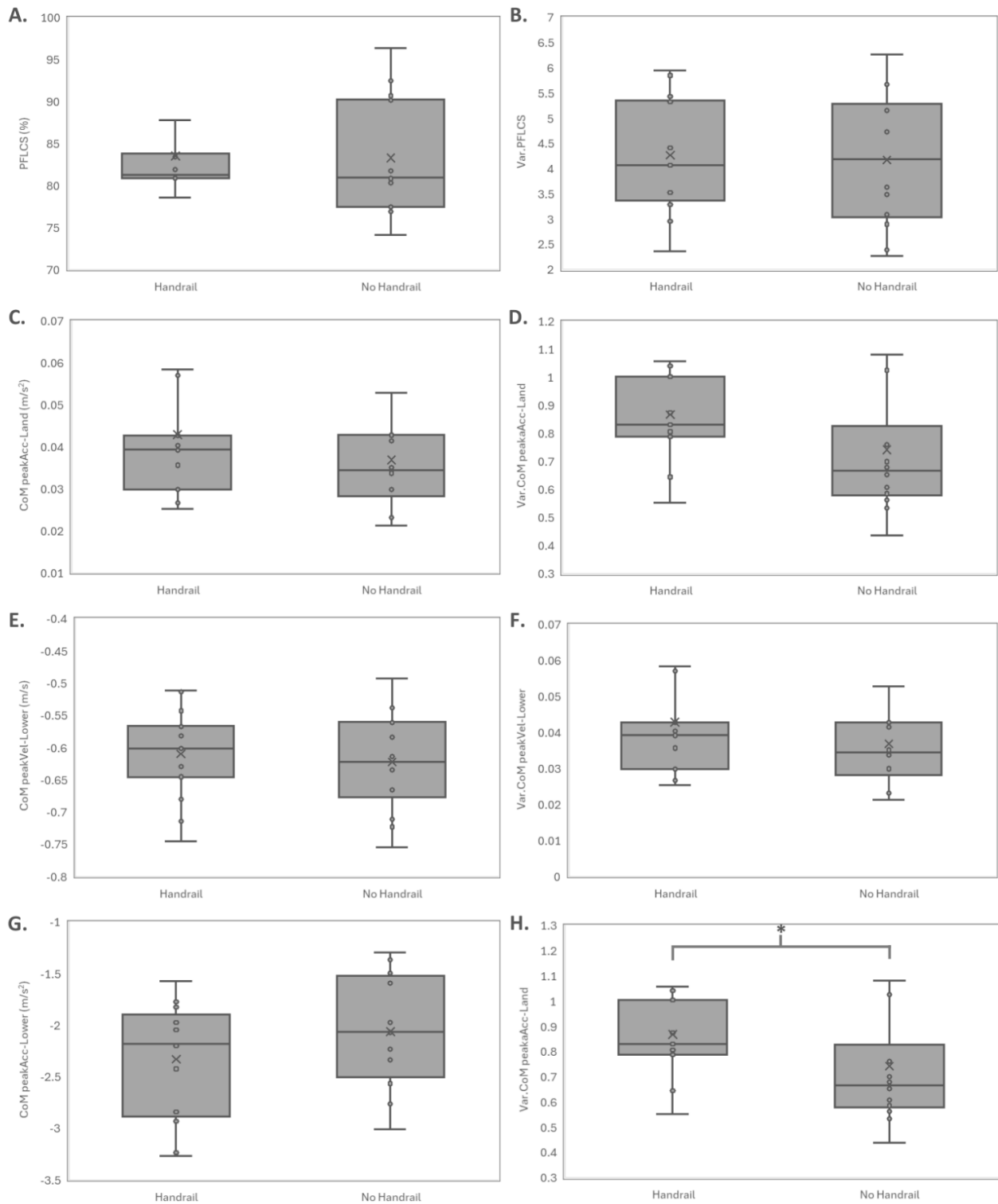


Figure 4.2. Stair descent data. Stair descent data presented across all conditions are as follows (A), PFLCS, Proportion of foot length in contact with step, (B), PFLCS variance, (C), CoM peak acceleration-land, (D), CoM peak acceleration-land variance (E), CoM peak velocity-lower, (F), CoM

4.4.1. Questionnaire and functional fitness characteristics

Questionnaire scores and Functional Fitness Scores are summarised in Table 4.2. The short FES-I scores for all participants was 8.43 (SD = 1.87), with scores <11 generally indicating low concern for fear of falling ^[121]. ABC scores are expressed as percentages, with scores above 80% considered high confidence ^[120]. Participants demonstrated high balance confidence, with a mean ABC score of 93% (SD = 0.08). NEADL mean score of 20.86 (SD = 1.56) suggest high functional independence ^[123]. MOCA (Montreal Cognitive Assessment) scores ≥ 26 are typically used as a threshold for normal cognitive function ^[122]. All participants cognitive function was within normal limits, as shown by the average score of 26.64 (SD = 3.13). FRAT (Falls Risk Assessment Tool) scores range from 0–5, with higher scores indicating greater risk; most participants scored low, mean 0.93 (SD = 1.44), suggesting minimal fall risk in this sample ^[124].

Table 4.2. Participant characteristics: questionnaire and functional fitness scores by fall history.

	All Participants (n=14)	Fallers (n=4)	Non-fallers (n=10)
Questionnaires			
Short FES-I	8.43 (1.87)	8.25 (2.50)	8.50 (1.72)
NEADL	20.86 (1.56)	20.75 (1.89)	20.90 (1.52)
ABC (%)	93 (0.08)	95 (0.10)	92 (0.08)
MOCA	26.64 (3.13)	28.75 (1.26)	25.80 (3.29)
FRAT	0.93 (1.44)	1.75 (2.22)	0.60 (0.97)
Functional Fitness			
Chair Stand (per min)	13.29 (4.29)	12.25 (1.26)	13.7 (5.03)
Arm Curl (per min)	21.57 (10.23)	20.75 (3.20)	21.90 (12.13)
2-Minute Step (step/min)	93.79 (15.34)	101 (18.60)	90.90 (13.86)
Chair Sit and Reach (cm)	8.14 (16.24)	9.5 (19.42)	7.60 (15.94)
Back Scratch (cm)	6 (11.72)	-1.33 (14.98)	8.44 (10.28)

Time Up and Go (s)	7.99 (1.92)	8.06 (0.99)	7.97 (2.23)
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All values are presented as mean (SD).

Short FES-I, The Short Falls Efficacy Scale-International ^[86]; NEADL, The Nottingham extended Activities of Daily Living ^[123]; ABC, The Activities Specific Balance Scale ^[120]; MOCA, The Montreal Cognitive Assessment ^[122]; FRAT, The Falls Risk Assessment Tool ^[124]; Functional Fitness, Fullerton Function Fitness Test ^[125]

4.5. Discussion

This study explored whether using the handrails in their preferred way during stair descent affected foot placement and CoM control in older adults, grouped according to whether they reported a stair fall(s)/near stair fall(s) during the COVID-19 lockdown period. Handrail had no effect on PFLCS, CoM peak acceleration (landing), CoM peak acceleration (lowering), CoM peak velocity (lowering), and overall variance within steps and between trials. CoM peak acceleration variability during the lowering phase increased with handrail use, which was not expected, suggesting potential changes in control strategies. CoM peak acceleration reflects the ability to control the body against gravitational forces as it descends and stabilises on the step. Variability in the CoM peak acceleration during the lowering phase of stair descent is a risk factor for falls, as higher variance indicates inconsistent control of downward movement and a person's inability to maintain a steady and safe movement pattern ^[35,37,119,126]. The relative magnitude of fall risk linked with inconsistent CoM control is not known, and although we measured foot placement and CoM parameters, we did not find evidence that increased CoM variability directly impacted foot trajectory or step placement. However, previous research suggests that such variability could result in inaccuracies in foot trajectory between steps and consequent placement on the step, and/or an inability to decelerate the body effectively on contact with the step below ^[35,37,38]. Despite the perceived safety benefits of handrail use ^[41,42,51-53], increased CoM control variability suggests that our participants adopted less consistent movement patterns when using the handrail, possibly due to increased confidence and perceived assurance that the handrail could arrest a fall if initiated while moving from one step to the next below.

While greater movement variability was observed with handrail use, this must be interpreted within the broader context that handrail use remains an inherently safer strategy for stair negotiation. Handrails are most beneficial when balance is actively challenged, such as during rapid or unexpected perturbations and are particularly useful for recovering balance during sudden losses of stability ^[42], a scenario that was not examined in the present study. Moreover, handrails are useful for tactile guidance for the visually impaired

or in reduced visibility (e.g., poor lighting), to assist those with mobility issues and to increase the perceived stability of stair negotiation, especially for those with a fear of falling ^[51-53]. Therefore, external variables such as lighting, stair surface, and environmental distractions (e.g., objects on the stairs) could influence the extent to which handrails are relied upon ^[127-129]. Individual factors, such as reduced attention due to dual-tasking ^[31,130], the presence of other people on the stairs ^[131,132], or visual aspects ^[61,133] could also alter handrail use in real-world settings. Simulating these external conditions in a controlled lab setting is technically challenging and we did not assess these factors, which may explain why handrail use did not significantly affect fall risk in this study. A practical approach could be to assess these biomechanical parameters in real-world staircases using advancements in marker-less motion capture ^[134,135] and wearable sensors ^[136,137]. This would allow for the measurement of stair-specific biomechanical parameters, such as foot placement, and CoM parameters, in natural environment. Increasing the sample size and capturing more hazardous events during real-life stair negotiation could reveal subtle patterns in handrail use and balance control that are not observable in lab-based studies.

Few researchers have directly investigated measures of stability or balance during stair negotiation in older adults between handrail conditions. While previous studies reported improved stability with handrail use, such as reduced CoP–CoM separation ^[41] and lower centre of pressure velocity (VCOP) for older adults with a fear of falling ^[51], we did not observe significant improvements in CoM control in this group of high functioning older adults. Several factors may explain why handrail use did not produce the expected biomechanical benefits. One factor may be methodological differences. In previous studies by Reeves et al. ^[41] and Reid et al. ^[51], the participants were asked to descend the stairs in prescribed ways, using the non-dominant hand to glide rather than grip, and relying on the handrail only as a guide rather than for support ^[41,51]. The present study allowed participants to use the handrails in any way they preferred. If the handrail was not consistently gripped, glided, or actively used for support, it may have provided limited benefit ^[138]. Notably, when we separated the data between participants who glided their hands ($n = 9$) and those who used the handrail in the same way they typically did at home ($n = 3$), we observed no consistent differences. Some gliders showed a reduction, and others an increase in CoM peak acceleration variability during the lowering phase.

Another factor that should be considered is the participants' relatively high balance confidence and functional fitness. Both our study and Reid et al. ^[51] reported above average ABC scores, indicating that participants were generally confident in their ability to maintain balance. Interestingly, Reid et al. ^[51]

reported no significant difference in cadence or VCOP between stair conditions (handrail vs. no handrail) for older adults with high confidence. However, older adults who had a fear of falling had lower confidence scores, increased VCOP, and may have benefited more from handrail support due to greater underlying instability^[51]. This suggests that individuals with higher confidence may not rely on handrails for mechanical support to the same degree as more vulnerable individuals. Additionally, the functional fitness and cognitive findings further support this interpretation ([Table 4.2](#)). The mean FES-I score indicates low fear of falling, and a MOCA score reflects average cognitive function. Furthermore, performance on functional fitness tests, such as the Chair Stand and Time Up and Go, suggests that our participants were physically capable and within the expected range for healthy older adults. Together, these factors likely contributed to a greater perception of safety and reduced reliance on handrail support during stair descent.

One additional explanation for the limited effect of handrail use on fall risk during descent could lie in the interaction between task difficulty and participant capability. Several factors, including stair dimensions, lighting, and environmental complexity, can influence the degree of challenge for stair descent^[30,32]. Although our staircase had a higher pitch than in previous studies where handrail use improved balance control^[41,51], this increased demand may still not have exceeded the physical capacity or challenged attentional demands, or dual-task capacity of our participants, who had high functional fitness and confidence. While steeper stairs increase CoM control demands and reduce safe foot placement area^[25,32,126], the task may not have been sufficiently challenging for healthy older adults with relatively high functional fitness to show the stabilising benefits of handrail use based on the biomechanical risk factors studied. Specifically, handrail use did not produce a measurable advantage in reducing overstepping (as reflected by PFLCS) or loss of balance during the lowering phase (as reflected by CoM acceleration and velocity parameters).

4.5.1. Limitations

Several limitations should be acknowledged. First, the measurements were conducted on an experimental staircase within a laboratory environment using a safety harness. While the harness was necessary for participant safety, it may have influenced participants' psychological state and stair negotiation strategies compared to navigating stairs in their own homes. However, participants were given time to familiarise themselves with the staircase and all reported feeling confident in negotiating it. Second, the participants consisted of healthy older adults with relatively high balance confidence and were not fearful of falling, as

indicated by their high ABC and low FES-I scores. This limits the generalisability of the findings to older adults with poorer balance or a fear of falling^[37], who might respond differently to handrail use^[51]. Third, we did not administer a scale or questionnaire immediately after each handrail condition to assess participants' perceived confidence or psychological state during stair descent. Such information could have provided valuable insight into how subjective feelings of safety and stability influenced stair negotiation strategies. Additionally, no qualitative data were collected, as the study prioritised biomechanical measurement of stair descent and handrail use. However, incorporating brief audio recordings or post-task reflections in future research may provide valuable insight into participants' perceived stability, confidence, and decision making. Future research should aim to recruit more diverse participants, including older adults with greater fall risk, and incorporate post-trial confidence assessments to better understand the psychological factors influencing stair descent performance.

4.6. Conclusion

This study investigated whether using the handrails in their preferred way during unperturbed stair descent influences biomechanical parameters linked to fall risk in older adults with and without history of falling during COVID-19 lockdown. We expected that handrail use would improve foot positioning and CoM control, but our findings did not support this. Interestingly, handrail use increased the variability in CoM peak acceleration during the lowering phase, suggesting that participants may have adopted less cautious movement patterns when using the handrail. Future research should explore the interaction between handrail use, stair complexity, and individual differences in balance confidence to better understand the role of handrails in reducing fall risk.

CHAPTER 5:

General Discussion

5.1. Purpose

The overall purpose of the PhD was to investigate home stair fall risk in older adults during the COVID-19 pandemic. The long-term goal is to inform better fall prevention strategies and affordable home interventions by understanding behaviour, environment, and biomechanics. This would allow the design and implementation of targeted interventions for improving stair safety in older adults.

5.2. Summary of findings

To achieve the aims outlined above, this PhD used a mixed-method approach of survey, interview, home assessments, and biomechanical assessments. These studies were designed to build progressively upon one another. Participants in Chapter 3 were recruited from the initial national survey cohort in Chapter 2, enabling a deeper exploration of home environments and individual perceptions of stair safety in context of COVID-19 pandemic. Similarly, participants in Chapter 4 were drawn from those who took part in the home visits in Chapter 3, allowing for a more targeted biomechanical assessment based on real-world insights. Together, the studies in this thesis contribute to a more nuanced, context-specific understanding of home stair fall risk in older adults and provide a foundation for targeted interventions in both research and public health domains. The findings collectively highlighted that stair fall risk is shaped by a complex interplay of behavioural, psychological, environmental, and physical factors.

5.2.1. Study 1: survey (COVID-19 and stair falls)

A national exploratory survey was conducted to examine whether the COVID-19 pandemic contributed to an increase in home stair falls among older adults (Chapter 2). We found that COVID-19 lockdown did increase stair falls. Additionally, findings indicated that self-isolation and lockdown restrictions may have influenced the rise in home stair falls during this period. Participants also reported a decline in physical activity levels, a known risk factor for falls. Furthermore, older adults living alone were more likely to experience a home stair fall, and injury severity from a stair fall increased with age. Notably, there was a disparity between individuals' perceptions of stair safety and the actual risks present in their home environments.

5.2.2. Study 2: mixed-methods home visits

To build on the survey findings, a nested mixed-methods study was conducted to explore older adults' experiences of independent living and home stair falls during and after the COVID-19 pandemic (Chapter 3). The study also examined their perceptions of staircase safety and whether these perceptions align with the staircase features and design that influence stair fall risks. Findings confirmed a disconnect between perceived and actual stair safety. The results also revealed a range of environmental (e.g. patterned carpet, no handrails, and steep stairs), behavioural (e.g. carrying items on stairs, rushing, and not using handrails), and socioeconomic (e.g. accessing care services, heating their homes, and putting on the lights in their homes) barriers to safe stair use and home adaptations. While the COVID-19 lockdown provided a unique context to examine stair fall risk, the insights gained extend beyond the pandemic. The participants had a strong desire to continue living independently in their own homes, even though stair falls and near-falls notably impacted how they navigated their environments. Importantly, the study highlighted the need for objective assessments of stair safety and emphasise the role behavioural factors may play in stair safety. These findings showed the complexity of sustaining independence at home in later life, suggesting that fall prevention must go beyond physical modifications to also address education, perceptions, behaviours, and broader situational factors.

5.2.3. Study 3: biomechanical lab study

Adding onto these findings, Chapter 4 used a biomechanical approach to explore whether using the handrails in their preferred way during stair descent affected foot placement and CoM control in older adults. While participants in Chapter 3 often described relying on handrails for perceived safety and stability, findings from Chapters 2 and 3 suggested a gap between perception of stair safety and actual stair fall risk. This study aimed to bridge that gap by linking preferred handrail use strategies with objective biomechanical parameters and determine whether handrails help mitigate stair fall risk in physically capable older adults. Preferred handrail use had no significant effect on foot placement (PFLCS) or CoM peak acceleration and velocity during the lowering and landing phase. However, CoM peak acceleration variability during the lowering phase increased with handrail use, suggesting less consistent movement patterns, possibly due to increased confidence and perceived assurance that the handrail could arrest a fall.

Across all studies, these findings highlight a recurring gap between perceived stair safety and actual risk. Many older adults stated that their stairs were safe, even when objective home assessments identified

structural non-compliance. Importantly, even behaviours typically considered protective, like handrail use may not grant stability benefits if they are used inconsistently. This disconnect suggests that interventions must go beyond structural modifications to also address awareness, perception, and behavioural factors. Educational efforts should help older adults identify stair-related hazards in their home and reflect on their own movement strategies. Tailored interventions should promote not only safe environments but also consistent, purposeful use of safety features like handrails, while identifying those whose confidence and physical capacity differ. Additionally, findings across chapter 2, 3, and 4 revealed that stair falls are not solely the result of age-related physical decline but emerge from a complex interplay of individual, environmental, and behavioural factors. These are further shaped by situational factors such as the COVID-19 pandemic.

5.3. Individual factors affecting stair fall risk

Across all studies, individual-level characteristics emerged as contributors to stair fall risk. In chapter 2, the older adults who were in a higher age group experienced increased injury severity (e.g., broken bones or concussions) from stair falls. Age is one of the factors that can contribute to frailty and is associated with an increased stair fall risk, which can also be affected by other factors such as chronic illnesses, cognitive impairment, and physical inactivity^[30]. The increased physical inactivity during lockdown may be linked to increased stair fall risk^[16,30,87-89], potentially through mechanisms such as rapid muscle deconditioning, loss of balance, and functional decline^[63]. Low muscle strength may limit older adults' ability to respond effectively to perturbations on stairs^[41,42], while small joint RoM, and diminishing mobility may impair safe step clearance or landing^[19,41]. Similarly, poor balance reduces older adults' ability to make postural adjustments for perturbation recovery^[19]. We acknowledge that chapter 2 did not include the data needed to establish a link between increased exposure to risk and a higher likelihood of a home stair fall, neither did the results confirm physical deconditioning as the singular cause for the rise in home stair falls during the lockdown. Nevertheless, older adults need to be more aware of their heightened vulnerability to such incidents during home confinement. The potential relationship should impact the need for stair fall risk awareness, alongside supporting physical activity interventions during future pandemic events to prevent stair falls in older adults^[30]. Additionally, it highlights the need for implementation of effective exercise programmes for older adults especially during periods of self-isolation and home-confinement^[30].

Chapter 4 provided further insight into individual capacity, showing that participants with high functional fitness and balance confidence did not have improved stability and foot placement from handrail use under

controlled conditions. Several factors, including stair dimensions, lighting, and environmental complexity, can influence the degree of challenge for stair descent [30,32]. This could suggest that for healthier, more confident individuals, the physical demands of stair descent may not exceed their capabilities. While greater movement variability (as reflected by increased peak CoM acceleration variability during the lowering phase) was observed with handrail use, this must be interpreted within the broader context that handrail use remains an inherently safer strategy for stair negotiation [51-53]. In line with this interpretation, handrail use also did not provide a measurable advantage in reducing overstepping (PFLCS) or improving balance control during landing and lowering, as indicated by CoM acceleration and velocity measures. Handrails offer mechanical support through redistributing load to reduce demands on the lower limbs [51,53], and can be useful for recovering balance during sudden losses of stability [42]. Moreover, handrails offer tactile feedback for those with visual or mobility impairments, or in reduced visibility (e.g. poor lighting) and psychological reassurance for individuals with a fear of falling [51-54]. Individual factors, such as reduced attention due to dual-tasking [31,130], the presence of other people on the stairs [131,132], or visual aspects [61,133] could also alter handrail use in real-world settings. Simulating these external conditions in a controlled lab setting is technically challenging and we did not assess these factors, which may explain why handrail use did not significantly affect fall risk in this study. A practical approach could be to assess these biomechanical parameters in real-world staircases using advancements in marker-less motion capture [134,135] and wearable sensors [136,137]. This would allow for the measurement of stair-specific biomechanical parameters, such as foot placement, and CoM parameters, in natural environment. Increasing the sample size and capturing natural behaviours during real-life stair negotiation could reveal subtle patterns in handrail use and balance control that are not observable in lab-based studies.

Cognitive and psychological factors such as concern about falling, attentional focus, and visuomotor control also played a role. In both chapter 2 and 3, anxiety and confidence were found to influence behaviour on stairs. For example, in chapter 2 interviews, several participants described becoming more hesitant and anxious when navigating stairs after a fall, leading to slower walking speeds, increased reliance on the handrail, and frequent visual checking of each step. Reduced confidence and increased anxiety can change visuomotor behaviour during obstacle negotiation, such as decreased walking speed [44,46] and reduced visibility [47]. One participant reported avoiding looking ahead and instead focusing narrowly on their feet to reduce the risk of missteps, a behaviour associated with increased postural instability and greater likelihood of tripping. Similarly, in chapter 3, participants with higher confidence levels and low concern about falling scores demonstrated less consistent handrail use and more variable CoM acceleration during stair descent,

possibly reflecting a sense of perceived safety that reduced attentional focus on stability. These behaviours reflect how individual psychological states may shape visuomotor control and the degree of active safety-seeking strategies during stair negotiation. While individual factors such as strength, vision, and psychological factors influence stair negotiation, these factors do not operate in isolation. They are shaped by their environment in which stair negotiation occurs.

5.4. Stair safety and environmental hazards

Older adults face a heightened risk of stair falls due to unaddressed hazards on their staircases. Such unaddressed hazards may include poorly designed or absent handrails, stairs that are too steep and narrow, step surfaces or coverings in poor condition, objects left on steps, and poor lighting ^[3]. Findings from chapter 3 revealed a disconnect between older adults' perceptions of stair safety and the objective presence of hazards in their homes. Every single stair faller perceived their stairs as safe, despite a substantial proportion (40%) of them having staircases that did not meet British Standard BS5395-1 for stair pitch, rise, and going. Notably, our measurements of stair dimensions did not distinguish between those who had experienced home stair falls and those who had not. This indicated that both groups equally did not meet the safety standards. Instead, features like turning staircases with quarter landings (90°/180°) were identified as influential factors in home stair safety. Chapter 2 also highlighted this perceptual gap. A majority of home stair fallers rated their stairs as safe, even when they described features like narrow treads or poor step coverage within their home, suggesting a lack of hazard awareness. It is clear that home adaptations can play a key role in supporting older adults to live independently for longer, equally, it can act as a preventive measure against the escalation of care requirements as a result of stair falls and accidents within the home ^[48]. Our findings reinforce the need for educational interventions aimed at improving environmental risk recognition.

Adhering to safety standards, specifically those set by the British Standard BS5395-1, could potentially reduce the risk of falls by 60% ^[55]. Our interviews supported the importance of adhering to safety standards, especially the provision of handrails, with several instances where their use prevented more severe falls. While the structural transformation of existing stairs (pitch, rise and going) poses challenges, updating building regulations for new constructions emerges as a proactive preventive strategy ^[58]. For homes with non-compliant staircases, interventions targeting elements of safety standards, such as slip resistance, stair coverings, and the provision of handrails, can be effective ^[58,104]. Additionally, further research is required

to explore the behavioural aspects of stair safety to understand additional perceptions and differences in stepping techniques between fallers and non-fallers, informing effective fall prevention interventions.

5.5. Behavioural factors affecting stair fall risk

In addition to individual and environmental contributors, behavioural factors emerged as influencer on stair safety across chapter 2, 3, and 4. Behaviours such as leaving items on the stairs or neglecting to use handrails and décor choices such as patterned carpet were identified as influential factors in home stair safety. Chapters 2 and 3 revealed that many participants failed to perceive décor-related hazards as stair fall risks. For example, 90% of participants with patterned stair carpets did not recognise them as problematic. Surface colour and/or pattern can affect visually locating step edges or judging distances, reduce confidence and increase anxiety for stair negotiation ^[44,61]. Participants acknowledged worn or loose stair coverings as hazardous, but not within the context of their own home. Additionally, visual elements such as colour and pattern were also overlooked. This reflects a broader lack of awareness around how visual cues in the home influence stepping behaviour and fall risk. Educational initiatives that inform older adults about the role of behaviour and décor choices in home stair safety are imperative ^[30]. Increasing the older adults, family members, and their carer's ability to identify hazards, with the knowledge of how to access support for home adaptations can minimise the stair fall risk and risky behaviours ^[30]. This underscores the need for targeted interventions to modify behaviour and promote safer stair practices among older adults.

Interview data from chapter 3 highlighted behavioural factors such as carrying items on stairs, rushing, failing to use handrails, and leaving objects on steps were frequently refer to as contributing to falls, suggesting that situational context and habit strongly influence safety. Most participants described modifying these behaviours only after experiencing a fall, suggesting a reactive response to increased anxiety rather than preventative for the fallers. For some, experiencing a stair accident had considerable impact on their well-being, with consequences such as broken bones, discomfort, and feeling fearful navigating their homes. Therefore, these findings highlight the urgent need for proactive behavioural interventions that promote hazard awareness and encourage safer stair practices before a fall occurs. Educational efforts should focus on identifying risky habits, reinforcing the consistent use of safety features like handrails, and fostering situational awareness to reduce reliance on reactive behaviour change following a stair-related injury.

Chapter 4 revealed that participants often used the handrail in varying, non-standardised ways (e.g., gliding, gripping, or intermittently using them depending on perceived need), potentially reducing handrails mechanical benefit. Inconsistent handrail use may reflect overconfidence or habitual underutilisation, especially as the participants had a high functional fitness and a low fear of falling. Participants' self-selected handrails usage showed increased variability in CoM control, suggesting that perceived safety through handrail use may not always align with improved biomechanical stability. These findings underscore that stair fall risk is not only shaped by what safety features are available but also by how and whether individuals choose to use them. Educational programmes should therefore include behavioural training not just environmental modifications to maximise their impact. Promoting proactive safety behaviours before a fall occurs, rather than relying on reactive adaptations, will be essential to reducing stair fall incidence among older adults.

This interconnectedness of individual, environmental, and behavioural risk factors highlights the importance of multifactorial fall prevention strategies that go beyond addressing physical impairments alone. Effective interventions must also consider home design, environmental modifications, and behavioural adaptations to support safe stair use and preserve independence among older adults.

5.6. Impact of the COVID-19 pandemic on stair fall risk

The COVID-19 pandemic exacerbated existing vulnerabilities and introduced novel challenges to stair safety. In Chapter 2, survey data found an increase in home stair falls during the lockdown period, likely due to greater exposure to home stairs and reduced physical activity. Lockdown measures disrupted regular routines and access to outdoor or community-based exercise, leading to reduced physical activity. This decline in physical activity likely contributed to reduced muscle strength, impaired balance, and overall deconditioning ^[30,49], factors known to increase susceptibility to stair falls, particularly among older adults ^[63].

Additionally, in chapter 2 we found that loneliness and social isolation, particularly among those living alone during the pandemic, were also linked to higher fall rate. Loneliness and reduced social engagement, conditions widely reported during the pandemic are linked with emotional distress, reduced self-esteem, and symptoms of depression, all of which can negatively affect overall well-being and functional independence ^[69,70]. In chapter 3 we found that the frustration caused by restricted social engagement manifested coping mechanisms such as increased engagement in domestic projects, increased exposure to

risk, such as rushing on the staircase or neglecting to use handrails which may have impacted fall risk and consequences ^[68–70]. The experience of a stair fall seemed to have further intensify this isolation for some individuals, as physical injury resulting from a stair fall lead to reduced mobility and independence, limiting individuals' ability to engage in social and physical activities ^[1]. This may have created a cyclical risk, where reduced participation in meaningful activities exacerbates loneliness, while also weakening strength, balance, and confidence, which are critical factors in fall prevention ^[71–73]. Therefore, it is necessary to consider interventions and support systems aimed at reducing social isolation during future pandemics and beyond, ultimately contributing to enhanced safety and well-being ^[73].

Chapter 3's findings provided further insight into the older adults experiences of the pandemic by detailing how lockdown disrupted daily routines, reduced access to support services, and heightened anxiety all of which contributed to unsafe stair behaviours and environments. Many participants reported becoming more sedentary, with increased time spent indoors watching television or attending virtual meetings, and reduced engagement in community or outdoor activities. This lifestyle shift may have further contributed to physical deconditioning, with potential implications for strength, gait stability, and stair confidence ^[71–73]. Several participants voiced difficulty returning to pre-pandemic activity levels, suggesting that the long-term consequences of lockdown may persist beyond the end of the pandemic. Our findings amplify the need for effective interventions that address habitual physical activity and exercise programmes for older adults especially during periods of self-isolation and home-confinement ^[30].

Furthermore, access to healthcare and essential facilities encountered substantial hurdles during the pandemic ^[48,63–65], adding further layers of complexity to the endeavour of fostering safe and independent living among older adults. Our findings highlight the multifaceted challenges faced by older adults, as they navigated the constraints of the COVID-19 pandemic. The connection of emotional well-being, social factors, and physical health, all play roles in maintaining a safe home environment for older adults. Implementing multicomponent interventions such as community fostering, housing adaptations, and physical activity recommendations could all potentially help prevent home stair falls for older adults ^[30], and need to be addressed in future research.

Together, these studies revealed that the pandemic acted as a magnifier of existing risk factors while also introducing new ones. In preparing for future public health emergencies, such integrated strategies will be essential:

- Physical activity programmes tailored to restricted environments;
- Education around environmental hazards and stair safety;
- Financial and practical support for home adaptations;
- Social connection initiatives to reduce loneliness and isolation

Preventive measures should not only focus on physical fall risk factors but must also address social, behavioural, and environmental factors. Future research should explore how to implement fall prevention interventions remotely or in digitally excluded populations, ensuring equitable protection for all older adults regardless of socio-economic status or location. By exploring the interface between biomechanics, perception, and lived experience, this thesis underscores the limitations of one-size-fits-all interventions and the necessity for flexible, tailored strategies that empower older adults to live safely and independently in their homes during future pandemics and beyond.

5.7. Strengths

This thesis is one of the first to specifically explore the extent to which the COVID-19 pandemic may have been linked to stair falls in older adults using a mixed method approach. It provides a comprehensive, multi-dimensional investigation of home stair fall risk in older adults, bridging public health, qualitative research, environmental design, and biomechanics.

A primary strength of this thesis is its sequential mixed-methods design, in which each study was designed to inform the next. Rather than treating the survey, home visits, and laboratory study as isolated components, the research adopted a nested, progressive approach. This progression ensured that the biomechanical analysis was grounded in lived experience rather than theoretical assumptions, strengthening the relevance laboratory outcomes. Collectively, by identifying perception and behaviour gaps, leveraging a unique pandemic context, and using ecologically valid biomechanics to identify stair falls risks strengthen the thesis. By capturing stair falls, near-falls, and behavioural adaptations during this period, the thesis offers historically and clinically valuable insights. Additionally, these findings extend beyond the pandemic context, providing an understanding for fall risk during future periods of isolation, illness, or restricted mobility.

Furthermore, the use of PPIE is another key strength of this thesis. Public advisors contributed to study design, survey development, interview guides, interpretation of findings, and dissemination, ensuring that the research remained grounded in lived experience and public relevance. In addition, the thesis

demonstrates methodological reflexivity and transparency, acknowledging the researcher's positionality, the challenges of in-home data collection, and the ethical and emotional dimensions of conducting research with older adults during a pandemic. This reflexive approach enhances the trustworthiness and credibility of the findings.

5.8. Limitations

While this thesis provides novel insights into stair fall risk in older adults, several limitations must be acknowledged. A key limitation shared across all studies was limited generalisability. Firstly, limited generalisability to frail older adults, particularly those with low physical function, cognitive impairments, or high fear of falling. The biomechanical study, for instance, included only healthy older adults with high balance confidence, limiting relevance to higher-risk populations^[37]. Secondly, self-selection bias may also have influenced the sample, particularly in the survey and home visit studies. Participants with prior experiences or strong opinions related to stair safety may have been more likely to participate, again limiting the generalisability of the findings to the wider older adult population. Lastly, the homogeneity of our participants may impact the generalisability of our findings and the representation of diverse communities may not have been captured. The study included participants that were from a White ethnic background, living in more affluent areas (IMD Quintiles 3, 4, and 5) and mostly homeowners. This limited representation may not fully capture disparities present in other populations, including ethnic minorities and individuals from lower-income backgrounds. Inclusivity and representation in studies is vital for recognising and addressing the needs of diverse communities and socio-economically disadvantaged areas^[65,93]. This lack of diversity may obscure important contextual influences on stair safety and home adaptation practices, especially in communities more affected by digital exclusion, poor housing conditions, and systemic health disparities. Recruitment strategies in future research should aim to engage harder-to-reach groups including those in under-resourced settings through community partnerships, non-digital methods, and inclusive engagement strategies.

Additionally, although the IMD was used to assess socio-economic status, this measure has limitations when used as a proxy for housing conditions. The IMD is weighted heavily toward income and employment, and only a small proportion (9.3%) reflects the living environment. It does not capture individual-level variation in housing stock, stair design, or safety features. For example, a household within a IMD score of 5 (low deprived area) could still face significant fall risks due to poorly designed stairs or missing handrails. This

may explain the unexpected finding that individuals in less deprived areas reported more stair falls. In addition, stair falls are complex and difficult to predict as they are determined by multiple changing factors, including cognitive, perceptual, psychological, physical, as well as biomechanical parameters ^[92], therefore may not have a strong association with IMD.

Recall bias was another limitation, particularly in the survey and interviews. Participants were asked to report past fall events, behaviours, and perceptions, some of which occurred during the early stages of the COVID-19 pandemic. Age-related variability in memory, combined with emotional or contextual influences, may have impacted the accuracy of these accounts ^[107–111]. Although interview methods aimed to mitigate this (e.g. guided prompts), future studies should consider data triangulation (e.g. Hospital Episode Statistics, GP records) to validate self-reported falls and improve fall history data ^[112].

5.9. Reflections of methods

This PhD adopted a sequential mixed-methods design to capture the multifactorial nature of home stair fall risk in older adults, combining survey, qualitative, environmental, and biomechanical approaches. This methodological progression was intentional, allowing each study to address limitations and unanswered questions from the preceding work, while balancing ecological validity with experimental control.

The national survey (Study 1) provided breadth, enabling rapid data collection during COVID-19 lockdowns and capturing stair falls that may not have resulted in medical attention. However, reliance on retrospective self-report limited the ability to explore contextual detail, individual reasoning, and environmental features in depth. These limitations directly informed the design of Study 2, which incorporated semi-structured interviews and objective home stair assessments to explore lived experience, perceptions of safety, and real-world stair environments.

Study 2 demonstrated the value of combining qualitative insight with physical measurements, revealing a consistent disconnect between perceived and objective stair safety. However, while this approach captured context and meaning, it could not determine whether commonly reported safety strategies, particularly handrail use conferred measurable biomechanical benefits. This methodological gap informed Study 3, which prioritised laboratory-based biomechanical assessment to analyse stair descent and handrail use.

The biomechanical design in Study 3 did not capture qualitative methods, limiting insight into participants' perceptions, confidence, and decision-making during stair negotiation. While this was a deliberate choice

to avoid cognitive load, safety risks, and task interference, it represents a methodological trade-off. Future research could incorporate brief post-task reflections or audio-recorded verbal reports to integrate perceptual data alongside biomechanical outcomes.

Across studies, recruitment through community organisations, public involvement networks, and repeated contact attempts strengthened inclusion during a period of social restriction, but opportunity sampling limits generalisability. Furthermore, participants who volunteered for home visits and laboratory testing may represent a more confident or physically capable subgroup of older adults, potentially underestimating risk in more vulnerable populations.

Overall, the mixed-methods approach strengthened the thesis by allowing triangulation across self-report, observation, and objective measurement. The methodological reflections across studies highlight the importance of integrating behavioural, perceptual, environmental, and biomechanical perspectives when examining stair fall risk. Rather than a single-method explanation, the findings support a layered understanding of falls, reinforcing the need for prevention strategies that address not only physical hazards but also awareness, behaviour, and confidence in older adults living independently.

5.10. Recommendations

5.10.1. For research

To address both the broad and project specific limitations of our work, and build on current findings, several key avenues for future research are recommended:

- **Real-world biomechanical parameters:** Future studies should integrate marker less motion capture or wearable sensors (e.g. inertial measurement units) to capture foot placement, CoM parameters, and balance control in real home environments. This would allow more ecologically valid insights into stair negotiation strategies and behaviours, especially in homes with varied stair dimensions and hazards. In addition, incorporating qualitative methods alongside biomechanical assessments, such as brief post-trial interviews or audio recordings could provide valuable insight into participants' perceptions of stability, confidence, and handrail reliance during laboratory tasks, offering context for observed movement patterns that cannot be inferred from biomechanical data alone.

- **Increase representative sampling:** There is a need to recruit more ethnically and socio-economically diverse participants. Socio-economic status should be assessed through more direct measures of housing quality, individual financial hardship, and access to services. The IMD, while useful at a policy level, lacks details for evaluating individual living environments. Collaborating with community organisations, housing associations, and care networks may facilitate access to marginalised groups and improve study inclusivity.
- **Longitudinal designs:** Longitudinal research is needed to examine how perceptions, behaviours, and biomechanical performance evolve over time and how they relate to actual fall outcomes. Such designs would help identify predictive markers of stair falls and clarify subtle pathways between risk factors and fall events.
- **Multifactorial interventions and evaluation:** Future research should test the effectiveness of multi-domain interventions combining home modifications, behavioural education, and physical training tailored to specific risk profiles. Evaluating these interventions using mixed-methods and implementation of developed frameworks will help ensure scalability and real-world impact.

5.10.2. For practice

- **Enhance handrail use and hazard awareness:** While handrail availability is essential, correct and consistent use is equally critical. Education and training programmes for older adults should incorporate practical guidance on safe handrail use to support balance recovery and fall prevention. Additionally, increasing awareness of environmental hazards such as worn carpets, inadequate lighting, or obstructed steps could allow individuals to identify and mitigate risks in their own homes.
- **Integrate stair-specific screening in fall risk assessments:** Existing fall risk screening tools, such as those recommended by NICE, focus on general risk factors including balance, strength, medication use, vision, and home hazards. However, they rarely include stair-specific elements. Expanding these assessments to include behavioural practices (e.g., rushing, carrying items, or inconsistent handrail use), psychological factors (e.g., confidence, fear of falling), and stair environment features (e.g. patterned carpet or items on stairs). This would facilitate more targeted and effective intervention strategies.

- **Improve access to home adaptations:** Many participants reported that cost and lack of information deterred home modifications. Provision of accessible information and increased availability of financial assistance (e.g. charities such as Care and Repair England ^[139]) especially in socio-economically deprived areas are necessary to promote equitable uptake of home safety improvements.
- **Shift from reactive to preventative strategies:** Occupational therapists and fall prevention teams are often engaged post-fall. Greater investment in pre-emptive assessments, education, and home visits could prevent first falls and reduce overall care costs. While current NICE guidelines focus on professional assessments, there could be emerging opportunity for carers to conduct assessments as they are often the first responders to hazards. Through structured training, carers could serve as third-party observers. Training programs and accessible at home stair assessments could be utilised and should specifically target the hazards identified in this thesis, such as visual patterns and inconsistent handrail use.

5.10.3. For policy

- **Update housing regulations:** Existing housing design standards, including British Standard BS5395-1, should be more rigorously implemented across both new-build and retrofitted properties. Requirements for compliant handrails, safe step dimensions, and adequate lighting should be enforced within national building codes to enhance stair safety in the long term.
- **Invest in at-risk housing:** Older adults living in poor-quality or outdated housing require targeted policy support. Public investment in upgrading these homes, particularly those with unsafe staircases should be prioritised as a preventative health strategy to reduce the stair falls and cost of fall-related injuries.
- **Restore and expand fall prevention services:** Many community-based fall prevention programmes were paused or scaled back during the pandemic. These services must be resumed and prioritised, with funding directed toward multidisciplinary, community-based prevention.

In summary, while this thesis highlights critical aspects of stair fall risk among older adults, addressing these limitations through inclusive, longitudinal, and real-world methodologies will be essential to advancing fall prevention and ensuring safe ageing in place. Although many stair falls can be prevented, effective

prevention requires more than generalised approaches ^[1,30]. Specifically, stair fall prevention interventions must identify individuals at risk ^[30,126] and the factors contributing to their stair fall risk, such as unsafe stepping behaviours, reduced confidence, poor lighting, or non-compliant stair dimensions. Targeted, multidomain interventions, which may include a combination of environmental modifications, behavioural education, and physical training are most effective when they are predictive, preventative, personalised, and participatory ^[30]. Such tailored approaches not only reduce fall risk but also support older adults' independence and improve overall quality of life ^[30].

5.11. Conclusion

This thesis aimed to explore older adults' experiences, behaviours, and biomechanical performance on stairs through a multi-method approach, as a consequence of the COVID-19 lockdown.

Findings across studies highlight the multifactorial nature of stair fall risk and underscore the limitations of addressing these risks in isolation. Safe stair negotiation depends not only on individual capability, but also on environmental design, housing quality, social support, and behavioural awareness. The COVID-19 pandemic underscored the fragility of older adults' independence when exposed to prolonged confinement, reduced physical activity, and suspended support services. Experiences from the COVID-19 pandemic must inform future preparedness, with stair safety considered an integral part of public health and ageing-in-place strategies. To reduce stair fall injuries in the older population, we must adopt a holistic approach one that bridges biomechanics with lived experience, aligns housing policy with health needs, and centres the voices of those most at risk.

Appendices

Appendix A: Survey questions

2. Have you fallen more on stairs at home since the COVID-19 pandemic?

Required

Yes

No

General Questions

3. What is your age? ? *Required*

- 50 - 59
- 60 - 69
- 70 - 79
- 80 +

4. What do you identify as? ? *Required*

- Female
- Male
- Prefer not to say
- Other

4.a. If you selected Other, please specify:

5. Please enter your postcode (please note we are interested in the local area, not your specific address) **Make sure you haven't got a space at the end of your postcode and it is in BLOCK capitals* ? *Required*


Please enter a valid UK postcode.

Your answer should be no more than 8 characters long.

6. How would you describe your ethnicity  *Required*

6.a. If you selected Other, please specify:

Concern about the possibility of falling

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

	1 Not at all concerned	2 Somewhat concerned	3 Fairly concerned	4 Very concerned
Getting dressed or undressed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Taking a bath or shower	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Getting in or out of a chair	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Going up or down stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reaching for something above your head or on the ground	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Walking up or down a slope	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Going out to a social event (e.g. religious service, family gathering or club meeting)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Falls

We are interested to learn whether you have previously fallen.

We define a **fall** as an event (e.g. trip/slip/stumble) that results in a person **losing their balance and coming to rest inadvertently (e.g. by accident) on the ground or floor or other lower level.**

The UK entered the first lockdown in response to the COVID-19 pandemic on **23rd March 2020**. We are also interested to learn whether your experiences of falls have changed since the beginning of the first lockdown.

8. Have you experienced a fall/falls within the last two years? *Required*

Yes

No

Falls

9. Did you experience a fall before the COVID-19 pandemic (**before** 23rd March 2020)? *Required*

Yes

No

10. Have you experience a fall since the COVID-19 pandemic (**after** 23rd March 2020) *Required*

Yes

No

11. Did you experience a fall after the lockdown restrictions started to ease (after 12th April 2021)? *Required*

Yes

No

12. After the fall(s), did you seek medical advice? *Required*

Yes

No

Prefer not to say

Falls

13. Was the COVID-19 pandemic responsible for you not seeking medical advice?

Required

- Yes
- No
- Prefer not to say

Falls

14. Did you experience any injuries because of your fall(s)? *Required*

- Fracture or broken bone
- Banged head/concussion Cuts
- and bruises
- Aches and Pains
- Stiffness
- None
- Other

14.a. If you selected Other, please specify:

15. After the fall(s), did you experience a long lie (e.g. difficulty getting up and remained on the floor for an hour or more)? *Required*

- Yes
- No

16. Regarding your fall(s), what activity/activities were you doing within the environment at the time? You can select multiple options. *Required*

- Walking
- Running
- Standing
- Moving quickly/rushing

- Carrying an item
- Turning Exercising
- Playing with children/pet
- Responding to a phone call/knock at the door Talking
- with someone
- Under the influence of alcohol/recreational drugs
- Other

16.a. If you selected Other, please specify:

17. If you use a walking aid such as a cane, walker etc., were you using it when the fall(s) occurred? Required

- Yes
- No
- I do not use a walking aid
- Prefer not to say

18. Regarding your fall(s), what caused your fall at the time? You can select multiple options if they apply. Required

- Falling over objects on floor/ground
- Falling over furniture
- Falls on step or stairs
- Falls over the door frame/door trim/door threshold Falling

Other

18.a. If you selected Other, please specify:

19. If you would like to provide additional details about your fall(s), please detail them below. *Optional*

Falling on a step or stairs

We are interested to learn whether you have previously **fallen on steps or stairs**.

Stair falls in older people have severe consequences for the faller, their carer's, and the NHS. The inactivity enforced by home confinement due to the COVID-19 pandemic is a significant risk for a stair fall. This risk will be further increased with more frequent use of the stairs during home confinement.

Documenting falls on steps and stairs will hopefully improve stair safety for older adults after the pandemic and/or if we are in similar situations in the future.

20. Did your fall(s) occur on steps/stairs? *Required*

Yes

No

Falling on a step or stairs

21. Did the fall(s) occur on indoor or outdoor steps/stairs? *Required*

- Indoor
- Outdoor
- Both
- Other

21.a. If you selected Other, please specify:

22. Which direction were you traveling on the steps/stairs? *Required*

- Going up the steps/stairs
- Going down the steps/stairs
- Both

23. Did your fall(s) on steps/stairs occur in the home environment or outside the home environment? *Required*

- Home environment (home, garden, apartment stairs, etc.)
- Outside the home environment (shopping, beach, park, public areas, etc.) Both
-

Falling on a step or stairs

24. Thinking about your fall(s) on the steps/stairs. Did any of the following factors affect the fall? Select multiple if it applies. *Required*

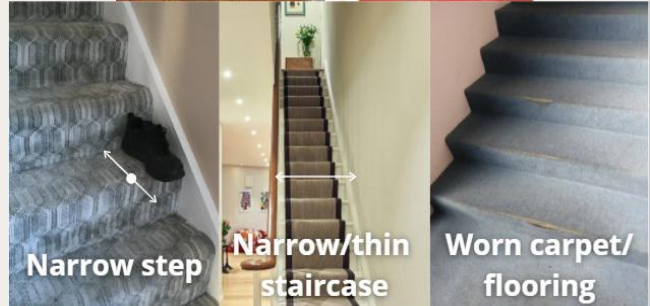
- Footwear
- Misjudged the step/stair edge location
- Objects/clutter around on the steps/stairs
- Busy/distracting
- steps/stairs
- Poor/dim lighting
- Darkness
- Colour of the steps/stairs
- Glare from natural light
- Not wearing spectacles/wearing incorrect spectacles (eye-glasses)
- No handrails/grabrail
- Wet surface

24.a. If you selected Other, please specify:

25. Do any of these describe the steps/stairs you fell on? *Required*



- Uneven step/stair surface
- Steep step/stairs
- Narrow step (struggle to fit the majority of your foot on the step)
- Narrow/thin staircase (railing/walls are close together)
- Worn carpet/flooring
- None of the above



25.a. If you selected Other, please specify:

26. Do you think your steps/stairs at home are safe? *Required*

- Yes
- No

Near-falls

We define a near-fall (sometimes referred to as a near-miss) as an event (e.g. trip/slip/stumble/loss of balance) **that would have resulted in a fall if you had not managed to recover your balance.**

i.e. by using an unplanned movement of your arms to catch yourself on a nearby wall or object, or using an unplanned stepping movement with your legs, to prevent a fall.

27. Have you experienced a near-fall/falls within the last two years? *Required*

Yes

No

Near-falls

28. Did you experience a near-fall before the COVID-19 pandemic (**before** 23rd March 2020)? *Required*

Yes

No

29. Have you experience a near-fall since the COVID-19 pandemic (**after** 23rd March 2020) *Required*

Yes

No

30. Did you experience a near-fall after the lockdown restrictions started to ease (after 12th April 2021)? *Required*

Yes

No

31. After the near-fall(s), did you seek medical advice? *Required*

Yes

No

Prefer not to say

Near-falls

32. Was the COVID-19 pandemic responsible for you not seeking medical advice?

Required

- Yes
- No
- Prefer not to say

Near-falls

33. Did you experience any injuries because of your near-fall(s)? *Required*

- Fracture or broken bone
- Banged head/concussion Cuts
- and bruises
- Aches and Pains
- Stiffness
- None
- Other

33.a. If you selected Other, please specify:

34. Regarding your near-fall(s), what activity/activities were you doing within the environment at the time? You can select multiple options. *Required*

- Walking
- Running
- Standing
- Moving quickly/rushing
- Carrying an item Turning
- Exercising
- Playing with children/pet
- Responding to a phone call/knock at the door Talking
- with someone
- Under the influence of alcohol/recreational drugs

Other

34.a. If you selected Other, please specify:

35. If you use a walking aid such as a cane, walker, etc., were you using it when the near-fall(s) occurred? *Required*

- Yes
- No
- I do not use a walking aid
- Prefer not to say

36. Regarding your near-fall(s), what caused your fall at the time? You can select multiple options if they apply. *Required*

- Falling over objects on floor/ground
- Falling over furniture
- Falls on step or stairs
- Falls over the door frame/door trim/door threshold
- Falling in/over the bath/shower tray/shower door frame
- Other

36.a. If you selected Other, please specify:

37. If you would like to provide additional details about your near-fall(s), please detail them below.

Near-falls on a step or stairs

We are interested to learn whether you have previously had a **near-fall on steps or stairs**.

Stair falls in older people have severe consequences for the faller, their carer's, and the NHS. The inactivity enforced by home confinement due to the COVID-19 pandemic is a significant risk for a stair fall. This risk will be further increased with more frequent use of the stairs during home confinement.

Documenting near-falls on steps and stairs will hopefully improve stair safety for older adults after the pandemic and/or if we are in similar situations in the future.

38. Did your near-fall(s) occur on steps/stairs? *Required*

Yes

No

Near-falls on a step or stairs

39. Did the near-fall(s) occur on indoor or outdoor steps/stairs? Required

- Indoor
- Outdoor
- Both
- Other

39.a. If you selected Other, please specify:

40. Which direction were you traveling on the steps/stairs? Required

- Going up the steps/stairs
- Going down the steps/stairs
- Both

41. Did your near-fall(s) on steps/stairs occur in the home environment or outside the home environment? Required

- Home environment (home, garden, apartment stairs, etc.)
- Outside the home environment (shopping, beach, park, public areas, etc.) Both
-

Near-falls on a step or stairs

42. Thinking about your near-fall(s) on the steps/stairs. Did any of the following factors affect the near-fall? Select multiple if it applies. *Required*

- Footwear
- Misjudged the step/stair edge location
- Objects/clutter around on the steps/stairs
- Busy/distracting steps/stairs
- Poor/dim lighting
- Darkness
- Colour of the steps/stairs
- Glare from natural light
- Not wearing spectacles/wearing incorrect spectacles (eye-glasses)
- No handrails/grabrail

Wet surfaces

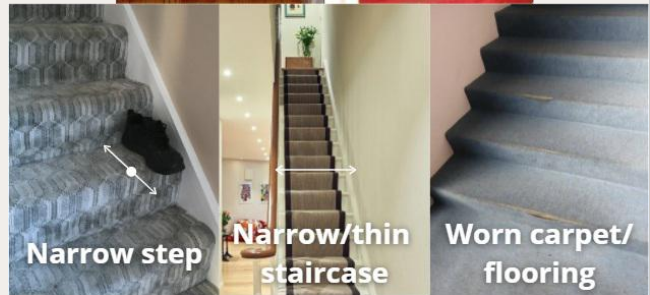
42.a. If you selected Other, please specify:

43. Do any of these describe the steps/stairs

you had a near-fall(s) on? Required



- Uneven step/stair surface
- Steep step/stairs
- Narrow step (struggle to fit the majority of your foot on the step)
- Narrow/thin staircase (railing/walls are close together)
- Worn carpet/flooring
- None of the above/Other



43.a. If you selected Other, please specify:

44. Do you think your steps/stairs at home are safe? Required

- Yes
- No

Occupation

45. What is your current occupation status? *Required*

- Full-time work
- Part-time work
- Volunteer
- Retired
- Prefer not to say
- Other

45.a. If you selected Other, please specify:

46. If you **work full-time/part-time/volunteer**, how many hours do you work per week (on average)?

- 0 - 20
- 20 - 40
- 40 - 50
- 50 +
- Not Applicable

47. If you selected **retired**, how many hours did you previously work/volunteer per week (on average)?

0 - 20

20 - 40

- 40 - 50
- 50 +
- Not Applicable

Health and Exercise

48. Do you use a walking aid (cane, walker, or other) to move around your environment? *Required*

Yes

No

48.a. If you selected yes, please specify:

49. Do you have existing medical conditions or long-term illnesses? *Required*

Yes

No

Prefer not to say

49.a. If you answered yes, and you are happy to expand on the question above, please enter your existing medical conditions or long-term illness in the text box below.

50. Do you take any medications for existing medical conditions or long-term illnesses? *Required*

Yes

No

Prefer not to say

Health and Exercise

51. If you are happy to provide details, please can you select how many medications you currently take? *Required*

- 1
- 2
- 3
- 4
- 5+
- Prefer not to say

Health and Exercise

52. In general, how do you perceive your health? Required

Please don't select more than 1 answer(s) per row. Please

select at least 1 answer(s).

	1. Bad	2. Not so good	3. Satisfactory	4. Good	5. Very good
Perceived Health	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

53. How physically active are you? Required

- I am regularly physically active (e.g. walking/exercise classes/gardening/household tasks)
- I don't get out as much as I used to but I'm still mobile I
- am not able to exercise at all
- Prefer not to say

Health and Exercise

54. During the COVID-19 pandemic (after 23rd March 2020) could you comment on your physical activity level? *Required*

Please don't select more than 1 answer(s) per row. Please

select at least 1 answer(s).

	1. Significantly less physically active	2. Less physically active	3. No change in my physical activity level	4. More physically active	5. Significantly more physically active
Physical activity level	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Housing

55. Where do you live? Required

56. What best describes your current living situation? Required

- Living on your own/independently
- Living with someone
- Living alone in retirement housing
- Living with someone in retirement housing
- Other

56.a. If you selected Other, please specify:

Housing

57. Could you please specify how many occupants live in your home? *Required*

Housing

58. Type of property you currently live in? *Required*

- Flat/Apartment
- Terraced housing
- Semi-detached
- Detached
- Bungalow
- Annex (a building joined to or associated with the main building) Other

58.a. If you selected Other, please specify:

59. Which of the following best describes how you pay for your home? *Required*

- Owned outright
- Owned with a mortgage/loan
- Shared ownership/shared equity loan I
- live in a family/friends home
- Rented
- I live in temporary accommodation
- Prefer not to say

59.a. If you selected Other, please specify:

Modifications

60. What best describes the temperature of your home? *Required*

Please select at least 1 answer(s).

- Cold
- Damp
- Humid
- None of the above Other

60.a. If you selected Other, please specify:

61. Has your home previously been modified to help with mobility around the home (e.g. grab rails/handrails, edge highlighters, outdoor light fitted, adapted bathroom)?
Required

- Yes, before I moved in
- Yes, since I moved in No
- I don't know
-

61.a. Could you please specify what adaptations/modifications? *Optional*

62. Have your home modifications/improvements been put on hold or stopped due to COVID-19 (e.g. grab rails/handrails, edge highlighters, outdoor light fitted, adapted bathroom) *Required*

Yes

No

62.a. If you selected yes, please expand on this:

63. Has your home repairs been put on hold or stopped due to COVID-19 (e.g. changing light bulbs, removing damp/mold, fixing carpet/flooring etc.) *Required*

Yes

No

63.a. If you selected yes, please expand on this:

64. Did you have any help with completing this survey (i.e. from a family member, carer, or friend) *Required*

Yes

No

65. Are you happy to be contacted about a follow-up on your fall experiences?
Required

Yes

No

65.a. If you selected yes, please leave your contact details below (e.g. phone number/email):

Appendix B: Semi-structured topic guide used in interviews.

Q1. Can you tell me a bit about your home?

Q2. Reflecting on a typical week before the pandemic. What were your reasons to leave the house?

Q2a. How did that change during home-confinement/lockdown?

Q3. Can you talk me through how you spent a typical day in lockdown?

Q3a. Do you feel you used your home stairs more during the lockdowns?

Q4. How did you feel during lockdown/home-confinement, when living on your own/when living with others?

Q5. In the survey you said you felt...ADD PHYSICAL ACIVITY LEVEL ("more physically active during lockdown"), why do you think this?

Q6. How do you feel about COVID-19 now when leaving the house?

Q7. Thinking about home stair falls. Have you experienced a new stair fall in your home since you completed the survey?

Q7a(i). If you experienced a home stair fall, do you feel you fell on your stairs more during lockdown?

Q7a(ii). If you experienced a near home stair fall, do you feel you nearly fell on your stairs more during lockdown?

Q7a (iii). If you haven't experienced a home stair fall, why do you think you haven't experienced a stair fall at home?

Q8. Reflecting about the home stair fall/near home stair fall that's most memorable, could you talk me through what happened?

Q8a. What impact has this had on you?

Q9. Thinking about your home stairs, you said that they were...ADD SURVEY RESPONSE (“safe” or “unsafe”). What key features make your stairs safe? Or What key features make your stairs a hazard?

Q9a. What barriers do you have to making your stairs safe?

Q10. Is there anything else you feel is important to mention which we have not covered yet?

Appendix C: Stair assessment protocol for evaluating staircase safety.

Visual Assessment

Location of dwelling

Participant details

House number

Postcode

Position at start of fall

At the top

Near the top

Near the middle

Near the bottom

At the bottom

Don't know

Stair type

Straight stairs

Alternating tread stairs

Turning stairs (quarter landing or turn through 90°/180° to a second flight)

Narrow steps on one side (winders)

Spiral/helical stairs

Landing between floor levels

Don't know

Other

Number of steps

Visibility through gaps

Yes

No

Don't know

Type of banister/handrails (Right side)

Wall, no handrail

Wall with handrail

Banister with vertical rails

Ranch-style banister

Banister with intricate patterning

Solid banister

No banister/handrail/wall

Don't know

Other (add description)

Type of banister/handrails (Left side)

Wall, no handrail

Wall with handrail

Banister with vertical rails

Ranch-style banister

Banister with intricate patterning

Solid banister

No banister/handrail/wall

Don't know

Other (add description)

Stair appearance

Plain carpet

Pattern carpet

Exposed wood

Exposed metal or concrete

Lino/vinyl

Don't know

Other

Damage or wear

Broken or missing tread

Broken guarding

Broken handrail

Loose handrail

Damaged stair covering

Items left on steps

Stair characteristics (Likert scale)

Too steep

Too narrow

Poorly lit

Needs repair

Handrail needs repair

Covering needs repair

Stairs are safe to use

Visibility

Artificial lighting

Two-way switch available at both top and bottom

Steps well-lit with no shadows hiding nosing

Easy to change bulbs

Bulbs covered with diffused shade

Daylight/windows over stairs

Steps well-lit with no shadows hiding nosing

Windows reachable for cleaning

Windows operable (open/close)

Curtains/hangings manageable

No glare from windows when using stairs

Surrounding Environment

Room type at the top of stairs

Landing

Hall/lobby

Bedroom

Loft/attic

Living/dining area

Kitchen/utility room

Bathroom/toilet

Other

Moveable item at top of stairs

Yes

No

Room type at bottom of stairs

Landing

Hall/lobby

Bedroom

Loft/attic

Living/dining area

Kitchen/utility room

Bathroom/toilet

Other

Moveable item at bottom of stairs

Yes

No

Measurements and Dimensions

Participant's height

Participant's shoe size

Measure risings/goings

Handrail height (mm)

Handrail cross-section design

1½" Round

2½" Round

3" Round

2½" Decorative

3" Decorative

2½" Tapered

3" Tapered

Stair width (mm)

Foot overhang (mm)

Accident Assessment

Past incidents

Has anyone else fallen on these stairs?

Yes

No

Don't know

Relation to the accident participant

Myself

Husband/wife/partner

Son/daughter

Friend/visitor/stranger

Other

Usual stair negotiation (Up)

Use handrail

Sideways placement of body

Glance at feet

Step over step

Step by step

Other

Usual stair negotiation (Down)

Use handrail

Sideways placement of body

Glance at feet

Step over step

Step by step

Other

Appendix D: Marker placement

Full-body six-degrees of freedom model using a 15 segment (head, thorax, pelvis, upper arms, lower arms, hands, thighs, shanks, feet) defined by 74 reflective markers (diameter 14 mm; Appendix, [Figure 3](#)) was obtained to gain full-body kinematics. Markers for segment definition were attached to the calcaneus, lateral/medial calcaneus, first and fifth metatarsus head, lateral/medial malleolus, second cuneiform, proximal phalange halux, lateral/medial femoral condyle, iliac crest, acromion, anterior/posterior head, lateral/medial epicondyle of the humerus, styloid process of the radius and ulna, third metacarpal head (all left and right), sacral crest, cervical vertebrae 7, thoracic vertebrae 10, clavicular notch and xiphoid process of the sternum. In addition, marker clusters for segment tracking were attached to the lateral sides of the shanks and thighs (four markers per cluster), on the second and third metatarsal (three markers per cluster) and single markers were attached on the forearms, upper arms, above the auricular points, right scapula.

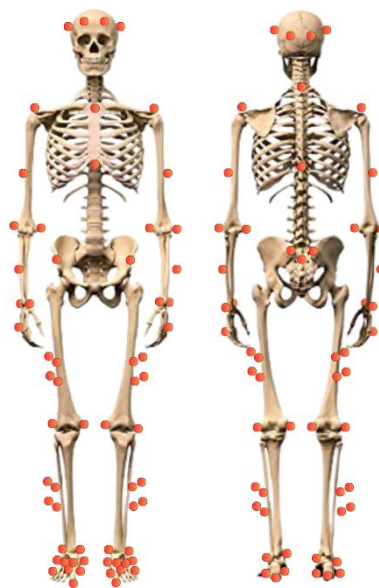


Figure D.1. Front and back view of the attachment locations of the 74 reflective markers.

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