Single leg squats predict independent stair negotiation ability in older patients referred for a physiotherapy mobility assessment at a rural hospital

Author
Rowena Hockings
Rehabilitation Physiotherapist
Shoalhaven District Memorial Hospital
Illawarra Shoalhaven Local Health District
E-mail: rowena.hockings@sesiahs.health.nsw.gov.au
Phone: 02 4423 9719
Fax: 02 4423 6183

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LIST OF ABBREVIATIONS

NSW	New South Wales
HETI-Rural	Health Education and Training Institute – Rural Directorate
RRCBP	Rural Research Capacity Building Program
ISLHD	Illawarra Shoalhaven Local Health District
ADL	Activity of daily living
BMI	Body mass index
LGA	Local Government Area
mm	Millimetre
NRS	Numerical Rating Scale
SD	Standard deviation
UOWISLHD	University of Wollongong and Illawarra Shoalhaven Local Health District
HREC	Human Research Ethics Committee
CI	Confidence interval

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ABSTRACT

Aim: To determine whether single leg squats predict ability to negotiate stairs in older patients at a rural hospital on the NSW South Coast.

Methods: This cross-sectional analytic study recruited a systematic sample of 146 older patients, who presented to the Shoalhaven Hospital emergency department or were admitted to the acute wards and were referred for a physiotherapy mobility assessment. Three participants were excluded from data analyses because they did not meet the study criteria. Participants' ability to complete up to 18 single leg squats and negotiate up to 18 steps were measured. Covariates including knee range of motion, level of mobility, demographic data and patient experience variables such as pain, were collected through direct measure, interview or from medical records. Exact logistic regression was used to evaluate the predictive ability of single leg squats to negotiate stairs.

Results: Data was analysed for 143 participants with a mean age of 80.0 ± 6.8 years (50.3% male, 49.7% female). The squat test had 86% sensitivity, 100% specificity, 100% positive predictive value, and 49% negative predictive value in correctly predicting stair negotiation ability. Participants who could complete single leg squats were 57 times more likely to be able to independently negotiate stairs than participants who could not complete squats. Multivariate regression analysis indicated that frame use at time of assessment, pain severity and whether participants lived alone were significant and independent predictors of ability to negotiate stairs independently in the model with squat test. Thirteen percent of participants were unable to complete the squat test, but could negotiate stairs. This was partially explained by pain severity, frame use and whether participants lived alone. There was perfect agreement (K = 1.0) between assessors on assessment of ability to complete squats and negotiate stairs.

Conclusions: Single leg squats are an accurate predictor of stair negotiation ability in older acute patients, though a traditional stairs assessment would be required if older patients are unable to complete the squat test and may be required if older patients have moderate to severe pain, walk with a frame or do not live alone. Different physiotherapists assessments' of older patients' ability to complete single leg squats and negotiate stairs would likely be the same. The squat test is a more efficient assessment tool than traditional stairs assessments in determining patients' ability to negotiate stairs and suitability for discharge where reduced mobility is an issue.

Implications for practice: The use of the squat test would deliver benefits to the patient and hospital system through streamlining of the discharge process, potentially decreasing length of stay, improving patient flow and ensuring effective use of health professionals' and patients' time.

KEYWORDS: Stairs assessment, older patients, squat, rural, discharge planning

EXECUTIVE SUMMARY

Why was this study done?

Mobility and stair negotiation ability is often reduced in older people following illness or surgery and inability to negotiate stairs often prevents their discharge from hospital. Physiotherapists commonly complete mobility and stairs assessments to assist multidisciplinary team decision of an older patient's suitability to be discharged home. Completion of stairs assessments at Shoalhaven Hospital are time-consuming, as they require considerable patient porterage time from the emergency department or ward to the physiotherapy department where the set of stairs used for assessments is located.

There are many physical and psychosocial factors associated with ability to negotiate stairs, but without sufficient lower limb strength and power it is impossible to ascend and descend stairs. Therefore, single leg squats were chosen as a potentially more efficient assessment tool to determine stair negotiation ability among older acute patients at a large rural hospital as they require the recruitment of similar muscle groups to stair negotiation, they measure leg power and they can be completed in the emergency department or ward environment.

This study recruited older patients as stair negotiation becomes more difficult with increasing age and falls risk increases with age and inactivity, especially among people who are unwell and in hospital. This study investigated whether single leg squats predict ability to independently negotiate stairs in older patients referred to physiotherapy for a mobility assessment at a rural hospital.

What did this study find and what does this study mean?

Single leg squats are an accurate measure of ability to negotiate stairs

The squat test had a specificity of 100%, sensitivity of 86%, positive predictive value of 100% and negative predictive value of 49%. This means that among older acute patients who were referred for a physiotherapy mobility assessment, the squat test predicted stair negotiation ability. The squat test's negative predictive value of 49% indicates that patients who cannot squat may still be able to negotiate stairs and a stairs assessment is clinically indicated.

Older patients who could complete single leg squats were much more likely to be able to negotiate stairs

Patients who could complete the squat test were 57 times more likely to be able to negotiate stairs independently than patients who could not squat.

Single leg squats are a more efficient measure of determining stair negotiation ability in older patients

The results of the squat study show the use of the squat test will reduce time required by health professionals to determine patients' ability to negotiate stairs and suitability for discharge when reduced mobility is an issue. If the squat test was used, less time would be required to determine stair negotiation ability for 75% of acute older patients, as the squat test could be completed on the ward or in the emergency department and these patients would not need to be taken to the physiotherapy department to complete a traditional stairs assessment. Only 25% of older patients who required stairs assessments would need to be taken to the physiotherapy department so a traditional stairs assessment could be completed. The squat test is a more efficient assessment tool compared to traditional stairs assessments, and will deliver benefits to the patient and hospital system through potentially decreasing length of stay, improving patient flow and ensuring effective use of patients' and health professionals' time.

Different physiotherapists' assessments of older patients' ability to complete single leg squats and negotiate stairs are likely to be the same

The results of this study showed that inter-rater agreement for the squat test and stairs assessments were excellent (100% inter-rater agreement and Kappa = 1.0). If two or more physiotherapists assessed the same older patient's ability to complete the squat test and negotiate stairs they would likely end up with the same result.

The study findings are transferable to clinical practice and hospital settings

This study methodology utilised a clinical setting and equipment routinely available and regularly used by physiotherapists in the acute hospital setting. This enhances the translation of the study findings to clinical practice and universal hospital settings.

Further research into the use of the squat test as an alternative assessment tool for stair negotiation ability is necessary

This is the first study to assess the use of a squat test to predict ability to negotiate stairs. Further research is required to influence changes in physiotherapy stairs assessments that are more efficient and evidence-based.

How was the study conducted?

A cross-sectional analytic study design was employed to assess the ability of single leg squats to predict independent stair negotiation in older patients. Study participants were patients aged 65 years or older who presented to the emergency department or were admitted to the acute wards of Shoalhaven Hospital, were referred for a physiotherapy mobility assessment, and in whom the physiotherapist determined a stairs assessment was clinically indicated to assist multidisciplinary team decision of suitability to be discharged home.

One hundred and forty three patients referred for stairs assessments between June and October 2011 were included in the study. Participants were compared to non-participants to ensure a representative sample. Assessment of ability to complete single leg squats whilst holding onto a railing preceded stairs assessment (with or without holding onto rails), which was the primary outcome measure. Participants were given a rest in between assessment components. A range of demographic, physical and functional measures were collected to explore factors which predict stairs ability. Exact and multivariate exact logistic regression techniques were used to assess outcomes and contributing variables to stairs ability. The agreement of the two investigators' assessments of participants' ability to negotiate stairs and complete squats was calculated using Cohen's kappa.

Where to from here – future recommendations?

Publication of study results

To ensure information about the use of the squat test to predict ability to negotiate stairs is publicly available, this report will be available on the NSW Health Education and Training Institute – Rural Directorate website and distributed to allied health professionals. Research papers will be submitted to peer reviewed journals for potential publication.

Further studies with larger sample sizes in other rural locations, patient groups of all ages with different medical conditions, and assessments of squat test by different health professionals

This study was conducted in a group of participants who represent the typical group of older patients who are usually referred for stairs assessments. Further research with larger sample sizes, in other acute and sub-acute health care facilities, and including patients of all ages with different conditions, is needed to support the findings of this study and influence effective practice changes in the completion of stairs assessments. The accuracy of the squat test should be assessed in patient groups with different conditions (such as orthopaedic, medical and general surgical patient populations), to determine which patient groups this assessment tool is most suitable to be used with. The accuracy of the squat test assessment completed by other health professionals (in addition to physiotherapists) in determining stair negotiation ability should also be investigated. Inter-rater agreement data collection and analysis should be incorporated into these studies.

INTRODUCTION

Stairs are an essential, though difficult activity of daily living (ADL). Loss of ability to complete this activity independently following illness or surgery results in inability to be discharged home if stairs are located at house entries, decreased independence, reduced quality of life, social isolation and depression. Physiotherapists commonly complete mobility and stairs assessments to assist multidisciplinary team decision of an older person's suitability to be discharged home. Completion of stairs assessments in many hospitals are time-consuming, as patients often need to be transported from the emergency department or ward to the physiotherapy department to access a set of stairs to complete the assessment.

This report describes the squat study, which investigated the predictive ability of single leg squats to independently negotiate stairs among older patients at Shoalhaven Hospital. The squat test was developed as a potentially more efficient assessment tool for determining stair negotiation ability among older patients who presented to the emergency department or were admitted to the acute wards at a large rural hospital. Evaluation of physiotherapy assessment and intervention strategies is an important aspect of high quality physiotherapy service delivery and evaluation of more efficient assessment techniques results in service delivery improvements and continued development of evidence-based practice. This research is particularly relevant to physiotherapists and other health professionals who complete functional assessments, especially those who work in rural areas where short-staffing and busy emergency departments and wards are common.

BACKGROUND

Published literature was sought discussing stairs as an ADL, reduced mobility and stair negotiation ability among older people following illness and surgery, role of physiotherapists in assessing and improving patients' mobility and stair negotiation ability and the biomechanics of single leg squats and negotiating stairs. The rationale for the development of the squat test as an alternative assessment of stair negotiation ability is discussed. The literature databases searched from the earliest record available up to June 2012 were PEDro, OTseeker, Pubmed, PREMEDLINE, MEDLINE, CINAHL Plus, Proquest, PsycINFO, EMBASE and the Cochrane Library. The search strategies (including search terms) employed to locate papers relating to stair negotiation and single leg squat biomechanics are detailed in Appendix 1. Background information about Shoalhaven Hospital, the setting of this study is also presented.

Stairs as essential though difficult ADL

Negotiation of stairs is an essential, though one of the most difficult, ADLs for older people (1-9). Freedman and Martin (1998) (10) reported that 22% of people aged over 50 and 45% over 80 have difficulty negotiating stairs, with women being 1.4 times more likely than men to have impaired stair negotiation ability. Loss of ability to complete this activity without assistance results in decreased independence (11), reduced quality of life (2, 4, 12), depression (13) and social isolation.

Ability to negotiate stairs depends on many intrinsic and external factors. Intrinsic factors include musculoskeletal capacity, cognition, vision, glasses use, fear of falling, somatosensation, fatigue, vestibular input (2, 7, 14) and cardiovascular fitness (2, 7, 14, 15). Extrinsic factors include distractions, footwear, clothing, lighting, stair design (number, slope and surface), presence of rails and maintenance (2, 7, 16). Different factors influence individual people's stair negotiation capacity (2). Sufficient cognition is crucial for safe stair negotiation, especially in public places, as sensory input from many sources needs to be integrated during task completion (17). Cardiovascular fitness is a significant and independent predictor of stairs climb time in older women (15). In addition, pessimism is associated with reduced stair negotiation performance, though optimism is not related to improved stair negotiation performance (18). Stair descent requires less energy use than stair ascent (7).

Whilst there are many physical and psychosocial factors associated with ability to ascend and descend stairs in older people (19), sufficient lower limb strength (4, 19-24) and power (20, 25) is required. Physical factors associated with stair negotiation speed in older people include knee flexor and extensor strength, edge contrast sensitivity, sensation, dynamic balance, reaction time (19), lower limb proprioception (19, 26) and pain (19, 26, 27). Psychosocial factors include fear of falling and vitality (19). Older people who have difficulty negotiating stairs and are reliant on a rail are more likely to have impaired balance, strength and vision, reduced vitality and increased fear of falling (19). Thoracic kyphosis is also independently and significantly associated with reduced stairs ascent speed (28).

Changes in stair negotiation speed and timing of each phase in older people may be due to reduced strength, decreased proprioception or changes in postural control [7]. Most studies reported older people negotiate stairs more slowly than younger people [8, 29, 30], except one study by Reeves et al (2009) [6]reported same time taken by younger and older people to ascend stairs and another study by Benedetti et al (2007) [31] reported similar time taken by younger and older people to ascend a step. Older people also spend longer in the double stance phase [31, 32] and have reduced trail limb swing phase than younger people [31, 32].

Stair negotiation [33, 34] and squatting [34] are more difficult among people who are obese. Topp et al (2000) [27] reported an association between stair negotiation speed and increased body weight in a group of mainly older adults with knee osteoarthritis. Similarly van Sloten et al (2011) [35] reported a significant association between body mass index (BMI) and stair negotiation speed in a group of mainly older adults with type two diabetes. Obese women find squatting, rising from a squat and climbing stairs significantly more difficult and painful than non-obese women [34]. In contrast, Marks (1994) [26] reported there was no association between stair negotiation speed and weight in a group of older women with knee osteoarthritis and Stevens-Lapsley et al (2010) [36] reported there was no association between stair negotiation speed and BMI in a group of older adults in the first six months post single knee replacement surgery.

Stairs and falls risk

Falls risk increases with age [37] and inactivity and falls commonly occur on stairs, especially in the community [19]. The largest proportion of falls among older people occurs on stairs [29]. Functional decline with increasing age is complex, with weakness, reduced range of movement or mobility, impaired sensation, cardiovascular fitness, proprioception, balance or vision, angina, shortness of breath, fear and pain contributing to difficulty with this everyday task [3, 6, 7, 14, 16, 19, 37]. Stair-related accidents are one of the leading causes of falls-related injuries [7, 38]. Stair-related accidents are more common, more likely to result in multiple, serious injuries and require hospital admission in older compared to younger people [39]. Falls are much more common during descent than ascent, with between 75% and 80% [38, 40, 41] of falls on stairs occurring during descent, though one study reported more falls occurred on ascent than descent [2]. Falls on stairs are the cause of around 10% of falls-related deaths [7].

Functional decline as described above may necessitate the use of compensatory strategies to allow successful stair negotiation, as older peoples' functional limits are reached due to age-related physical and physiological changes [6-8, 14, 16, 19, 37]. Compensatory techniques used by older people during stair negotiation include ascending and descending stairs using a step-to patterns to allow the preferred lower limb to lead or provide support [7, 42], increased use of handrails (increased dependency on upper limb), negotiating stairs using a sideways technique and negotiating stairs at a slower speed [7]. For example, older people with impaired balance negotiate stairs in a cautious manner at a slower speed to enhance stability [6, 19]. The use of compensatory strategies requires the use of more energy than usual stair negotiation techniques [7].

In older adults, risk-taking behaviours during stair negotiation is related to confidence levels [43]. In a group of community dwelling older adults, those with lower stairs self-efficacy used more precautionary behaviours during stair negotiation. These behaviours included more reliance on rail, being positioned closer to the rail and slower stair negotiation speed. Older people used more precautionary behaviours during stair descent than ascent and women had lower stairs self-efficacy than men and used more precautionary behaviours [43]. Loss of confidence and fear of falling could result in limited stairs use in an older person with sufficient mobility. In contrast, older people with high confidence levels, limited mobility and increased risk-taking behaviours during stair negotiation are at increased risk of falls [43].

Mobility difficulties following illness and surgery and role of physiotherapist in assessing and improving mobility

Mobility and stair negotiation ability is often reduced in older people following illness or surgery. Following hospitalisation regaining safe mobilisation [4] and stair negotiation capacity [16, 44] are important factors in determining older patients' suitability for discharge, as the majority of homes have stairs [2]. If a patient is unable to negotiate stairs they are not usually able to be discharged to their house if there are stairs at the entry. In this instance, the patient may need to stay with family or friends who live in a house with a flat entry, move house or transfer to living in a residential aged care facility [16, 44].

Standard performance-based mobility and functional assessments are commonly completed by physiotherapists and occupational therapists to determine suitability of an older person to be discharged home following a hospital admission. Physiotherapists commonly complete stairs assessments as part of mobility assessments to determine an older person's independence and safety on stairs [44]. These assessments are assumed to replicate completion of similar tasks in the home environment. West et al (1997) [44] reported good association between functional task performance in clinical and home environments and the most significant predictor of functional task performance at home was task performance in the clinical setting. In a group of well-functioning older people there was a good correlation between stair negotiation in the clinic and at home. The correlation for ascending stairs between clinic and home was 0.77 and for descending stairs was 0.76 [44]. Older people with visual impairments have superior functional task performance at home compared to in clinical settings [44]. Stairs were usually negotiated at a faster speed at home compared to in the clinic, possibly due to familiar environment and use of usual compensatory techniques [44].

Many residents in the Shoalhaven are older retirees who reside in homes which have stairs at their entries and thus need to be able to negotiate stairs to return home following hospitalisation. Physiotherapists at Shoalhaven Hospital commonly complete stairs assessments to assist multidisciplinary team decision of older patients' suitability to be discharged home. Completion of stairs assessments at Shoalhaven Hospital are time-consuming, as patients often need to be transported from the emergency department or ward to the physiotherapy department to access a set of stairs to complete the assessment. Therefore if a potentially more efficient assessment tool to determine stair negotiation ability was developed, it would potentially improve patient flow through emergency departments and wards and release clinicians to undertake other tasks.

Rationale for squat test as an alternative tool to assessing stair negotiation ability

Biomechanics of stairs

Sufficient lower limb strength [4, 19-24] and power [20, 25] is required to successfully negotiate stairs and stair negotiation requires more lower limb strength than most ADLs [7]. Knee extensor and flexor strength accounts for more than one third of variance in stair negotiation performance in older people [19] and knee extensor and psoas major (hip flexor) muscle mass are correlated with stair negotiation speed [45]. Ankle dorsiflexor and plantarflexor strength [46], quadriceps muscle strength [27, 47-50], hamstrings strength [27, 49], hip abduction strength [48], quadriceps muscle power [51], hand grip strength [35] and ankle dorsiflexor power [52] are significant predictors of ability to negotiate stairs in healthy [46, 51, 52] and unhealthy [27, 35, 47-50] mainly older populations. Concentric leading lower limb extensor muscle force generation is required for stairs ascent to propel the body up steps through an increase in centre of mass height [31, 53-56], along with sufficient toe clearance of each step and steady swing foot placement on each step [31]. Stance limb eccentric knee and ankle extensor muscle activity is required during descent, to control the body's descent whilst controlling the body's centre of mass inside a continually altering base of support [53, 54, 56]. Lateral pelvic shift is essential during stair ascension to allow weight transference [57] and an ability to maintain stability is required, through use of strategies to adapt to variations in stairs environments such as height, width and rails [53, 54].

Usual foot over foot stair negotiation requires a predictable pattern of movement as it is a kinematically controlled task [7] and the kinematics of stair ascent [58] and descent [58, 59] are usually reproducible among healthy people. During stairs ascent the stance hip and knee extend and the ankle plantarflexes [33, 60]. During stairs descent the stance hip and knee flex and the ankle mainly dorsiflexes [33, 60]. Studies have examined the kinematics of usual stair negotiation in older healthy [4-6, 8, 9, 29, 31, 61-64] and unhealthy [63-65] populations. Studies reporting stairs kinematics used steps or stairs with a slope of between 27 and 33 degrees [4-6, 8, 9, 29, 31, 61-65]. Reported maximal joint movement required for stair negotiation were between 63 and 123 degrees knee flexion [4-6, 8, 9, 29, 31, 61-65], between minus 16 and 16 degrees knee extension [4-6, 8, 9, 29, 62, 64, 65], between 11 and 33 degrees ankle dorsiflexion [4-6, 8, 29, 31, 61, 64], between nine and 27 degrees ankle plantarflexion [4-6, 8, 29, 61, 64], between 31 and 83 degrees hip flexion [4, 8, 9, 29, 31, 61, 63, 64], between minus 26 and 16 degrees hip extension [4, 8, 9, 29, 64] and between zero and 12 degrees hip abduction [4, 8, 29, 63]. More hip and knee flexion is required by the leading than the trailing limb when ascending stairs [42]. Interestingly there are large differences in reported maximum joint ranges of movement, which could be due to different methodologies including participant selection, measurement techniques, stair case designs [9, 31, 60], or gait speed, measurement error [31], or individual differences in motor performance, especially during transition steps from negotiating stairs to level walking [58], between different studies. When comparing data from different studies and applying it to clinical situations, it must be acknowledged that studies have mainly included older people without significant co-morbidities, joint or motor impairments [31] and kinematics of step negotiation may be different among people with reduced movement, balance, sensation or strength [42]. Studies could not be located which examined kinematics of stair negotiation using compensatory techniques.

Biomechanics of single leg squats

Single leg squats are a complex, though functional multi-joint exercise [11, 66] requiring simultaneous co-ordination of ankle, knee and hip musculature [11, 67] in a consistent pattern which replicates functional muscle recruitment patterns [67]. Single leg squats are characterised by weight-bearing through a single leg with base of support shift to the stance limb [68], along with knee and hip flexion and ankle dorsiflexion from a standing position on a stable surface to lower the body's centre of mass. This action is controlled by eccentric quadriceps and gluteus maximus muscle activity. This action is followed by hip and knee extension to a standing position to raise the body's centre of mass, which is characterised by concentric quadriceps and gluteus maximus muscle contractions [11, 66-75].

Other muscles recruited during a single leg squat include the hamstrings, hip adductors, hip abductors and triceps surae [66-70, 73-75]. The hamstrings are only moderately active during single leg squats, as due to their biarticular nature, length and force output remains fairly constant and they also co-contract with the quadriceps during this movement [66]. The main role of gluteus medius during single leg squats is to stabilise the pelvis [67, 68, 76]. Trunk stabilisation during single leg squats is achieved by isometric activity of stabilising muscles including the erector spinae, trapezius, rhomboids and abdominal muscles [66]. The depth of a single leg squat is associated with the available range of motion and strength of the stance leg [77]. Quadriceps strength, though not hip strength or ankle range of motion, predicts maximum knee flexion angle achieved during a single leg squat [77]. Higher degrees of hip and knee flexion may be associated with greater lower limb strength [70]. Also, high ankle range of movement is required to assist control and balance during a squat [66]. When ankle movement is reduced, the heel tends to rise off the floor during squats with higher degrees of knee flexion [66]. Fatigue extensively alters squat kinematics and kinetics [66].

When comparing data from different studies and applying it to clinical situations it must be noted that the characteristics of single leg squat biomechanics discussed above are derived from studies conducted mainly in healthy younger people without significant comorbidities, joint or motor impairments. Only one study [11] was identified which discussed the kinematics and kinetics of single leg squats among older (and in this case healthy) adults. Differing kinematics and kinetics reported in different studies were probably due to differences in methods used [69, 71] including participant selection [69, 70], data collection, data analysis [71], use of upper limb support during squat [71, 72], exercise performance [68], and trunk and pelvic postures which influenced magnitude of muscle recruitment [67]. Studies were not located which examined kinematics and kinetics of single leg squats among older unwell people who may use different techniques when squatting.

Similarities of stair negotiation with squats

An assessment tool which includes measures of strength and power was selected to assess stair negotiation ability. Single leg squats were chosen as they are a biomechanically similar action to stair negotiation, with both requiring the recruitment of similar muscle groups and both concentric and eccentric quadriceps control through a large range of knee flexion [11, 31, 53-56, 66-75]. Eccentric and concentric control of hip and ankle extensors are also required to guide these joints in both stairs and squat actions [11, 31, 53-56, 66-75]. An extensive literature search did not locate any studies which assessed the use of a squat to predict stair negotiation ability. The portability and time efficiency of the squat test has potential to improve efficiency of physiotherapy mobility assessments, thus releasing these clinicians to undertake other tasks and improving patient flow through emergency departments and wards. This is particularly pertinent in rural hospital settings where short-staffing and busy emergency departments and wards are common.

Shoalhaven Hospital: the study setting

Shoalhaven District Memorial Hospital is a large rural hospital on the NSW South Coast which services the Shoalhaven Local Government Area (LGA) stretching from Berry in the north to North Durras in the south. The estimated population of the Shoalhaven LGA was 96 967 in 2010 and 22.3% of the population were aged 65 years or over [78]. Shoalhaven Hospital is a 186 bed hospital which had 20 550 patient episodes of care and 31

137 emergency department attendances during 2008-2009 and the average acute length of stay (excluding single day admission) was four and a half days during the same period [79].

Research question

Do single leg squats predict ability to independently negotiate stairs in older patients referred to physiotherapy for a mobility assessment at a rural hospital?

Null hypotheses:

- Ability to complete single leg squats does not predict ability to independently negotiate stairs in older patients referred for a physiotherapy mobility assessment at Shoalhaven Hospital

The objectives of this study were to:

- Determine the ability of single leg squats to predict independent stair negotiation ability within the study group
- Determine whether other variables influence any relationship between older patients' ability to complete single leg squats and negotiate stairs
- Establish the inter-rater agreement of ability to complete single leg squats and negotiate stairs

METHODS

Study design

A cross-sectional analytic study design was employed to assess the ability of single leg squats to predict independent stair negotiation in older patients.

Setting and participants

Study participants were patients aged 65 years or older who presented to the emergency department or were admitted to the acute wards of Shoalhaven Hospital, were referred for a physiotherapy mobility assessment and in whom the physiotherapist determined a stairs assessment was clinically indicated. A stairs assessment was deemed clinically indicated in patients with reduced mobility during their hospital presentation and where these patients have stairs at their home entry or use stairs in the community.

Exclusion criteria:

– unable to follow instructions due to minimal English language skills and an interpreter was not available

– unable to follow required instructions due to cognitive barriers

– unable to fully weight bear or weight bear as tolerated on both lower limbs

– dependant on a forearm support frame, crutches, wheelchair or hands-on assistance for mobilisation indoors

– when stairs assessment was contraindicated due to severe visual impairment or medical issues

– lower limb amputations higher than the mid-foot

– when inpatient rehabilitation was required prior to discharge

Recruitment and non-participants

Recruitment for this study was conducted by the probability sampling method of consecutive systematic sampling to enhance the representativeness of the sample to the population [80], with the aim to recruit all patients during the study period who met study inclusion criteria. Acute ward and emergency department physiotherapists identified potential participants for study inclusion. Written informed consent was obtained from all participants prior to their participation.

As this study was conducted in a clinical setting not all potential participants were recruited due to availability of investigators to complete participant assessments, which was dependent on their usual physiotherapy caseload. To ensure the sample recruited was representative of the population at the time of the study (older patients referred for a mobility assessment and in whom a stairs assessment was clinically indicated), demographic data (age, sex, diagnosis, length of stay and discharge destination) was collected from available physiotherapy ward lists and medical records for eligible non-participants who underwent a stairs assessment during the study period. Eligible non-participants were patients not assessed for study inclusion due to logistical reasons and patients who declined to participate.

Sample size

A sample size of 143 participants allowed detection of a minimum difference in the proportion of subjects that could negotiate three steps independently, between the group of subjects who could perform three squats and the group of subjects who could not complete three squats, of 0.301 [81]. A significance level of 0.05, power of 0.8 and that the proportion of participants who were able to perform the squats was 0.8, were assumed. Detailed information on completed sample size calculations is presented in Appendix 2.

Primary data collection: squat and stairs assessments

All assessment components were completed in the one session, with participants allowed a seated rest between squat and stairs assessment components. The squat assessment was completed prior to the stairs assessment, as single leg squats were investigated as a predictor of ability to negotiate stairs independently.

Prior to attempting either assessment component, participant ability to single leg stand on their non-preferred leg for three seconds was assessed with participants standing facing a wall and holding onto an 883 millimetre (mm) height hospital corridor railing with one hand. This allowed the researcher to assess whether the participant had the required strength and control to weight-bear through their non-preferred leg. Weight-bearing through the non-preferred leg is essential in stair negotiation to allow safe swing through of the preferred leg up or down a step [54] and it was clinically reasoned that three seconds is enough time to allow the swing leg to be moved up or down a step.

Figure 1: Single leg squat assessment

Single leg squats were assessed whilst participants were standing facing a wall with an 883 mm height hospital corridor railing and tip of their big toe 50 mm from the wall (Figure 1). This method of measuring single leg squat depth was chosen as squats performed using this technique could be easily standardised and replicated. Values obtained in the weight-bearing ankle dorsiflexion lunge measure (distance between the tip of the big toe and the wall when a lunge is completed so the knee touches the wall) have been reported to be between 27 mm and 129 mm among healthy adults and adults with ankle injuries [82, 83]. Thus it was clinically reasoned that most older patients would have adequate ankle dorsiflexion range of movement to complete squats to this depth and squats of this depth would allow adequate assessment of participants' lower limb concentric and eccentric muscle strength. Participants were instructed to complete up to 18 squats standing on their preferred leg until their knee touched the wall, whilst holding onto the railing with one or both hands.

Figure 2: Stairs assessment

Stair negotiation was assessed using a three step staircase with a rail on each side, rise of 150 mm, depth of 280 mm and slope of 28 degrees (Figure 2). This is the set of stairs that is usually used for stairs assessments at Shoalhaven Hospital. Flights of stairs are not usually used for stairs assessments to ensure patient safety is maintained. Participants were instructed to ascend and descend the set of three steps up to six times using one or two rails if required. Participants were asked to complete up to 18 steps as this is the maximum number of steps permitted in a flight of stairs as per the

Australian Standards [84] and is the usual maximum number of steps patients need to negotiate in their home environment and in the community.

For regression and inter-rater agreement analyses, ability to complete both single leg squats and stairs were measured as dichotomous outcomes, either able or not able to complete three single leg squats or three steps once independently with or without one rail. During both the squat and stairs assessments participants were instructed to stop if they felt fatigued, had pain or felt they needed to stop for any other reason.

Secondary data collection

Demographic and functional data

General demographic and functional data was collected through participant interview and medical record review. Age, gender, place of residence and whether the participant lived alone or with someone else prior to hospital presentation were recorded. Mobility history including gait aid use (indoors and outdoors) prior to hospital presentation, any assistance with mobility required prior to hospital presentation, self-reported falls on stairs and total number of falls in past 12 months, the maximum number of steps needed to negotiate to return home and presence of rails, and presence of fear or reduced confidence on stairs were recorded. Presence, site and severity of pain at time of recruitment at up to two body sites were obtained through interview. The Numerical Rating Scale (NRS) was used to assess pain severity. The NRS is a valid and reliable 11 point self-report scale commonly used to rate pain, with zero representing "no pain" and ten "worst possible pain" [85, 86]. Diagnosis, length of stay and discharge destination were collected from participants' medical records.

Functional assessments

Current indoor mobility aid and assistance required was collected from medical records if mobility status had not changed since last physiotherapy review. These measures were obtained by direct observation if it was the participants' first physiotherapy mobility review for this hospital presentation or if their mobility status had changed since last physiotherapy review.

Right and left knee flexion active range of motion was measured in sitting using a clear plastic 360-degree goniometer with arms 320 mm in length, according to the technique described by Norkin and White (2003) [87]. The fixed proximal arm of the goniometer was aligned parallel to the longitudinal axis of the femur using the greater trochanter as the reference point. The mobile distal arm was aligned parallel to the longitudinal axis of the fibula using the lateral malleolus as the reference point. The centre of the fulcrum was positioned over the lateral femoral condyle. The intra-rater reliability of goniometry to measure knee flexion range of motion has been reported as good [88-93] and the inter-rater reliability as moderate to good in most studies [88-90, 92-97].

Inter-rater agreement

The assessments of participants negotiating stairs and completing single leg squats were used to assess inter-rater agreement. Detailed information on required sample size for inter-rater agreement is detailed in Appendix 2. Two investigators independently scored participants on their ability to negotiate three steps independently with or without a rail and ability to complete three single leg squats as described above. Both investigators either assessed the patient together (with independent scoring) or the assessments were videotaped by the second investigator and independently reviewed and scored by the primary investigator. Investigators were blinded to each others' results.

Statistical analyses

Descriptive statistics are presented as mean ± standard deviation (SD) for normally distributed variables, median (range) for non-normally distributed variables and proportions (percentages) as appropriate. The Shapiro-Wilks test was used to assess whether quantitative variables were normally distributed. Independent samples t tests were used to assess differences in demographic and functional normally distributed quantitative variables between participants who could and could not negotiate three steps. Wilcoxon rank-sum tests were similarly used for non-normal variables, chi-square tests for demographic and functional categorical variables when observed frequencies in each cell were five or greater and Fisher's exact test for categorical variables when the observed frequency in at least one cell was less than five. These tests of univariate associations were completed for variables which are routinely collected and considered clinically relevant to stair negotiation ability.

Site and severity of pain for the primary pain site only were included in data analyses, as only 7.7% of participants reported pain at more than one body site at time of assessment. The Wilcoxon signed rank sum test was used to determine differences between right and left knee flexion range of movement. The greater of the two knee flexion movement measures for each participant was included in the data analyses, as for the majority of participants knee flexion movement was greater on the preferred stair negotiation leg and there was no significant difference between right and left knee range of movement measures ($z = -0.63$, $p = 0.53$). Knee flexion measures were included for 142 participants in the data analyses, as data for this variable was missing for one participant.

Specificity, sensitivity, positive predictive value and negative predictive value were calculated to assess the accuracy of the squat test in predicting stair negotiation ability. Pearson correlation coefficient was calculated to examine the relationship between number of stairs participants were able to negotiate and number of squats they were able to complete. Exact logistic regression was used to evaluate the predictive ability of single leg squats to negotiate stairs. Multivariate exact logistic regression was used to determine the associations between stair negotiation ability and demographic and functional variables. Variables with a univariate association with ability to negotiate stairs at the level of $p < 0.15$ and which were clinically reasoned to be possible predictors or confounders of stair negotiation ability were included in multivariate models with squat test. Median pain severity instead of presence of pain was included in multivariate regression analyses, as it measures both pain magnitude and presence, is a more clinically meaningful and precise measure of pain than presence of pain and both these variables were associated with ability to negotiate stairs at the level of $p < 0.15$. Each covariate was entered into a model with only squat test.

Variables with an association with stair negotiation ability and squat test at the level of $p < 0.1$ were then entered with squat test result into a multivariate model for whether or not each participant could or could not negotiate three steps independently. Model validity and assumptions were checked using appropriate diagnostic and statistical tests. Fisher's exact tests were used to assess differences in mobility aid use at time of assessment between participants who could and could not negotiate three steps.

To ensure the sample recruited was representative of the population independent t-tests, Wilcoxon rank-sum tests, chi-square statistics and Fisher's exact tests were used as appropriate to determine if there were differences between participants and non-participants. Differences were considered significant where $p < 0.05$. The agreement of the two investigators' assessments of participants' ability to negotiate stairs and complete squats was calculated using Cohen's kappa. Data was analysed using STATA statistical software version 11 (StataCorp LP, College Station, Texas).

Ethics

Ethical approval for this study was obtained from the Joint University of Wollongong and Illawarra Shoalhaven Local Health District (UOWISLHD) Health and Medical Human Research Ethics Committee (HREC) in May 2011 (UOWISLHD Ethics Number: HE 11/038 and Au RED Number: HREC/11/WGONG/13).

RESULTS

Participant flow through study

Participant recruitment to the study is outlined in Figure 3. One hundred and sixty six acute patients underwent a physiotherapy stairs assessment at Shoalhaven Hospital between June and October 2011. One hundred and forty six participants were approached, consented to participate in the study and underwent assessments. Three were excluded because of protocol non-adherence (incorrect instructions given to participants during assessment process). Data were analysed for the remaining 143 participants. Two patients were readmitted during the study period and were included twice as new hospital presentations and physiotherapy referrals. Twenty potential participants (identified from available physiotherapy ward lists and medical records) were not assessed during the study period due to logistical reasons. These patients formed the non-participant group.

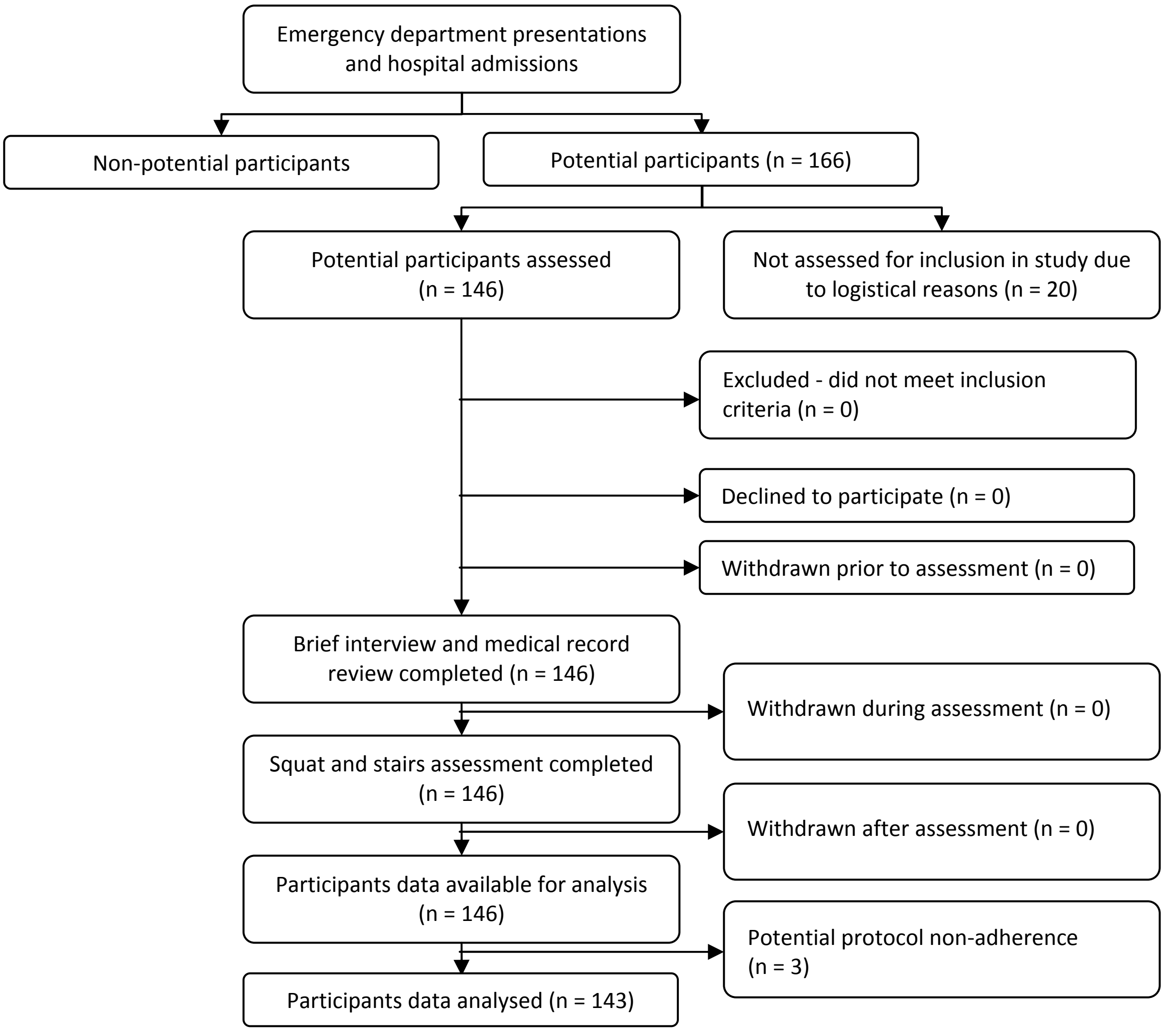

Figure 3: Flow of participants through the stairs study

Characteristics of study participants and non-participants

Demographic and functional characteristics for the 143 participants and 20 non-participants are presented in Table 1. The mean age of participants (80 ± 7 years) was significantly greater than the mean age of non-participants (75 ± 7 years). The proportion of men and women in the participants and non-participants groups were almost equal. Primary diagnoses were significantly different between participants and non-participants. The most common diagnoses were cardiovascular events and orthopaedic surgery for participants and neurological events for non-participants. Median length of stay for participants and non-participants were similar and the majority of participants and non-participants were discharged home. Gender, discharge destination and length of stay were not significantly different between participants and non-participants.

Additional demographic and functional characteristics for the 143 participants are presented in Tables 2 and 3 and Appendix 3. One hundred and forty (98%) participants were recruited from the acute wards and only three from the emergency department (2%). The majority of participants lived at home (97%) and most were independently mobile with nil aid prior to hospital presentation (see Appendix 3 and Table 2). The median number of falls in the past 12 months reported by participants was zero (range 0 to 30). The majority of participants reported not having fallen on stairs in the past year (92%) and not being fearful of or having reduced confidence with stair negotiation (81%). The median number of steps participants needed to be able to negotiate to access their own home was two (range 0 to 40). Availability of a handrail varied with participants reporting nil (33%), one (47%) or two (20%) rails on their steps at home. Median length of stay for participants was seven days and the majority (89%) were discharged home.

Table 1: Demographic and functional characteristics of study participants and non-participants

Demographic and functional characteristics	Participants	Non-participants	p-value
Mean age in years (SD)	80.0 ± 6.8	74.7 ± 6.8	<0.01*
Gender			0.65
Male	72 (50.3%)	9 (45.0%)	
Female	71 (49.7%)	11 (55.0%)	
Primary diagnosis			<0.01*
Cardiovascular	30 (21.0%)	1 (5.0%)	
Respiratory	19 (13.3%)	0 (0.0%)	
Gastroenterological	17 (11.9%)	0 (0.0%)	
General surgery	2 (1.4%)	0 (0.0%)	
Genitourinary	4 (2.8%)	0 (0.0%)	
Musculoskeletal	6 (4.2%)	0 (0.0%)	
Orthopaedic surgery	25 (17.5%)	4 (20.0%)	
Neurological	21 (14.7%)	14 (70.0%)	
Falls	11 (7.7%)	0 (0.0%)	
Other	8 (5.6%)	1 (5.0%)	
Median length of stay (range)	7 (1 – 41)	6 (2 – 13)	0.15
Discharge destination			
Home or caravan	127 (88.8%)	18 (90.0%)	0.83
Another hospital	11 (7.7%)	2 (10.0%)	
Low level care	3 (2.1%)	0 (0.0%)	
High level care	1 (0.7%)	0 (0.0%)	
Passed away	1 (0.7%)	0 (0.0%)	

All results are n (%) unless stated
*Indicates statistically significant finding $p < 0.05$

At time of study participation around a third of participants reported pain, most commonly in the lower legs (including knees) (see Table 3). The majority of participants (92%) were independently mobile, with 38% requiring nil aid and 29% a four wheel frame for mobilisation (see Table 2). Median knee active range of motion was 100 degrees (range 66 to 135). No adverse events occurred during study recruitment and assessment.

Table 2: Participants gait aid use and mobility assistance required prior to hospital presentation and assessment of participants' current gait aid use and mobility

Gait characteristic	Prior to hospital presentation		At time of assessment
Gait assistance			
Independent	142 (99.3%)		132 (92.3%)
Supervision	0 (0.0%)		8 (5.6%)
Stand-by assistance	1 (0.7%)		3 (2.1%)
Gait aid	**Indoors**	**Outdoors**	
None	102 (71.3%)	88 (61.5%)	54 (37.8%)
Walking stick	24 (16.8%)	27 (18.9%)	29 (20.3%)
Two walking sticks	2 (1.4%)	2 (1.4%)	14 (9.8%)
Pick up frame	0 (0.0%)	0 (0.0%)	2 (1.4%)
Two wheel frame	1 (0.7%)	1 (0.7%)	2 (1.4%)
Four wheel frame	14 (9.8%)	24 (16.8%)	42 (29.4%)
Wheelchair	0 (0.0%)	1 (0.7%)	0 (0.0%)

All results are n (%)

Table 3: Assessment of participants' presence of pain, pain severity and location

Pain characteristic	
Pain (at time of assessment)	
No	91 (63.6%)
Yes	52 (36.4%)
Median pain severity on NRS (range)	0 (0-9)
Pain location	
Upper limb – shoulder to hand	4 (7.7%)
Neck and back	9 (17.3%)
Abdomen and chest	5 (9.6%)
Hip and thigh	11 (21.2%)
Lower leg including knee	23 (44.2%)

All results are n (%) unless stated

Inter-rater agreement of assessments of squats and stair negotiation

Inter-rater agreement analysis of 99 participants' assessments found a perfect agreement (K = 1.0), with percentage agreement at 100% and percentage disagreement 0% for both assessment of squats and stair negotiation.

Assessment of ability to complete single leg squats and negotiate stairs

The results of the squat and stairs assessments are presented in Table 4. One hundred and eight (76%) participants could complete three single leg squats and negotiate three steps independently with or without a rail. Conversely, no participants could complete the squats and not negotiate stairs. Eighteen (13%) participants could not complete squats, though could negotiate stairs and 17 (12%) participants could not complete the squats or negotiate the stairs. The squat test had a specificity of 100% (95% confidence interval (CI) 0.8 to 1.0), sensitivity of 86% (95% CI 0.8 to 0.9), positive predictive value of 100% (95% CI 1.0 to 1.0) and negative predictive value of 49% (95% CI 0.3 to 0.7). There was a moderate positive correlation between number of squats (up to 18) participants could complete and number of steps (up to 18) participants could negotiate ($r = 0.63$, $p < 0.01$).

Table 4: Assessment of participants' ability to complete three single leg squats and negotiate three steps independently with or without a rail

		Able to complete stairs		
		Yes	**No**	**Total**
Able to complete squats	**Yes**	108 (75.5%)	0 (0.0%)	108
	No	18 (12.6 %)	17 (11.9%)	35
	Total	126	17	143

All percentages represent proportions of total count

Exact logistic and multivariate exact logistic regression analyses

Univariate analyses were performed to determine whether there were significant differences in demographic and functional variables that were clinically reasoned to be possible predictors of stair negotiation ability, between participants who could and could not negotiate three steps. The results of the univariate analyses are presented in detail in Appendix 4. The results of the multivariate exact logistic regression models where each covariate was entered into a model with only squat test are presented in Appendix 5. The three covariates (walking frame use at time of assessment, pain severity and whether participants lived alone) with an association with stair negotiation ability and squat test at the level of $p < 0.1$ were then entered into a final multivariate regression model with squat test.

The results of the exact logistic regression and final multivariate exact logistic regression used to determine factors associated with independent stair negotiation ability are presented in Table 5. The exact median unbiased estimate of the coefficient for squat test was statistically significant. The unadjusted odds that a participant who could complete the squat test, could independently negotiate three steps, were 134 times greater than the odds for a patient who could not complete the squat test. The upper CI extended to infinity since there were no participants who could complete squats but not negotiate stairs independently. The adjusted odds of independent stair negotiation among participants who were able to complete the squat test compared to those who could not complete squats was 57 and similar to the univariate regression analysis, the upper CI extended to infinity. This odds ratio was adjusted for whether participants lived alone, pain severity and frame use at time of assessment. This effect of being able to complete the squat test is statistically significant and independent of effects related to whether each participant lived alone, pain severity and frame use.

The final multivariate exact regression analyses indicated that the effects for whether participants lived alone and pain severity were also statistically significant in the multivariate model. As the p-value for walking frame use at time of assessment was equal to 0.0503 (odds ratio = 0.60, 95% CI = 0.246 to 0.963) and nearly statistically significant, it was treated as statistically significant in this instance and will be discussed in this report as statistically significant, as the effect of frame use in the multivariate model is significant from a clinical perspective. Whether participants lived alone, pain severity and frame use each have an effect that is statistically significant and independent of the effects of the other covariates and squat test. Thirteen percent of participants who could not complete the squat test were able to negotiate stairs independently. These differences in the results of the squat test and stair negotiation ability are partially explained by whether or not participants lived alone, pain severity and whether or not participants required a frame when walking at time of assessment.

The adjusted odds ratios of independent stair negotiation among participants who lived alone compared to those who did not live alone, among participants who were reliant on a frame compared to those who did not require a frame when walking and among participants with differing pain severities are presented in Table 5. The odds of independent stair negotiation among participants who did not live alone compared to participants who lived alone was 0.1. The odds of independent stair negotiation for each one point increase in pain severity on the NRS reported by participants at time of assessment decreased on average by a factor of 0.6. Because pain severity is not a dichotomous variable and is interpreted on a scale of one to ten, the odds of independent stair negotiation among participants who reported a pain severity of five on the NRS compared to zero was 0.08 and the odds among participants who reported a pain severity of nine compared to zero was 0.01. The odds of independent stair negotiation among participants who were reliant on a frame when walking at time of assessment compared to participants who did not require a frame when walking was 0.1.

A statistically significant association was identified between participants who used nil mobility aid at time of assessment compared to participants who required a mobility aid and stair negotiation ability ($p < 0.01$). A statistically significant association was also identified between participants who required nil aid or one or two walking sticks at time of assessment compared to participants who required a frame when walking and stair negotiation ability ($p < 0.01$). Ninety four percent of participants who could not negotiate three steps independently required a walking frame when mobilising at time of study assessment.

Table 5: Results of exact logistic regression and multivariate exact logistic regression used to determine factors associated with independent stair negotiation ability

Univariate exact logistic regression			
Predictor variable	**Coefficient (95% CI)**	**Odds ratio (95% CI)**	**p-value**
Ability to complete three single leg squats	4.90 (3.068 to infinity)	134.08 (21.504 to infinity)	<0.01
Multivariate exact logistic regression			
Predictor variables	**Coefficient (95% CI)**	**Odds ratio (95% CI)**	**p-value**
Ability to complete three single leg squats	4.05 (2.159 to infinity)	57.12 (8.662 to infinity)	<0.01
Place of prior residence (whether participants lived alone)	-2.15 (-infinity to -0.015)	0.12 (0.000 to 0.985)	<0.05
Pain severity	-0.51 (-1.404 to -0.374)	0.60 (0.246 to 0.963)	0.03
Gait aid at time of assessment (no frame/frame)	-2.42 (-6.504 to 0.002)	0.09 (0.001 to 1.002)	0.05

DISCUSSION

This is the first study to demonstrate that a single leg squat test accurately predicts stair negotiation ability in older acute patients who were referred for a physiotherapy mobility assessment at an Australian rural hospital. The squat test had a specificity of 100% and sensitivity of 86% as a predictor of stairs ability and participants who could complete the squat test were 57 times more likely to be able to independently negotiate stairs compared to participants who could not complete the squat test. It should however be noted that whilst both ends of the 95% CI were greater than zero, the CI was very wide. Taking the lower limit of the

95% CI it can be confidently stated that the odds of participants who could complete the squat test being able to independently negotiate stairs was at least 9 times higher than for participants who could not squat. There was also a moderate association between number of squats participants could complete and number of steps participants could negotiate. Single leg squats were chosen as they are a biomechanically similar action to stair negotiation [11, 31, 53-56, 66-75] and the squat test is a portable and time efficient assessment tool. The results of this study support the use of the squat test as an alternative assessment tool to determine an older patient's suitability for discharge when reduced mobility is an issue. The use of the squat test would deliver benefits to the patient and hospital system through potentially decreasing length of stay, improving patient flow through emergency departments and wards and allowing clinicians to undertake other tasks. This is particularly pertinent in rural hospital settings where short-staffing and busy emergency departments and wards are common.

The study results show that 75% of participants could have been accurately assessed with the squat test as being able to negotiate stairs independently. The squat test could be completed on the ward or in the emergency department with 75% of older acute patients in whom stairs assessments are clinically indicated, eliminating the need for this high proportion of patients to be taken to the physiotherapy department to complete a traditional stairs assessment. Only 25% of older patients who require stairs assessments would then need to be taken to the physiotherapy department so a traditional stairs assessment could be completed. Implementing the squat test as an alternative measure of stair negotiation ability would significantly improve the efficiency of stairs assessments and determination of older patients' suitability for discharge when reduced mobility is an issue.

Thirteen percent of participants who could not complete the squat test were able to negotiate stairs independently. Among older acute patients ability to complete single leg squats predicts ability to negotiate stairs, though it is important to note that if a patient cannot complete squats they may still be able to negotiate stairs. In circumstances where older patients have reduced mobility following illness or surgery and require a physiotherapy stairs assessment, if they are not able to complete the squat test, a traditional stairs assessment would be required to ensure they are able to negotiate stairs and can be discharged home.

Ability to negotiate stairs depends on many intrinsic and extrinsic factors including musculoskeletal factors, fatigue, vestibular input, sensation, cognition, fear of falling, vision [2, 7, 14], cardiovascular fitness [2, 7, 14, 15], clothing and environmental factors [2, 7, 16]. Different factors influence individual people's stair negotiation capacity [2]. Independent stair negotiation was much more difficult among participants who did not live alone, were reliant on a frame when walking and especially participants with moderate to severe pain at time of study assessment. Participants who were reliant on a gait aid at time of assessment were significantly more likely to not be able to negotiate three steps independently compared to participants who were able to mobilise with nil aid and the majority of participants who were unable to negotiate stairs independently were reliant on a frame when walking. The finding that 13% of participants could negotiate stairs but not complete the squat test is partially explained by whether participants lived alone, pain severity and frame use at assessment. Pain severity, whether patients live alone and reliance on a frame for walking are factors that would need to be considered when assessing a patient using the squat test to determine their likely ability to negotiate stairs. A traditional stairs assessment may be required in these circumstances to ensure these older patients are able to negotiate stairs and can be discharged home, as they may not be able to complete the squat test, but may still be able to negotiate stairs independently.

Inter-rater agreement for the squat test and stair negotiation was excellent. There was perfect agreement ($K = 1.0$) between assessors on assessment of ability to complete single leg squats and negotiate stairs. Different physiotherapists assessments' of older patients' ability to complete single leg squats and negotiate stairs would likely be the same. With an excellent level of inter-rater agreement for the squat test and stairs assessments, both of these assessment tools can be used between clinicians with confidence.

Every attempt was undertaken to ensure participants recruited into the study were representative of a general population of older hospital patients who are referred for a physiotherapy mobility and stairs assessment. Participants were comparable to non-participants in terms of gender, discharge destination and length of stay, but not age, with the mean age of participants (80 years) significantly higher than for non-participants (75 years). The participant group contained a lower proportion of patients with neurological conditions than the non-participant group, due to non-recruitment of a group of patients from the Acute Stroke Unit because the investigators were not available to recruit these patients. It is reasonable to interpret that the patients recruited to this study are likely to be representative of all older patients who require physiotherapy mobility and stairs assessments at Shoalhaven Hospital following illness or surgery. Consequently, the results of this study are likely to be generalisable to other Australian rural and possibly metropolitan acute hospitals which admit older patients who have reduced mobility following illness or surgery and require physiotherapy mobility and stairs assessments.

To the best of the researchers' knowledge this is the first study to assess the use of a single leg squat to predict ability to negotiate stairs. Further research with larger sample sizes, in other rural and metropolitan acute and sub-acute health care facilities and including patients of different ages with different conditions, is needed to support the findings of this study and influence effective practice changes in the completion of stairs assessments. The accuracy of the squat test should be assessed in patient groups with different conditions (such as orthopaedic, medical and general surgical patient populations), to determine which patient groups this assessment tool is most suitable to be used with. Inter-rater agreement data collection and analysis should also be incorporated into further studies, to assess the accuracy of the squat test assessment completed by other health professionals (in addition to physiotherapists) in determining stair negotiation ability.

Limitations

One limitation of this study is that for each participant the same assessor completed both the squat and stairs assessments and was therefore not blinded to participants' squat ability when their stairs assessment was completed. It was not feasible to blind the investigator who assessed each participants' stair negotiation ability, to each participants' squat ability and was a potential source of observer bias [98]. Potential bias also occurred as one of the two assessors (the main investigator) also completed the data analysis. A further limitation is the exclusion of three participants from the study due to non-adherence to the study protocol, although the study results were unlikely to have been altered if the results of these participants were included. Multiple statistical hypothesis tests were completed for the univariate analyses so there was potential for the occurrence of Type I errors. However, only variables which were clinically reasoned to be possible predictors or confounders of stair negotiation ability were included in the univariate analyses and the univariate analyses were completed to guide which covariates to include in the multivariate exact regression models, so were not reported as the main study findings. Also, the original sample size calculations were based on those for logistic regression using the maximum likelihood ratio technique, but due to a zero cell count in one of the cells of the two by two table (nil participants could not complete the squat test and still negotiate stairs independently) the data was analysed using exact logistic regression as logistic regression using the maximum likelihood ratio technique was not possible in this circumstance [99]. Using the exact approach for the multivariate analyses with squat test and one other covariate makes the results more stable.

Body weight and BMI are potential confounders not considered in this study. Research has shown that stair negotiation [33, 34] and squatting [34] are more difficult among people who are obese. Participants' weight may influence ability to complete single leg squats and negotiate stairs, due to the increased force placed through the lower limb joints with increasing body weight. Further studies assessing the accuracy of single leg squats as a measure of stair negotiation ability should include participant weight and BMI as potential confounding variables.

Strengths

The study used a cross-sectional analytic design. The reporting of study findings followed recommendations in the STROBE statement [100] to enhance the generalisability and transparency of the study. This study methodology used a clinical setting and equipment routinely available and regularly used by physiotherapists in the acute hospital setting. This enhances the translation of the study findings to universal hospital settings and clinical practice. Investigators were also blinded to each others' results in assessment of inter-rater agreement of stair negotiation and squat ability.

CONCLUSION

The results of this study indicate that single leg squats accurately predict independent stair negotiation ability in a sample of older acute patients referred for a physiotherapy mobility assessment at an Australian rural hospital. Pain severity, whether participants lived alone and frame use at time of assessment influenced the relationship between ability to complete squats and negotiate stairs. Inter-rater agreement for the squat test and stair negotiation were excellent. The results of this study support the use of the squat test as an alternative assessment tool to determine an older patient's suitability for discharge when reduced mobility is an issue. The squat test is a more efficient assessment tool compared to traditional stairs assessments and its use would deliver benefits to the patient and hospital system through streamlining of the discharge process, potentially decreasing length of stay, improving patient flow and ensuring effective use of health professionals' and patients' time.

Thirteen percent of participants could negotiate stairs independently but not complete the squat test. This finding is partially explained by pain severity, whether participants lived alone and reliance on a frame for walking. A traditional stairs assessment would be required if older patients are unable to complete the squat test and may be required if older patients are in pain, walk with a frame or do not live alone, to ensure they are able to negotiate stairs and can be discharged home.

To the best of the authors' knowledge, this is the first study to assess the use of a potentially more efficient assessment tool to predict stair negotiation ability among older acute patients. To support the findings of this study and influence effective practice changes in the completion of stairs assessments, further studies with larger sample sizes are required to assess the predictive ability of single leg squats in determining stair negotiation ability in rural and metropolitan health settings across acute and sub-acute patient groups of all ages. Specific strategies for implementation of suggested recommendations based on study findings are discussed in Table 6 below.

IMPLICATIONS AND RECOMMENDATIONS

Table 6: Suggested strategies for implementation of study recommendations based on project findings

Implication (what project findings signify and indicate)	**Recommendation (based on study findings suggested changes to improve clinical practice or policy)**	**Implementation (suggestions on how to put recommended changes into practice or to change policy)**
Squats are an accurate measure of stair negotiation ability in older acute patients referred for a physiotherapy mobility assessment. As the squat test is a more efficient assessment tool compared to traditional stairs assessments, it will deliver benefits to the patient and hospital system.	The squat test could be used in groups of older acute patients as an alternative assessment tool to determine patients' ability to negotiate stairs and suitability for discharge when reduced mobility is an issue following illness or surgery.	Education and discussion sessions with physiotherapists and managers are required, to ensure the process of modifying relevant protocols, policies and clinical practices associated with stairs assessments are completed, which will improve efficiency of stairs assessments.
Patients who do not live alone, have moderate to severe pain or are reliant on a frame for walking may not be able to complete the squat test. If older patients are unable to complete the squat test, a traditional stairs assessment would be required to determine patients' ability to negotiate stairs and suitability for discharge from a functional perspective.	The squat test could be used in certain groups of older patients as a more efficient assessment tool compared to traditional stairs assessments. However, certain older patients who are unable to complete the squat test may require a traditional stairs assessment to determine their ability to negotiate stairs and suitability for discharge when reduced mobility is an issue.	Education and discussion sessions with physiotherapists and managers are required, to ensure the squat test is used to determine stair negotiation ability amongst appropriate patient groups. Policies, protocols and clinical practices associated with stairs assessments would need to be modified to incorporate the scope of the stairs test as a more efficient measure of stair negotiation ability.
Inter-rater agreement for the squat test and stair negotiation was excellent. Different physiotherapists' assessments of older patients' ability to complete single leg squats and negotiate stairs would likely be the same. This is particularly relevant in health care facilities where patients are not always seen by the same physiotherapist on each occasion.	Both of these assessment tools can be used between physiotherapists with confidence that if two or more physiotherapists assessed the same older patient they would likely reach the same outcome. The accuracy of the squat test assessment in determining stair negotiation ability should be investigated among other health disciplines to determine whether these assessments could be completed by other health professionals in circumstances where physiotherapists are not readily available, such as at small rural hospitals.	Education sessions with physiotherapists are required to educate and assure that these assessments can be used by different physiotherapists with confidence of obtaining the same outcome. Further research into the use of the squat test as an assessment method in determining stair negotiation ability by other health professionals should be funded by the NSW Ministry of Health or other funding bodies to broaden the potential benefits of the squat test.
This is the first study to assess the use of a squat test to predict ability to negotiate stairs.	Future research into the use of the squat test as an alternative assessment tool for stair negotiation ability is necessary, to support the findings of this study and influence changes in physiotherapy stairs assessments that are more efficient and evidence-based. Further research should include studies with larger sample sizes, completed in rural and metropolitan acute and sub-acute health care facilities and include patient groups of different ages and with different conditions to support the findings of this study.	Further research into the use of the squat test as an alternative assessment method should be funded by the NSW Ministry of Health or other funding bodies to allow the completion of vital additional research to improve the rural health evidence-base and subsequently rural clinical practice.
The squat test is a new assessment tool that has been designed to be used as a portable and more efficient assessment for determining stair negotiation ability. Therefore comparison of results with previous literature and recommendations is not possible.	Publish the results of this study so information on the accuracy and benefits of the squat test in determining stair negotiation ability is publicly available to broaden the potential benefits of the squat test.	This report will be publicly available on the HETI-Rural website, will be distributed to allied health professionals and research papers will be submitted to peer reviewed journals for potential publication.

REFERENCES

1. Bergland A, Sylliaas H, Jarnlo GB, Wyller TB. Health, balance, and walking as correlates of climbing steps. Journal of Aging & Physical Activity. 2008;16(1):42-52.
2. Gill DL, Kelley BC, Williams K, Martin JJ. The relationship of self-efficacy and perceived well-being to physical activity and stair climbing in older adults. Research Quarterly for Exercise & Sport. 1994;65(4):367-71.
3. Mian OS, Narici MV, Minetti AE, Baltzopoulos V. Centre of mass motion during stair negotiation in young and older men. Gait and Posture. 2007;26 (3):463-9.
4. Nadeau S, McFadyen BJ, Malouin F. Frontal and sagittal plane analyses of the stair climbing task in healthy adults aged over 40 years: What are the challenges compared to level walking? Clinical Biomechanics. 2003;18 (10):950-9.
5. Reeves ND, Spanjaard M, Mohagheghi AA, Baltzopoulos V, Maganaris CN. The demands of stair descent relative to maximum capacities in elderly and young adults. Journal of Electromyography and Kinesiology. 2008;18 (2):218-27.
6. Reeves ND, Spanjaard M, Mohagheghi AA, Baltzopoulos V, Maganaris CN. Older adults employ alternative strategies to operate within their maximum capabilities when ascending stairs. Journal of Electromyography and Kinesiology. 2009;19 (2):e57-e68.
7. Startzell JK, Owens DA, Mulfinger LM, Cavanagh PR. Stair negotiation in older people: A review. Journal of the American Geriatrics Society. 2000;48 (5):567-80.
8. Mian OS, Thom JM, Narici MV, Baltzopoulos V. Kinematics of stair descent in young and older adults and the impact of exercise training. Gait and Posture. 2007;25 (1):9-17.
9. Samuel D, Rowe P, Hood V, Nicol A. The biomechanical functional demand placed on knee and hip muscles of older adults during stair ascent and descent. Gait and Posture. 2011;34(2):239-44.
10. Freedman V, Martin L. Understanding trends in functional limitations among older Americans. American Journal of Public Health. 1998;88:1457-62.
11. Flanagan S, Salem GJ, Wang M-Y, Sanker SE, Greendale GA. Squatting exercises in older adults: kinematic and kinetic comparisons. Medicine & Science in Sports & Exercise. 2003;35(4):635-43.
12. Tiedemann AC, Sherrington C, Lord SR. Physical and psychological factors associated with stair negotiation performance in older people. Journals of Gerontology Series A: Biological Sciences & Medical Sciences. 2007;62A(11):1259-65.
13. Lampinen P, Heikkinen E. Reduced mobility and physical activity as predictors of depressive symptoms among community-dwelling older adults: An eight-year follow-up study. Aging - Clinical and Experimental Research. 2003;15 (3):205-11.
14. Cavanagh PR, Mulfinger LM, Owens DA. How do the elderly negotiate stairs? Muscle & Nerve Supplement. 1997;5:S52-5.
15. Binder EF, Birge SJ, Spina R, Ehsani AA, Brown M, Sinacore DR, et al. Peak aerobic power is an important component of physical performance in older women. J Gerontol A Biol Sci Med Sci. 1999;54(7):M353-6. Epub 1999/08/26.
16. van Iersel MB, Olde Rikkert MGM, Mulley GP. Is stair negotiation measured appropriately in functional assessment scales? Clinical Rehabilitation. 2003;17(3):325-33.
17. Templer J, Archea J, Cohen H. Study of factors associated with risk of work-related stairway falls. Journal of Safety Research. 1985;16:183-96.
18. Brenes GA, Rapp SR, Rejeski WJ, Miller ME. Do optimism and pessimism predict physical functioning? Journal of behavioral medicine. 2002;25 (3):219-31.
19. Tiedemann AC, Sherrington C, Lord SR. Physical and psychological factors associated with stair negotiation performance in older people. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 2007;62(11):1259-65.
20. Bean JF, Kiely DK, Herman S, Leveille SG, Mizer K, Frontera WR, et al. The relationship between leg power and physical performance in mobility-limited older people. J Am Geriatr Soc. 2002;50(3):461-7. Epub 2002/04/12.
21. Ploutz-Snyder LL, Manini T, Ploutz-Snyder RJ, Wolf DA. Functionally relevant thresholds of quadriceps femoris strength. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 2002;57(4):B144-B52.
22. Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ. High-intensity strength training in nonagenarians. Effects on skeletal muscle. JAMA. 1990;263(22):3029-34.
23. Salem GJ, Wang MY, Young JT, Marion M, Greendale GA. Knee strength and lower- and higher-intensity functional performance in older adults. Med Sci Sports Exerc. 2000;32(10):1679-84. Epub 2000/10/20.
24. Fiatarone MA, O'Neill EF, Ryan ND, Clements KM, Solares GR, Nelson ME, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. New England Journal of Medicine. 1994;330(25):1769-75.
25. Bassey EJ, Fiatarone MA, O'Neill EF, Kelly M, Evans WJ, Lipsitz LA. Leg extensor power and functional performance in very old men and women. Clin Sci (Lond). 1992;82(3):321-7. Epub 1992/03/01.
26. Marks R. An investigation of the influence of age, clinical status, pain and position sense on stair walking in women with osteoarthrosis. International Journal of Rehabilitation Research. 1994;17 (2):151-8.
27. Topp R, Woolley S, Khuder S, Hornyak J, Bruss A. Predictors of four functional tasks in patients with osteoarthritis of the knee. Orthopaedic nursing / National Association of Orthopaedic Nurses. 2000;19 (5):49-58.
28. Ryan SD, Fried LP. The impact of kyphosis on daily functioning. J Am Geriatr Soc. 1997;45(12):1479-86. Epub 1997/12/24.
29. Hsue BJ, Su FC. Kinematics and kinetics of the lower extremities of young and elder women during stairs ascent while wearing low and high-heeled shoes. Journal of Electromyography and Kinesiology. 2009;19 (6):1071-8.
30. Williams K, Bird M. The aging mover: a preliminary report on constraints to action. International Journal of Aging & Human Development. 1992;34(3):241-55.
31. Benedetti MG, Berti L, Maselli S, Mariani G, Giannini S. How do the elderly negotiate a step? A biomechanical assessment. Clinical Biomechanics. 2007;22(5):567-73.
32. Heasley K, Buckley JG, Scally A, Twigg P, Elliott DB. Falls in older people: effects of age and blurring vision on the dynamics of stepping. Invest Ophthalmol Vis Sci. 2005;46(10):3584-8. Epub 2005/09/28.
33. Riener R, Rabuffetti M, Frigo C. Stair ascent and descent at different inclinations. Gait & Posture. 2002;15(1):32-44.
34. Evers Larsson U, Mattsson E. Functional limitations linked to high body mass index, age and current pain in obese women. Int J Obes Relat Metab Disord. 2001;25(6):893-9. Epub 2001/07/06.
35. van Sloten TT, Savelberg HH, Duimel-Peeters IG, Meijer K, Henry RM, Stehouwer CD, et al. Peripheral neuropathy, decreased muscle strength and obesity are strongly associated with walking in persons with type 2 diabetes without manifest mobility limitations. Diabetes Res Clin Pract. Ireland: 2010 Elsevier Ireland Ltd; 2011. p. 32-9.

36. Stevens-Lapsley JE, Petterson SC, Mizner RL, Snyder-Mackler L. Impact of body mass index on functional performance after total knee arthroplasty. Journal of Arthroplasty. 2010;25(7):1104-9.
37. Brown M, Sinacore DR, Host HH. The relationship of strength to function in the older adult. Journals of Gerontology Series A-Biological Sciences & Medical Sciences. 1995;50 Spec No:55-9.
38. Svanstrom L. Falls on stairs: an epidemiological accident study. Scand J Soc Med. 1974;2(3):113-20. Epub 1974/01/01.
39. Hemenway D, Solnick SJ, Koeck C, Kytir J. The incidence of stairway injuries in Austria. Accident Analysis & Prevention. 1994;26(5):675-9.
40. Hamel KA, Okita N, Bus SA, Cavanagh PR. A comparison of foot/ground interaction during stair negotiation and level walking in young and older women. Ergonomics. 2005;48(8):1047-56.
41. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. New England Journal of Medicine. 1988;319(26):1701-7.
42. Smutnick JA, Bohannon RW. Hip and knee flexion of lead and trail limbs during ascent of a step of different heights by normal adults. Physiotherapy. 2009;95 (4):289-93.
43. Hamel KA, Cavanagh PR. Stair Performance in People Aged 75 and Older. Journal of the American Geriatrics Society. 2004;52 (4):563-7.
44. West SK, Rubin GS, Munoz B, Abraham D, Fried LP. Assessing functional status: Correlation between performance on tasks conducted in a clinic setting and performance on the same task conducted at home. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 1997;52 (4):M209-M17.
45. Masuda K, Kim J, Kinugasa R, Tanabe K, Kuno SY. Determinants for stair climbing by elderly from muscle morphology. Perceptual and motor skills. 2002;94 (3 Pt 1):814-6.
46. Duncan PW, Chandler J, Studenski S, Hughes M, Prescott B. How do physiological components of balance affect mobility in elderly men? Archives of Physical Medicine & Rehabilitation. 1993;74(12):1343-9.
47. Madsen OR, Lauridsen UB, Sorensen OH. Quadriceps strength in women with a previous hip fracture: relationships to physical ability and bone mass. Scandinavian Journal of Rehabilitation Medicine. 2000;32(1):37-40.
48. Piva SR, Teixeira PE, Almeida GJ, Gil AB, DiGioia 3rd AM, Levison TJ, et al. Contribution of hip abductor strength to physical function in patients with total knee arthroplasty. Physical therapy. 2011;91(2):225-33.
49. Madsen OR, Egsmose C. Associations of isokinetic knee extensor and flexor strength with steroid use and walking ability in women with rheumatoid arthritis. Clinical Rheumatology. 2001;20(3):207-12.
50. Yoshida Y, Mizner RL, Ramsey DK, Snyder-Mackler L. Examining outcomes from total knee arthroplasty and the relationship between quadriceps strength and knee function over time. Clinical Biomechanics. 2008;23(3):320-8.
51. Clemencon M, Hautier CA, Rahmani A, Cornu C, Bonnefoy M. Potential role of optimal velocity as a qualitative factor of physical functional performance in women aged 72 to 96 years. Arch Phys Med Rehabil. United States2008. p. 1594-9.
52. Suzuki T, Bean JF, Fielding RA. Muscle power of the ankle flexors predicts functional performance in community-dwelling older women. Journal of the American Geriatrics Society. 2001;49 (9):1161-7.
53. Cesari P, Formenti F, Olivato P. A common perceptual parameter for stair climbing for children, young and old adults. Hum Mov Sci. 2003;22(1):111-24. Epub 2003/03/08.
54. McFadyen BJ, Winter DA. An integrated biomechanical analysis of normal stair ascent and descent. Journal of Biomechanics. 1988;21 (9):733-44.
55. Moffet H, Richards CL, Malouin F, Bravo G. Impact of knee extensor strength deficits on stair ascent performance in patients after medial meniscectomy. Scand J Rehabil Med. 1993;25(2):63-71. Epub 1993/06/01.
56. Yu B, Stuart MJ, Kienbacher T, Growney ES, An KN. Valgus-varus motion of the knee in normal level walking and stair climbing. Clinical Biomechanics. 1997;12 (5):286-93.
57. Collen FM, Baer GD, Ashburn AM. Stepping onto a single step: a kinematic study. Physiotherapy Research International. 2005;10(2):81-92.
58. Yu B, Kienbacher T, Growney ES, Johnson ME, An KN. Reproducibility of the kinematics and kinetics of the lower extremity during normal stair-climbing. Journal of Orthopaedic Research. 1997;15 (3):348-52.
59. Husa-Russell J, Ukelo T, List R, Lorenzetti S, Wolf P. Day-to-day consistency of lower extremity kinematics during stair ambulation in 24-45 years old athletes. Gait Posture. 2011;33(4):635-9. Epub 2011/03/25.
60. Protopapadaki A, Drechsler WI, Cramp MC, Coutts FJ, Scott OM. Hip, knee, ankle kinematics and kinetics during stair ascent and descent in healthy young individuals. Clinical Biomechanics. 2007;22 (2):203-10.
61. Wang MY, Flanagan S, Song JE, Greendale GA, Salem GJ. Lower-extremity biomechanics during forward and lateral stepping activities in older adults. Clin Biomech (Bristol, Avon). 2003;18(3):214-21. Epub 2003/03/07.
62. Rowe PJ, Myles CM, Walker C, Nutton R. Knee joint kinematics in gait and other functional activities measured using flexible electrogoniometry: how much knee motion is sufficient for normal daily life? Gait & Posture. 2000;12(2):143-55.
63. Hicks-Little CA, Peindl RD, Hubbard TJ, Scannell BP, Springer BD, Odum SM, et al. Lower extremity joint kinematics during stair climbing in knee osteoarthritis. Medicine and Science in Sports and Exercise. 2011;43(3):516-24.
64. Onodera AN, Gomes AA, Pripas D, Mezzarane RA, Sacco IC. Lower limb electromygraphy and kinematics of neuropathic diabetic patients during real-life activities: Stair negotiation. Muscle Nerve. 2011. Epub 2011/06/24.
65. Almeida GJ, Schroeder CA, Gil AB, Fitzgerald GK, Piva SR. Interrater reliability and validity of the stair ascend/descend test in subjects with total knee arthroplasty. Arch Phys Med Rehabil. United States: 2010 American Congress of Rehabilitation Medicine. Published by Elsevier Inc; 2010. p. 932-8.
66. Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. Journal of Strength & Conditioning Research. 2010;24(12):3497-506.
67. Ayotte NW, Stetts DM, Keenan G, Greenway EH. Electromyographical analysis of selected lower extremity muscles during 5 unilateral weight-bearing exercises. Journal of Orthopaedic & Sports Physical Therapy. 2007;37(2):48-55.
68. Boudreau SN, Dwyer MK, Mattacola CG, Lattermann C, Uhl TL, McKeon JM. Hip-muscle activation during the lunge, single-leg squat, and step-up-and-over exercises. Journal of Sport Rehabilitation. 2009;18(1):91-103.
69. Beutler AI, Cooper LW, Kirkendall DT, Garrett WE, Jr. Electromyographic Analysis of Single-Leg, Closed Chain Exercises: Implications for Rehabilitation After Anterior Cruciate Ligament Reconstruction. J Athl Train. 2002;37(1):13-8. Epub 2003/08/26.
70. Dwyer MK, Boudreau SN, Mattacola CG, Uhl TL, Lattermann C. Comparison of lower extremity kinematics and hip muscle activation during rehabilitation tasks between sexes. J Athl Train. 2010;45(2):181-90. Epub 2010/03/10.

71. Boren K, Conrey C, Le Coguic J, Paprocki L, Voight M, Robinson TK. Electromyographic analysis of gluteus medius and gluteus maximus during rehabilitation exercises. Int J Sports Phys Ther. 2011;6(3):206-23. Epub 2011/10/29.

72. Lubahn AJ, Kernozek TW, Tyson TL, Merkitch KW, Reutemann P, Chestnut JM. Hip muscle activation and knee frontal plane motion during weight bearing therapeutic exercises. Int J Sports Phys Ther. 2011;6(2):92-103.

73. Richards J, Thewlis D, Selfe J, Cunningham A, Hayes C. A biomechanical investigation of a single-limb squat: implications for lower extremity rehabilitation exercise. J Athl Train. 2008;43(5):477-82. Epub 2008/10/04.

74. Shields RK, Madhavan S, Gregg E, Leitch J, Petersen B, Salata S, et al. Neuromuscular control of the knee during a resisted single-limb squat exercise. Am J Sports Med. 2005;33(10):1520-6. Epub 2005/07/13.

75. Zeller BL, McCrory JL, Kibler WB, Uhl TL. Differences in kinematics and electromyographic activity between men and women during the single-legged squat. Am J Sports Med. 2003;31(3):449-56. Epub 2003/05/17.

76. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J Anat. 1989;166:179-89. Epub 1989/10/01.

77. Morcos A, Myers G, Nelson A, Sigward SM. Clinical predicators of knee flexion angle during a single-leg squat... 2008 Combined Sections Meeting...Nashville, Tennessee, February 6-9, 2008. Journal of Orthopaedic & Sports Physical Therapy. 2008;38(1):A26-7.

78. Australian Bureau of Statistics. National Regional Profile: Shoalhaven (C) (Local Government Area) Canberra2011 [updated 1st November 2011; cited 2012 18th June]; Available from: http://www.abs.gov.au/AUSSTATS/abs@nrp.nsf/Latestproducts/LGA16950Population/People12006-2010?opendocument&tabname=Summary&prodno=LGA16950&issue=2006-2010.

79. NSW Health. NSW Health Services Comparison Data Book 2008/2009. In: Demand and Performance Evaluation Branch NH, editor. December 2010.

80. Ingleton C. Populations and samples: identifying the boundaries of research. In: Crookes PA, Davies S, editors. Research into practice: essential skills for reading and applying research in nursing and health care. 2nd ed. Edinburgh: Bailliere Tindall; 2004. p. 113-28.

81. Hsieh FY, Bloch DA, Larsen MD. A simple method of sample size calculation for linear and logistic regression. Stat Med. 1998;17(14):1623-34. Epub 1998/08/12.

82. Kasuyama T, Sakamoto M, Nakazawa R. Ankle joint dorsiflexion measurement using the deep squatting posture. Journal of Physical Therapy Science. 2009;21(2):195-9.

83. Jones R, Carter J, Moore P, Wills A. A study to determine the reliability of an ankle dorsiflexion weight-bearing device. Physiotherapy. 2005;91(4):242-9.

84. Standards Australia. Australian standard 1657: fixed platforms, walkways, stairways and ladders - design, construction and installation. 3rd ed. Sydney: Standards Association of Australia; 1992.

85. Ware LJ, Epps CD, Herr K, Packard A. Evaluation of the Revised Faces Pain Scale, Verbal Descriptor Scale, Numeric Rating Scale, and Iowa Pain Thermometer in older minority adults. Pain Manag Nurs. 2006;7(3):117-25. Epub 2006/08/26.

86. Taylor LJ, Harris J, Epps CD, Herr K. Psychometric evaluation of selected pain intensity scales for use with cognitively impaired and cognitively intact older adults. Rehabil Nurs. 2005;30(2):55-61. Epub 2005/03/26.

87. Norkin C, White DJ. Measurement of joint motion : a guide to goniometry. 3rd ed. Philadelphia: F.A. Davis Co.; 2003.

88. Boone DC, Azen SP, Lin CM, Spence C, Baron C, Lee L. Reliability of goniometric measurements. Physical Therapy. 1978;58(11):1355-60.

89. Brosseau L, Tousignant M, Budd J, Chartier N, Duciaume L, Plamondon S, et al. Intratester and intertester reliability and criterion validity of the parallelogram and universal goniometers for active knee flexion in healthy subjects. Physiotherapy Research International. 1997;2(3):150-66.

90. Brosseau L, Balmer S, Tousignant M, O'Sullivan JP, Goudreault C, Goudreault M, et al. Intra- and intertester reliability and criterion validity of the parallelogram and universal goniometers for measuring maximum active knee flexion and extension of patients with knee restrictions. Archives of Physical Medicine and Rehabilitation. 2001;82(3):396-402.

91. Clapper MP, Wolf SL. Comparison of the reliability of the Orthoranger and the standard goniometer for assessing active lower extremity range of motion. Physical Therapy. 1988;68(2):214-8.

92. Jakobsen TL, Christensen M, Christensen SS, Olsen M, Bandholm T. Reliability of knee joint range of motion and circumference measurements after total knee arthroplasty: does tester experience matter? Physiotherapy Research International. 2010;15(3):126-34.

93. Unver B, Karatosun V, Bakirhan S. Reliability of goniometric measurements of flexion in total knee arthroplasty patients: with special reference to the body position. Journal of Physical Therapy Science. 2009;21(3):257-62.

94. Cibere J, Bellamy N, Thorne A, Esdaile JM, McGorm KJ, Chalmers A, et al. Reliability of the Knee Examination in Osteoarthritis: Effect of Standardization. Arthritis and Rheumatism. 2004;50(2):458-68.

95. Lenssen AF, van Dam EM, Crijns YHF, Verhey M, Geesink RJT, van den Brandt PA, et al. Reproducibility of goniometric measurement of the knee in the in-hospital phase following total knee arthroplasty. BMC Musculoskeletal Disorders. 2007;8:83.

96. Rheault W, Miller M, Nothnagel P, Straessle J, Urban D. Intertester reliability and concurrent validity of fluid-based and universal goniometers for active knee flexion. Physical Therapy. 1988;68(11):1676-8.

97. Theiler R, Stucki G, Schutz R, Hofer H, Seifert B, Tyndall A, et al. Parametric and non-parametric measures in the assessment of knee and hip osteoarthritis: interobserver reliability and correlation with radiology. Osteoarthritis & Cartilage. 1996;4(1):35-42.

98. Webb P, Bain C. Essential epidemiology: an introduction for students and health professionals. 2nd ed. New York: Cambridge University Press; 2011.

99. Mehta CR, Patel NR. Exact logistic regression: theory and examples. Stat Med. 1995;14(19):2143-60. Epub 1995/10/15.

100. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61(4):344-9. Epub 2008/03/04.

101. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. Physical Therapy. 2005;85(3):257-68.

APPENDICES

Appendix 1

Search strategies employed for the literature review and background section of the report

Appendix 2

Sample size calculations

Appendix 3

Additional demographic and functional characteristics of study participants

Appendix 4

Univariate analyses to determine differences between participants who could and could not negotiate stairs

Appendix 5

Multivariate exact logistic regression models used to determine factors associated with independent stair negotiation ability with each covariate entered into a model with only squat test

Appendix 1

Search strategies employed for the literature review and background section of the report

The following search strategy was employed to locate papers relating to stair negotiation:-

1. step* OR stair*

2. old* OR elder* OR mature OR aged

3. predict* OR determin* OR influenc* OR associate* OR correlat* OR link* OR relat* OR connect*

4. negotiat* OR ascend* OR descend* OR climb*

5. abilit* OR capacit* OR capabilit* OR skill* OR perform*

6. movement* OR range* OR motion* OR active* OR passive* OR ROM OR AROM OR PROM OR power* OR strength* OR force* OR physical* OR pain* OR function* OR ADL* OR endurance OR fitness OR balance OR flexib* OR biomechanic* OR mobility* OR walk* OR 'activities of daily living' OR 'activity of daily living'

7. 1 AND 2 AND 3 AND 4 AND 5 AND 6

The following search strategy was employed to locate papers relating to single leg squat biomechanics:-

1. (single OR one) AND leg AND squat*

2. movement* OR range* OR motion* OR power* OR strength* OR balance OR biomechanic* OR force* OR kinetic* OR kinematic* OR AROM OR ROM OR PROM

3. predict* OR determin* OR influenc* OR associate* OR correlat* OR link* OR relat* OR connect*

4. 1 AND 2 AND 3

The star (*) symbol is a used as a truncation so all papers including all variations of each search term as per the truncation are identified during the search process. Only articles available in English were included. Reference lists of relevant papers were searched to identify studies missed by the electronic search process. Papers citing relevant studies were also indentified using the Science Citation Index.

Appendix 2

Sample size calculations

The sample size calculations provided are based on those for logistic regression in Hsieh et al (1998) [(81)]. The primary outcome of this study was a binary variable, ability to negotiate a three step staircase independently with or without a rail. The primary independent variable was a binary variable, ability to perform three single leg squats on participants' dominant leg. The research team aimed to detect a minimum difference in the proportion of subjects that could negotiate three steps independently, between the group of subjects who could perform three squats and the group of subjects who could not complete three squats, of 0.301. A significance level of 0.05, power of 0.8 and that the proportion of participants who were able to perform the squats was 0.8, were assumed. As an extensive literature search was unable to locate any previous studies which have investigated the proportion of older people who could perform single leg squats, the investigators were reliant on clinical reasoning to determine this figure. The investigators estimated that 80% of older hospital inpatients for whom a physiotherapy stairs assessment was clinically indicated would be able to complete the single leg squats.

The proportion of subjects who would have been able to negotiate three steps from the groups who could and could not complete three squats was not known prior to the study, hence a range of required sample sizes (to much the assumptions discussed above) for a range of values of these proportions was determined (see Figure 4). Note the proportion of subjects that can negotiate stairs amongst the group who are able to perform the squats, is the proportion of subjects that can negotiate stairs amongst the group who are not able to perform the squats plus the minimum detectable difference (0.301). Sample sizes were calculated for the primary study analysis, namely logistic regression with one binary covariate (sample sizes shown in red in Figure 4). It is clear from Figure 4 that a sample size of approximately 130 subjects was adequate to answer the primary research question in all scenarios.

A secondary analysis was aimed at assessing the impact of potential confounders on participants' ability to negotiate stairs using a multivariate logistic regression. The sample size for a multivariate logistic regression depends on the relationship (correlation) between the dependent variable and the potential confounders, and it was expected this relationship would be weak. The research team conservatively chose this correlation to be 0.3. It is clear from Figure 4 that a sample size of approximately 143 subjects was adequate to analyse the impact of potential confounders (sample sizes shown in blue in Figure 4).

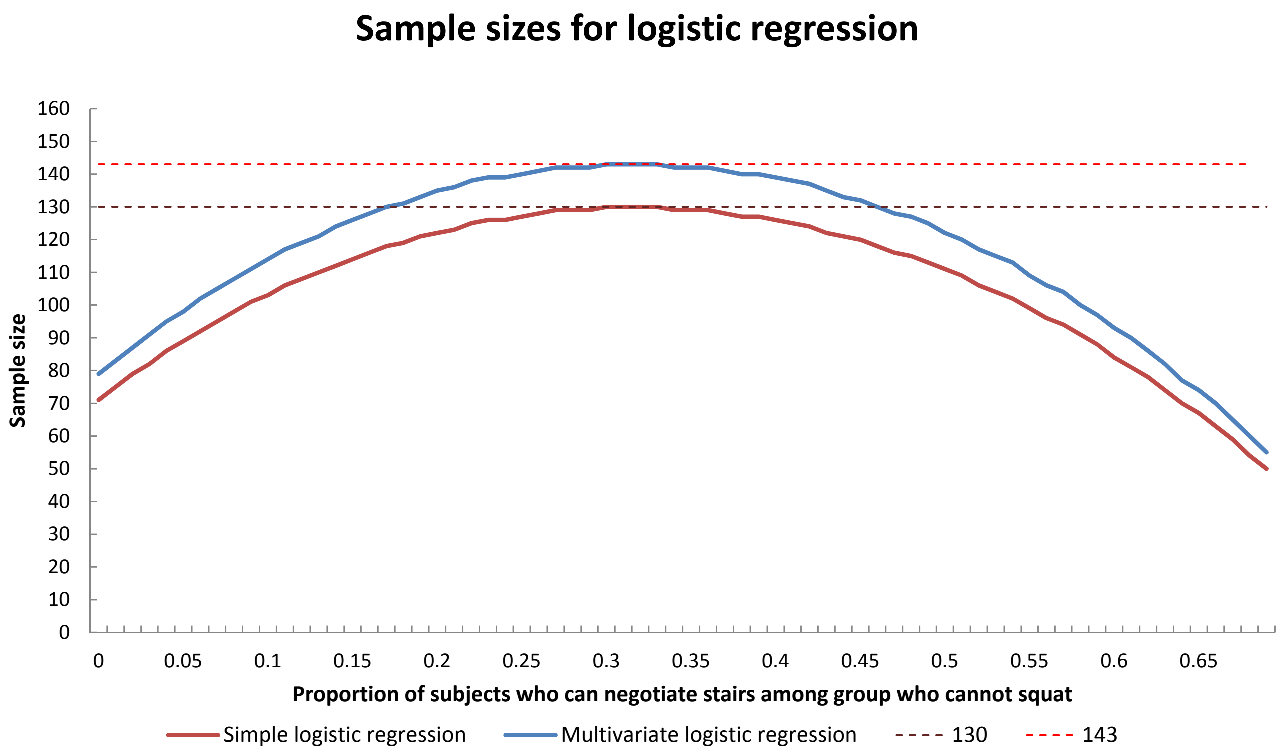

Figure 4: Range of required sample sizes for logistic regression for a range of values of these proportions (a significance level of 0.05, power of 0.8 and that the proportion of participants who were able to perform the squats was 0.8 were assumed)

The sample size calculations provided below for determining inter-rater agreement are based on those for the Kappa statistic in Sim and Wright (2005) [101]. A sample size of 85 participants allows detection of a Kappa of 0.7 assuming the proportion of positive ratings is between 0.3 and 0.7 and a sample size of 102 participants allows detection of a Kappa of 0.8 assuming the proportion of positive ratings is between 0.1 and 0.9, assuming the null hypothesis of Kappa is 0.4 and power is 80%. These are worst case scenarios. Thus a sample size of 85 to 102 is appropriate to detect a clinically acceptable and statistically significant Kappa coefficient.

Appendix 3

Table 7: Additional demographic and functional characteristics of study participants

Demographic and functional characteristics	Participants
Place of prior residence	
Home alone	54 (37.8%)
Home accompanied	85 (59.4%)
Self-care unit alone	1 (0.7%)
Self-care unit accompanied	3 (2.1%)
Median number falls in past 12 months (range)	0 (0 – 30)
Fall on stairs in past 12 months	
Yes	12 (8.4%)
No	131 (91.6%)
Median maximum number of steps needed to negotiate to return home (range)	2 (0 – 40)
Rails on steps	
Nil	40 (33.3%)
One	56 (46.7%)
Two	24 (20.0%)
Fear of negotiating stairs	
Yes	27 (18.9%)
No	116 (81.1%)

All results are n (%) unless stated

Appendix 4

Univariate analyses to determine differences between participants who could and could not negotiate stairs

Univariate analyses were performed to determine whether there were statistically significant differences in demographic and functional variables that were clinically reasoned to be possible predictors of stair negotiation ability, between participants who could and could not negotiate three steps. The results of the univariate analyses are presented in Table 8. Participants who could negotiate three steps independently differed significantly ($p < 0.05$) from those who could not on a range of variables including gait aid use indoors and outdoors prior to hospital presentation, knee flexion range of movement, gait assistance at time of assessment and gait aid use at time of assessment. The differences between the other demographic and functional variables were not significant.

Table 8: Univariate analyses for demographic and functional variables between participants who could and could not negotiate three steps

Variable	**Able to complete stairs (yes/no)**	
	Test statistic	**p-value**
Sex*	χ^2=0.65	p=0.42
Age†	t=-0.24	p=0.81
Recruitment – acute wards/emergency department‡		p=0.68
Diagnosis‡		p=0.05
Place of prior residence (whether participants lived alone)‡		p=0.08
Place of prior residence (type of accommodation)‡		p=0.60
Gait assistance prior to hospital presentation‡		p=0.88
Gait aid prior to hospital presentation – indoors‡		p<0.01§
Gait aid prior to hospital presentation – outdoors‡		p<0.01§
Maximum number steps needed to negotiate to return home‖	z=-1.19	p=0.24
Number of rails on steps needed to negotiate to return home‡		p=0.12
Number falls in past 12 months‖	z=1.64	p=0.10
Falls on stairs in past 12 months – yes/no‡		p=0.43
Fear of negotiating stairs*	χ^2=3.39	p=0.07
Presence of pain – yes/no*	χ^2=2.29	p=0.13
Median pain severity‖	z=-1.94	p=0.05
Pain location‡		p=0.71
Knee flexion range of motion‖	z=-3.42	p<0.01§
Gait assistance at time of assessment‡		p=0.03§
Gait aid at time of assessment‡		p<0.01§
Preferred leg for squat test‡		p=0.18

*Chi-squared test used
†Independent t-test equal variance used
‡Fishers exact test used
§Indicates statistically significant finding $p < 0.05$
‖Wilcoxon rank-sum test used

Appendix 5

Multivariate exact logistic regression models used to determine factors associated with independent stair negotiation ability with each covariate entered into a model with only squat test

All variables with a univariate association with ability to negotiate stairs at the level of $p < 0.15$ and were clinically reasoned to be possible predictors of stair negotiation ability were included in the multivariate models with squat test. Each covariate was entered into a model with only squat test. The results of the multivariate exact logistic regression models used to determine factors associated with independent stair negotiation ability are presented in Table 9. Multivariate exact regression analyses indicated walking frame use at time of assessment and pain severity were statistically significant and independent predictors of stair negotiation ability in the model with squat test. A near statistically significant effect was identified for whether participants lived alone. The squat test was statistically significant in all models where it was included with another covariate predicting stair negotiation ability. Other covariates did not significantly predict stair negotiation in the model with squat test. The three covariates with an association with stair negotiation ability and squat test at the level of $p < 0.1$ were then entered into a final multivariate regression model with squat test.

Table 9: Results of multivariate exact logistic regression models used to determine factors associated with independent stair negotiation ability with each covariate entered into a model with only squat test

Multivariate exact logistic regression (each covariate entered into model with only squat test)			
Predictor variables	**Coefficient (95% CI)**	**Odds ratio (95% CI)**	**p-value**
Knee flexion range of motion	0.05 (-0.024 to 0.133)	1.05 (0.976 to 1.142)	0.21
Number of rails on steps needed to negotiate to return home	0.13 (-0.998 to 1.281)	1.14 (0.369 to 3.600)	1.00
Place of prior residence (whether participants lived alone)	-1.49 (-3.487 to 0.200)	0.22 (0.031 to 1.222)	0.09*
Gait aid prior to hospital presentation – indoors (nil aid/aid use)[†]	-0.59 (-2.182 to 0.942)	0.56 (0.113 to 2.566)	0.59
Gait aid prior to hospital presentation – indoors (no frame/frame)[†]	-1.17 (-3.673 to 0.836)	0.31 (0.025 to 2.306)	0.35
Gait aid prior to hospital presentation – outdoors (nil aid/aid use)[†‡]	-0.93 (-2.709 to 0.698)	0.40 (0.067 to 2.009)	0.34
Gait aid prior to hospital presentation – outdoors (no frame/frame)[†‡]	-0.68 (-2.381 to 0.937)	0.51 (0.092 to 2.552)	0.54
Gait aid at time of assessment (nil aid/aid use)[†]	-0.86 (-infinity to 1.722)	0.42 (0.000 to 5.594)	0.51
Gait aid at time of assessment (no frame/frame)[†]	-3.12 (-7.045 to -0.911)	0.04 (0.001 to 0.402)	0.00*
Gait assistance at time of assessment (independent/assistance required)	-0.42 (-2.515 to 1.548)	0.66 (0.081 to 4.704)	0.93
Diagnosis – Cardiovascular (Yes/No)	1.03 (-0.974 to 3.531)	2.80 (0.377 to 34.148)	0.45
Diagnosis – Respiratory (Yes/No)	1.76 (-0.400 to infinity)	5.82 (0.671 to infinity)	0.12
Diagnosis – General medical and surgical (Yes/No)[§]	1.13 (-1.511 to 5.183)	3.10 (0.221 to 178.292)	0.65
Diagnosis – Musculoskeletal (Yes/No)	-0.06 (-infinity to 3.606)	0.94 (0.000 to 36.833)	0.97
Diagnosis – Orthopaedic surgery (Yes/No)	-1.43 (-3.909 to 0.508)	0.24 (0.020 to 1.663)	0.19
Diagnosis – Neurological (Yes/No)	-1.26 (-5.310 to 1.386)	0.28 (0.005 to 3.998)	0.56
Diagnosis – Falls (Yes/No)	-0.06 (-4.480 to 4.362)	0.94 (0.011 to 78.442)	1.00
Diagnosis – Other (Yes/No)	-0.52 (-3.134 to 1.787)	0.59 (0.044 to 5.973)	0.94
Number falls in past 12 months	-0.02 (-0.279 to 0.230)	0.98 (0.757 to 1.259)	0.91
Fear of negotiating stairs	-0.34 (-2.033 to 1.309)	0.71 (0.131 to 3.704)	0.91
Pain severity	-0.36 (-0.734 to -0.072)	0.70 (0.480 to 0.931)	0.01*

*Indicates $p < 0.1$

[†]Gait aid prior to hospital presentation (indoors and outdoors) and at time of assessment was dichotomised in two different ways (nil aid/aid and frame/no frame) as it was clinically reasoned that participants who required nil aid or walking sticks when walking were more likely to be able to negotiate stairs independently compared to participants who were reliant on a frame. Participants who were reliant on any aid for walking from a clinical perspective were also less likely to be able to negotiate stairs independently compared to participants who did not require an aid.

[‡]One participant was reliant on nil aid indoors and a wheelchair outdoors for mobilisation prior to hospital presentation, as they were unable to mobilise long distances due to poor endurance. Instead of excluding this participant from analysis, wheelchair was included in the mobility aid category for analysis of gait aid prior to hospital presentation outdoors (nil aid/aid) and in the frame category for analysis of gait aid prior to hospital presentation outdoors (no frame/frame).

[§]Gastroenterological, genitourinary and general surgery diagnostic categories were combined for the multivariate exact logistic regression data analyses due to small number of participants in the genitourinary and general surgery diagnoses categories.