FRAILTY IN ACUTE HIP FRACTURE PATIENTS: PREVALENCE AND CLINICAL IMPLICATIONS

By

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SUMMARY

Hip fractures and frailty are major global public health concerns. Geriatric low-impact hip fracture incidence continues to rise, and despite medical advances, they are major life events with high risks of negative health outcomes.

While there is no consensus regarding the definition, diagnosis, and management of frailty, it can be described as an expression of aging poorly. Vulnerability to stressors is increased in all body systems, increasing the risk of poor recovery.

Several risk factors for sustaining a hip fracture have been described in the literature. Many of these factors are also part of the wider appearance of frailty.

The exploration of the clinical utility of frailty tools in hip fracture patients was thus deemed valuable.

A systematic review conducted for the research presented in this thesis demonstrated a high prevalence of frailty, measured by hand grip strength, in hip fracture patients. Hand grip strength has been part of a test battery for diagnosing sarcopenia for two decades and has been suggested to be a sole indicator of frailty. Hand grip strength in hip fracture patients was found to be decreased beyond age and gender-stratified values.

An observational study was conducted to investigate the association of frailty with various primary outcome variables in older adults with hip fractures. The main aim was to assess the prevalence of frailty in acute hip fracture patients and to explore the clinical utility of frailty measures in this population. The study found that frailty, measured by both hand grip strength and the reported Edmonton frailty score, was associated with longer hospital stays, poorer mobility status at discharge, and specific discharge destinations. Frailty was also associated with higher mortality rates at 3 months and 12 months. The study provided adjusted and unadjusted analyses; odds ratios varied widely in size and had to be interpreted for their clinical relevance. Clinical applications of frailty in discharge planning and management of hip fracture patients could be recommended.

Further research was suggested to explore hand grip strength beyond cut-off values and to assess healthcare providers' knowledge about frailty qualitatively.

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Katharina Denk

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Donald Bramwell, I never stopped hearing your voice in my head, telling me that there is only one option, and that is to finish this thesis.

Lastly, I feel much gratitude towards my loving family who (almost) never ran out of patience with me during this rocky journey.

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ABBREVIATIONS

ACSQHC	Australian commission on safety and quality in health care
ADL	Activities of daily living
AHFCCS	Australian hip fracture clinical care standard
AIHW	Australian institute of health and welfare
ANZHFR	Australian and New Zealand hip fracture registry
APA	American psychological association
ASA	American society of anaesthesiologists
ASHT	American society of hand therapists
BMD	Bone mineral density
BMI	Body mass index
CAP	Care awaiting placement
CFS	Clinical frailty scale
CFSR	International conference on frailty and sarcopenia research
CNS	Central nervous system
DMS	Discharge mobility status
DNA	Deoxyribonucleic acid
DXA	Dual energy x-ray absorptiometry
EFS	Edmonton frailty scale
EPIDOS	Epidemiology of Osteoporosis
EWGSOP	European working group on sarcopenia in older people
FRAX	Fracture risk assessment tool
GEM	Geriatric evaluation and management unit
GFI	Groningen frailty indicator
GRADE	Grading of recommendations assessment, development and evaluation
HGS	Hand grip strength
HMBLR	Hierarchical multiple binary logistic regression
HMLR	Hierarchical multiple linear regression
ICD-10	International classification of diseases version 10
ISAAC	Integrated South Australian activity collection
JBI	Joanna Briggs Institute
MRN	Medical record number
MUST	Malnutrition universal screening tool
NICE	National institute for health and care excellence
OACIS	Open architecture clinical information system
PBMR	Paper based medical records
RACF	Residential aged care facility
RCD	Routinely collected health data
RCT	Randomised controlled trial
RECORD	Reporting of studies conducted using observational routinely collected health data
SEARCHeD	Supporting evaluation, analysis and reporting of routinely collected health data
SOOB	Sit out of bed
STROBE	Strengthening the reporting of observational studies in epidemiology
TCP	Temporary care placement
TFI	Tilburg frailty indicator

1 THESIS OVERVIEW

1.1 Background and justification

Hip fractures and frailty are health concerns of global magnitude in aging populations. Hip fractures and frailty were both linked to adverse health outcomes and/or negative life events.

It seems unlikely that there is a single cause for sustaining a hip fracture; a multitude of reasons, including osteoporosis, sarcopenia, physical inactivity, impaired cognition, and falls were suggested in the literature. All these factors might be attributed to frailty. Hand grip strength was proposed as a single marker of frailty. The exploration of hand grip strength in hip fracture patients was therefore considered viable.

People with hip fractures are treated in acute hospitals where wards are busy, and patient turnovers are high. Timely discharge of patients is crucial to avoid jammed emergency departments and suboptimal patient care. Prolonged hospital stays are not just expensive for the healthcare system, they also increase patients' risks for negative health outcomes and complications.

Hip fractures can be major life events, most patients cannot be discharged home directly. Requirements for inpatient rehabilitation or interim care are high; permanent changes of primary residences are common. Arranging necessary home alterations or rehabilitation and care placements takes time and depends on current availabilities. On a busy ward, early discharge planning is often hard to achieve. An indicator tool suggesting the most appropriate discharge destination might facilitate the early initiation of all required organisational steps.

Hand grip strength and the reported Edmonton frailty score both correlate with negative health outcomes and can be used in an acute hospital setting on non-ambulatory patients. The strength of their clinimetric properties for early discharge planning has not been previously explored.

1.2 Aim

The research presented in this thesis aimed to explore the presence of frailty in acute hip fracture patients and to assess the clinical utility of frailty measures in this population. The main interest was to explore the utility of two frailty measures in the planning of discharge destinations following acute hospitalisation. The reported Edmonton frailty scale as well as hand grip strength were investigated.

1.3 Structure of thesis

This thesis is divided into five parts.

This overview (chapter one) is followed by chapter two, which provides an overview of hip fractures and frailty. Relevant anatomy, fracture management, epidemiology, and risks associated with this injury were covered. Associated risks concerned fracture risk as well as risks of negative outcomes post fracture.
Frailty as a multi-faceted concept was described, acknowledging the ambiguity over its mechanisms, and the lack of consensus regarding a clear definition. A selection of its many measurement tools was presented. Amongst them were the reported Edmonton frailty score and a simple hand grip strength measure.
A possible link between hip fractures and frailty was explored.
Arguably, some of the information provided in chapter one is not directly relevant to the research questions investigated in chapters two and three of this thesis. Yet everything outlined in chapter one is considered vital for the understanding of the broader context around the research described in chapters two and three.

Chapter three comprises a systematic review investigating hand grip strength in hip fracture patients. Cut-off values suggested in the literature for detecting frailty were considered. While a meta-analysis was not possible due to the heterogeneity of the included studies, hand grip strength values could be compared to assess the prevalence of frailty.

Chapter four describes an observational study investigating the clinical use of hand grip strength and the reported Edmonton frailty score in hip fracture patients. The focus was on discharge planning. Only routinely collected data was used for this study, reasons for this methodology were justified.

Chapter five presents final conclusions and proposes future research to continue to fill knowledge gaps.

This thesis was referenced using the style proposed by the American Psychological Association (7th edition). Their recommendations for the reporting of numbers and statistics were also followed.

2 INTRODUCTION

2.1 Hip fractures

2.1.1 Anatomy & definition

The adult human skeleton consists of 206 bones. The femur, or thighbone, is the longest and heaviest bone in the body. It comprises a shaft, or body, and two ends. The rounded upper end of the femur is referred to as head. The head and shaft are connected through the cervix, or neck. The neck distends medially off the shaft at an average angle of 126 degrees inclination. There is a large eminence on the lateral side of the proximal end of the femur, the grater trochanter, located just over 1 cm below the head in most people. The lesser trochanter is a pointed eminence on the posteromedial side of the proximal femur, just below the junction of shaft and neck. Greater and lesser trochanters are connected via

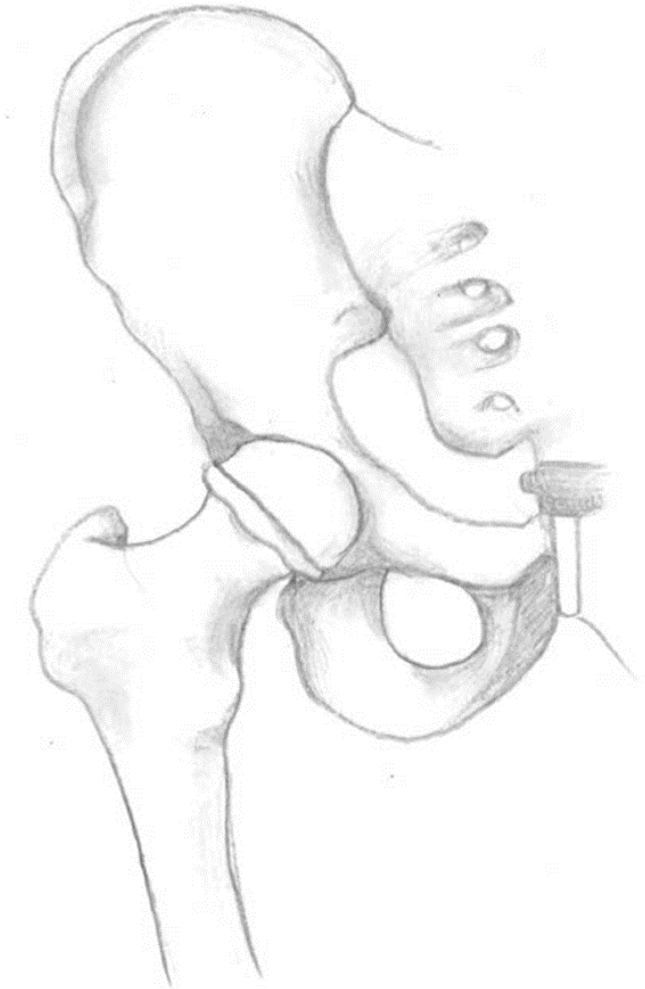

Figure 1: Coxa (Artist: Sasha Simpson)

the intertrochanteric crest on the posterior side of the femur. The proximal half of the femoral shaft is smooth anteriorly and rougher on the posterior side. The lower end of the femur concludes as two rounded surfaces (condyles) that allow articulation at the knee joint (Jenkins, 2008; Moore et al., 2017).

The hip joint (coxa) is a deep ball-and-socket joint, with the femoral head being the ball and the acetabulum (inferior part of the ilium) being the socket. The ilium is one of three parts of the hip bone, or pelvis. The acetabulum is enlarged by a fibro cartilaginous structure, the acetabular labrum, and the transverse acetabular ligament. The hip joint is encircled by a strong joint capsule. The capsule consists of a synovial membrane, and a fibrous external layer which is attached proximally to the acetabulum, and distally to the anterior femoral neck along the intertrochanteric line. The joint capsule is reinforced by three strong intrinsic ligaments (Jenkins, 2008; Moore et al., 2017). The depth of the socket and the strength of capsule and intrinsic ligaments provide the hip joint with great passive stability in most limb positions. The peri-articular muscles that rotate the thigh medially and laterally also contribute to the joint's structural integrity. Together, ligaments and rotating muscles are pulling the femoral head medially into the acetabulum and ensure dynamic stability of the joint during movement (Moore et al., 2017).

Contraction of the large hip flexor and extensor muscles increases the strain energy within the joint (Martelli et al., 2014).

In an upright position, the upper body weight is transferred from the pelvis through to the femoral head and neck. For effective weight transfer, the femoral head lies directly inferior to the weight bearing part of the ilium.

The strong femoral bone supplies stable attachment areas for large hip and knee muscles that are vital for joint stability as well as locomotion and other dynamic movements (Jenkins, 2008; Moore et al., 2017).

Fractures of the proximal femur, henceforth referred to as hip fractures, can be classified broadly according to their anatomic location: head, neck (cervical), and trochanteric region (inter- or per-trochanteric and sub-trochanteric (Lu & Uppal 2019).

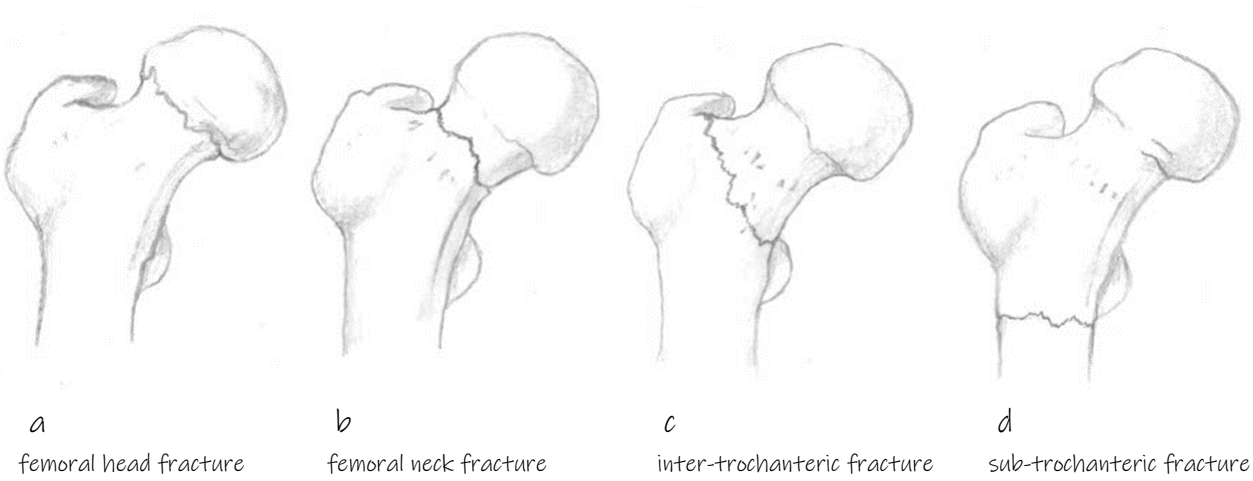

Figure 2: Fracture types (Artist: Sasha Simpson)

Hip fractures mostly affect older adults as a result of low impact trauma such as a stumble or fall from standing height, or a fall from a chair while seated.
In rarer cases, these fractures can occur in individuals of all ages as the result of a high impact trauma like a car accident or fall form a greater height (e.g. off a ladder).

This thesis focuses only on hip fractures caused by low impact trauma.

2.1.2 Incidence & population

Globally, the average life expectancy rose from 45 years in 1900 to 80 years in 2016. The world population is also dramatically rising, from 1.6 billion in 1900 to 7.8 billion in November 2020 (Worldometer, 2020). Consequently, the global number of people aged ≥60 years is rapidly increasing; the number is estimated to rise from 900 million in 2015 to 2 billion by 2050 (World Health Organisation, 2020).

Hip fractures mainly affect people ≥60 years old; in Australia, the median age was 84 in 2015-2016 (Australian Institute of Health and Welfare, 2018).

In 2010 alone, an estimated 2.8 million low impact trauma fractures of the hip and spine have occurred worldwide (Wade et al., 2012), making hip fractures a global health concern. Total numbers of hip fractures are projected to have increased by 35% in 2022, causing overall annual costs of A$1.27 billion in Australia alone (Watts et al., 2013).

Historically, hip fracture rates have been highest in developed Scandinavian and Central European countries such as Denmark, Norway, Sweden, and Austria; and lowest in developing countries such as Tunisia, Ecuador, Morocco and Colombia (Kanis et al., 2012). However, developing regions such as Asia now report hip fracture rates to rapidly rise (Kanis et al., 2012; The World Bank, 2015). It has even been suggested that more than 50% of all hip fractures might occur in Asia by the year 2050 (Dhanwal et al., 2011).

Kanis et al. attempted to map out global hip fracture rates based on data available to them in 2012. They estimated incidences to range from 58 per 100,000 people in Tunisia to 574 per 100,000 people in Denmark (Kanis et al., 2012). More recent data shows Australia to sit somewhere in between, with 199 per 100,000 people aged 45 and over having sustained a hip fracture in 2015-2016 (Australian Institute of Health and Welfare, 2018).

Data on the global lifetime risk for hip fracture was published in 2002, which demonstrated large differences between geographic locations. Lifetime risk at the age of 50 has been estimated to span from 1% (Turkey) to 28.5% (Sweden) in women, and 1.8% (Turkey) to 13.1% (Sweden) in men. In Australia, this risk is believed to be 17.7% for women and 6.3% for men (Kanis et al., 2002).

In many developed countries as well as China the age-adjusted incidence rate is declining in both genders, most likely due to public health campaigns. However, population ageing is overriding this effect, absolute numbers of hip fractures are still rising (Icks et al., 2013; Omsland et al., 2012; Turkington et al., 2012; Zhang et al., 2020). In Australia, hip fracture the age-adjusted incidences decreased by 20% in women and 13% in men over a 9-year

period (1997-1998 to 2006–2007) (Crisp et al., 2012). In the USA, incidences declined between 2002 and 2012, then plateaued in the following three years (Lewiecki et al., 2018). However, despite the age-adjusted incidence rate declining, the absolute number of low impact hip fracture cases continues to rise. In Australia, there were 14,769 incidences in 1997–1998, 16,412 in 2006–2007, and 18,746 in 2015-2016 (Australian Institute of Health and Welfare, 2018; Crisp et al., 2012).

Hip fracture patients are a heterogeneous group, affecting both males and females. However, females are twice as likely as men to sustain a hip fracture. Australian data showed that 70% of hip fracture related hospitalisations were affecting women. On the other hand, men are more likely to die within 12 months of hip fracture than women; this might be due to men having stronger bone but increased frailty. The likelihood of sustaining a hip fracture dramatically increases with age for both genders. The median age for sustaining a first hip fracture in Australia in 2015 -2016 was 84 (Australian Institute of Health and Welfare, 2018; Sullivan et al., 2016).

In summary, hip fractures are predominantly a geriatric condition with often devastating and life changing consequences. Women are affected more than men. Absolute numbers of hip fracture cases continue to rise worldwide due to global population ageing. Thus, hip fractures are likely to remain a main focus for health care providers, hospitals, and public health agencies.

2.1.3 Diagnosis, management & early rehabilitation

Hip fractures are orthopaedic-geriatric conditions. Optimal patient-centred care is provided in a trauma centre by a multidisciplinary team (Roberts et al., 2015).

The fracture must be diagnosed rapidly via adequate x-ray imaging; if a facture is suspected despite a negative or inconclusive x-ray image, a MRI or CT (if MRI is unavailable or contraindicated) is required for clarification (NICE, 2011). Recent research is also exploring the possibility of using convolutional neural networks (artificial intelligence

systems) for detecting hip fractures on x-rays; it is hoped that this could lead to more accurate, cost and time effective diagnoses (Urakawa et al., 2019).

Hip fracture management is almost always operative. Symptomatic non-operative management (reduction of pain and anxiety) may only be considered for palliative patients too ill to undergo surgery, and with very limited remaining life expectancy (Whitehead et al., 2003). Generally, even for palliative treatment, surgery should be considered for pain relief and mobility, depending on individual patients' end-of-life needs (NICE, 2011).

Once a fracture is confirmed, delirium prevention is crucial for attaining best patient outcomes: Regional analgesia (fascia iliaca nerve block) for effective pain control, (Guay et al., 2018) minimal use of narcotics, timely surgical repair, and adequate nutrition are vital. Correctable comorbidities such as anaemia, blood sugar levels, cardiac or chest issues, coagulation, and electrolyte imbalances need to be identified and treated immediately to avoid delaying surgery. Surgery should take place within 24 to 48 hours of injury (Anthony et al., 2017). Delayed surgery has been shown to lead to increased complications such as delirium, hospital acquired infections, venous thromboembolism, and respiratory issues due to prolonged bed rest; thus, it also leads to prolonged hospital stay and increased mortality (Basu et al., 2016; Bhandari & Swiontkowski, 2017; Frenkel Rutenberg et al., 2018; NICE, 2011; Roberts et al., 2015).

The aim of surgical hip fracture repair is to enable full weight bearing immediately post operatively, allowing for early mobilisation. Early mobilisation is crucial to avoid complications related to prolonged bed rest, and to facilitate early hospital discharge. In-hospital rehabilitation should start on the first day after surgical fracture repair; mobilisation out of bed under the guidance of a physiotherapist should be offered at least once per day (NICE, 2011). For patients with dementia, several short sessions per day might be more beneficial than one long session (Uda et al., 2019).

2.1.4 Outcomes

Recovery from hip fracture is difficult (Tang et al., 2017). Between 40 and 60% of people never recuperate their pre-injury functional capacity which leads to a loss of independence; 10 -20% of people from industrialised countries have to permanently relocate to a care facility following hip fracture (Dyer et al., 2016). Thus, people often cannot recover to their previous health related quality of life (Peeters et al., 2016). Mortality after hip fracture is high. For the first 3 months post fracture, the risk for all-cause mortality is increased 5 to 8-fold. Risk remains elevated after this period, more so for men than women (Haentjens et al., 2010). Spanish hospital data on hip fracture patients showed a 2% increase in 12 months mortality from 1999 to 2015 (Guzon-Illescas et al., 2019). This could potentially be due to the fact that the average age of hip fracture patients was higher in 2015 than in 1999, which means that the former had a higher baseline mortality risk. The risk for sustaining a subsequent (hip) fracture is very high, especially during the first few months post hip fracture (Ryg et al., 2009). Harvey et al. (2018) conducted a large (n= 24,500) population based study in Sydney, Australia. They found that a second hip fracture was sustained by one in 11 older people.

2.1.5 Risk factors & prevention

Two of the most widely recognised reasons for older people sustaining low impact hip fractures are falls (Jarvinen et al., 2008) and osteoporosis (Kanis, 1994). Other factors include low muscle mass (sarcopenia), muscle weakness (dynapenia), and physical inactivity. Clinical factors such as impaired cognition, prescription drugs for chronic health conditions, substance and alcohol abuse, and impaired vision also play an important role; so do environmental hazards (e.g. thresholds, rugs) (Marks, 2010).
Many of these risk factors are inter-related, and many are modifiable to some degree.

2.1.5.1 Falls

Falls from ground level (standing, walking, getting up from a chair, slipping off a chair, falling out of bed, etc.) were recognised as the most common mechanisms of injury for sustaining a low impact hip fracture more than two decades ago (Hayes et al., 1996). Not

every fall results in a fracture; the outcome is largely dependent on direction, height, and force (Hwang et al., 2011). A postero-lateral or sideways fall on the greater trochanter poses the highest risk (Nankaku et al., 2005).

Additionally, bone health (structural integrity), soft tissue support (cushioning), and neuro-motor-control (reaction) contribute to the consequences of the fall (Montero-Odasso et al., 2022; Montero-Odasso et al., 2021).

Older people are at increased risk of falling (Voermans et al., 2007). This is due to intrinsic factors specific to an individual such as older age and being female; decreased balance, gait issues, vertigo/dizziness, and vision impairment; frailty and cognitive impairment; decreased strength in the lower body; cardiovascular diseases; medications; and mental health problems. Furthermore, obstacles in the home (rugs, steps, thresholds, etc.) and poor lighting pose major extrinsic risks (Ambrose et al., 2013).

As all risk factors for falling are also risk factors for sustaining a hip fracture, several of the above-mentioned factors will be discussed separately in the next sections.

2.1.5.2 Osteoporosis

Osteoporosis (Greek: osteo – bone; poro – porous, weak) is a metabolic bone disorder that can affect both genders, but due to hormonal changes during menopause occurrences are higher in women. It is characterised by a decrease of bone mineral density (BMD) and bone strength; bone production cannot keep up with bone resorption and the microarchitecture of bone tissue depreciates (Eastell et al., 2016). This leads to increased brittleness of the bone and hence increased risk of fracture (Akkawi & Zmerly, 2018).

Osteoporosis is diagnosed by measuring the BMD of hip and spine with dual-energy x-ray absorptiometry (DXA) which uses spectral imaging (Kanis, 2002).

T-scores are used to illustrate changes in BMD compared to the average adult peak bone mass. A T-score between 1.0 and 2.5 standard deviations below the peak bone mass indicates osteopenia (Greek: osteo – bone; penia – loss), demonstrating that bone has lost

some of its density. If a person's T-score is 2.5 standard deviations or more below this peak bone mass, they are considered osteoporotic (Reid & McClung, 2024). DXA scans have limitations as they are only providing information about BMD and leaving out other determinants crucial for overall bone strength (Eastell et al., 2016). Recent advances have deepened the understanding of bone strength, highlighting the impact of bone size and geometry, cellular microarchitecture, and cell turnover, as well as the structure of mineralised bone matrix (Williams et al., 2024).

Factors leading first to osteopenia and then to osteoporosis are: postmenopausal oestrogen deficiency in women, hormone imbalances, genetic predisposition, small body frame, sedentary lifestyle, smoking, alcohol consumption, vitamin D deficiency, insufficient calcium intake, eating disorders (food restrictions, too low or too high body weight), wrecking gastric surgeries (limited nutrient resorption), use of corticosteroid medications, health conditions affecting stomach, bowel or kidneys, and autoimmune diseases (Akkawi & Zmerly, 2018; Bogoch et al., 2012; Eastell et al., 2016).

Osteoporosis was established as the leading factor for sustaining a hip fracture over 20 years ago (Kanis, 1994). Over the decades, there was some controversy in the literature as to how strong this factor really is. Some research showed that only between 10% and 44% of fractures occur in people with osteoporosis (Jarvinen et al., 2015; Stone et al., 2003). Data from Denmark, where numbers declined in recent years, suggests that only less than 20% of the reduction in hip fracture incidences can be attributed to pharmacological treatment of osteoporosis (Abrahamsen et al., 2019). Evidence summarised by Ray Marks (2010) shows large overlap in BMD between hip fracture patients and matched controls. Many risk factors for hip fracture such as sidewise falling, low body mass, or compromised mobility remain the same irrespective of BMD (Wei et al., 2001).

A 2011 study found that osteoporosis does not increase the risk of falling or have a negative impact on balance (Smulders et al., 2011). However, awareness about the diagnosis 'osteoporosis' and its increased fracture risk has shown to increase fear of falling,

which in turn increases the risk of falling (Resnick et al., 2014). Whilst these are notable findings, there is continuing consensus for osteoporosis to be the main factor for low impact hip fractures in the current literature (e.g. Storm Ronnquist et al., 2022; McCloskey et al., 2024). A paper by Reid & McClung (2024) highlighted that 60% of Caucasian women over the age of 64 are osteopenic. Due to their greater number, more fractures occur in osteopenic women compared to osteoporotic women. The authors therefore suggest that this should be considered in risk assessment and pharmacological treatment indication should be reconsidered. These statements might help explain the findings by Jarvinen et al. and Stone at al. as described at the beginning on this paragraph.

2.1.5.3 Sarcopenia and dynapenia

The term sarcopenia (Greek: sarx – meat; penia – loss) was originally implemented to give a name to the visible, age related, decline of lean body mass (Rosenberg, 1989). Over the years, its definition became more and more complex. In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) proposed an operational definition of sarcopenia based on three criteria: 1. low muscle mass, 2. low muscle strength, and 3. low physical performance. Sarcopenia is present if criteria 1 plus either criteria 2 or 3 are detected (Cruz-Jentoft et al., 2010). Sarcopenia is a recognised risk factor for hip fracture in both genders. Sarcopenic people are likely to have less soft tissue cushioning and thus decreased capacity to absorb shock around the hip area (De Laet et al., 2005; Oliveira & Vaz, 2015). Decreased (voluntary) muscle strength, dynapenia (Greek: dyna – power; penia – loss), is also regarded a part of sarcopenia. It is associated with increased neuromuscular response time, which makes it more likely to lose balance, and less likely to be able to stop a resulting fall from happening (Sherrington & Henschke, 2013). In addition, the lack of compressing muscle force on the hip bones will have negative effects on bone strength longer term (Martelli et al., 2014).

Sarcopenia will be discussed in more detail in section 2.2.2.3.

2.1.5.4 Physical inactivity

Coupland et al. (1993) were able to demonstrate that physical inactivity is an independent risk factor for older people sustaining a hip fracture three decades ago. Supporting these findings, a 2020 systematic review and meta-analysis including 24 papers found high quality evidence for physical activity reducing fracture risk in people 60 years and older (Cunningham et al., 2020).

The consequences of physical inactivity are detrimental for the musculoskeletal system (Cavedon et al., 2020). Physical inactivity contributes to the development of osteoporosis, sarcopenia and dynapenia, whose problematic effects on falls and fractures haven been discussed above.

Beck Jepsen et al. (2022) found that no single functional measure can predict the risk of falling on their own; only for gait speed could they find moderate evidence, which suggests its use within a battery of tests.

2.1.5.5 Impaired cognition

Globally, around 47 million people suffer from dementia; it is anticipated that numbers will have risen to 131 million by 2050 (Alzheimer's Disease International, 2015). Ageing is a primary risk factor for dementia; most hip fracture patients are in their 80s (Arvanitakis et al., 2019; Australian Institute of Health and Welfare, 2018).

Persons suffering from dementia are three times more likely to sustain a hip fracture than those without a cognitive impairment (Friedman et al., 2010). This is mainly due to increased risk of falling (Wang et al., 2014) as a result of confusion, agitation, and side effects of pharmacological treatment of dementia (Friedman et al., 2010).

If not performed in an appropriate environment, dementia can also hinder effective rehabilitation and hence lead to poor post-operative outcomes, leaving patients at a high risk for sustaining further falls and fracture (Seitz et al., 2016; Seitz et al., 2014).

2.1.5.6 Medications, substance abuse, mental health conditions

Medications such as psychotropic and sedative drugs (prescribed for improving sleep, reducing anxiety, and treating depression), non-steroidal anti-inflammatories (for treating pain and inflammation), or cardiovascular drugs (for conditions of the heart, stroke and vascular diseases, high blood pressure, etc.) have been linked to increased risk of falling and fracture (Glab et al., 2014; Woolcott et al., 2009; van der Velde et al., 2023).

Older people suffering from mental health conditions and/or alcohol or substance dependency are between 1.5 and 4.5 times more likely to sustain a fall related injury (de Jong et al., 2013).

2.1.5.7 Environmental hazards and vision impairment

While environmental hazards are important risk factors to consider (Pighills et al., 2019; Powell-Cope et al., 2018), Norton et al. (1997) established that within their cohort of almost 1000 participants only 25% of potentially injurious falls could be attributed to environmental hazards. Impaired vision increases the risk of falling not only in relation to environmental hazards, but it also negatively impacts postural control and balance (Lord, 2006).

2.1.5.8 Prevention

Some risk factors for sustaining a hip fracture are modifiable to various degrees, others, such as age and gender, are not.

The most widely used tool for assessing hip fracture risk is the Fracture Risk Assessment Tool (FRAX®). FRAX is based on 12 variables (age, sex, weight, height, previous fracture, parent fractured hip, current smoking, glucocorticoids, rheumatoid arthritis, secondary osteoporosis, alcohol -three or more units/day, and femoral neck BMD) (The University of Sheffield, 2011). When excluding the BMD, the FRAX does not screen better than just considering risk based on age and previous fractures (Rubin et al., 2013; Sambrook et al., 2011). Variables such as physical activity, dynapenia and sarcopenia, previous falls, or types of previous fractures are not considered (Silverman & Calderon, 2010).
Modifiable factors need to be targeted.

a) Falls risk

Exercise programs, both group and home-based, that contain balance and strength components are effective in reducing falls (Gillespie et al., 2012). This also includes Tai Chi (Huang et al., 2017), and potentially Yoga (Nick et al., 2016; Smith et al., 2017).
Environmental modifications such as removal of rugs and thresholds, decluttering spaces, installing night lights, and possibly wearing hip protectors, are recommended (Pighills et al., 2019; Powell-Cope et al., 2018). A 2012 Cochrane systematic review found that home safety improvements carried out by an occupational therapist were effective in reducing

the risk of falling for people living in the community. They also found that cataract surgery can reduce falls in women, but only if the procedure is carried out early, on the first affected eye. Modifications of prescription drugs were found to reduce the risk of falling, whereas discontinuation of psychotropic drugs reduced the incidence of falls but not the risk of falling (Gillespie et al., 2012).

b) Muscle health

Physical activity and adequate nutrition to maintain/improve muscle strength and mass are vital to reduce injurious falls leading to hip fractures (Elhakeem et al., 2019; Fiatarone Singh, 2014). Strengthening exercises help improve and maintain neuromuscular response time and balance (Karlsson et al., 2008). Adequate muscle compression forces around the hip are important to maintain bone strength (Martelli et al., 2014). Resistance training can improve both muscle strength and size even in the oldest population (Grgic et al., 2020).

c) Bone health

Exercise (especially weight bearing) has shown to have a restoring effect on BMD in women post menopause, and thus decreases fracture risk (Howe et al., 2011). Muscle compression around the proximal femur and pelvis has revealed to improve bone strength in the area (Martelli et al., 2014). Life-style choices and modifications regarding nutrition (adequate calcium and vitamin D intake, limited intake of non-essential food items), consumption of stimulants (avoidance of alcohol, tobacco, non-prescription drugs), and physical activity also have powerful effects on bone health in terms of prevention as well as management. Certain medications such as hormone replacement therapy (increased bone turnover/anabolic agents) or bisphosphonates (reduction of bone resorption) can slow down osteoporosis to some extent. Anabolic agents appear to offer greater fracture protection and density gains, but effects are not long lasting; hence a combination therapy with intermittent drug holidays is required. The most effective duration for these three phases is not yet established. (van der Burgh et al., 2021; Reid & Billington, 2022). Bisphosphonates have been linked to atypical femur fractures as well as osteonecrosis of

the jaw; based on current literature, incidences are suggested to be very low, and benefits outweigh risks. More research is however needed to fully understand long-term effects of this medication (Lu et al., 2019). Population screening for osteoporosis has been suggested to have a significant impact on facture prevention (Merlijn et al., 2020); this might however not be a sufficient measure on its own, as it leaves out all other risk factors.

In summary, next to measures such as medication reviews and removal of environmental hazards, physical activity (including all types of exercise that comprise weight bearing, strength and balance training) effectively minimises falls risk and maximises bone and muscle health, and thus reduces the likelihood of fracture.

2.2 Frailty

2.2.1 Ageing versus frailty

> "Ageing may be inevitable, but the rate of ageing may not be so, if we recognise the cause of ageing." Rafi and Alavi, 2017

As outlined previously, hip fractures are sustained predominantly by people over the age of 65. Human life expectancy has increased steadily and immensely over the past 160 years, at a rate of almost three month per year (Oeppen & Vaupel, 2002). Nevertheless, every living organism is certain to age, as ageing is an inherent, progressive process that inevitably affects every organism (Vijg & Le Bourg, 2017).

Ageing has become a much-researched subject since the middle of the 20th century (Hayflick, 2007), but the biological processes and mechanisms of ageing are not yet fully understood. While many theories of ageing developed over the last century, there is no consistent definition for the term 'ageing' (Chmielewski, 2019; Cohen et al., 2020; Semba et al., 2010). In 1990, the Russian biologist and historian Zhores Medvedev reviewed more than 300 different theories of ageing. He concluded that it seemed unlike to ever find a single or main cause of ageing, because most theories do not contradict each other but run in parallel, looking at different aspects of senescence and longevity (Medvedev, 1990). Despite Medvedev's conclusion, many researchers have continued to search for a single theory of ageing, mostly by following one of two primary themes: a) ageing is a genetically programmed process, and b) ageing is caused by cellular and molecular damage that occurs either at random or is accumulated throughout life (Young & Maguire, 2019). There are ample arguments to support either view (Brooks-Wilson, 2013; Gladyshev, 2013; Hayflick, 2007; Kirkwood, 2005; Melzer et al., 2020; Sinclair & Oberdoerffer, 2009). Some inconsistencies also exist, due to inept separation of ageing (biological decline) and longevity (increase in lifespan), two distinct phenomena (McDonald & Ruhe, 2011). With better understanding about processes such as, for example, telomere shortening, the border between the genetic program theory and the wear and tear theory becomes more indistinct (Semba et al., 2010; Young & Maguire, 2019). Telomeres are DNA-proteins that

protect the genome, located on both ends of chromosomes (Shammas, 2011). Telomeres shorten with age as they shorten with each DNA replication. Once they reached a certain length, the cell will undergo apoptosis, which is the programmed process of cellular death. As much as telomere shortening is a genetically programmed process, it is also heavily influenced by lifestyle choices: smoking and obesity for example have been shown to increase the rate of telomere shortening (Young & Maguire, 2019). Based on these overlaps, ageing can be considered a complex process of progressive decline in multiple systems, influenced by several cellular, molecular, genetic, and environmental (nutrition, trauma, exposure) factors (Young & Maguire, 2019).

While there is debate about the mechanisms underlying the ageing process, there is relative agreement on the characteristics of aging: Ageing is characterised by reduced organ function, functional decline, decreased capability to counteract stress, inadequate homeostatic responses, and increased risk of disease (Cohen et al., 2020; Kuo et al., 2020).

Presentations, inceptions, and rates of ageing vary greatly; chronological age is thus not an adequate measure of aging (Vijg & Le Bourg, 2017). As mentioned before, it is important to recognise that ageing and longevity are not the same: ageing is biological, lifespan is chronological (McDonald & Ruhe, 2011). Whilst life expectancy at birth has risen and continues to rise steadily, about 3 years per generation (Zuo et al., 2018), healthspan has not increased by much; the average age of onset for most health problems attributed to ageing remained relatively stable (Crimmins, 2015). Therefore, living longer is mostly due to advances in medicine that prolong life whilst battling ageing related diseases. Delays in ageing and increased healthspan are still secondary (Passarino et al., 2016).

Longevity has been researched in conjunction with ageing and on its own since many decades. Professor Thomas Johnson from the University of Colorado was one of the pioneers in genetic research on longevity (Passarino et al., 2016). In his 1982 paper, he demonstrated that the heritability of lifespan in hermaphroditic nematode worms is between 20% and 50% (Johnson & Wood, 1982). Further research by Johnson and many

others clearly verified that genetic variations influence lifespan also in humans (Passarino et al., 2016). A lot more research is required to better understand how and, more over, which genes influence lifespan variability. At this point it is believed that the heritability of lifespan is about 25%; this is largely based on twin studies and on studies of first-degree relatives of the centenarians (Murabito et al., 2012). The larger part (75%) of lifespan-determining factors seems to be dependent on the environment and interactions between environmental factors and the genotype (Brooks-Wilson, 2013; Kirkwood, 2005).

Longevity and (delayed) ageing are not the same but the two phenomena are interconnected in ways that still need to be understood. Studies looking at centenarians have shown that most of them had been exceptionally healthy throughout their lives (Brooks-Wilson, 2013).

Ageing is a risk factor for many negative health outcomes, such as disease in general (Niccoli & Partridge, 2012), cancer (Leonardi et al., 2018; Smetana et al., 2016), osteoarthritis (Valdes & Stocks, 2017), and neurodegenerative disease (Hou et al., 2019), to name a few. Whilst chronological age is a reliable predictor of mortality on population level (Gompertz law), this is not true on individual level (Mitnitski et al., 2017). It would therefore be clinically useful to have a metric of biological aging. A task that will remain very challenging as long as the very roots of ageing are not fully understood (Ferrucci et al., 2020; Kuo et al., 2020). As outlined above, the course of ageing is very heterogeneous. Some individuals are ageing much more rapidly than the population average, while others are ageing a lot slower (Kuo et al., 2020; Mitnitski et al., 2017). An early approach for measuring biological ageing looked at biomarkers, traits in different physiological domains, to predict ageing and mortality more accurately than chronological age. In a recent paper analysing data from the Baltimore Longitudinal Study of Aging, Kou et al. demonstrated the non-linearity of ageing domains looking at changes throughout the lifespan in body composition, energy regulation, homeostatic mechanisms and neurodegeneration. They provided a current and comprehensive evaluation of phenotypic changes that occur throughout the lifespan. They also proposed the need for intensive

longitudinal research on people starting from middle age or younger. This is to enhance the understanding of ageing processes and to enable early identification of individuals at risk of progressive ageing. This would also provide normative data, essential for the assessment of the effectiveness of treatment approaches for ageing related diseases (Kuo et al., 2020).

A better understanding and clearer definitions of ageing phenotypes have been proposed as potentially clinically useful also by others, such as the Dutch professor Raoul Hennekam (2020) and the New Zealand researchers Alice Dawson and Elaine Dennison (2016). Hennekam's approach was very broad, but Dawson et al. focused on musculoskeletal aspects and their suggestions are in keeping with the ideas of Kuo et al. (2020): they aim for early identification of people at increased risk for certain musculoskeletal diseases such as osteoarthritis, osteoporosis and sarcopenia to enable early interventions.

Mitnitski et al. (2017) analysed the ability of ageing biomarkers (two approaches) and accumulated deficit indices (three approaches) to measure heterogeneity of biological ageing based on individual mortality. Their statistical analyses showed that ageing biomarkers available to them were significantly correlated to chronological age. This is not surprising, as in one of the two approaches chronological age itself was treated as a biomarker, which they concluded was less favourable: for biological age to have clinical value, the difference between it and chronological age is of interest to identify people with increased vulnerability to disease and decline. In this light, accumulations of deficits indices were more beneficial. Accumulations of deficits indices were originally designed to measure frailty.

Frailty is a syndrome resulting from accelerated aging (Hoogendijk et al., 2019). Historically referred to as 'failure to thrive in old age' (Brown et al., 1988), frailty has been discussed in the literature for several decades (Van Kan et al., 2008). Comprehensive concepts of frailty started to develop in the mid-1990s (Fried et al., 2001; Rockwood et al., 1994; Strawbridge et al., 1998). Rodriguez-Manas et al. (2013) attempted to find consensus for a generalised

operational definition of frailty. They found available evidence to be insufficient at that time.

While there is still no universally accepted definition for general frailty (Pilotto et al., 2020), there is broad agreement on the underlying processes: decreased reserve in multiple biological systems leads to increased vulnerability to internal and external stressors, and thus increased risk of negative health outcomes and disabilities (Clegg et al., 2013; Fried et al., 2001; Rockwood et al., 1994). While the biological processes of frailty overlap with the biological ageing processes, frailty takes a more rapid and detrimental course (Hoogendijk et al., 2019). In contrast to aging, frailty is believed to be in part reversible, and seems to undergo fluctuations (Kojima, 2019; Stolz et al., 2019). Frailty is not a compulsory aspect of aging, not every ageing person will become frail (Dent, Morley, et al., 2019).

2.2.2 Perspectives on frailty

For frailty to be a clinically useful concept, it must be differentiable from normal aging (Carson, 2018). While the above-mentioned underlying processes of frailty are generally accepted, clinical utilisation and research application are controversial. Multiple metrics for, definitions of, and approaches toward frailty have been suggested in the literature (Junius-Walker et al., 2018; Rockwood & Mitnitski, 2007). The two most prevalent concepts of frailty are each following a quite different approach, with one being defined as a clinical syndrome or phenotype (Frailty Phenotype) (Fried et al., 2001), and the other counting accumulative health deficits (Frailty Index) (Mitnitski et al., 2001; Rockwood et al., 1994; Rockwood et al., 2005). Even though they are often seen as alternatives, they should be looked at as complementary. Both concepts have been created for different purposes and should be used accordingly (Cesari et al., 2014).

Most of the other proposed frailty scores are built on phenotype or deficit accumulation; some of them will be discussed later in this chapter.

2.2.2.1 Physical frailty: the frailty phenotype

The physical characteristics of frailty form the frailty phenotype, as described by Linda Fried et al. in 2001, and validated in the Cardiovascular Health Study (Fried et al., 2001). The frailty phenotype presents as a possibly non-permanent, partly reversible syndrome, characterised by functional decline and weight loss. In this context, frailty is not equivalent to comorbidity or disability; but comorbidity is a determinant for frailty, and disability is a likely consequence of frailty. The frailty phenotype is assessed by looking at five criteria: weight loss (unintentional, self-reported), exhaustion (self-reported), physical activity status (self-reported), slow walk time (15 feet), and weak hand grip strength (kg). Three or more out of five criteria must be met to identify a person as frail; if one or two criteria are met, a person is considered pre-frail; and if no criteria are met, a person is considered not frail, but robust (Fried et al., 2001). The phenotype can be assessed without a full clinical evaluation, allowing it to be used by a health practitioner at first contact with a patient (Cesari et al., 2014).

In the same year as Rodriguez-Manas et al. (2013) were unable to present a consensus definition for general frailty, Morley et al. (2013) could agree on four consensus points around the physical aspects of frailty. They concluded that 1) physical frailty is a medical syndrome and should be recognised as such; 2) physical frailty might be preventable and reversible through measures such as exercise and nutrition; 3) simple screening tests for physical frailty are available and should be routinely used; and 4) all individuals aged 70 and older, as well as all individuals that report significant unintentional weigh loss should be screened for physical frailty.

Cesari et al. (2014) pointed out that the frailty phenotype may be most useful for screening relatively healthy older individuals, since the theory behind the frailty phenotype suggests that frailty causes disability, also in the absence of (pre-) disease. The phenotype could therefore act as an alert, detecting people at risk for disability and disease.
Op het Veld et al. (2015) made a similar remark. They found phenotypic frailty to be significantly associated with poor outcomes in terms of social, psychological, and physical

function. Based on these findings, they suggested that being physically frail could indicate deficits in other domains. The phenotype assessment could therefore be a pre-screening tool to assess risks that can be followed by more complex assessments.
In 2019, the International Conference on Frailty and Sarcopenia Research (ICFSR) published clinical practice guidelines for identification and management of physical frailty (Dent, Morley, et al., 2019). They used the GRADE approach (Guyatt et al., 2008) to form recommendations on screening, assessment, management, exercise, nutrition, pharmacology interventions and additional interventions. While the working group was confident in their recommendations, the certainty of the underlying evidence was predominantly low or very low. In terms of screening, they did not specifically recommend the use of the phenotype criteria, but the use of a validated tool appropriate for the given situation. Bieniek et al. (2016) evaluated the usefulness of the phenotype criteria in 500 geriatric inpatients. They concluded that, despite diagnostic limitations, the screening value was high; they promoted the routine inclusion of the phenotype criteria at the start of the Comprehensive Geriatric Assessment.

While the frailty phenotype is a widely used measure, there are some limitations. It contains measures that are not always routinely taken for every patient, such as hand grip strength. It also does not take psychosocial factors into consideration (Dent et al., 2016).

2.2.2.2 Accumulation of deficits: frailty indices

The second concept sees frailty as a nonspecific state, wherein individuals are at increased risk of disease and disability; this is based on the number of health deficits accumulated during the ageing process. An index is used to assess the degree of frailty: the number of deficits present in one person is matched to the deficits listed on the index; the total number is divided by the number of all deficits incorporated in the index. A frailty index does not allow for the distinction between frailty and disability (Cesari et al., 2014; Mitnitski et al., 2001; Rockwood et al., 1994; Rockwood & Mitnitski, 2007). Unlike the phenotype criteria, a frailty index can only be completed after a comprehensive clinical (geriatric) assessment has been done. It can however be completed without additional patient

assessments, as it can be based on routinely documented data (Cesari et al., 2014; Jones et al., 2005).

The original frailty index was introduced by a team of Canadian researchers (Mitnitski et al., 2001; Rockwood et al., 1994; Rockwood et al., 1996). It was validated with data from the Canadian Study of Health and Aging (Jones et al., 2005) and included 70 items. Due to its strong correlation with mortality risk, it was suggested to be a proxy measure of biological aging (Kulminski et al., 2007; Mitnitski et al., 2001). Later research showed that any index comprising of about 40 random relevant items generates meaningful information about risk of mortality and adverse health outcomes (Rockwood & Mitnitski, 2006, 2007). The frailty index ranges from 0 to 1. It increases with chronological age. The highest score measured throughout research and clinical applications was 0.70, demonstrating that there is no ceiling effect (Drubbel et al., 2014; Rockwood & Mitnitski, 2006). When someone's frailty index reaches 0.2, the individual is starting to approach frailty. The higher the index score, the more vulnerable a person is (Dent et al., 2014; Mitnitski et al., 2004).

An index allows to quantify frailty which can aid in monitoring vulnerability (Searle et al., 2008). A change of .03 in a person's frailty index can be considered clinically meaningful when testing an intervention (Theou et al., 2020).

A systematic approach for the creation of a frailty index was suggested in 2008, using data from the Yale Precipitating Events Project cohort study (Searle et al., 2008). With increased availability of electronic health data, frailty indices based on routinely collected data have become more interesting (Kim et al., 2018; Lo et al., 2020). A machine learning approach for predicting disability, fracture, emergency or urgent admissions to hospital, and mortality based on a 58-item index showed also showed promise (Tarekegn et al., 2020).

2.2.2.3 Frailty and sarcopenia

Sarcopenia is often discussed alongside physical frailty.

Human muscle mass continuously decreases with chronological aging (Doherty & McNally, 2003). The term sarcopenia was originally used to describe age related loss of muscle mass (sarco = flesh) (Evans, 1995). It could be demonstrated that decreased muscle mass was a

predictor for functional decline (Morley et al., 2001). It was later found that decreased muscle strength rather than size leads to functional decline. Findings from studies investigating the relationship between age related loss of muscle strength (maximal voluntary force) and muscle mass or size demonstrated only a weak correlation. Decline of strength as well as mass were thought to be related to degeneration of neuro-musculoskeletal pathways (Manini & Clark, 2012). The increased understanding of age related muscle changes and their clinical consequences subsequently led to broader operational definitions: sarcopenia is characterised by loss of muscle mass and strength (Studenski et al., 2014), as well as decline in physical performance (Bhasin et al., 2020; Chen et al., 2014; Cruz-Jentoft et al., 2010; Cruz-Jentoft et al., 2019; Dam et al., 2014; Fielding et al., 2011; Morley et al., 2011). As with ageing and frailty, no universally accepted consensus for definition and diagnostic criteria of sarcopenia could be reached to date.

Sarcopenia and physical frailty are both geriatric syndromes, and there is considerable overlap in some diagnostic criteria. The criteria suggested by the EWGSOP (Cruz-Jentoft et al., 2010; Cruz-Jentoft et al., 2019) - shrinking, weakness, slowness – are all part of the five criteria for Fried's physical frailty phenotype- shrinking, exhaustion, decreased physical activity, weakness, slowness (Fried et al., 2001).
Sarcopenia has been described as the physical manifestation of frailty, or even its precursor (Wilson et al., 2017). This was based on findings that showed slowness and weakness to be the most frequently positive phenotype criteria (Rothman et al., 2008), the ones older individuals are at highest risk to develop (Xue et al., 2008). This view was shared by others (Dawson-Hughes & Bischoff-Ferrari, 2016; Morley et al., 2014). In keeping, Mijnarends et al. (2015) found sarcopenia to be more likely in frail than in robust people. In contrast, Davies et al. (2018) found frailty and sarcopenia to correlate, but sarcopenia to be present in more robust than frail people. Reijnierse et al. (2016), Ibrahim et al. (2019), as well as Bernabeu-Wittel et al. (2019) found frailty to be significantly more prevalent than sarcopenia in their respective cohorts.

The clinical inconsequentiality of the question around the causal relationship between sarcopenia and frailty was highlighted together with the mention of the unlikeliness of an answer (Cesari et al., 2014). Both conditions are considered distinct yet interlinked, their pathophysiology incompletely understood (Davies et al., 2018).

2.2.3 Frailty: a global public health concern

Clegg et al. (2013) viewed frailty as 'the most problematic expression of population aging'.

2.2.3.1 Prevalence of frailty

The true global prevalence of frailty is hard to determine, due to heterogeneity in methodologies. Different frailty measures lead to very different results (Ntanasi et al., 2020). Several systematic reviews and meta-analyses have been conducted, including studies using countless different frailty measures.

A 2018 meta-analysis by O'Caoimh et al. (2018) found an overall frailty prevalence of 18%. This was based on 68 data sets, including 13,932 European individuals of various ages, health statuses, and functional independence levels. Subgroup analyses revealed vast differences in prevalence between geographic locations and settings: 75.6% prevalence amongst nursing home residents in Poland (aged 65 and older), and 2% prevalence amongst an Irish community dwelling cohort (aged 50 and older).

Another meta-analysis looked at differences in frailty and pre-frailty prevalence between upper middle-income countries and high-income countries. They found (pre-)frailty to be more prevalent in upper middle-income countries, which could have important implications for public health considerations (Siriwardhana et al., 2018).

Ofori-Asenso et al. (2019) undertook a meta-analysis and concluded that one in six community-dwelling older people may be frail. In keeping with Siriwardhana et al. (2018), they also found a lower prevalence with higher income.

A very recent attempt to measure the global prevalence of frailty via a meta-analysis of 240 studies form 62 countries also found data to be too heterogeneity for a meaningful

conclusion. When looking only at data derived from nationally representative data bases, they found physical frailty to be present in 7% of the assessed population, and frailty defined by an index in 24% (O'Caoimh et al., 2021).

A recent Australian cross-sectional study looked at frailty prevalence in people of both genders, aged ≥ 60 years old. Using the Fried phenotype criteria, they found 18.3% of women to be frail, 54.1% of women to be pre-frail, and 22.9% of women to be robust. For men, 13.1% were frail, 47.8% pre-frail and 27.3% robust (Tembo et al. 2020).

Another cross-sectional study based on the Fried criteria looked at community dwelling people aged ≥ 60 in Saudi Arabia. They did not distinguish between genders and found overall pre-frailty to be 47.3% and frailty to be 21.4% (Alqahtani et al., 2021).

A 2015 study by Kistler et al. (2015) found 51% of acute hip fracture patients to be frail. This was based on only 35 participants but is mentioned here due to its relevance for this thesis.

Despite heterogeneity between studies, considering the available data there can be no doubt about frailty being a massive global public health concern.

2.2.3.2 Negative health outcomes and health care expenditure

Frailty is highly prevalent in the ageing population and linked to many negative health outcomes.

Based on a meta-analysis of 31 studies, frailty in community dwelling older people increases the risk of hospitalisation, mortality, loss of independence in activities of daily living, physical decline, falls, and fractures (Vermeiren et al., 2016).

A meta-analysis from 2019 showed that amongst community dwelling older people, the presence of frailty predicts utilisation of emergency departments (Kojima, 2019).

A frailty index calculated for hip fracture patents on admission to acute hospital care was linked to 30-day mortality and increased length of acute hospitalisation for patients that scored 0.40 or above (Krishnan et al., 2014).

Another frailty index calculated on admission to an acute hospital was demonstrated to predict post-operative delirium, in-hospital falls, incidence of pressure ulcers, in-hospital mortality, increased length of stay, and change of discharge destination, if <0.40 (Hubbard et al., 2017).

A meta-analysis of 19 papers also found that the presence of frailty on admission increased the risk of prolonged hospitalisation, functional decline, and (in-hospital) mortality (Cunha et al., 2019).

Chao et al. found that in a cohort of persons diagnosed with type 2 diabetes, pre-frailty and frailty based on the FRAIL scale increased mortality risk and cardiovascular incidents, as well as the need for healthcare interventions (Chao et al., 2018).

Frailty is also considered a risk factor for incident dementia, (injurious) falls (Nowak & Hubbard, 2009), and long-term care (Clegg et al., 2013).

The above-mentioned studies are just a snapshot, outcomes of many more studies have highlighted the negative impact of frailty on health outcomes.

Implications of frailty are large, not just for individuals but also for the health care systems (Hoogendijk et al., 2019; Salinas-Rodriguez et al., 2019).

Almost all above-described risks associated with frailty are cost intensive, such as visits to the emergency department, hospitalisation, prolonged hospital stays, increased primary care consultations, and loss of independence/need of permanent care. Several recent studies have been evaluating frailty related health care expenditure, confirming the detrimental effect on hospital as well as primary care cost (Ensrud et al., 2018; Fuertes-Guiro & Viteri Velasco, 2020; Han et al., 2019; Kojima, 2019; Mondor et al., 2019; Wilkes et al., 2019). As with prevalence, the heterogeneity amongst studies makes them hard to compare, but their outcomes unmistakably confirm the profound impact of frailty on health care cost (Hoogendijk et al., 2019).

2.2.3.3 Risk factors and considerations for clinical practice

Since frailty seems to be a dynamic, preventable and possibly reversible process, and is linked to multiple negative health outcomes, clinical relevance is very high.

Determination of risk factors and effective prevention and management strategies is difficult, due to afore mentioned heterogeneities.

Espinoza and Fried (2007) suggested four possible risk factor categorise for physical frailty, based on the evidence available to them at that time: 1. Physiological factors (increased inflammation, compromised immunity, anaemia, changes in the endocrine system, low weight, obesity, and age); 2. comorbidities; 3. psychological and sociodemographic factors (depression, ethnicity, socioeconomic status, female); 4. disabilities affecting activities of daily living.
Several systematic reviews have since explored risk factors for frailty and came to a similar result. Risk appears to increase with advancing age; dementia, depression, comorbidities, obesity, poor nutrition, compromised ability to perform activates of daily living, being female, ethnic background, demographics, low education, low socioeconomic status, access to health care, and being unmarried, also increases the odds of developing frailty (Feng et al., 2017; He et al., 2019; Ntanasi et al., 2020).

Puts et al. (2017) looked at evidence in the literature for interventions that can reduce or prevent frailty in independently living older people. The limited available and diverse evidence did suggest that regular exercise, adequate nutrition, cognitive training, targeted management based on a comprehensive geriatric assessment, and impairment directed rehabilitation and prehabilitation were feasible options to manage frailty in general.
The ICFSR guidelines for prevention and management of physical frailty were previously mentioned in section 1.2.2.1 in terms of screening and assessment. The guidelines also included specific recommendations for management. In keeping with Puts et al. (2017), they highlighted the importance of a comprehensive geriatric assessment as the base of a comprehensive management program. Geriatric involvement was deemed vital. Pre-frail and frail people should receive a guided multi-component physical activity program that includes as resistance training component, and nutrition intake to be optimised and monitored (Dent, Morley, et al., 2019).

However, overall evidence for best practice management is deficient, on both patient and system level. Further research is required to determine, efficacy, feasibility and cost effectiveness of frailty interventions (Dent, Martin, et al., 2019).

2.2.4 Frailty measures

The frailty phenotype and frailty indices have already been discussed earlier in this chapter. Additional relevant commonly used frailty measures are outlined below.

2.2.4.1 The FRAIL questionnaire

FRAIL has been developed by the International Association of Nutrition and Aging. Their aim was to provide a tool that is simple enough to use in any clinical setting and that can even be completed by a relative or friend, or by oneself. It consists of five components: fatigue (how much time a person felt tired for over the past 4 weeks), resistance (independently walking up 10 steps), ambulation (independently walking several 100 yards), illnesses (five or more out of 11), loss of weight in the past year (>5%). An older person is considered frail when three or more out of five criteria are present, pre-frail when of one or two criteria are present, and robust with no criteria present (Morley et al., 2012).

FRAIL has been validated for the use in longitudinal studies of older women (Gardiner et al., 2015; Susanto et al., 2018). It was deemed cost – and time effective for screening frailty in older people (Aprahamian et al., 2017) and has been considered useful as a first screening step within a multi-step care approach (Woo et al., 2015). FRAIL was also found useful for predicting mortality (Woo et al., 2012), short term outcomes after hip fracture (Gleason et al., 2017), and long-term outcomes in patients with acute coronary syndrome (Rodriguez-Queralto et al., 2020).

2.2.4.2 The clinical frailty scale

The clinical frailty scale (CFS) is a measure based on clinical judgement. It was originally proposed as a seven-point scale in 2005 (Rockwood et al., 2005). It was revised to a nine-point scale in 2007 by the same researchers, followed by further revisions in 2020 (Rockwood & Theou, 2020). The scale is used to summarise information on the level of

fitness and frailty gained through clinical interactions with a patient. It consists of a description as well as illustration of each of the nine levels of frailty. The scale ranges from one (very fit) to nine (terminally ill). The nine-point scale has been widely used in clinical settings as well as epidemiological research (Church et al., 2020). It predicted adverse outcomes in hospitalised older people (Basic & Shanley, 2015; Wallis et al., 2015), short term mortality in older patients in the emergency department (Pulok et al., 2020), functional decline and mortality for patients in a general medical ward (Gregorevic et al., 2016), institutionalisation and mortality for patients in a critical care unit (Papageorgiou et al., 2020), length of stay for patients in an acute medical unit (Juma et al., 2016), and unplanned hospitalisation and death for community dwelling patients with cirrhosis (Tandon et al., 2016). The consistent association of the CFS with health outcomes demonstrates its value for the use in clinical management of older individuals (Church et al., 2020). The interrater agreement when completing the score was also established as being high (Young & Smithard, 2020).

2.2.4.3 The Groningen frailty indicator

The Groningen frailty indicator (GFI) is a self-reported screening instrument developed in the Netherlands in 2001 (Steverink et al., 2001). It comprises of 15 items covering four domains: physical (nine questions), cognitive (one question), social (three questions), and psychological (two questions). Scores range from zero (unrestricted activities) to 15 (completely disabled). Frailty is considered present with a sore of four and above. Feasibility, reliability, and construct validity of the GFI for both institutionalised and community dwelling older people were established (Peters et al., 2015; Peters et al., 2012). The GFI was also deemed appropriate for discrimination between frail and non-frail patients undergoing hip or knee arthroplasty (Meessen et al., 2018), and has demonstrated to predict post-operative complications and discharge to a nursing home after vascular surgery (Visser et al., 2019).

Whilst the Groningen frailly indicator was mostly used and evaluated in the Netherlands (Dent et al., 2016), an Arabic (Khamis et al., 2019) and a Chinese version (Tian et al., 2020) have recently been validated.

2.2.4.4 The Tilburg frailty indicator

The Tilburg Frailty Indicator (TFI) is another self-reported score developed in the Netherlands (Gobbens et al., 2012b; Gobbens et al., 2010). The authors reasoned that a frailty score must be multi-dimensional and should include physical and psychosocial functioning and should not include disabilities. As they did not find that any of the existing scores met these criteria, they created the two-part TFI. Part A consists of 10 questions about presumed life course determinants for frailty; the questions cover demographics, life events, and general wellbeing. Part B consists of 15 questions across three domains: physical, psychological, and social. Frailty is present with a score ≥5. The authors were able to show that the TFI is a valid tool to predict mortality, disability and negative health outcomes, and an indicator for six domains of health care utilisation and quality of life (Gobbens et al., 2020; Gobbens & van Assen, 2014; Gobbens et al., 2012a; Gobbens et al., 2014; Gobbens & Andreasen, 2020; Gobbens et al., 2021). Most of the research around the TFI has been done by its creators. In addition, X. Zhang et al. (2020) could demonstrate reliability and validity of the TFI across five European countries (Croatia, Greece, Spain, the Netherlands, and the UK), and Hayajneh (2019) found the TFI to be a valid and reliable measure for frailty in Jordanian older people. The score does not appear to have been widely adopted.

2.2.4.5 The Edmonton frail scale

The Edmonton frail scale (EFS) has been created to measure frailty in the acute hospital setting. It has been validated and its reliability has been demonstrated (Rolfson et al., 2000; Rolfson et al., 2006). The score consists of nine domains, totalling to 17 points: Cognition, general health, functional independence, social support, medication use, nutrition, mood, continence, and functional performance. A score of 0 to 5 is considered as not frail, 6 to 7 is classified as apparently vulnerable, 8 to 9 as mildly frail, 10 to 11 as moderately frail, 12

to 17 as severely frail (Rolfson et al., 2006). A reported Edmonton frail scale (REFS) was proposed and validated in 2006. The REFS consists of the same nine domains as the EFS but has a total of 18 possible points. The REFS was developed to account for the inability of many older inpatients to perform the timed up and go test, the test used to measure functional performance in the EFS. Instead, performance is self-reported by answering three questions about their functional abilities two weeks ago. (Hilmer et al., 2009)
The EFS and the REFS have been demonstrated to predict negative health outcomes, post-operative complications and morbidity, length of hospital stay, and mortality (Amabili et al., 2019; He et al., 2020; Nguyen et al., 2019; Roopsawang et al., 2020; Rose et al., 2014); the EFS also predicts unplanned medical follow up after elective outpatient surgery (Bautista et al., 2021).

2.2.4.6 Hand grip strength

> "The human hand is so beautifully formed, it has so fine a sensibility, that sensibility governs its motions so correctly, every effort of the will is answered so instantly, as if the hand itself were the seat of that will; its actions are so powerful, so free, and yet so delicate, as if it possessed a quality of instinct in itself, that there is no thought of its complexity as an instrument, or of the relations which make it subservient to the mind." Sir Charles Bell (1833): The hand; its mechanism and vital endowments, as evincing design, p. 13.

Hand grip strength (HGS) is a measure of the maximum force generated by hand and forearm muscles, also known as power grip. Power grip is one of seven biomechanical manoeuvres of the hand. It is produced by flexion of all five fingers and the palm of the hand, with the wrist being stabilised in some degree of extension. Power grip generates a low precision, generalised, high force movement (Clarkson, 2008; Duncan et al., 2013; Platzer, 2009). Decreased HGS has been demonstrated to be associated with negative health outcomes such as chronic disease, multi-morbidity, disability, fracture, postoperative complications, cognitive impairment, and mortality. It was also linked to poor nutrition, poor physical performance, decreased mobility, prolonged hospital stays, and change in residential status (Bohannon, 2008; Buckner et al., 2019; Cheung, Nguyen, et al., 2012; Cheung, Tan, et al., 2012; Di Monaco et al., 2015; Keevil et al., 2013; Lloyd et al., 2009;

Norman et al., 2011; Rijk et al., 2016; Roberts et al., 2012). Decreased HGS has also been suggested to be a sole marker of frailty (Syddall et al., 2003), but might be more sensitive in conjunction with gait speed (Lee et al., 2017). Furthermore, HGS is part of the test battery for the frailty phenotype, and part of the test battery for sarcopenia, as described previously in this chapter. It is important to note that HGS is gender specific and must be analysed based on gender specific stratified values.

HGS is often describes as a 'simple' measure. This would make the action of power grip a 'simple' task. Looking at it in more detail, the performance of power grip appears to be far from 'simple'. To perform any goal directed task, motor neurons need to be recruited by the central nervous system (CNS), and different muscle groups need to work together in a coordinated manner, and even fibres within a muscle need to collaborate (Ambike et al., 2014; Carson, 2018; Schieber & Santello, 2004).

A large variety of instruments is available and applied for measuring HGS. The two main types of instruments are hydraulic dynamometers and pneumatic vigorimeters.
One of the most common instruments used for measuring HGS is the sealed hydraulic Jamar hand grip dynamometer (Lupton-Smith et al., 2022), manufactured in the USA by Lafayette. It displays isometric strength from 0 to 90 kilograms. Its inter- and intra-rater reliability, as well as test-retest reliability is well established. It has an adjustable handle that can be placed in five different grip positions (3.5cm to 8.5cm); it weighs 1500 grams (Lafayette, 2020; Roberts et al., 2011; Sousa-Santos & Amaral, 2017). Most available normative reference data for HGS is measured with a Jamar hydraulic hand dynamometer and reported in kilograms (Wang et al., 2018). Several standardised approaches for measuring HGS with the Jamar hydraulic hand dynamometer have been suggested. In 1996, the American Society of Hand Therapists (ASHT) recommended the use of a calibrated Jamar hydraulic hand dynamometer as the gold standard for measuring HGS (Firrell & Crain, 1996). They advise that the handle setting should not be adjusted but kept permanently in the second position. In contrast, the protocol by Roberts et al. (2011), commonly referred to as the Southampton protocol (Schaap et al., 2016), suggest

adjusting the handle position according to hand size. In terms of body position, both protocols ask for subjects to be seated. The ASHT protocol gives very specific instructions about arm positions; Roberts et al. are proposing to simply rest the forearms on the arms of the chair. Researchers from Royal Melbourne Institute of Technology University (Firrell &

Figure 3: HGS measured with a sealed Jamar hydraulic dynamometer (Artist: Sasha Simpson)

Crain, 1996; Mehmet et al., 2020) conducted a scoping review to analyse the different protocols for HGS measurements in the older and, finding not much consensus, proposed their own recommendations, which are a somewhat simplified version of the Southampton protocol. With its 1.5 kilograms, a Jamar hydraulic hand dynamometer is quite heavy, and the accuracy of results depends on the measurement being taken in an appropriate position. This can be difficult to achieve in acute and/or geriatric clinical settings. That has prompted some research into the Martin vigorimeter which is arguably easier to handle; it

has been demonstrated to produce comparable results to the Jamar hydraulic hand dynamometer in terms of reliability and has been suggested to be more practical in acute and/or geriatric settings. The part of the device that needs to be compressed is lightweight and small, and the response is claimed to be less position dependant. It does however measure compression forces in kilo Pascal which makes it difficult to relate to most available normative HGS data and clinical cut-off points (Neumann et al., 2017; Sipers et al., 2016).

An explanation for the relationship between HGS, the before mentioned health and fitness outcomes, and frailty, is not immediately obvious. HGS must be more than just an indicator of general weakness, especially as it is unclear if HGS represents overall muscle strength (Wind et al., 2010; Woo et al., 2015). If HGS is considered to depend on more than just muscle fitness, its relationship to frailty can be looked at from a different angle. Age and health related changes in HGS do not appear to be dependent on changes in mass or fibre quality of the relevant muscles (Carson, 2018). HGS can increase through exercise before the occurrence of muscle hypertrophy; in fact, HGS has shown to increase by purely training the contralateral side – even of an immobilised limb (Boyes et al., 2017; Farthing et al., 2011; Speed & Campbell, 2012). Similarly, increase of muscle mass through food supplementation or hormone replacement therapy did not appear to have any significant effect on HGS (Srinivas-Shankar et al., 2010). Musculoskeletal factors lay an important role for HGS in healthy and younger individuals. Variations of HGS in later life or related to compromised health seem to have a strong neurological component (Carson, 2018).

As stated above, hand grip is not a simple task. The hand has evolved together with all systems required for task orientated fine and gross motor skills (Santello et al., 2013). The hand consists of 19 bones, 17 joints, and 19 (intrinsic) muscles; hand and finger movements are aided by an additional 20 tendons of five extrinsic muscles of the forearm (Carson, 2018; Platzer, 2009). This gives the hand many possible degrees of freedom to move, which creates many redundancies and consequently requires extreme control when performing a targeted movement. Control is not just required for hand and forearm muscles but also muscles involved in posture control. The CNS cannot achieve this level of

control by targeting each involved muscle individually. Coordinated movements are created by controlling muscle synergies: a group of muscles is recruited in a synchronised manner with the aim of performing a specific movement or task. The CNS controls the synergies rather than individual muscles, and the level of this neuro-muscular control determines the quality of a specific task or movement (Carson, 2018; Santello et al., 2013). The performance of power grip is a composite synchronized action that is facilitated by complex activities across brain networks. Variations in HGS might be indicators of changes in neurological function and brain health (Carson, 2018).
In summary, variations in HGS seem to be less dependent on changes in muscle morphology but appear to be more related to the ability of the CNS to control and coordinate neuro-muscular synergies. Frailty is a complex multidimensional syndrome with decreased physiological and cognitive reserves, hence considering the arguments above, the association between HGS and frailty becomes a new meaning.

2.3 Summary – Frailty and hip fractures are major, often life changing events for older people globally. Many risk factors for sustaining a hip fracture are interrelated; many risk factors are also attributes of being frail. It therefore seems important to explore practical clinical implications of frailty in the event of a hip fracture. HGS appears to be a simple and reliable measure that is strongly linked to sarcopenia and potentially frailty. It is deemed a feasible measure to be used on ana acute hospital ward. The self-reported EFS is considered an appropriate tool to capture more individual aspects of frailty and was shown to be useful in patients with hip fractures. The two measures individually, combined, and compared are anticipated to increase knowledge and understanding about frailty in hip fracture patients and resulting personal and clinical consequences.

This thesis will investigate if most hip fracture patients are indeed frail; implications of frailty regarding recovery and change of life circumstances; and the clinical utility of this new information.

3 THE ASSOCIATION BETWEEN DECREASED HAND GRIP STRENGTH AND HIP FRACTURE IN OLDER PEOPLE: A SYSTEMATIC REVIEW

The content of this chapter has been published as:
Denk, K., Lennon, S., Gordon, S., & Jaarsma, R. L. (2018). The association between decreased hand grip strength and hip fracture in older people: A systematic review. *Exp Gerontol, 111*, 1-9. doi:10.1016/j.exger.2018.06.022

This review was registered with PROSPERO (The University of York, 2013) prior to conducting. Registration number: CRD42014010080.

Reporting was based on the process proposed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009; Moher et al., 2009; Page, McKenzie, et al., 2021; Page, Moher, et al., 2021).

3.1 Rational and objective

As outlined and discussed in chapter 2hip fractures as well as frailty are major global public health concerns related to population ageing. Frailty might be the overarching risk factor for hip fractures. Variations in HGS are suggested to strongly relate to frailty.
As stated in the summary chapter 2.3, it needs to be investigated if hip fracture patients are indeed mostly frail. As a first step, the strength of evidence underlying the association between hip fracture incidences and HGS (pre-injury or at acute presentation) was assessed based on existing published literature.

3.2 Methods

3.2.1 Eligibility criteria

For a study to be included in this review, it had to involve adults 50 years of age or older; HGS measures of participants had to be taken at least once during the course of the study; and hip fractures had to be a main outcome. Systematic reviews, randomised trials, and observational studies (cohort, longitudinal, cross sectional, case control) were included.

Studies written in a language other than English were excluded. Studies including patients under the age of 50, studies investigating recovery from hip fractures (as compared to acute and subacute periods), and studies looking at pathological fractures were also excluded. Case studies, expert opinions, letters to the editor, grey literature (including unpublished data, abstracts, theses, conference proceedings, book chapters, and research reports) were not included.

3.2.2 Information sources and search strategy

Information was derived from Ovid MEDLINE(R), PubMed, Embase, CINAHL, Scopus, and Cochrane Library (both controlled trials and reviews) via systematic online database searches. Searches were conducted for studies published from each database's earliest inception data to January 2018, when the final searches were run (20th of January 2018).

Search terms were first created for Ovid MEDLINE(R). Medical Subject Headings (MeSH terms), explode functions (brackets to break a string into an array), keyword searching, truncations (to retrieve all alternative terms), adjacency (to narrow search) and Boolean operators (connectors AND/OR) were used. Two search batteries were created (one for HGS and one for hip fracture) and combined. The search strategy used for Ovid MEDLINE(R) is presented in table 1 below.

Table 1: Search Strategy for Ovid MEDLINE(R)	
	Hand Strength/
2	"grip strength".mp.
3	(hand* adj3 (strength* or grip* or grasp*)).mp.
4	Muscle Strength Dynamometer/ or dynamom*.mp
5	1 or 2 or 3 or 4
6	hip fractures/ or femoral neck fractures/ or proximal femur fracture
7	Femoral Fractures/ and (Femur Head/ or Femur Neck/)
8	(("femoral neck" or "femoral head" or "femur neck" or "femur head" or trochant* or intertrochant* or "inter-trochant*" or subtrochant* or "sub-trochant*" or intratrochant* or "intra-trochant*" or peritrochant* or "peri-trochant*") and fracture*).mp.
9	6 or 7 or 8
10	5 and 9

As a second step, the search strategy was amended for each data base to satisfy their specific search requirements. As a third step, after retrieving and selecting all relevant

studies from the database searches, we performed a 'snowball' search of the reference lists of included studies for further relevant papers, and used Google Scholar to screen studies that were citing them.

3.2.3 Selection process, data collection process, and data items

Relevant studies were selected by two reviewers (KD and RJ) independently through a multi-step process. References returned through searches of all databases were pooled together, and duplicates were removed. Title screens were performed first, followed by abstract screens and full text reviews, continuously narrowing down the results and finally confirming eligibility. Where the two reviewers could not agree upon including or excluding a particular study, a third reviewer (SL) was consulted. One reviewer (KD) screened the reference lists of all included studies to search for potential additional relevant studies, as well as papers citing eligible studies. In doubt, a second reviewer was consulted (RJ or SL).

Relevant data was extracted by two reviewers (KD and SL) independently into a spreadsheet. It was then discussed and combined. Data items extracted from each study were: study design; main objective of study; characteristics of study population; interventions, indicators, scales, measures, outcomes; primary/relevant findings; reported statistics.

3.2.4 Study critical appraisals and grading of overall evidence

All included studies were assessed for methodological quality using the Joanna Briggs Institute (JBI) Critical Appraisal Checklists (Joanna Briggs Institute, 2016) by two reviewers (KD and SL) independently. Where no agreement could be reached, a third reviewer (RJ) was consulted. The JBI checklists are based on an extensive body health care research (Pearson et al., 2007) and were chosen also because they have appraisal checklists tailored to 13 different study designs, omitting the need to use different styles of checklists.

The available evidence was graded based on criteria first suggested by Lievense et al. (2002), and later used by Brennan et al. (2011) and others. The score grades strength of

overall evidence into five levels: strong, moderate, limited, confliction, none. A detailed description of the criteria is presented in table 2 below.

Table 2: Grading the evidence (Brennan et al. 2011 and Lievense et al. 2002)

Level of evidence	Criteria
Strong evidence	Generally consistent findings in: • multiple high-quality cohort studies
Moderate evidence	Generally consistent findings in: • one high-quality cohort study and two or more high quality case–control studies • three or more high-quality case–control studies
Limited evidence	Generally consistent findings in: • a single cohort study • one or two case–control studies • multiple cross-sectional studies
Conflicting evidence	<75% of studies reported consistent findings
No evidence	No studies could be found

3.2.5 Reporting of characteristics and relevant findings of individual studies

Study design, patient characterises, and reported HGS measures were added to a table. For comparability, HGS measures were converted into Kilograms (kg) when presented in Newton. HGS presented in Kilopascal (kPa) was not convertible, as it can only be translated to kg force per square meter.

3.3 Results

3.3.1 Study selection

The total number of returns from the searches in all included data bases was 526 studies. Two additional studies were identified through screening of reference lists; no more studies were found via citations checks of included studies. Duplicates were removed in Endnote X8, leaving 271 studies for title and abstract screening. Full-text reviews were undertaken for 76 studies; 10 studies were finally included in this review (see figure 4). One hundred and ninety-two studies identified through the data base searches proved ineligible based on title and abstract screening, a further 65 were discarded through full-text reviews. The most frequently occurring factors for eliminating studies were: participants younger than 50 years old; HGS was assessed in relation to minimal trauma fractures of all sites combined (vertebra, wrist, hip etc.); the association between HGS and outcomes post hip fracture were assessed; HGS was correlated with BMD and other outcomes like falls. Only one study was excluded due to being written in a language other than English. One study was excluded as reported outcomes in text and tables did not match; we tried to contact authors for clarification without success.

3.3.2 Study characteristics and participants

Studies included in this review were published between 1992 and 2014. Six case-control (Bean et al., 1995; Coupland et al., 1993; Elliot et al., 1992; Lan et al., 2010; Lau et al., 1993; Meyer et al., 1995) and four cohort studies (Cawthon et al., 2008; Karkkainen et al., 2008; Kauppi et al., 2014; Robbins et al., 2005) met the eligibility criteria. Refer to table 3 for a summary of the included studies.

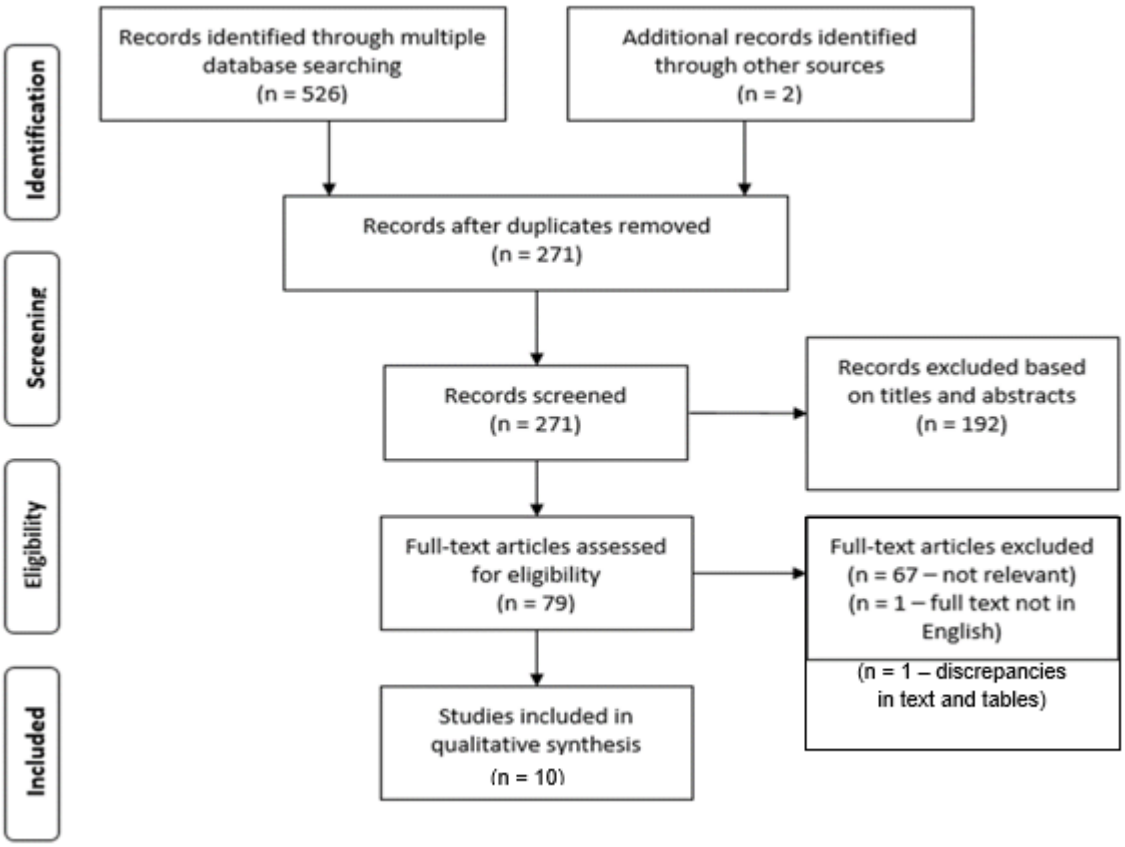

Figure 4: Search flow diagram

With an average of 4682 participants, the four included cohort studies had very large sample sizes; hip fracture incidences were however very low in these studies: 2.25% on average, ranging from .3% (Karkkainen et al., 2008) to 3.8% (Robbins et al., 2005). In contrast, the six case control studies had much smaller populations, 414 on average; but they had much higher hip fracture incidence, a minimum of 30%.

The authors of all studies included in this review aimed either to evaluate the relationship between hip fracture and selected relevant variables, or to establish key risk factors for sustaining a hip fracture. Across the included studies, 74 different variables were tested for associations with hip fractures. Although the relationship between HGS and hip fracture incidences/risk was investigated in all included studies, it was never the primary objective.

In nine out of the included studies, participants were aged 70 years or older. In one study the mean age was reported as 59 years (Karkkainen et al., 2008), and another included participants 50 years or older (Coupland et al., 1993).

Cawthon et al. (2008) exclusively investigated a male population. Bean et al. (1995), Karkkainen et al. (2008), and Robbins et al. (2005) included only female participants. All other included studies included participants of both genders. Meyer et al. (1995) did not discriminate between genders, but in all remaining studies, the number of females was a lot higher than males, which is in keeping with the global demography of hip fractures (Dhanwal et al., 2011).

Cognitive impairments or the inability to provide informed consent were exclusion criteria in six studies (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Elliot et al., 1992; Meyer et al., 1995; Robbins et al., 2005). In the remaining studies, the cognitive status of participants was not discussed.

Five of the six case control studies matched participants according to age and gender, while Lau et al. (1993) used random samples. Samples were obtained from co-existing epidemiological studies, or the community.

Table 3: Summary of included studies

Author / year / location	Study design/ numbers	Mean age in years (SD)	Gender Female %	Relevant results – HGS	HGS values in kg	Normative HGS values*
Bean et al. 1995 UK	**Case control** Age matched +/- 3 years, 1:1 Total: n=100 Cases: n=50 Controls: n=50	Cases 79.5 (8.4) Controls 79.6 (7.7)	100	**T-test:** **HGS** weaker in cases p<.001 **Stepwise multiple regression:** Multiple R=.59 R^2=.35 p<.0001	Females with # =11.63 (mean) Females without # =18.63 (mean)	Females: 19.1 (80)
Cawthon et al., 2008 USA	**Retrospective cohort** Total: n=5902 Hip fractures: n=77 Mean follow-up: 5.3 years	≥65 (71.9 to 77.2)	0	**Cox regression:** **HR (95% CI) of hip fracture (multiple adjusted):** worst quartile: HR 1.63(.65- 4.14) unable: HR 4.50 (1.32-15.35) p for trend=.184	Worst quartile: Males <36	Males: 39.1 (70)
Coupland et al. 1993 UK	**Case control** Age and sex matched, 1:2 Total: n=579 Cases: n=197 Controls: n=382	>50 (65% >75)	85.3	**Multiple regression:** **OR (95% CI) of hip fracture (multiple adjusted):** worst tertile: OR male: 49.5(1.5-1618) p for trend <.0001 OR female: 5.3(2.4-11.7) p for trend <.0001	Worst tertile: Males <28.0 Females <14.3	Males: 35.6 (75) Females: 21.4 (75)
Elliot et al. 1992 NZ	**Case control** Age and sex matched, 1:2 Total: n=108 Cases: n=36 Controls: n=72	Cases 79.1(1.0) Controls 78.4(0.7)	78	**T-test:** **HGS** weaker in cases p<.001 **Logistic regression:** p=0.003 (coefficient=.14)	Females and males combined with # =11.4 (mean) Females and males combined without # =19.2 (mean)	Males: 32.2 (80) Females: 19.1 (80)
Karkkainen et al. 2008 FI	**Retrospective cohort** Total: n=2928 Hip fractures: n=8 Mean follow-up: 8.3 years	59.1(2.9)	100	**Cox regression:** **HR (95% CI) of hip fracture (multiple adjusted):** HR: 1.046 (1.005-1.088); p for trend=.026	No values available	
Kauppi et al. 2014 FI	**Retrospective cohort** Total: n=2300; hip Fractures: n=96 Mean follow-up: 9.8 years	Cases 74.29(7.92) Controls 66.08(8.11)	58.87	**T-test:** **HGS** weaker in cases p<.0001 **HR (95% CI) of hip fracture (multiple adjusted):** HR .64 (.44-.93)p for trend=not provided	Females and males combined with # =25.0 (mean) Females and males combined without # =32.4 (mean)	Males: 35.6 (75) Females: 21.4 (75)
Lan et al. 2010	**Case control**	80.1(7.9)	Cases: 71.5 Controls: 69.4	**Logistic regression:** **OR (95% CI) of hip fracture (adjusted):**	Worst tertile: Males	Males: 32.2 (80)

TW	Age and sex matched 1:1 or 1:2 Total: n=725 Cases: n=228 Controls: n=497			best tertile: OR males **(group adjusted):** .10(0.03-0.35) p for trend<.001 OR females **(multiple adjusted):** .29(0.10-0.55) p for trend<.001 worst tertile: OR males: 1.00, referent OR females: 1.00, referent	≤15 Females ≤15	Females: 19.1 (80)
Lau et al. **1993** **HK**	**Case control** No matching Total: n=480 Cases: n=163 Controls: n=317	Cases males 76(8) Controls males 74(6) Cases females 79(8) Controls females 76(9)	80.4	**T-test:** **HGS** weaker in cases p<.01 **Multiple regression:** **RR (95% CI) of hip fracture (age adjusted):** worst quartile: RR male: 4.9(1.3-17.6) P for trend <.01 RR female: 2.0(1.1-3.9) P for trend<.01	Males with # =14.1 (mean) Males without # =23.0 (mean) Females with # =7.8 (mean) Females without # =10.8 (mean)	Males: 35.6 (75) Females: 19.1 (80)
Meyer et al. **1995** **NO**	**Case control** Age matched +/- 4 years Total: n=492 Cases: n=246 Controls: n=246	Cases males 74(0) Controls males 74(9) Cases females 79(9) Controls females 79(8)	Not specified	**Logistic regression:** **OR (95% CI) of hip fracture (multiple adjusted):** worst quartile: OR: 3.27(1.54-6.97) p for trend=.0005	Worst quartile: Males ≤26.5 Females ≤14.0	Males: 3 5.6 (75) Females: 19.1 (80)
Robbins et al. **2005** **FR**	**Retrospective cohort** Total: n=7598 Hip fractures: n=293 >3-yaers follow-up	Cases 82.4(4.5) Rest of cohort 80.4(3.7)	100	**T-test:** **HGS weaker in cases p<0.001** **Cox regression:** **HR (95% CI) of hip fracture (age adjusted):** right: HR: .82(.73-0.93); p=.001 left: HR: .77(.68-.87); p<.001	**Values in kPa** Females with # =49 (mean) Females without # =53 (mean)	No reference values

HGS, handgrip strength; HR, hazard ratio; OR, odds ratio; RR, relative risk; #, fracture.
*HGS in kg, normative data for age and gender based on Dodds et al. (2014)

3.3.3 Critical appraisal and assessment of overall strength of evidence

Quality of evidence was assessed by two reviewers (KD and SL) independently, 95% agreement was reached initially; discussion between the two reviews resulted in full agreement. Overall scores following the JBI criteria can be viewed in table 4 below, with shortcomings also being outlined.

While one study score below 50% (Lau et al., 1993), six of the 10 included studies scored 100% (Cawthon et al., 2008; Coupland et al., 1993; Karkkainen et al., 2008; Kauppi et al., 2014; Lan et al., 2010; Meyer et al., 1995), with the other four scoring somewhere in between. Studies lost points due to poor reporting, lack of follow up time, failure to address confounding factors, and poorly described methodology of HGS measures.

Table 4: Critical appraisal and quality rating

Author (year)	Score	Factor(s) that reduced quality
Bean et al. (1995)	77.7%	Confounding factors not addressed
Cawthon et al. (2008)	100%	
Coupland et al. (1993)	100%	
Elliot et al. (1992)	90%	Insufficient follow up time
Karkkainen et al. (2008)	100%	
Kauppi (2014)	100%	
Lan et al. (2010)	100%	
Lau et al. (2003)	30%	Poor reporting through out
Meyer et al. (1995)	100%	
EPIDOS study		
Robbins et al. (2005)	90.91%	Measurement of outcome (HGS) not specified

Overall evidence was graded based on the method suggested by Brennan et al. (2011), shown in table 2 above. All included studies were observational and provided strong evidence for a relationship between HGS and hip fracture incidences, based on "generally consistent findings in multiple high quality cohort studies".

Despite having found strong evidence for a relationship between HGS and hip fractures, due to the heterogeneity between the included studies, it was not possible to conclude on the strength of this relationship. Study designs, populations, primary objectives, methods of HGS measures, and analyses, were not comparable; meta-analyses were not possible.

3.3.4 Results of individual studies: fracture incidences, HGS values, and risk

A total of 21,197 participants were included across the 10 studies. Out of those, 1392 (6.56%) has sustained a hip fracture during the courses of the respective studies.

A relationship between hip fracture incidences and HGS was described in all studies.

HGS was found to be significantly reduced in participants at the time of hip fracture when compared to controls ($p < 0.001$) (Bean et al., 1995; Elliot et al., 1992; Lau et al., 1993). In cohort studies, HGS was decreased at baseline in individuals that later sustained a hip fracture (Kauppi et al., 2014; Robbins et al., 2005). In the remaining studies, differences in HGS between cases and controls or participants without hip fracture was not reported.

In all included studies, decreased HGS was associated with increased risk of sustaining a hip fracture. Cawthon et al. (2008), who had included only male participants, found an association between fracture risk and very low HGS; and they did find an even stronger association between fracture risk and the inability to perform the HGS test.
Independence of HGS as a risk factor was assessed in six studies (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Kauppi et al., 2014; Lan et al., 2010; Lau et al., 1993). HGS was found to be an independent risk factor for sustaining a hip fracture in three studies (Bean et al., 1995; Coupland et al., 1993; Lan et al., 2010).
In cohort studies, risks were assessed using Cox regressions. In case-control studies risks were established through multiple and logistic regressions. Independence of risk factors were determined via multivariate models. Odds ratios, hazard ratios, and relative risks were used to present risks.
Though hip fracture risk was demonstrated to increase with decease in HGS in all included studies, the amount of risk increase was diverse. It ranged from .6 times increase in likelihood (Kauppi et al., 2014) to 49.5 times more likely in another (Coupland et al., 1993).

3.3.5 HGS values of included studies assessed against normative data and cut-off points

HGS values reported in the included studies were assessed against age and gender stratified normative HGS data presented by Dodds et al. (2014). They were also assessed against cut-off points recommended by Cruz-Jentoft et al. (2010) - 20 kg for western females and 32 kg for western males, and Chen et al. (2014) – 14.3 kg for Asian females and 22.4 kg for Asian males.

HGS of individuals with hip fracture was reported in five studies.

Bean et al. (1995), who had looked at a female population from the UK, found the mean HGS of hip fracture cases to be 39.1% below the stratified mean, and the HGS of the control group 2.46% below the mean. The mean dominant HGS of all cases was well below the recommended cut-off point of 20 kg.

Lau et al. (1993) had investigated cases and controls from Hong Kong, including both genders. All their reported HGS values were also below the stratified mean, cases more significantly than controls: male cases 60.6% below the mean, and male controls 35.1% below the mean; female cases 58.9% below the mean and female controls 43.15% below the mean. HGS values of cases were also far below the recommended cut-off points.

Robbins et al. (2005) examined a female French population. HGS was reported in kPa. While cases were statistically significantly weaker than controls, values could not be compared to stratified means or cut-offs, as they are all presented in kg.

Two studies (Elliot et al., 1992; Kauppi et al., 2014) had not discriminated between genders. This made a valid comparison to stratified means and cut-off points impossible. However, a general statement for both studies can be made: HGS of individuals with hip fracture was well below stratified means and cut-off point for western females.

Cawthon et al. (2008), Coupland et al. (1993), , Karkkainen et al. (2008), Lan et al. (2010) and Meyer et al. (1995) divided HGS values of all included individuals into tertiles or quartiles;

no discrimination between participants with and without hip fracture was made. Merely the number of hip fractures occurring in each tertile/quartile was reported.

3.3.6 Timing and methods of HGS measures in included studies

Individuals participating in cohort studies had baseline HGS measures taken well before the event of hip fracture. In these instances, duration between baseline measures and fracture was not reported.

Populations of case-control studies did not have pre-fracture baseline HGS measures taken, but the time between hip fracture and measurement was either below 72 hours, or between 72 hours and two weeks post fracture.

HGS was measured using a range of different instruments, ranging from a custom-built strain gauge to a Jamar hydraulic hand dynamometer. Three studies did not report on the type of HGS measuring device was used (Coupland et al., 1993; Lau et al., 1993; Robbins et al., 2005).

Measurement approaches also differed widely between studies, with some measuring both hands (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Lau et al., 1993; Robbins et al., 2005), others the dominant hand (Elliot et al., 1992; Karkkainen et al., 2008; Lan et al., 2010) and one measuring the non-dominant hand (Meyer et al., 1995).
Repetitions of measures also varied, ranging from the best of two (Cawthon et al., 2008; Kauppi et al., 2014) to the best of six attempts (Bean et al., 1995).
Robbins et al. (2005) did not report any details about their measurement approach.

3.4 Discussion

3.4.1 Summary of findings and interpretation of results

The aim of this systematic review of current literature was to explore the evidence for an association between HGS and hip fracture incidences. The findings of this review clearly demonstrate an existing relationship between HGS and hip fracture incidences. Individuals with hip fracture appear to have decreased HGS at the time of injury; and decreased HGS is a risk factor for sustaining a hip fracture.

HGS has previously shown to predict mortality, decrease in mobility, and cognitive decline in older people. (Rijk et al., 2016) HGS also plays an important part in frailty; some authors even proposed HGS to be a potential single marker of frailty (Chainani et al., 2016; Syddall et al., 2003). Frailty in turn is a risk factor for falls (Cheng & Chang, 2017; Kojima, 2015), and falls pose a great risk for (hip) fracture (Hayes et al., 1996). The findings of this review add to the evidence linking frailty, hip fractures, and HGS.

Studies included in this review had various primary and secondary objectives; none of the studies singularly looked at HGS in relation to hip fractures. Overall, 74 variables were considered across all 10 studies. Many of these variables were mentioned in only one study, but some came up more frequently. Low BMD in relation to hip fracture was investigated in five studies (Cawthon et al., 2008; Elliot et al., 1992; Lan et al., 2010; Lau et al., 1993; Robbins et al., 2005), significant associations were found in three (Lan et al., 2010; Lau et al., 1993; Robbins et al., 2005). Falls and fractures were investigated in five studies (Cawthon et al., 2008; Elliot et al., 1992; Lan et al., 2010; Meyer et al., 1995; Robbins et al., 2005), significant results were found in two (Lan et al., 2010; Robbins et al., 2005). The high prevalence of BMD and falls as variables in studies investigating hip fractures confirms the perceived overrepresentation of the two. While both decreased BMD and falls undisputedly play an enormously important role in the process of sustaining a hip fracture, the large number of other, also significantly related variables, including HGS, highlight the complexity of the pathogenesis of hip fractures. It also poses the question if perhaps frailty

is the overarching cause of hip fractures, and all other factors can be looked at as part of frailty.

Authors of three out of the 10 included papers briefly talked about frailty in their discussions (Cawthon et al., 2008;; Karkkainen et al., 2008; Lan et al., 2010). Beyond that however, frailty was not considered in any of the studies selected for this review. This might possibly be due to the fact that publication dates of most of the reviewed studies pre-date the wider recognition of frailty as a geriatric concept or syndrome.

3.4.2 Risk factors – some considerations

'Risk factors' were reported in all 10 included studies.

A risk factor is defined as an exposure that pre-dates an outcome; the exposure is in some way related to the respective outcome. There is no clarity on how strong the association between exposure and outcome has to be; neither is clear if the exposure must be causal to the outcome (Burt, 2001).

In relation to the studies included in this review, five were longitudinal studies where exposure clearly pre-dated the outcome, baseline measures were taken long before a hip fracture occurred. The six remaining studies however were case-control studies, the exposure is unlikely to have predated the outcome, most HGS measures were taken shortly after the hip fracture had occurred. For these studies, where relationships are based on prevalence data, Burt (2001) recommended to use the term risk 'indicator' rather than risk 'factor'.

As outlined in the results section, HGS was assessed for independence in seven studies, and was confirmed as an independent risk factor in three. It might however not be clinically relevant to establish independence, as it is a statistical paradigm depending on all variables selected for analysis in any particular model. As outlined by Brotman et al. (2005), differences in study populations, statistical methods, and co-variables lead to a single variable being an independent risk factor in one study but not the next. Statistical independence of a variable does also not inform about causality. A risk factor might be

viewed as more important than others based on its 'independence', while it is clinically less relevant.

3.4.3 HGS and hip fractures

Some potential links between hip fractures and HGS were already discussed previously in this chapter.

Lan et al. (2010), authors of one of the three papers in this review mentioning frailty, suggested a musculoskeletal chain reaction as a possible link. An individual with good HGS might be able to activate stabilising trunk muscles through activity in arm and shoulder muscles, which in turn might trigger contraction forces in the deeper muscles of the hip, making such a person less likely to fall and fracture. This fits with findings by Martelli et al. (2014) that demonstrated the importance of hip extensor contraction forces for bone strength around the hip. Sherrington and Lord (2005) found HGS to be an indicator for hip muscle strength. However, as discussed previously, HGS and its relationship with frailty and fractures is likely much more complex. Sherrington and Henschke (2013) highlighted the importance of the central and peripheral nervous systems in falls prevention, and Martin (2017) stated that weakness related to sarcopenia and frailty originate in large parts from neuro-degeneration. Which brings us back to our earlier proposal, suggesting the possibility that HGS and frailty are linked through the CNS and its ability to control neuro-muscular synergies. In the same way, HGS and frailty might be linked to hip fracture incidences, as poor neuro-muscular control leads to falls and decreased musculoskeletal health, including bone health.

3.4.4 Limitations of included evidence and the review process

We did not include papers written in a language other than English. This might have led to bias. However, we did not limit the data base searches to English language, and only had to exclude one paper that was written in Chinese.

Cognitive impairment was an exclusion criterion in six of the 10 reviewed studies. Dementia and delirium are very common in individuals sustaining a hip fracture; hence, this exclusion might introduce bias to the sample.

It is also important to note that hip fracture rates in the four cohort studies were very low, only 2.25% of participants sustained a hip fracture during the study periods.

The biggest limitation of this review was the vast heterogeneity of the included studies (different populations, objectives, methods, analyses, measuring tools, etc.) which did not allow for pooling of data and meta-analyses.

3.4.5 Clinical implications

While HGS measures alone might not be sufficient to prevent hip fractures, the results of this review suggest that HGS measures might be a viable tool to screen for people at elevate risk of sustaining a hip fracture. In agreement with Rijk et al. (2016), we suggest a wider use of HGS measures in the assessment of older people. HGS measures are cost-effective and relatively easy to perform in a wide range of health care settings. Normative age and gender stratified data for reference values is available, so are cut-off points, such as those proposed by Dodds et al. (2014).

3.4.6 Conclusion

Findings from this systematic review of the literature confirmed an association between (decreased) HGS and hip fractures in older people. Because of heterogeneity between the included studies, the strength of this relationship was not quantifiable. Nonetheless, based on our findings we believe that HGS should be investigated further as a tool for identifying vulnerable older people at potentially heightened risk of sustaining a hip fracture.

These literature findings suggested the need for an observational study to assess HGS as well as the EFS in a large hip fracture cohort. This was to consolidate findings of decreased HGS in this patient group, but also to investigate if HGS can truly capture the multi-facetted presentation of frailty. The latter was attempted by also using the reported EFS

individually and for comparisons/overlap with HGS. It was anticipated that this would add valuable information about the clinical and personal consequences of frailty for hip fracture patients.

4 FRAILTY IN ACUTE HIP FRACTURE PATIENTS: AN OBSERVATIONAL STUDY INVESTIGATING PREVALENCES AND ASSOCIATED RISK INDICATORS

In this chapter, an observational study investigating the implications of frailty on discharge destinations and patient outcomes will be described, aiming to inform clinical decision making.

4.1 Preface: The use of routinely collected health data for research

The use of routinely collected health data (RCD) for research is increasing (Benchimol et al., 2015; Ollivere et al., 2020). While there are clear advantages associated with this practice, it comes with its own challenges and controversies (Peek & Rodrigues, 2018).

The most obvious advantage of using RCD for research is the opportunity to access readily available data sets (Kennes, 2017).

Many institutions progressed to documenting and storing health records electronically, which makes them relatively easily accessible. These data bases can be vast, and data from different sources can be linked to create even larger data sets.

Hard copy patient health records can provide equally relevant and valuable information for research, the work involved in obtaining and extracting the information is however substantially more laborious.

RCD provides real-life information, gathered in clinical settings rather than in research environments (Radel & Walter, 2019). RCD provides an inclusive real-life picture of actual care and outcomes. Descriptive statistics play an important role in capturing these clinical realities; summarisation of this type of data can provide excellent insights into day-to-day practices and practicabilities (Kennes, 2017).

Using RCD is believed to avoid the neglect or under-representation of certain patient groups, such as older and/or cognitively impaired patients. Some of the main reasons for

non-participation in research are health issues, language barrier, dementia, frailty, and hospitalisation (Gaertner et al., 2016; McMurdo et al., 2011). Under-representation of older people leads to an ill-match between research participants and real word patients, which is cause for concern (McMurdo et al., 2011). Basing research on RCD omits the obstacles and barriers associated with recruiting old, physically ill, and cognitively impaired patients. It provides an opportunity to gather comprehensive information about a complex population group without exclusions (Todd et al., 2020; Kennes, 2017).

Challenges and potential risks associated with the used of RCD must also be acknowledged. Johan van der Lei (1991) highlighted that the original purpose of RCD was clinical, not research. He warned against the use of data that has been removed from its original context, as this might lead to misinterpretations. This must be accepted as true for both electronic data bases and hard copy case notes.

Hemkens et al. (2016) raised concerns about the use of data without being able to verify its quality, as some human error must be expected, including coding errors and misclassifications. Thus, the inaccessibility of raw data might lead to inaccuracies. The arguments around accessibility of raw data seem to bare less merit when dealing with hard copy case notes compared to electronic data bases; human error and carelessness however apply equally to both. Extracting data from hard copies case notes involves challenges like decoding handwriting or dealing with missing pages and wrongful filing. Hence the potential of human error and carelessness must be accepted for the clinician documenting the information was well as the researcher extracting it.

Additionally, a strong limitation of using RCD for research is the impossibility to obtain any additional information beneficial for answering a research question (Hemkens et al., 2016).

The secondary use of RCD necessitates ethical considerations. Consensus about the ethics of using RCD in research is lacking not only in the general population but also amongst research professionals and clinicians (Peek & Rodrigues, 2018).

Data custody of health information is crucial to maintain patient confidentiality. Most institutions do not routinely obtain consent from all patients to use their data for research.

RCD is typically de-identified when used for research. Despite this, a large European survey amongst the general population revealed a strong aversion towards the use of electronic health information for research. This did not only include use of data by pharmaceutical and insurance companies, but also by academic researchers. On the other hand, people experiencing a health crisis themselves appeared to look very favourable at the use of RCD for research as they felt that inaccessibility of health information slows down the process of developing new treatments (Patil et al., 2016).

In summary, there are many valid arguments for and against the use of RCD in research. With appropriate ethical review and approval processes and responsible data management, the benefits outweigh the concerns. While research based on RCD can never replace randomised controlled trials (RCTs), it can complement them by providing information only obtainable through observation of specific cohorts.

The above considerations were imperative in the decision-making process when deciding on the appropriate methodology for the study described below. Old, frail and cognitively impaired patients comprise the majority of acute hip fracture patients. If many of them fail to be recruited, meaningful results cannot be obtained. Therefore, the research was conducted using RCD.

At the time of data collection, our institution was still recording and storing patient health information as hard copy case files. This led to lengthy laborious data extraction from mostly handwritten paper notes.

4.2 Background

4.2.1 Overview

For the observational study presented in this chapter, the use of two distinctive frailty measures in a hip fracture cohort was investigated. Frailty was established via HGS as well as the reported EFS. HGS and EFS were used to assess the prevalence of frailty; they were also assessed against each other, to evaluate the comparability of frailty results. The relationships of frailty with prolonged hospitalisation, discharge mobility, primary and secondary discharge destinations (including permanent change of residence), as well as three- and 12-month mortality were assessed. An effort was made to provide concrete recommendations for the clinical use of HGS and the reported EFS in acute hip fracture patients during early admission on an acute orthopaedic trauma ward.

4.2.2 Context

Hip fractures, aging, and frailty have been discussed in previous chapters. Impacts of hip fractures on affected individuals and the health care system were considered.

Measures such as the Frailty Phenotype, the Frailty Index, HGS and the reported EFS were shown to predict various short- and longer-term outcomes after hip surgery (Cooper et al., 2016; Kua et al., 2016; Selakovic et al., 2019; Song et al., 2022). The use of these measures in hospitalised geriatric hip fracture patients was encouraged by these authors; however, clear suggestions for clinical use were made.

Individuals with low-impact hip fractures form a large part of the patient load managed on the acute orthopaedic ward at our local trauma centre. Decisions concerning these patients' post-discharge arrangements can be challenging and extensive; most discussions don't only involve patients but include family members and social workers. This led to the assumption that patients' inabilities to return to their pre-injury residences immediately after acute discharge generate prolong hospital stays. Literature supports this assumption, which was a main reason for pursuing the presented study, aiming to assess the clinical use of frailty measures to assist discharge planning.

Prolonged hospital stays are undesirable for patients and the health care system alike. Length of stay can be the result of medical factors; patients must be medically stable and fit for transport to be discharged from an acute hospital. Older patients are more likely to require longer stays (Caccialanza et al. 2010). However, prolonged stays in acute settings are often due to the unavailability of appropriate follow-on placements (e.g. transition care or permanent residential aged care) on short notice. Staying in an acute hospital for longer periods was proven to increase the risks of cognitive and functional decline (hospital acquired disability), hospital acquired infections, malnutrition, and social isolation, to name a few (Carvalho et al., 2018; Agrawal et al., 2013).

Prolonged hospitalisations are financial burdens for health care systems. Primarily, the cost per patient on the ward increases. Secondarily, if patients cannot be discharged, there is no room for new admissions, leading to struggling emergency departments and ramping ambulances. Consequently, emergency care is severely compromised, including first responses.

Age, pre-injury cognitive ability, pre-injury ability to perform activities of daily living, pre-injury mobility, discharge mobility, and existing co-morbidities were demonstrated to influence patients' capabilities to return to their pre-injury residence following discharge from an acute hospital ward (Deakin et al., 2008; Vochteloo et al., 2012; Dartel et al. 2021). Timing of surgery, place of injury occurrence, and pre-fracture function were found to predict mobility status on day seven post hip fracture surgery (Fitzgerald et al., 2018).

Discharge destinations following acute stays were found to be variable by a team of Canadian researches; they found no pattern determining discharge locations (Pitzul et al. 2017). Age, pre-injury independence and function level, gender, and place of injury occurrence were found to influence discharge destinations in several studies (Deakin et al., 2008; Chow et al., 2023; Deemer et al., 2023). Similarly, factors determining a change of permanent primary residence as a consequence of sustaining a hip fracture were found to be age, pre-fracture cognitive and physical function (Vochteloo et al., 2012). More

specifically, Hayashi et al. (2016) investigated factors affecting discharge destination after rehabilitation of hip fracture patients that were previously living independently alone. Cognition was identified as a major factor for being able to return home after completing rehabilitation. Factors associated with direct home discharge were assessed by Baker et al. in 2017. They found that sustaining an intra-capsular fracture, being of younger age, being female, having good cognition, not suffering from comorbidities, not living alone, being able to walk independently without aid, and being independent with ADLs were predictors for direct home discharge. Correspondingly, Ryder at al. (2021) found that older patents with impaired function and cognition, suffering from multiple health conditions, were most likely to move into residential aged care facilities as a consequence of their hip fracture. In addition, they found that patients from rural areas were disadvantaged in terms of rehabilitation opportunities; they were often discharged to another ward or hospital due to the lack of availability of more appropriate destinations.

Van Dartel et al. (2021) found that age, pre-fracture mobility, pre-fracture independence of ADLs, the American society of anaesthesiologists (ASA) score, and cognition were independent predictors for discharge to pre-fracture independent living, versus geriatric rehabilitation or nursing home admission. The authors acknowledged that more research is needed to optimise their model for clinical application.

Three- and 12-month mortality after a hip fracture has been thoroughly assessed by many authors over the last four decades. A recent Australian report found that the 12-month mortality rate in individuals after hip fracture was not much different compared to an age-matched control group (25% and 25%, respectively); hip fracture patients were 2.1 times more likely to pass away within the following 12 months (Australian Institute of Health and Welfare, 2023). Reported risks associated with post-fracture mortality were age, gender, ASA grade, comorbidities, pre-fracture mobility, pre-fracture residence at a residential aged care facility (RACF), geographic location and socioeconomic status (accessibility to health care), and unplanned events peri-operatively (Paksima et al., 2008; Australian Institute of Health and Welfare, 2023). It could be assumed that these risk factors apply,

irrespective of hip fracture, which is supported by an observational study on mortality in dwellers from a RACF (Garcia-Gollarte et al., 2020).

In summary, multiple factors were identified by different authors in association with discharge destinations following acute hospitalisation for hip fracture management. Based on the information gained in the previous chapters, it seems fair to claim that most of these factors are also part of frailty, except for cohabitation and geographic location. Hence, it is believed worthwhile to explore if frailty measures alone can capture enough information to indicate the most likely appropriate discharge destination after acute hip fracture management. Findings from an earlier study by Dasgupta et al. (2009) are also encouraging: patients with medical problems who's EFS was greater than seven had only a 40% chance to be discharged to their pre-injury residence, compared to those with an EFS of seven or less.

4.2.3 Choice of frailty measures

For the presented study, HGS and EFS were chosen to assess the clinical use of frailty measures in discharge planning for hip fracture patients in an acute trauma setting.
Both HGS and the reported EFS are routinely assessed and documented for hip fracture patients on the orthopaedic ward at our local trauma centre.
The use of HGS and EFS for this study can be justified beyond simple availability.

Roopsawang et al. conducted a scoping review, published in 2022, investigating the use of frailty measures in older (≥ 65 years) orthopaedic inpatients. While they found that several validated frailty instruments were used in orthopaedic settings, they could not provide a recommendation for a gold standard tool or measure. This was due to the large number of different frailty instruments (15 were considered in this review, including the EFS), but also due to orthopaedic inpatients typically having musculoskeletal limitations, which impacts the appropriate use of many of these instruments. This study post-dates the planning and data collection period for this study.

Frailty determined by the EFS, self-reported and reported, has been shown to be a valid peri-operative tool to assess the risk of post-operative loss of independence in surgical patients 65 years and older (Oluwafemi et al., 2021; Sirisegaram et al., 2022). Higher EFS scores demonstrated an increased risk of re-admission of older medical patients (Stillman et al., 2017), and higher scores were associated with increased risk of adverse outcomes in older cancer patients (Nishijima et al., 2021). The EFS has been demonstrated to aid in the prediction of 30-day mortality of cardiac patients (Amabili et al., 2019).

Frailty assessments were identified as a promising strategy for improving outcomes of orthopaedic patients; however, there is no consensus on which tool to use (Lemos et al., 2021; Roopsawang et al., 2022). A pilot study from 2016 (Kua et al.) looked specifically at hip fracture patients with the aim to identify a frailty tool to use as a predictor for early post-operative complications; they found the reported EFS to be promising but were not able to give definite recommendations for clinical use.

As described in the previous chapter, some evidence suggests that HGS could be used as a solitaire frailty marker. Findings from our systematic review confirmed that HGS of hip fracture patients is decreased below the age and gender stratified norm, which supports the idea of investigating HGS measures in an acute clinical setting. The gold standard instrument for measuring HGS is a hydraulic dynamometer. The method of measuring HGS is not universally standardised, which leads to some heterogeneity when comparing outcomes of different research, or assessing against normative data (Mehmet et al 2020).

Due to the lack of concrete recommendations for a specific frailty tool, HGS and the reported EFS seemed reasonable measures to use in our study. The decision was made to investigate if HGS and the reported EFS are in fact useful tools to assist in the management of acute hip fracture patients, especially in discharge planning.

4.3 Aim and significance

The purpose of this retrospective observational study was to assess the impact of frailty on acute hip fracture patients, measured with EFS and HGS.

To understand the impact, the prevalence of frailty within the studied hip fracture cohort had to be established. Since HGS and EFS are vastly different measures, comparability of their outcomes had to be investigated.

The overarching aim of this study was to assess the potential for utilising HGS and/or the reported EFS in early discharge planning; the level of frailty might direct to the most appropriate post-acute setting and might suggest the likelihood of a person's ability to return to their pre-injury home. Discharge mobility was assumed to play a role in destination selection, hence its relationship with frailty was also assessed.
Aiming for a wider understanding of frailty, its relationship with length of hospital stays as well as mortality, was also investigated.

This research has great significance: it has potential to streamline early discharge planning and enable patients to get the best possible care at the most appropriate setting in a timely manner. In addition, timely discharge could reduce the financial and logistic burden on the health care system. Objective measures such as the EFS and HGS might also assist in discussions with next-of-kin, and aid in the difficult decision making around an older person's temporary or permanent change of primary residence.

A representative population could be included in this study by only using RCD, with patient informed consent being waivered by the local ethics committee. This allowed us to include cognitively impaired patients and patients with multi-morbidities, many of which would have been lost through other recruitment systems, as outlined in the preface.

To our knowledge, no study has made clear suggestions about the practical use of frailty measure such as HGS or the reported EFS for discharge planning in a hospitalised acute hip fracture population.

4.4 Objectives

Objective 1: to evaluate the prevalence of frailty (HGS and EFS) within an older hip fracture population. Frailty was established through HGS thresholds and EFS categories.

Objective 2: to investigate possible correlations between the HGS and EFS in hip fracture patients, and to assess the comparability of these two measures.

Objective 3: to assess the indicative power of HGS and/or EFS in an older hip fracture population regarding:

a. length of hospital stay (LOS)
b. mobility status on discharge
c. discharge destination after acute stay
d. discharge destination after staying at a provisional destination or rehabilitation facility
e. permanent change of primary residence post injury
f. 3- and 12- month mortality

Frailty assessment via EFS provided five levels of frailty (ordinal or dummy variables), a continuous variable, and a dichotomous variable (frail yes/no). Frailty assessment via HGS was based on gender specific thresholds and produced a dichotomous variable (frail yes/no), and a continuous variable.

4.5 Methods

4.5.1 Study design and setting

This single centre observational cohort study was conducted using RCD. A consecutive cohort was observed, matching was not required to answer the research questions.
Tang et al. (2017) highlighted the importance of including the very old and very sick in any study investigating individuals with hip fractures. To be able to include a valid representative sample of the hip fracture population, only RCD was collected and analysed; in line with local ethical requirements, no informed consent was obtained from participants.
The study took place at a Level 1 Trauma Centre, a major public tertiary teaching hospital in South Australia.

4.5.2 Ethics approval and reporting strategy

This study was approved by the local Human Research Ethics Committee (number 244.18). It was classified as low risk research. Governance approval for the secondary use of hospital data was granted by the Local Health Network. Refer to appendix I.

The study was reported in adherence with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (von Elm et al., 2008) statement and its extension, the Reporting of Studies Conducted using Observational Routinely Collected Health Data (RECORD) (Benchimol et al., 2015) statement. The Supporting Evaluation, Analysis and Reporting of Routinely Collected Health Data (SEARCHeD) (Ollivere et al., 2020) checklist was also respected.

4.5.3 Study population & selection

A consecutive series of in-patients, admitted under Orthopaedics for management of a hip fracture between May 2017 and June 2019 were considered for this study.

Inclusion criteria were: low impact proximal femur fracture; aged 50 years or older; post-surgical HGS reported (including ‘unable’); EFS data available.

Exclusion criteria were: pathological fracture; high impact fracture (i.e. motor vehicle accident, or a fall from a considerable height); non-operative palliative fracture management.

Patients were first identified based on ICD-10 (version 2016) codes for hip fracture: S72.0; S72.1; S72.2. A minimum age of 50 was applied to the filters. For more details, refer to the next section 4.5.4.

4.5.4 Data sources, access, collection, and management

A new data set was created by manually linking information derived from the Integrated South Australian Activity Collection (ISAAC), the Open Architecture Clinical Information System (OACIS), and paper based medical records (PBMR). Linkage was deterministic.

ISSAC allowed identification of the study population based on International Classification of Disease - 10th edition (ICD-10) codes for diagnoses and treatments, provided information about age, gender, length of hospital stay, and individual medical record numbers (MRNs). Based on MRNs, PBMRs were obtained, and additional information accessed from OACIS. Inconsistencies within the three sources were corrected according to majorities.

Authors had access to an extract from ISSAC containing all patients admitted under Orthopaedics during the required time period, and full access to OACIS as well as PBMR. Where required, data was cleaned manually.

4.5.5 Data items

Sixty-four variables were collected for each individual. All variables were inputted in a new data base as numerical codes. A full list of data items is provided in appendix A10.

Data items included variables directly required to answer the primary research questions, as well as variables to allow for ad hoc and exploratory findings.

Below, variables, retrieval strategies and purposes for collection were explained. Variables were grouped in six categories: demographics and baseline characteristics; fracture related

details; peri-operative information; other in-hospital assessed variables; unplanned events; post-discharge from acute hospital.

4.5.5.1 Demographics and baseline characteristics

Age and *gender* of all participants were extracted from OACIS. This information was gathered for descriptive statistics and epidemiological information.

Pre-injury primary residence had been documented in PBMR. It was collected and used for epidemiological information, to assess possible correlations with HGS and/or EFS, to assess against discharge destinations, and to establish changes of permanent residence post fracture.

General health information was derived from ISAAC and verified through manual reviews of PBMR. Morbidities were grouped into eight categories: renal and urogenital; gastro-intestine; endocrine; musculoskeletal; oncology; cardiovascular; neurological; and pulmonary. As the medical severity of each health concern could not be reliably determined, the total number of morbidity areas was recorded for each patient to establish the presence of multi-morbidities. This information was collected to correlate with LOS, HGS and/or EFS, and mortality, as well as for exploratory purposes.

Pre-fracture mobility was extracted from PBMR. Mobility was grouped into five categories: independent, independent with walking aid; physical help or constant supervision required; and unable to walk but able to sit out of bed (SOOB) and perform bed exercises; unable to SOOB or to perform bed exercises.
Mobility was of interest to assess possible associations with post-operative and discharge mobility status, LOS, as well as HGS and/or EFS.

Cognition (excluding delirium) and mental health statuses had been documented in PBMR. This data was collected for epidemiological information, descriptive statistics, and to explore any potential relationship with HGS and/or EFS.

Pre-injury osteoporosis diagnoses and pharmacological management was collected as documented in PBMR. Available data was used for epidemiological information and to relate to post fracture osteoporosis management.

Weight and height (extracted from PBMR) were used to calculate the body mass index (BMI) for each patient. BMI was used for epidemiological information, descriptive statistics, and to assess possible correlations with frailty. Specifically, to observe the distribution of BMI across people classified as frail by EFS or HGS (descriptive statistics).

Information about *previous hip fractures*, *history of falling, dependencies* (drugs, alcohol, and nicotine), *vision and hearing* impairments, and *incontinence* were derived from PBMR for descriptive statistics and exploration.

4.5.5.2 Fracture related details

Places of injury occurrence and *activities* when getting injured were derived from ISAAC and verified through manual reviews of PBMR. Data was used to confirm inclusion and exclusion criteria; high impact fractures were excluded.

Information about *fracture sides and types* were derived from ISAAC. ICD-10 codes with detailed diagnoses were collapsed into four categories: (1) sub-capital femoral neck fracture, (2) basic cervical femoral neck fracture, (3) per-trochanteric/intertrochanteric femur fracture, and (4) sub-trochanteric femur fracture.
Type of fracture information was collected to relate to age, gender, HGS, and EFS to explore potential patterns.

Information about *fracture repair* was derived from ISAAC (ICD-10 codes) and verified in OACIS. Procedures were grouped into seven categories: hemi arthroplasty of the femur; total hip arthroplasty; dynamic hip screws; short gamma nail; long gamma nail; cannulated screws; and other (such as synthes, trigen intertan, or affixus).
Type of fracture repair was collected to look for correlations with type of fracture, mobility at discharge, as well as EFS and HGS.

4.5.5.3 Peri-operative information

Information about *femoral nerve block* administration in the emergency department; *time to theatre* (from admission to in suite, in hours), *reason for theatre delay* (if applicable); *total time in suit* (in minutes); *general anaesthetics time* (start of operation until incision, in minutes); *duration of operation* (in minutes); and *time in recovery* (in minutes) were extracted form PBMR and OACIS.

The main purpose for collecting the above variables was for epidemiological information and exploration.

4.5.5.4 Other in-hospital assessed variables

The *ASA Physical Status Classification System* was derived from PBMR. This information had been documented by the treating anaesthetist.

The ASA system was first introduced in 1941 (Meyer, 1941) to subjectively classify patients' pre-surgical health into five categories to determine risks associated with the proposed surgery. While the risk prediction ability of the score is now controversial (Owens, 2001) correlations between (high) ASA scores and time to surgery, length of hospital stay, and one-month mortality could be demonstrated in hip fracture patients (Yeoh & Fazal, 2014). This data was extracted from PBMR and collected to establish potential correlations between EFS, HGS and ASA scores.

Malnutrition universal screening tool *(MUST)* was used during admission. Data had been documented by nursing staff and was collected from PBMR for descriptive statistics and exploration.

Mobility statuses had been documented by the treating physiotherapist or nurse. The information was derived from PBMR. For this research, mobility on day one post-surgery and the day of discharge were of interest. Mobility was grouped into five categories, same as for pre-injury mobility. This information was used to relate to pre-injury mobility, LOS, discharge destination, HGS and/or EFS.

Current in-hospital and post-discharge *falls risk* had been determined by the treating physiotherapists and was extracted from PBMR. Documented data from the nursing falls risk screening and assessment forms was very rare, thus was not extracted for this research. Falls risk information was collected for descriptive statistics and epidemiological information.

Diagnoses of *osteoporosis* and commencement of osteoporosis medication during acute admission had been documented in PBMR and/or discharge letters (OACIS). This information was collected for descriptive statistics and epidemiological information.

HGS measures (Bobos et al., 2019) had been taken post-operatively (within 36 hours) by the treating physiotherapist. A Jamar hydraulic hand dynamometer (JLW Instruments, Chicago, IL, USA) was used to establish strength in kilograms. Measurements were taken in a seated or half seated position with elbows at 90 degrees flexion and shoulders in neutral. The elbow was supported to assist with the weight of the device. Both hands were tested twice with one minute rest in between; the stronger measures of each side were entered into our data base. The inability to perform the test was also recorded.
HGS ≥16 kg for females and ≥27 kg for males (T-score of -2.5 below the gender stratified average) was considered as an indication for frailty.
HGS was derived from PBMR. It was collected to be compared with age and gender adjusted normative data, to establish the prevalence of frailty. Possible correlations with the EFS, discharge destination/change of residence, discharge mobility, length of hospital stay, and mortality (primary objectives), as well as several other variables (exploratory analyses) were also of interest.

The *reported EFS* (Sirisegaram et al., 2023) had been documented by the nurse in charge of the individual patient within the first 48 hours of admission and was retrieved from PBMR. The EFS consists of nine domains (cognition, general health status, functional independence, social support, medication use, nutrition, mood, continence, functional performance), with a maximum score of seventeen. The level of frailty is grouped in five

categories: 0-5 = not frail; 6-7 = vulnerable; 8-9 = mild frailty; 10-11 = moderate frailty; 12-17 = severe frailty. The reported EFS had been modified for the functional performance domain, as acute hip fracture patients are unable to complete a timed-up-and-go test; they had been asked to report on their pre-injury walking capacity instead.
The EFS was collected for much the same purposes as HGS. The main areas of interest were prevalence of frailty, and ability to predict discharge destination and /or change of residence.

LOS based on admission and discharge dates was derived from ISAAC and verified on OACIS. This data was collected to compare LOS of people that were living independently before sustaining a hip fracture to these with varying degrees of dependence. It was also assessed for correlations with HGS, EFS, and mobility.

'*Discharge destination 1*' was used to describe destinations patients moved to after having been discharged from the acute hospital ward. A distinction between interim destinations (for rehabilitation, medical, or logistic purposes), and permanent destinations (new post-injury primary residence, or return to pre-injury permanent residence) was made.
'*Discharge destination 2'* was used to describe where patients moved on from interim destinations (secondary interim residence, new post-injury primary residence, or return to pre-injury permanent residence).
This information was derived from PBMR and OACIS and used to correlate with HGS and/or EFS, and to establish post-injury changes to permanent changes of residence.

4.5.5.5 Unplanned events

Adverse events during admission were collected from PBMR and graded in accordance with Dindo et al. (2004) to relate to HGS and/or EFS. In the event of multiple adverse events only the highest grade was recorded.

Delirium was recorded separately to adverse events due to its high implications for several outcomes. Delirium information was collected from PBMR where it had been documented

as: alert and oriented; confused; confused and agitated; confused and drowsy. This information was collected for descriptive statistics and correlations with HGS and/or EFS.

4.5.5.6 Post-discharge from acute hospital

Occurrences of *readmissions* (up to 3 months post hip fracture) were extracted from OACIS. Reasons for readmission (injury related or other) were noted. This data was collected to perform descriptive statistics as well as correlations with EFS, HGS, mobility, co-morbidities, and adverse events during admission.

Mortality data was accessed via the epidemiology department of our hospital who have access to the state's death registry. Three- and 12-month mortality were used for analyses. Deaths were correlated with EFS and HGS.

Information about *permanents changes in residence* (pre-injury permanent residence versus post-injury permanent residence) was retrieved from OACIS and correlated with HGS, EFS, and co-morbidities.

4.5.6 Biases

Biases were considered and relegated as much as possible.

Selection/omission bias: Individuals with private health insurance were moved to the adjunct private hospital for hip fracture management; this caused an unavoidable selection bias. However, by choosing to use RCD for this research, it was possible to avoid under-representation of patient groups crucial for this research, such as cognitively impaired and multi-morbid individuals.

Observation bias was eliminated via the choice of research design.

Measurement & data collection bias: HGS was measured routinely by the treating physiotherapist. Measurement bias was reduced by having a standardised protocol for conducting those measures. Measurement standards were not implemented by researchers, there were pre-existing as part of standard care. Data collection bias was

avoided via the choice of study design; RCD was collected as per availability and entered into our database.

Confirmation bias: While impossible to avoid completely, confirmation bias was considered at all stages of the research. It was mitigated through ongoing consultations, discussions, and feedback from people not directly involved with this research.

Omitted variable bias: Confounding factors and respective variables were considered for statistical analyses to ensure the internal validity of our findings.

4.5.7 Study size, individual sample size calculations, and data analyses

To ensure statistical power of outcomes for all objectives, a minimum of 404 patients were required to be included in this study. Individual sample size calculations are outline below.

Frequency counts and percentages were used to describe baseline characteristics. Some gender differences were assessed using chi square tests of independence, and independent t-tests.

To establish the prevalence of frailty (objective 1), two-sided confidence intervals for a proportion in one sample were established: Binomial (Clopper-Pearson) 'exact' method based on the beta distribution were used (Fleiss et al., 2003; Newcombe, 1998).
A sample size of 402 produces a two-sided 95% confidence interval with a width equal to 0.100 when the sample proportion is 0.500. The sample proportion of 0.500 is in keeping with Kistler et al. (2015).

To assess correlations between the EFS and HGS (Objective 2), Pearson correlations were used conditionally upon fulfilling the assumption. Non-parametric Spearman's rho rank correlation was used if required (Coxe et al., 2009). A sample size of 404 produces a two-sided 95% confidence interval with a width equal to .100 when the estimate of Pearson's product-moment correlation is .700.

A similarity index was calculated to present the percentage of overlap between frailty measured by HGS and frailty measured by EFS.

The predictive power of HGS and EFS (Objective 3) was evaluated using hierarchical multiple regression (key known predictors go first and when controlled, the new variable is added to the model) and simple regression.

Interactions of HGS and frailty with other covariates were investigated (Coxe et al., 2009; Shrier et al., 2009), unadjusted and adjusted (after controlling for confounding factors).

Appropriate types of regression analyses were employed based on variable types and considering relevant assumptions (Ernst & Albers 2017; Casson & Farmer 2014).

Frailty measures were analysed as continuous and/or binary predictor variables. HGS and EFS were analysed separately. Outcome variables were continuous and binary.

Multinominal variables were either made into dummy variables or combined.

Hierarchical multiple linear regression (HMLR) and hierarchical multiple binary logistic regression (HMBLR) were used to assess the predictive power of frailty while adjusting for other, possibly confounding, variable.

Simple logistic regression (SLR) was used to assess the predictive power of frailty (yes/no for HGS and EFS) and each individual EFS category unadjusted on their own.

For HMLR, six assumptions were considered:

1. The outcome variable is continuous (fulfilled via choice of variable type)
2. Linearity (when comparing means, the deviation from linearity is non-significant).
3. No multicollinearity (correlation coefficients of predictor variables are <.7 or <-.7).
4. Independence of observations (fulfilled via the data entry and collection process)
5. Homoscedasticity (visual assessment via scatterplots and lawless curve)
6. No influential outliers (Cook's Distance <1)

For all logistic regressions, five assumptions were considered:

1. The outcome variable is binary (fulfilled via choice of variable type)
2. Linearity of independent variables and log odds (Box-Tidwell transformation)

3. No multicollinearity (correlation coefficients of predictor variables are <.7 or <-.7).

4. Independence of observations (fulfilled via the data entry and collection process)

5. No influential outliers (Cook's Distance <1)

For HMLR, standardised beta (β) was considered to assess relationship strengths between individual predictors and each outcome variable. The closer β was to 1 (or -1), the stronger the relationship was considered; the closer β was to 0, the weaker the relationship. For ease of interpretation, β of .0 to .33 (or -.33) was considered as weak, .34 (or -.34) to .66 (or -.66) as moderate, and .67 (or -.67) to 1 (or -1) as strong. Adjusted R^2 (0 to 1) was used to judge the predictive power of each model.
For HMBLR and SLR odds rations (OR) were used to quantify relationships.

A sample size of 309 was needed to achieve 80% power and to detect an R-Squared of 0.02 attributed to 1 independent variable(s) using an F-Test with a significance level (alpha) of 0.05000.

Samples size requirements were calculated using PASS 14 Power Analysis and Sample Size Software (2015). NCSS, LLC. Kaysville, Utah, USA (ncss.com/software/pass).

Statistical analyses were performed using IBM SPSS Statistics Version 28.0.1.1.

Statistical results were reported in compliance with the American Psychological Association (APA) guidelines.

4.6 Results

Our search request returned a total of 589 patients. However, 89 patients had been transferred to a private hospital for treatment, and 38 patients had been coded incorrectly (not hip fracture patients).

A total of 462 consecutive hip fracture patients admitted between May 2017 and June 2019 were included in this study. This number satisfied the pre-established requirements for statistical power. Mostly complete data sets were available via various hospital record systems.

Data was observed and analysed using the total number of valid cases for each variable category.

4.6.1 Population characteristics – descriptive

Selected population characteristics are outlined in table 5. Detailed information can be found in appendix A1.

Key characteristics are described below:

4.6.1.1 Age and gender

The age of included patients ranged from 50 to 103 years, with an average age of 82 years. The median age across the whole population was 84 years; 42% of patients were octogenarians, and 65% of patients were 80 years or older. Females were older (p=.004) than males, with an average age of 83 years, compared to 80.

Our cohort comprised 67% females and 33% males (p<.001).

4.6.1.2 Pre-injury primary residence and (in)dependent living

Four pre-injury residence categories were identified: living independently alone in a private residence; living independently with someone (cohabiting) in a private residence; living alone or with someone in a private residence or institution and requiring help (assisted living, low care); living in a residential aged care facility (high care).

More than half of the included patients (59%) had been living independently, either alone or cohabiting, prior to sustaining the hip fracture (65% of all males, versus 56% of all

females). Comparable numbers of males and females had been living independently alone; a higher number of males had been living independently cohabiting compared to females (43% versus 29%).

Table 5: Demographics and selected baseline characteristics – frequencies and percentages			
	Combined total	**Female**	**Male**
	N (%) of valid cases	N (%) of valid cases	N (%) of valid cases
Demographics			
Number of included patients	462 (100.0)	310 (67.09)	152 (32.90)
Age in years	Range: 50 – 103 Mean: 82 Median: 84 Std deviation: 10.23	Range: 50 – 103 Mean: 83 Median: 85 Std deviation: 9.84	Range: 51 – 101 Mean: 80 Median: 83 Std deviation: 10.74
Type of pre-injury primary residence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Private home – independent alone	116 (25.10)	83 (27.77)	33 (21.71)
Private home - independent cohabiting	156 (33.76)	90 (29.03)	66 (43.42)
Private or institutional home - low dependency	40 (08.65)	25 (08.06)	15 (09.86)
Residential aged care facility - high dependency	150 (32.46)	112 (36.12)	38 (25.00)
Mobility status pre-injury			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Independently mobile	231 (50.00)	145 (46.77)	86 (56.57)
Independent with aid	132 (28.57)	91 (29.35)	41 (26.97)
Physical help or supervision	94 (20.34)	72 (23.22)	22 (14.47)
Bed mobility and sitting only	5 (01.08)	2 (00.64)	3 (01.97)
Cognition and mental health pre-injury			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Dementia/Alzheimer's	164 (35.50)	127 (40.97)	37 (24.34)
Depression	138 (29.87)	105 (33.87)	33 (21.71)
Osteoporosis diagnosis pre-injury and resulting medication			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Diagnosed	112 (24.19)	98 (31.61)	14 (09.21)
Valid cases	*112 (100.0)*	*98 (100.0)*	*14 (100.0)*
On medication	104 (92.86)	91 (92.86)	13 (92.86)
History of falling			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Fallers	231 (50.00)	165 (53.23)	66 (43.42)

A small group of patients (9%) had been in need for low care assistance prior to sustaining the hip fracture.

Almost one third (32.5%) of patients had been residing at a residential aged care facility prior to sustaining the hip fracture. The group of high care patients comprised 25% of the total male population, and 36% of the total female population.

4.6.1.3 Morbidities

The maximum number of co-morbidity areas observed in our population was six (2% of patients). No morbidities had been documented for 4% of patients. The largest group of patients were the ones with three morbidities (28%).

4.6.1.4 Pre-injury mobility

Four mobility categories had been pre-established, as described in the methods. Fifty percent of all patients had been independently mobile, 29% had been independently mobile with a walking aid, 20% had been in need for help or constant supervision, and 1% had been immobile.

4.6.1.5 Dementia and depression

The presence of dementia, including Alzheimer's disease, had been documented for 35% of patients; females were more affected than males.

Information about depression had been documented for 30% of patients; again, females were more affected than males.

4.6.1.6 Osteoporosis

Osteoporosis had been documented as a pre-injury diagnosis for 24% of all included patients. Prevalence was higher within the female population (39%) compared to the male population (9%). Ninety-three percent of patients with a prior diagnosis had been receiving pharmacological treatment for this condition at the time of admission.

4.6.1.7 BMI

BMI was calculated from patients' weight and height that had been documented during admission. Just over half of patients were in a health weight range (54%); almost one third were overweight (29%). Only 8% of patients were underweight and 10% obese (see figure 5 below). A higher percentage of females (9%) were underweighted compared to males (5%); a higher percentage of males (56%) were in a health weight range compared to females (52%). Gender differences for being overweight or obese were negligible.

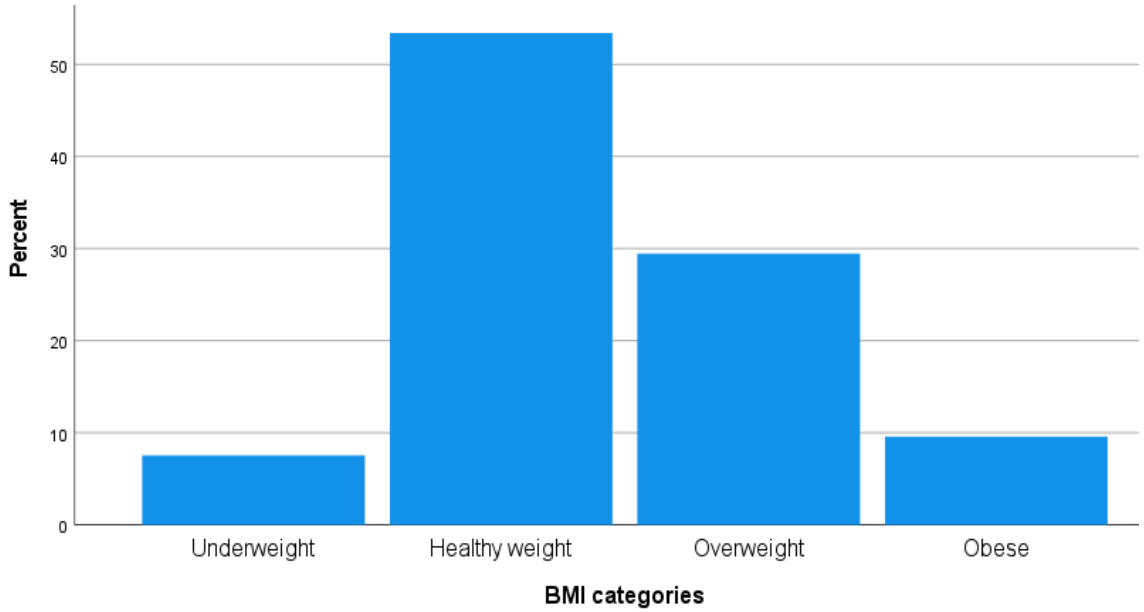

Figure 5: BMI categories for both genders combined

4.6.1.8 Prior hip fractures, related osteoporosis, and history of falling

Only 8% of patients had documented evidence of a previous hip fracture occurrence. For 46% of these patients, a diagnosis of osteoporosis prior to their current admission had been documented, with a medication rate of 88%.

For 50% of all patients included in this research, a 12-month history of falling had been documented. When only looking at patients that had suffered a previous hip fracture, 84% had a documented history of falling.

4.6.1.9 Other relevant patient information

For frequencies and percentages about dependencies, continence, hearing and vison impairments, refer to appendix A1.

4.6.2 Fracture and peri-operative information – descriptive

4.6.2.1 Place of occurrence and activity when injured

Hip fractures had mostly occurred indoors in private residences or residential aged care facilities (55% and 32% respectively). Seventy-four percent of people had had a fall from tripping while walking, 16% fell when attempting to get up from a chair. Refer to appendix A2 for more detail.

4.6.2.2 Types of fracture and repair

Table 6: Fracture types – frequencies and percentages

	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Fracture types			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Sub-capital	222 (48.05)	149 (48.06)	73 (48.03)
Basic cervical	26 (05.63)	18 (05.81)	8 (05.26)
Per/inter trochanteric	186 (40.26)	128 (41.29)	58 (38.16)
Sub trochanteric	28 (06.06)	15 (04.84)	13 (08.55)

As shown in table 6 above and in appendix A2, most fractures were either sub-capital or per/inter trochanteric. Short gamma nail (33%) and hemi arthroplasty (30%) were the most employed types of surgical repair (appendix A3).

4.6.2.3 Pain management and ASA scores

All patients (100%) received adequate pain management in the emergency department (femoral nerve block).

The ASA Physical Status Classification System score was recorded pre-operatively. Fifty-six percent of patients were classified as grade three, 20% of patients as grade four, and 18% as grade two. Only 1% of patients were classified as grade one.

4.6.2.4 Time to theatre

Seventy-five percent of patients were operated within 24 hours from admission to the hospital, 94% within 48 hours. General medical issues were the main reason for delays. Surgery times varied, ranging from 76 to 431 minutes total time in suite. Recovery time also varied widely, ranging from 0 to 617 minutes.
Refer to appendix A3 for more detail.

4.6.3 Relevant in-hospital assessed variables – descriptive

Detailed information about in-hospital assessed outcomes can be found in appendix A4.

4.6.3.1 Malnutrition Universal Screening Tool (MUST)

The MUST had been used to screen patients whilst admitted on the ward. It had been recorded for 162 patients of our cohort. Out of these, 67% of patients were not at risk for malnutrition, 16% were at moderate, and 17% at high risk of malnutrition. More women were at high risk of malnutrition compared to men (20% and 11%, respectively).

4.6.3.2 Mobility (post-surgery and day of discharge)

On the first day after surgery, 80% of patents were able to mobilise in some way. However, no one was able to walk independently without an aid, and less than 1% of patients were able to walk independently with an aid. Twenty-eight percent of patients were able to walk under supervision, either with an aid and/or with physical help; 51% were only able to sit out of bed and perform bed exercises.

On their day of discharge, 96% of patients were able to mobilise in some way. Fourteen percent of patients were able to walk independently with or without an aid; 57% of patients were able to walk under supervision, either with an aid and/or physical help; 23% were only able to sit out of bed and perform bed exercises.

4.6.3.3 Osteoporosis - new diagnosis

During their admission, 18% of patients were newly diagnosed with osteoporosis, females and males in similar proportions. Out of these, 66% were commenced on pharmacological

treatment. A higher percentage of newly diagnosed women (71%) was put on medication compared to men (54%).

4.6.3.4 HGS

HGS -2.5 SD below population strength (Dodds et al) was used as a threshold for frailty (≤16kg in females, ≤27kg in males). Since hand dominances were not known, the stronger side was used. As explained previously, HGS had been documented as the best of two for each hand. Eight patients had mechanical issues in at least one hand (arthritis or stroke) which impacted their abilities to perform the HGS test. For three of them (all female), both sides were affected (HGS data unavailable); the remaining five patients were able to perform HGS testing with the unaffected hand (HGS data available). Forty-nine patients (eight males and 41 females) were unable to perform the HGS testing due to severe cognitive impairments. Data of an additional three patients was missing. Therefore, HGS measures were available for 407 patients (265 females, 142 males).

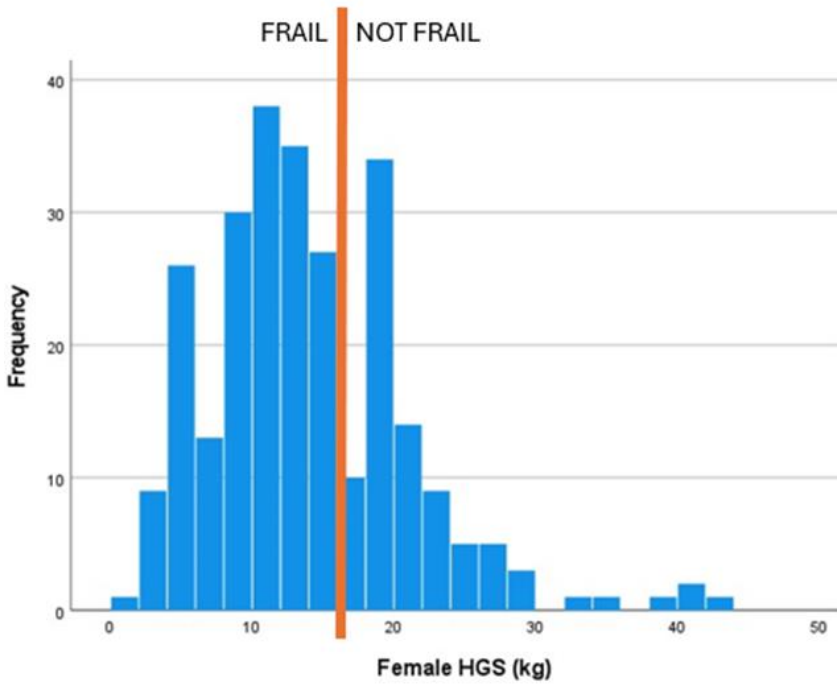

Figure 6: Female hand grip strength in kilograms and frailty cut-off line

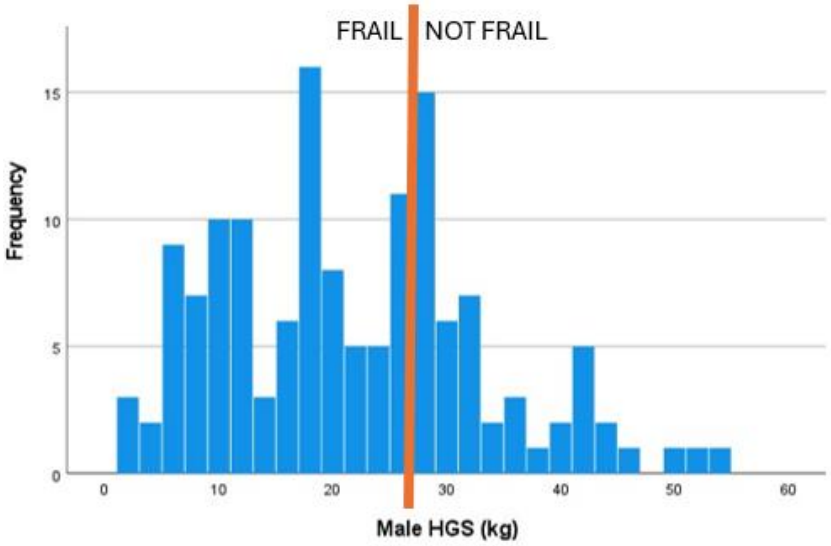

Figure 7: Male hand grip strength in kilograms and frailty cut-off line

Based on HGS cut-off values, a 69% prevalence of frailty overall with no difference between genders.

Figures six and seven show the distribution of HGS for each gender. Females had a mean HGS of 13 kilograms (*SD* = 7), and males 21 kilograms (*SD* = 11). Comparing people that had been living independently (alone or with someone) to patients that needed some level of care (low care setting or RACF) revealed a frailty prevalence of 57% and 91%, respectively.

Seventy-two percent of patients frail based on HGS were also frail based on their EFS scores.

4.6.3.5 EFS

The EFS was assessed as an ordinal variable (intrinsic ranking to reflect levels of frailty), as well as a categorical (not frail: 0 to 7 points; frail: ≥8 points), and a numerical variable. Levels of frailty and associated points are described in the methods.

Data was more complete compared to HGS, EFS recordings were missing for only three patients (one female, two males).

Frailty levels: Out of the total study population, 37% of patients were severely frail, and 28% of patients were not frail. Less patients had scores marking them as vulnerable, mildly frail, or moderately frail (11-12% per group). This was very similar when looking at females

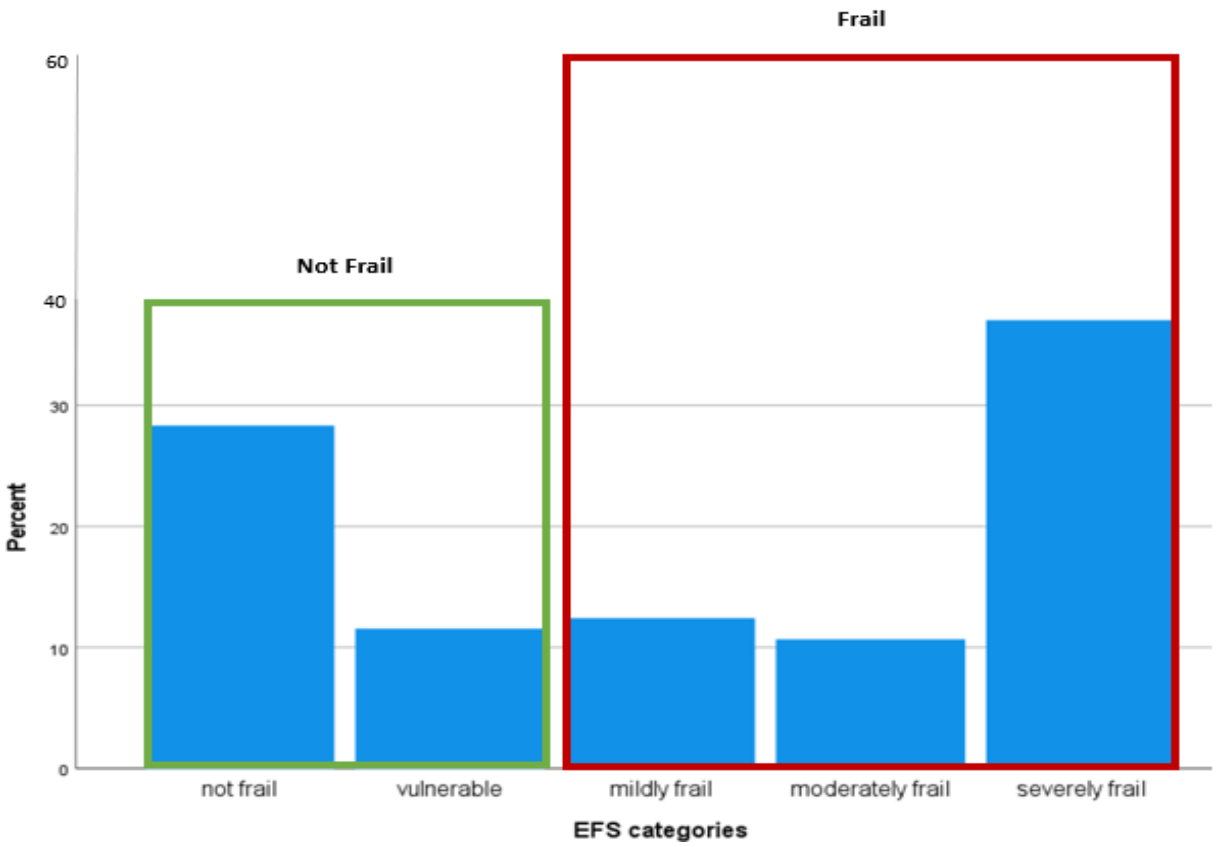

Figure 8: EFS categories and EFS binary frailty definition

only. Within the male population, the 'not frail' group outnumbered the 'severely frail group (32% and 27% respectively), and the other three groups were slightly bigger (12% to 15%), as shown in figure eight and outlined in appendix A4.

Frail (any level) versus not frail (including vulnerable): 60% of patients were frail overall, compared to 63% of females and 53% of males.

Figure nine shows the distribution of EFS points for both genders combined. The mean EFS was nine (*SD* = 4).

Patients that had been living independently (alone or with someone) pre fracture displayed a frailty prevalence of 35%, compared to patients that had been living in a care setting (low care or RACF) where frailty was more common (96%).

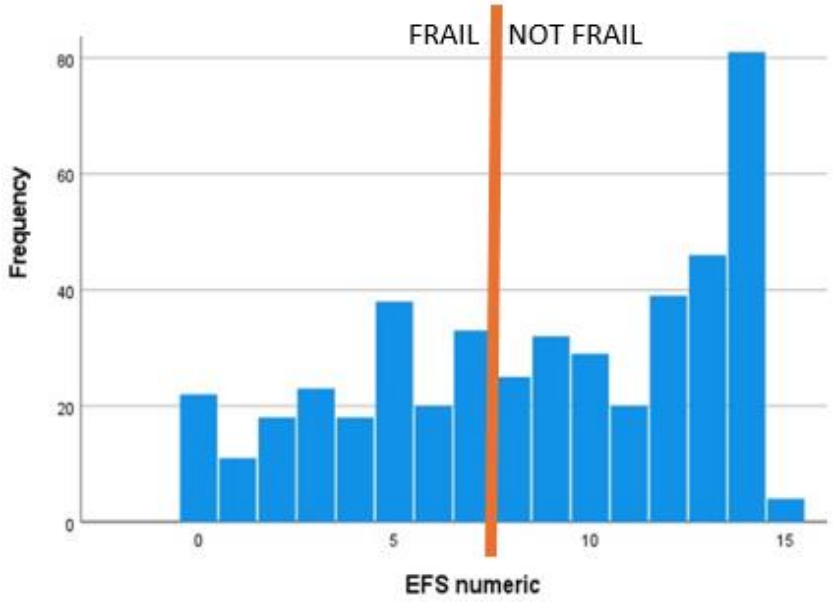

Figure 9: Frequency of each EFS point and frailty cut-off line

Table 7 shows the different EFS categories of patients that had been living independently versus those that had been dependent on some level of care.

Seventy-three percent of patients that were frail according to their EFS scores were also frail as per their HGS.

Table 7: EFS categories of patients that had been living independently versus dependently pre-fracture

	N (%) of valid cases	N (%) of valid cases
EFS categories	**Independent living pre-fracture**	**Dependent living pre-fracture**
Valid cases	*270 (100.0)*	*189 (100.0)*
not frail	127 (47.04)	3 (01.59)
vulnerable	49 (18.15)	4 (02.12)
mildly frail	49 (18.15)	8 (04.23)
moderately frail	30 (11.11)	19 (10.05)
severely frail	15 (05.55)	155 (81.01)

EFS, Edmonton frail scale.

4.6.4 Unplanned events and delirium during acute admission – descriptive

More than half of patients (53%) experienced some form of unplanned event during their hospitalisation, mostly minor to moderate complications. Total in-hospital mortality was three percent. Patients that had been residing at a RACF had the highest in-hospital mortality: six percent compared to two percent of the other three pre-fracture residence groups combined.

Delirium was experienced by 44% of patients during their admission. Different types of delirium had been documented in the notes and are reported in appendix A5.

4.6.5 Discharge destinations following acute hospital admission – descriptive

Ten types of discharge destinations were identified: all four pre-injury residence categories (private home independent alone, private home independent cohabiting, private or institutional home with low dependency, RACF with high dependency); general rehabilitation; geriatric evaluation and management unit (GEM); temporary care placement (TCP); care awaiting placement (CAP); transfer to another hospital; no destination due to in-hospital death.

Table 8: Discharge destinations – frequencies and precentages

	Total N (%) of valid cases
Destination type	
Valid cases	*462 (100.0)*
To private home – independent alone	10 (02.16)
To private home – independent cohabiting	31 (06.71)
To private or institutional home - low dependency	7 (01.51)
To residential aged care facility – high care	148 (32.04)
To rehabilitation unit	169 (36.58)
To geriatric evaluation & management unit	65 (14.07)
To temporary care placement	14 (03.03)
To care awaiting placement	2 (00.43)
To other hospital	3 (00.65)
In-hospital death	13 (02.81)
Direct home discharge (any destination)	183 (39.61)

General in-patient rehabilitation took place at designated rehabilitation hospitals, focusing on functional recovery and strengthening; near-independent mobility and medical wellness were requirements, as limited medical care was available. Services included mainly physiotherapy. GEM units were located within the acute hospital and also aimed to facilitate functional recovery; in addition to physiotherapy, nursing assistance was available. TCP included physiotherapy, nursing support and personal care and was also located within an acute hospital. CAP was a temporary stay in a nursing home, designed for people waiting for a permanent spot; services were less focused on functional recovery and more on nursing and personal care provision.

The main findings are outlined below; table 8 provides an overview of frequencies and percentages per destination. For more detailed information and gender specific data refer to appendix A6.

4.6.5.1 Direct home discharge to pre-injury primary residence

Forty percent of patients were directly discharged to their previous homes.

Seventy-five percent of patients that were able to go home directly had been residing at a RACF prior to their fracture; 91% of patients previously from a RACF were discharged home directly.

Seventeen percent of home discharge patients had been living independently in a private home together with someone else; 20% of patients previously from home with someone were discharged home directly.

Five percent of home discharge patients had been living independently in a private home alone; 9% of patients previously from home alone were discharged home directly.

Lastly, three percent of home discharge patients had been living in a private or institutional home with low dependency; 13% of patients previously receiving low dependency care were discharged home directly.

4.6.5.2 Discharge to private or institutional home - low dependency

Two percent of patients went to a low dependency destination after their acute stay. For 71% of these patients, this was a direct home discharge.

In addition, two women that had been previously living independently alone at private homes were discharged to a home providing low dependency care.

4.6.5.3 Discharge to residential aged care facility – high dependency

Discharge to a RACF was arranged for 32% of the total study population. For almost all of them this was a direct home discharge.

For two percent of patients this was a new destination. Most of them had previously been receiving low dependency care; only one had been living independently alone in a private home.

4.6.5.4 Discharge to rehabilitation

A large proportion (37%) of our study population went to a general rehabilitation unit after their acute hospital stay.

Out of these, 38% of patients had been living independently at home alone (accounting for 56% of this residence category), 53% had been living independently at home with someone (57% of this residence category), 8% had been receiving low dependency care (35% of this residence category); and one person had previously been living in a RACF.

4.6.5.5 Discharge to a temporary care placement

Only three percent of our study population was sent to TCP. Out of these, 36% of patients had been living independently at home alone, 28% had been living independently at home with someone, and 36% had been receiving low dependency care.

4.6.5.6 Discharge to geriatric evaluation & management unit

Fourteen percent of our study population were transferred to a GEM unit after their acute hospital stay.

Out of these, 46% of patients had been living independently at home alone (accounting for 26% of this residence category), 42% had been living independently at home with someone (17% of this residence category), 8% had been receiving low dependency care (13% of this residence category); and 5% had previously been living in a RACF (2% of this residential category).

4.6.5.7 Discharge to care awaiting placement and hospital transfer

Two patients were transferred to CAP, one previously from home alone, the other from a low dependency care home.

Three patients were transferred to another hospital, one previously from home alone, the other from home with someone.

4.6.5.8 Discharge destinations based on pre-injury primary residences

Figures 10 and 11 below outline the journeys of patients that were living independently pre-injury, alone and with someone. Where applicable, secondary discharge destination and permanent change of primary residence was stated.

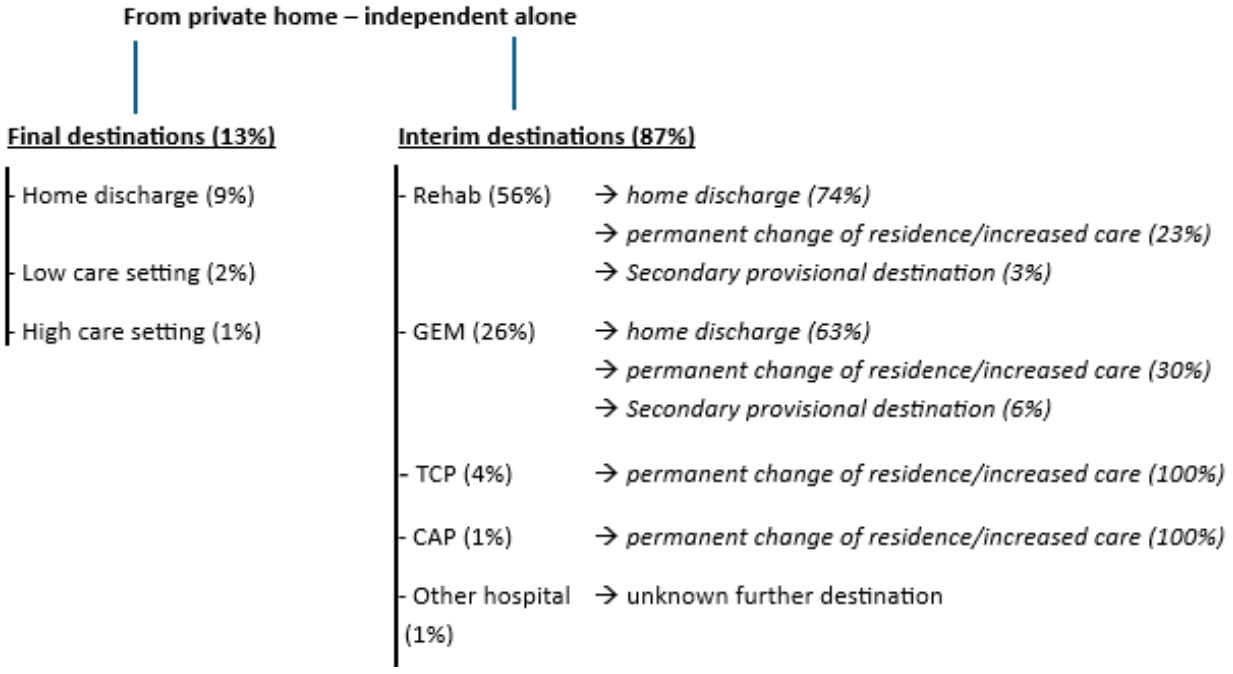

Figure 10: Discharge destinations for people that had been living independently alone

4.6.6 Post discharge – descriptive

4.6.6.1 Re-admissions and post discharge mortality

Re-admissions within three months after discharge from acute hospital stay were low: 4.1% of patients were re-admitted in relation to their fracture; 9.3% were re-admitted for other reasons.

Three-months mortality was higher in males (16%) compared to females (11%) and overall (13%). About 26% of patients passed away within 12 months from their hip fracture.

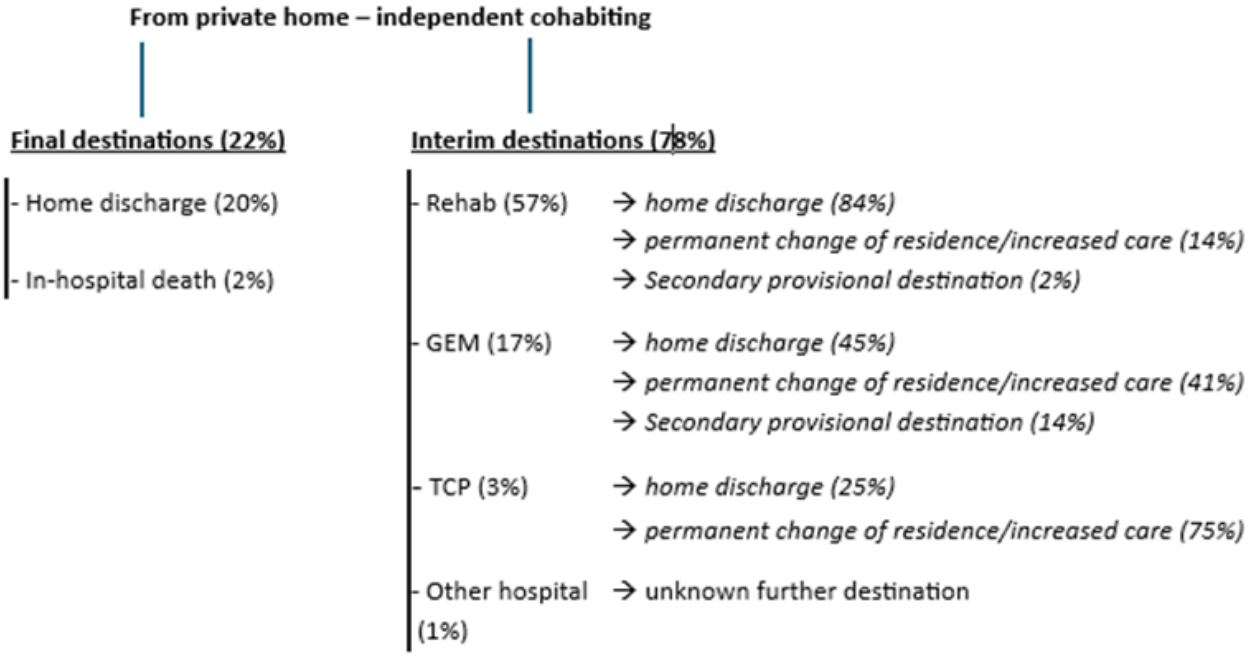

Figure 11: Discharge destinations for people that had been living independently cohabiting

4.6.6.2 Secondary discharge destinations

Figures 10 to 13 as well as appendices A7 and A8 provide information about secondary discharge destinations. Essentially, patients were either able to return to their pre-injury home, or required increased care provided in a new primary residence. Patents that could not be placed in a new higher-care residence in a timely manner required additional time at a different provisional destination.

4.6.6.3 Permanent changes of primary residence

Twenty-three percent of patients had to undergo a permanent change of primary residence due to increased needs and decreased independence as a result of sustaining the hip fracture. This was true for 21% of the female population, and 25% of the male population. Change of residence either occurred directly after discharge from acute hospital stay (23%), or after spending time at an interim destination (77%). Figure 14 outlines the pre-injury residence type of patients what had to move into a new home post-fracture. People with a higher independence level pre-fracture were more affected in not returning to their pre-injury residence. See appendices A7, A8 and A9 for more detail.

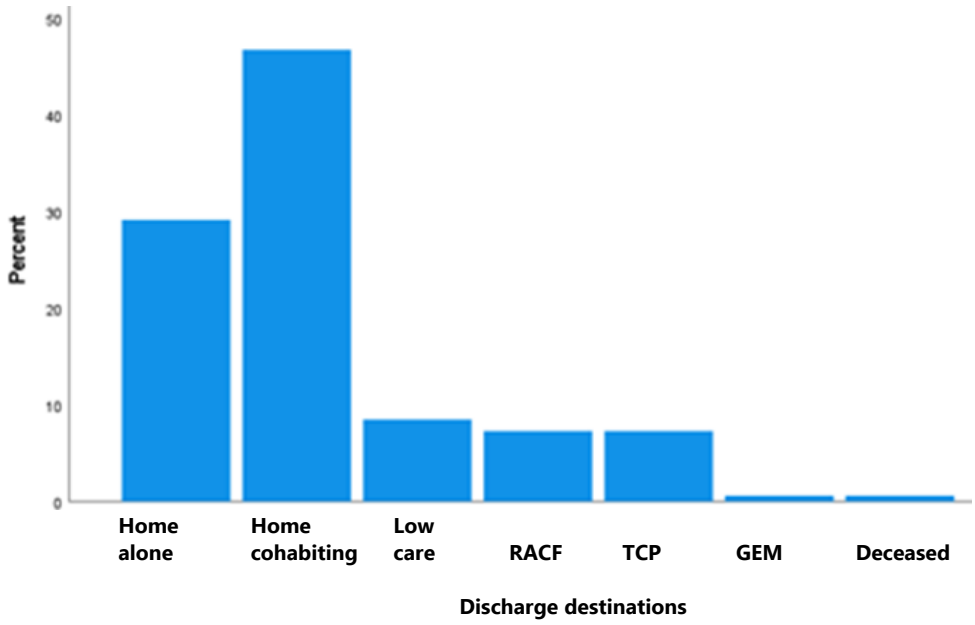

Figure 12: Secondary discharge destinations following general rehabilitation

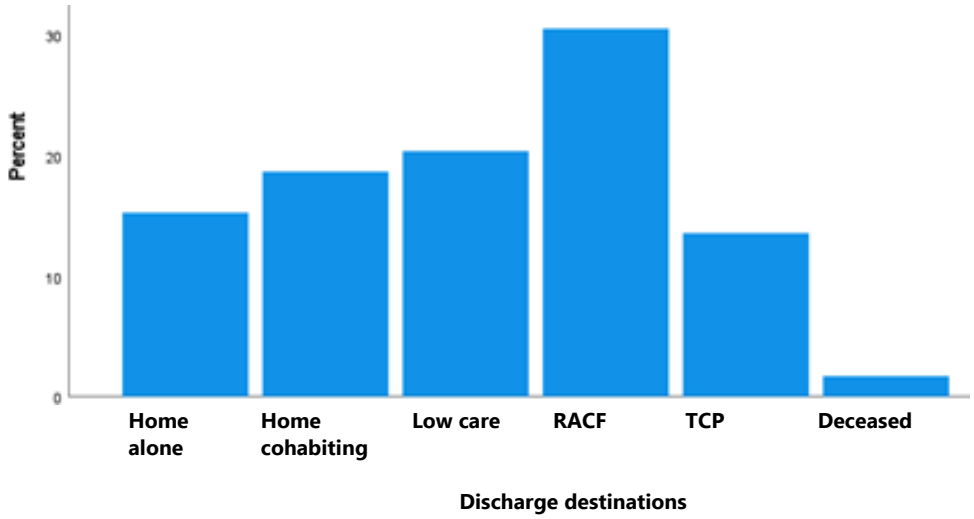

Figure 13: Secondary discharge destinations following geriatric evaluation and management

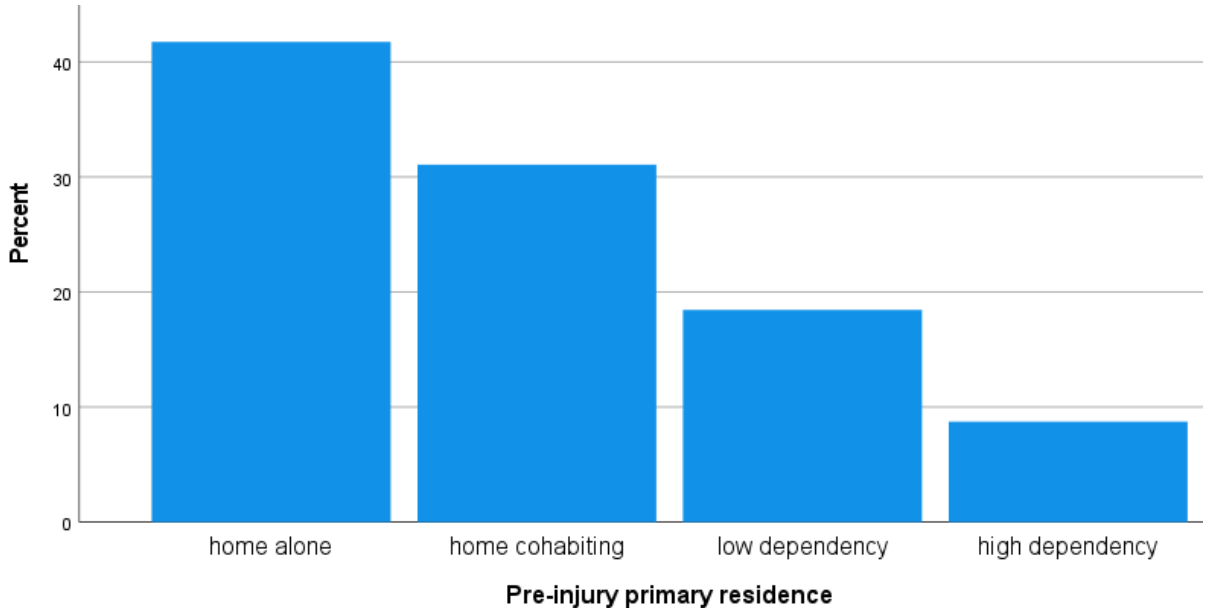

Figure 14: Pre-injury residence type of patients that permanently changed their primary residence

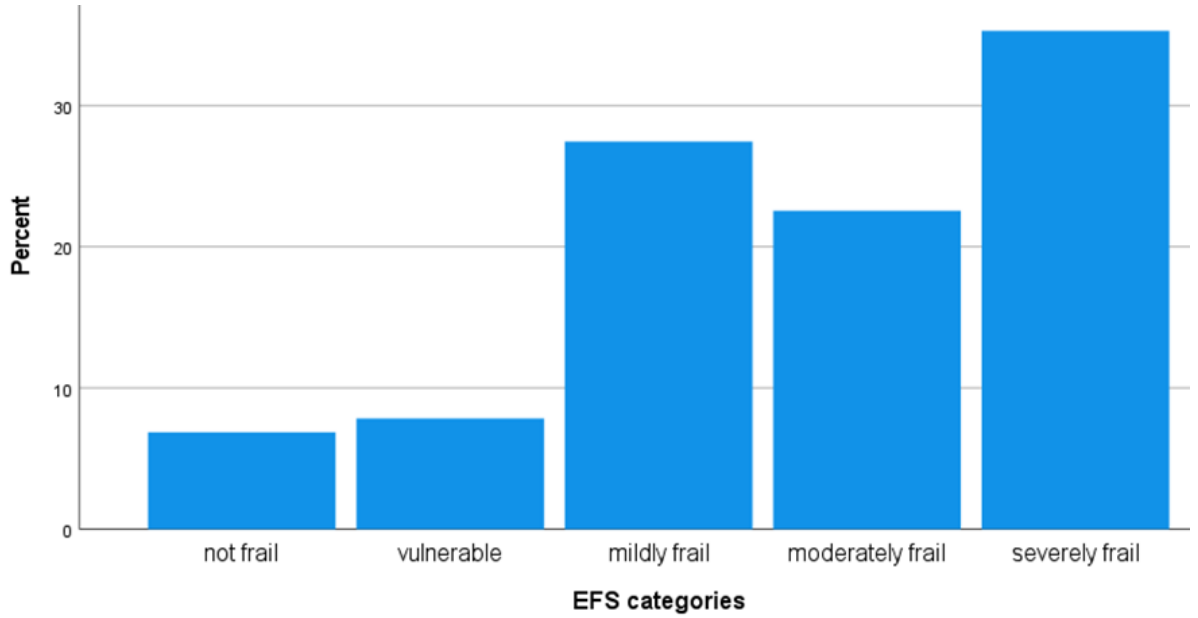

Figure 15: Distribution of EFS categories amongst patients that permanently changed their primary residences

EFS categories of patients that had to move into a new home are shown in figure 15. Exclusion of patients that had been living in a RACF pre-fracture did not make a marked difference.

Figures 16 and 17 show EFS categories of patients that were able to return to their pre-injury homes at some stage post-fracture. Figure 17 was created excluding data from patients that had been living in RACFs pre-fracture, drastically reducing the percentage of severely frail patients.

Frailty defined by EFS was present in 85% of patients what underwent a permanent change of primary residence post-fracture. In contrast, 53% of patients returning to their pre-injury homes were frail by the same definition.

HGS measures also showed a high prevalence of frailty (92%) amongst patients that changed their residence. In contrast, HGS suggested frailty in 61% of patient that were able to return to their pre-injury homes.

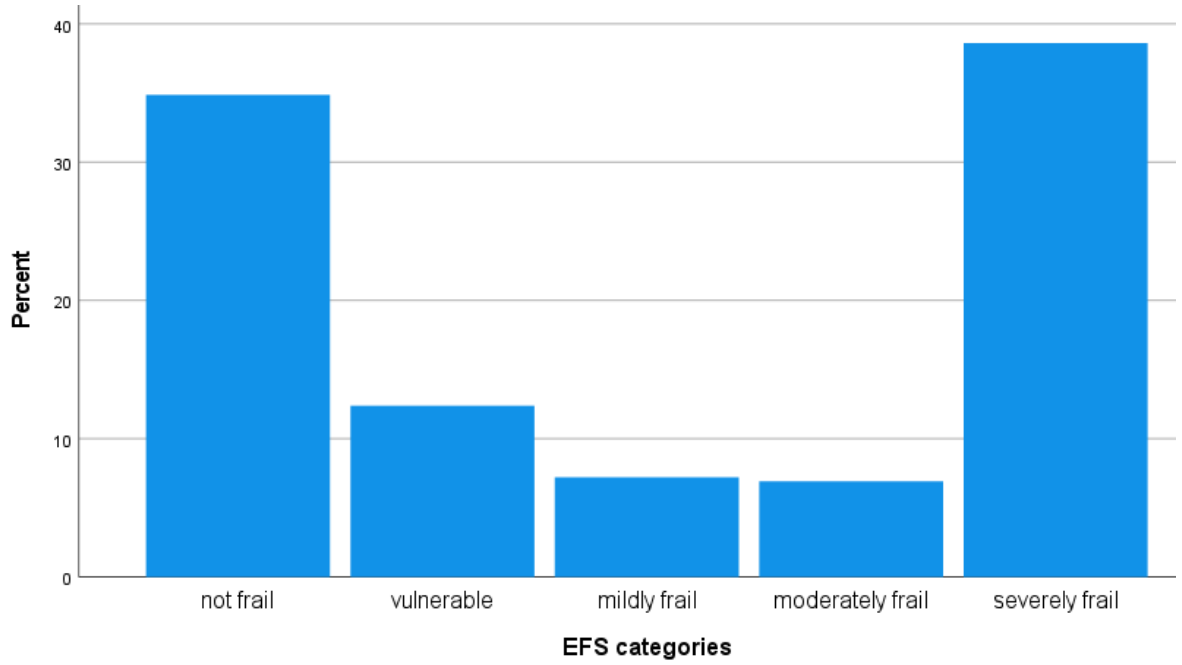

Figure 16: EFS categories amongst patients that were able to return to their pre-injury homes – full cohort

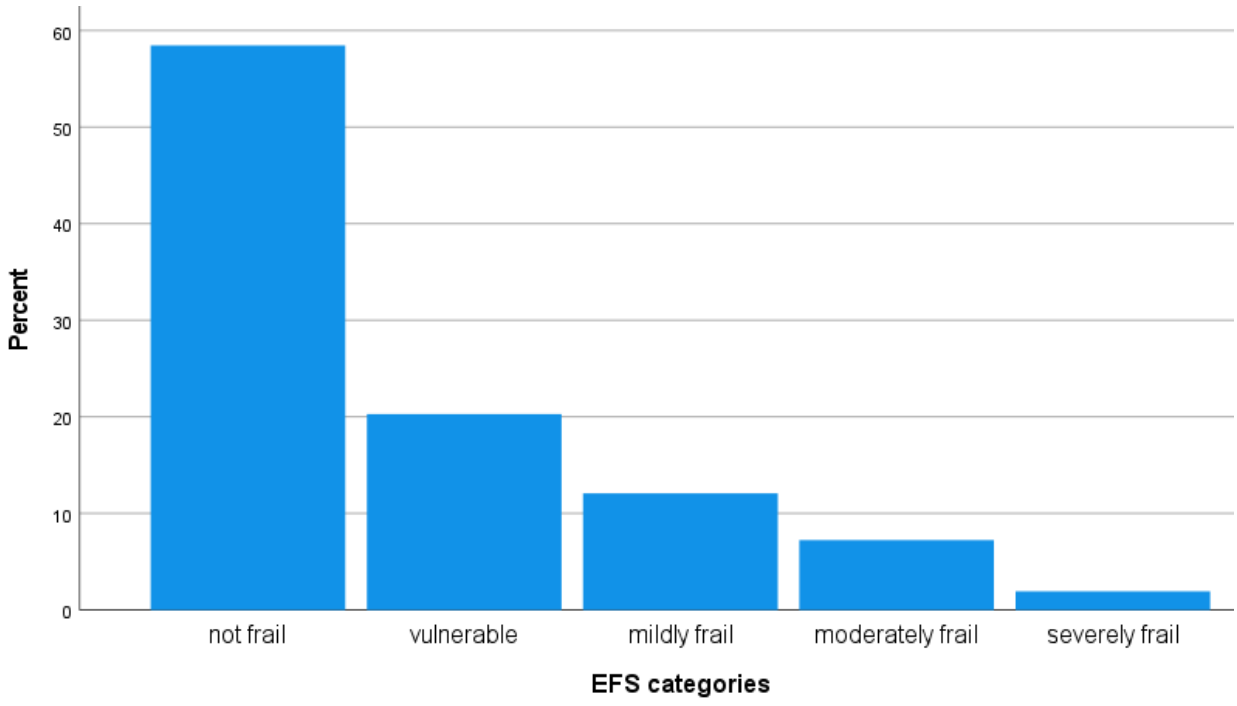

Figure 17: EFS categories amongst patients that were able to return to their pre-injury homes - excluding patient that had been living in a residential aged care facility pre-fracture

4.6.7 Findings regarding primary objectives

4.6.7.1 Objective 1: The prevalence of frailty

One-sample binominal tests confirmed that significantly (p <.001) more patients of our cohort were frail compared to not frail, defined by HGS (≤16kg / ≤27kg) as well as EFS (≥8 points). This was based on a pre-specified proportion assumption of .5, with a success value of 1 (frail). See table 9 below.

Table 9: 2-sided confidence intervals (CI) for a proportion in one sample (Clopper-Pearson)

Type of frailty measure	Proportion estimate	95% CI – lower	95% CI – higher
HGS	.690	.643	.735
EFS	.601	.555	.646

4.6.7.2 Objective 2: The relationship between HGS and EFS

The relationship between HGS and the EFS was explored in two ways, correlation and regression: (Schober et al. 2018)

1. Correlation: Both the HGS and the EFS variable were non-normally distributed, hence the assumptions for a Pearson's correlation were not fulfilled. A Spearman's rank correlation was used instead. A significant and strong negative relationship was found (p<.001 [2-tailed]; correlation coefficient -.69 [95% CI: lower -.766; upper -.642]).
2. Regression: Linear regression demonstrated a significant negative relationship between HGS and EFS, irrespective of which frailty measure was assumed as the predictor variable (p<.001 [2-tailed]). The coefficient of determination (R^2) suggested that 39% of variance in the respective dependent variable can be explained by the corresponding independent variable. This proposed a moderate dependency, as visualised via a scatter plot and linear fit line in figure 18.

Lastly, the similarity index between the two frailty outcomes was calculated to be 73%.

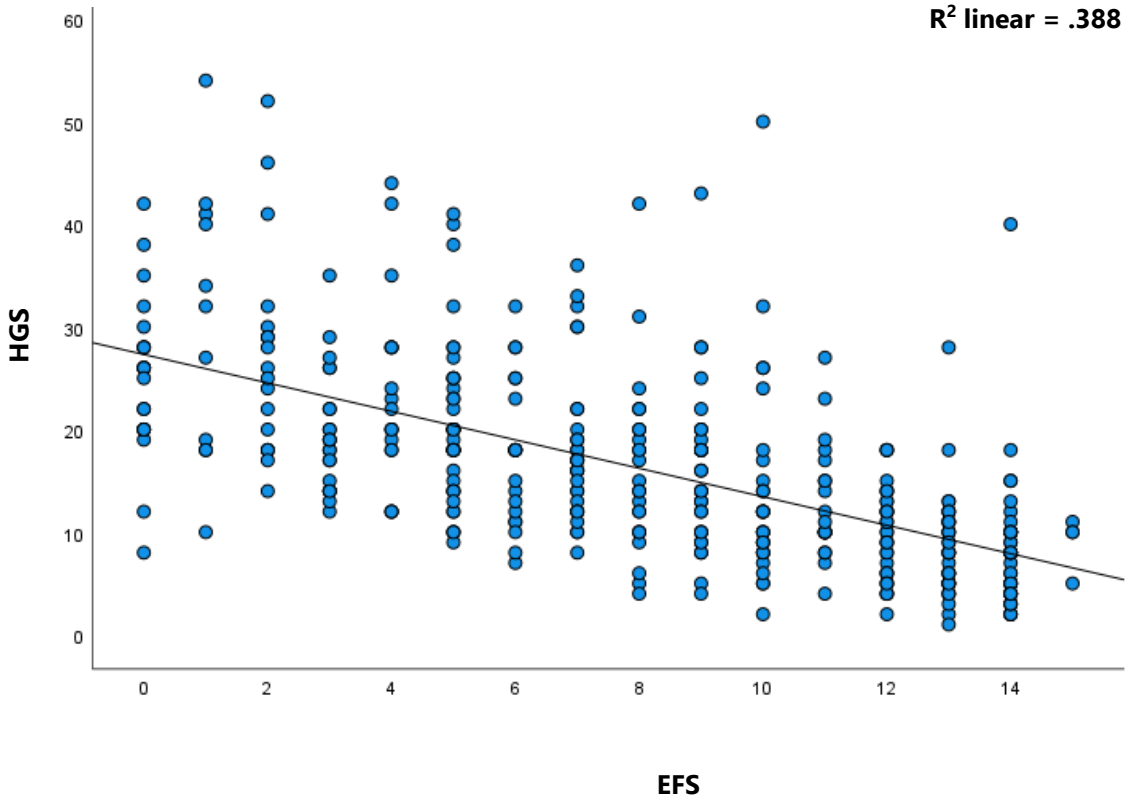

Figure 18: Association between HGS and EFS

4.6.7.3 Objective 3: Frailty as an outcome indicator

Outcomes assessed in this section are: a) length of hospital stay; b) mobility status at discharge; c) discharge destinations following acute hospitalisation; d) secondary discharge destinations following short term placements; e) permanent change of primary residence post fracture; f) mortality.

Tables 11 and 12 at the end of chapter 4.6.7.3 outlines the main findings for objective 3.

A: Frailty & length of hospital stay

LOS had been recorded in days (continuous variable). For analyses, an additional binary variable was created (short stays ≤12 days, and prolonged stays >12 days, as per local definition).

HMLR was conducted to establish the impact of frailty (EFS and HGS as continuous predictor variables) on prolonged LOS (continuous outcome variable).

Heteroscedasticity was detected for both HGS and EFS models (see appendix B1), resulting in loss of validity and reliability of the results. All other assumptions were fulfilled.

A three-step hierarchical approach was employed to control for the following confounding variables: age; residing at a RACF pre-injury; ASA grade; type of fracture; type of fracture repair.

In step one, age and residing at a RACF pre-injury were entered as predictors (model one). In step two, ASA grade, type of fracture, and type of fracture repair were added (model two). EFS (or HGS) was entered in a final step (model three).

The first HMLR was focused on EFS as the final predictor variable.

Model one significantly but not strongly predicted LOS (adj. R^2

= .086, F = 21.310, p <.001). Residing at a RACF pre-injury emerged as a significant (p <.001) negative predictor with weak strength (β = -.324).

Model two continued to significantly but not strongly predicted LOS (adj. R^2 = .137, F = 14.727, p <.001). Residing at a RACF pre-injury remained as a significant (p <.001) negative predictor with moderate strength (β = -.371); ASA grade emerged as another significant (p <.001) predictor with weak strength (β = .249).

Model three persisted to significantly predicted LOS (F = 22.347, p <.001), with now weak-to-moderate strength (adj. R^2 = .228). Residing at a RACF pre-injury remained as a significant (p <.001) and now moderately strong (β = -.636) negative predictor. ASA grade lost significance and power in this model. EFS emerged as significant, moderately strong predictor (β = .513, p <.001).

Overall, there was a significant rise in R^2 from model one to model two, and from model two to model three, suggesting increase in predictive power with each model.
Type of fracture and repair were not significantly associated with LOS in these models. Age was significant (p <.005) in model one only.

Refer to appendix B2 for more information.

A second HMLR was performed focusing on HGS. All three models significantly (p <.001) but not strongly predicted LOS. Adjusted R^2 ranged from .064 to .152, with a significant (p <.001) rise in R^2 with each model. As for individual variables, residing at a RACF pre-injury emerged and remained as a weak-to-moderate strength (β = -.278, β = -.310, β = -.378) significant (p <.001) negative predictor through all three models. Similarly, ASA grade emerged and remained as a significant (p <.001) but weak (β = .258, β = 231) predictor in models two and three. When entered in model three, HGS presented as a weak (β = -.221) significant (p <.001) negative predictor.

Age, type of fracture, and fracture repair type were not significantly associated with LOS. Refer to appendix B3 for more information.

HMLRs were also preformed entering the binary predictor variables for both EFS and HGS in model three. These tables can be found in appendices B4 and B5. Both times, all models significantly (p <.001) but not strongly predicted LOS. Residing at a RACF pre-injury remained a significant weak-to-moderate predictor throughout all models; ASA grade also was significant, but weak regarding its predictive power through the models. Age was significant in model one only. Frailty, defined by EFS as well as by HGS, was shown to be a significant but weak predictor for length of stay (β = .316, p <.001 and β = .214, p <.001 respectively).

Two HMBLR were performed to establish the impact of frailty (binary predictor variable) on prolonged hospital stay (binary outcome variable) after controlling for the following confounding variables: age; residing at a RACF pre-injury; ASA grade; type of fracture; type of fracture repair. A three-step hierarchical approach was employed.

All assumptions for HMBLR were fulfilled.

In step one, age and residing at a RACF pre-injury were entered as predictors (block one). In step two, ASA grade, type of fracture, and type of fracture repair were added (block two). EFS (or HGS) was entered in a final step (block three).

The first HMBLR was performed using EFS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Nagelkereke R^2, Horsmer and Lemeshow Test, and 2-log likelihood (refer to appendix B6).

The overall classification accuracy was high but did not significantly improve with each block.

Residing at a RACF pre-injury was, like in the HMLRs above, significantly associated with LOS (p <.05 in block one, and p <.001 in blocks two and three), with ORs of .297 in block one, .223 in block two, and .160 in block three. ASA grade was significant (p <.05) in block two only, with an OR of 1.929; none of the other variables entered were significantly associated with LOS. Frailty defined by EFS was entered in block three; it was significant (p = .001), with an OR of 3.684.

The second HBLR was performed using HGS as a binary predictor variable (frail or not-frail).

The model fit remained good and improved with each block. The overall classification accuracy also remained high without improving much with each block (refer to appendix B7).

Yet again, residing at a RACF pre-injury was significantly associated with LOS (p <.05 in blocks one, two and three), with ORs of .408 in block one, .341 in block two, and .312 in block three. ASA grade was significant (p <.05) in block two and three with ORs of 1.947 and 1.672; none of the other variables entered were significantly associated with LOS. HGS was entered in block three, presenting as significant (p <.05) with an OR of 2.621.

The above HMLRs and HBLRs were repeated after using the stratification method to adjust for residing at a RACF pre-injury: only patients that had NOT been residing at a RACF pre-fracture were included in the models. This did however not improve the predictive power of frailty while creating a loss of statistical power (decreased numbers of included patients). Numbers or tables were therefore not included in this thesis.

LOS/prolonged hospital stay was also assessed in relation to both frailty types (continuous and binary) in simple unadjusted regression models (appendices B8 to B13).

Simple linear regressions were performed: EFS (continuous) and LOS (continuous) were not significantly associated; EFS (binary) and LOS (continuous) had a significant (p <.05) weak (β = -.113; R^2=.013) association. HGS (continuous) and LOS (continuous) had a significant (p <.05) weak (β = -.122; R^2 = .015) negative association; HGS (binary) and LOS (continuous) had a significant (p <.001) weak (β = -.178; R^2 = .032) association.

Simple logistic regressions were performed: Both EFS and HGS were significantly (p <.05) associated with prolonged hospital stay (ORs of 2.067 and 2.545 respectively). Overall classification accuracy was 87% in both models.

Additional simple logistic regressions were performed for all EFS categories individually (dummy variables) in relation to prolonged hospital stay (appendices B14 to B18).

Severe and mild frailty as well as vulnerability were not significantly associate with prolonged hospital stay. Moderate frailty was significantly (p <.05) associated with prolonged stay, with an OR of 1.466. NOT being frail was significantly (p <.05) negatively associated with prolonged stay, with an OR of .249.

B: Frailty & mobility status at discharge

Discharge mobility status (DMS) was converted from a multinominal variable into a binary variable (independently mobile with or without an aid, versus dependent on personal assistance with mobility or immobile). This was done as the multinominal variable created too many categories for meaningful analyses.

Two HBLR were performed to establish the impact of frailty (binary predictor variable) on patients' DMS (binary outcome variable; event assessed: not being independently mobile) after controlling for age, pre-injury mobility, and ASA grade. Predictors were added employing a three-step hierarchical approach.

All assumptions for HBLR were fulfilled.

The first HBLR was performed using EFS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Nagelkereke R^2, Horsmer and Lemeshow Test, and 2-log likelihood.

The overall classification accuracy was 87% but did not significantly improve with each block.

Age at the time of injury was significantly (p <.001) associated with DMS in all three blocks, with ORs consistently just over one. Pre-injury mobility status was significantly (p >.001) associated with DMS in blocks one and two, but not three; ORs were larger than for age, 5.505 in block one and 4.780 in block two. ASA grade was not significantly associated with DMS. Frailty measured by EFS was entered in block three; it was significant (p <.001), with a large OR of 12.884.
Refer to appendix C1 for more details.

The second HBLR was performed using HGS as a binary predictor variable (frail or not-frail).

Variables were entered as above. The model fit was good based on the same criteria as above.

Age at the time of injury behaved in much the same way as in the previous model. Pre-injury mobility status was significantly associated with DMS in all three blocks, but gradually decreasing in strength. ASA grade was not significantly associated with DMS.

Frailty measured by HGS was entered in block three; it was significant (p <.001), with an OR of 3.745.
Refer to appendix B2 for more detail.

Simple logistic regressions were carried out for EFS and HGS as well as the individual EFS categories.

EFS emerged as a very strong significant (p <.001) predictor with an OR of 34.587; HGS was also significantly (p <.001) associated with DMS, but not quite as strongly with an OR of 9.882 (appendices C3 and C4).

Severe frailty was significantly (p <.001) and very strongly associated with DMS, with an OR of 48.031. Moderate and mild frailty were significant (p <.05) with ORs of 9.043 and 5.207, respectively. Vulnerability was not associated with DMS, and NOT being frail was significantly (p <.001) negatively associated with DMS, the OR of .053 was however small. Tables can be found as appendices C5, C6, C7, C8, and C9.

C: Frailty & discharge destinations following acute hospitalisation

Discharge destinations were converted from a multinominal variable into binary (dummy) variables and assessed individually. An additional variable had been created to assess direct home discharge.

Home discharge

The influence of frailty on direct home discharge was assessed using HBLR, as well as simple logistic regression.

As described previously, almost all the 150 patients that had been residing at a RACF pre-fracture were frail when tested on the ward (99.3% from EFS, and 95.1% from HGS). All but 13 (nine deceased, four went for rehabilitation) went back to their pre-injury home directly after acute hospitalisation. It was therefore considered to control for residing at a RACF pre-fracture by elimination. After experimenting with different models, no benefit was found, hence it was decided against elimination to avoid loss of statistical power.

Within the hierarchical model, it was controlled for age, residing at a RACF pre-fracture, and DMS. Controlling for ASA grade and LOS was also tested, but neither were significant, nor did they add anything to improve the model. Predictors were added employing a two-step hierarchical approach, adding all confounders to the first block and frailty to the second.

All assumptions for HBLR were fulfilled.

The first HBLR assessed frailty via the EFS. Model fit was good but did not improve much with each block, based on Nagelkereke R^2, Horsmer and Lemeshow Test, and 2-log likelihood. The overall classification accuracy was high, again without improving much from block one to block two.

Age at the time of injury was significantly (p = .001 and p = .002) associated with home discharge in both blocks, with ORs just under one. Not surprisingly, residing at a RACF pre-fracture was a significant (p >.001) predictor in both blocks with very large ORs of 846.845 and 1017.067. DMS was also significantly (p >.001) associated with home discharge in both blocks with ORs of 32.398 and 28.934. Frailty measured by EFS was entered in block two; it was non-significant (appendix D1).

The same HBLR was repeated for HGS. Model fit remained good and overall classification accuracy was high.

Results were very similar to the above assessment for EFS. Age, residing at a RACF pre-fracture, and DMS were significantly associated with home discharge, with similar ORs to the ones above. Frailty, now represented by HGS, was not significantly related to home discharge (appendix D2).

Simple logistic regressions were also performed, looking at the binary EFS and HGS variables, using the whole data set, and also a restricted data set excluding patients that had been living in RACFs pre-injury.

Using EFS as a binary variable, the overall clarification accuracy was only 61%. Being frail was significantly (p <.001) associated with home discharge (OR 3.303). Not being frail was significantly (p <.001) negatively associated with home discharge (OR .303). The regression table can be found as appendix D3.

The regression was repeated excluding patients that had been living in RACFs pre-fracture. Overall classification accuracy was 85%. Not surprisingly, positive and negative associations turned around: Being frail was negatively (p >.001; OR .108), and not being frail was positively (p <.001; OR 9.300) associated with home discharge (appendix D4).

Using HGS as a binary variable, the overall clarification accuracy was only 65%. Being frail (or not frail) was not significantly associated with home discharge (appendix D5).

Again, the regression was repeated excluding patients from RACFs. Being frail was negatively (p >.001; OR .157), and not being frail was positively (p <.001; OR 6.364) associated with home discharge (appendix D6).

Individual EFS categories were also assessed in simple linear regressions.

Overall classification accuracies were low at 60% for all five categories. Severe frailty was significantly associated with direct home discharge (p <.001; OR 13.132); moderate frailty had a negative association with home discharge (p <.05; OR .309). Mild frailty and vulnerability were negatively significant at a .001 level with ORs of .045 and .105. Not being frail also showed a negative association (p <.05) with an OR of .560 (appendices D7 to D11).

An additional simple linear regression was carried out to assess the relationship between direct home discharge and discharge mobility status for people NOT from a RACF. The overall classification accuracy was high (90%). Being independently mobile (with or without a walking aid) was significantly (p<.001) associated with the ability to return home after the acute hospital stay; the OR was 64.

Discharge to general rehabilitation

Discharge to general rehabilitation was investigated performing HBLR.

Within the hierarchical model, it was controlled for age, residing at a RACF pre-fracture, and DMS. Predictors were added employing a two-step hierarchical approach, adding all confounders to the first block and frailty to the second.

All assumptions for HBLR were fulfilled.

The first HBLR was performed using EFS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Nagelkereke R^2 and 2-log likelihood. The Horsmer and Lemeshow Test was significant on a .5 level, which is less desirable; overall classification accuracy was 75% in block one and increased to 81% in block two.

Age at the time of injury was negatively associated with discharge to rehabilitation in block one only (p = .018; OR .969). Residing at a RACF pre-injury showed a significant (p >.001) association in blocks one and two, with small ORs (.005 and .011). DMS (being independently mobile with or without aid) was significantly (p <.001) associated with discharge to rehabilitation in both blocks, with ORs of .5.382 and 14.304 respectively. Frailty measured by EFS was entered in block two; it was significant (p <.001), being frail showing a negative association (OR .110), and being NOT frail showing a positive association (OR 9.051).

Refer to appendix D12 for more details.

The same HBLR was performed using HGS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Horsmer and Lemeshow Test, Nagelkereke R^2 and 2-log likelihood. Overall classification accuracy was 86% in both blocks.

As in the EFS model above, age at the time of injury was negatively associated with discharge to rehabilitation in block one only (p = .035; OR .973). Residing at a RACF pre-fracture showed a significantly association in blocks one and two (p <.001), with small ORs of .007 and .008. DMS (being dependent with mobility) was significantly (p <.001) associated with discharge to rehabilitation in block one and two, with ORs of 5.267 and 9.234. Frailty measured by HGS was entered in block two; it showed a significant (p <.001) association with discharge to rehabilitation. Being frail was negatively associated with an OR of .264, being NOT frail was positively associated with an OR of 3.783

Refer to appendix D13 for more details.

Simple logistic regressions were carried out for the same predictor and outcome as above. Being frail defined by EFS was negatively associated with discharge to rehabilitation (p <.001; OR .108), while NOT being frail was positively associated (p <.001; OR 9.270). Being frail defined by HGS was also associated with discharge to rehabilitation, with a comparatively smaller OR for NOT frail (3.251). Refer to appendices D14 and D15 for more details.

Additional simple logistic regressions were carried out using individual EFS categories as predictor variables.

Discharge to a general rehabilitation unit was negatively associated with severe frailty (p >.001; OR .034) and no significant association was found with moderate frailty. Mild frailty was positively associated with discharge to rehabilitation (p = .018; OR 1.960). Vulnerability and NOT being frail both showed significant (p <.001) positive associations with ORs of 5.376 and 5.051, respectively. Refer to appendices D16 to D20 for more details.

Discharge to GEM

Discharge to GEM was investigated in the same way as discharge to rehabilitation, performing HBLR using a two-step approach, controlling for the same factors. EFS was assessed first.

All assumptions for HBLR were fulfilled, the model fit was good and improved with each block, based on 2-log likelihood. The Horsmer and Lemeshow Test was significant on a 0.5 level, and the Nagelkereke R2 decreased in block two, which is less desirable; overall classification accuracy was 86% in both blocks.

Age at the time of injury was associated with discharge to GEM in block one only (p = .005; OR 1.051). Residing at a RACF pre-injury showed a significant (p >.001) association in blocks one and two, with small ORs (.048 and .031). DMS (being independently mobile with or without aid) was significantly (p = .025) associated with discharge to GEM in block one only (OR 4.112). Frailty measured by EFS was entered in block two. Being frail was significantly (p <.001) associated with discharge to GEM (OR 3.971.)

Refer to appendix D21 for more details.

The same HBLR was repeated for HGS.

The model fit was good and improved with each block, based on Horsmer and Lemeshow Test, Nagelkereke R2 and 2-log likelihood. Overall classification accuracy was 85% in both blocks.

Age at the time of injury was associated with discharge to GEM in both blocks (block 1: p = .002, OR .973; block 2: p = .026, OR 1.043). Residing at a RACF pre-fracture showed a significantly negative association in blocks one and two (p <.001), with small ORs of .007 and .018. DMS (being dependent with mobility) was significantly (p <.001) associated with discharge to rehabilitation in block one (p = .030, OR 5.267), but not in block two. Frailty measured by HGS was entered in block two; it showed a significant (p <.001) association with discharge to GEM, with an OR of 3.600.

Refer to appendix D22 for more details.

Simple logistic regressions were carried out for the same predictor and outcome as above. Frailty was associated with discharge to GEM, EFS with an OR of 2.253 (p = .008), HGS with an OR of 3.554 (p = .001). Refer to appendices D23 and D24 for more details.

Additional simple logistic regressions were carried out using individual EFS categories as predictor variables.

Discharge to GEM was negatively associated with severe frailty (p <.001; OR .269). Moderate and mild frailty were positively associated with discharge to GEM (p <.001; ORs 13.602 and 5.847). Vulnerability was not significantly associated with discharge to GEM. NOT being frail showed significant (p <.001) negative associations with an OR of .224. Refer to appendices D25 to D29 for more details.

Discharge to a provisional setting

Discharge to a provisional destination (including TCP and CAP) was assessed for associations performing HBLR.

Within the hierarchical model, it was continued to control for age, residing at a RACF pre-fracture, and DMS. Predictors were added employing a two-step hierarchical approach, adding all confounders to the first block and frailty to the second.

All assumptions for HBLR were fulfilled.

The first HBLR was performed using EFS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on the Horsmer and Lemeshow Test, Nagelkereke R^2 and 2-log likelihood. Overall classification accuracy was 96% in both blocks.

Age at the time of injury was significantly (p <.05) associated with discharge to a provisional destination (block one: OR 1.119; block two: OR .995). Residing at a RACF pre-fracture was not significantly associated with discharge to a provisional destination. DMS was not significant in block one, but in block two (p <.05) with an OR of 17.206. Frailty

measured by EFS was entered in block two; it was significantly associated with discharge to a provisional destination (p <.001), with a large OR of 58.060.

Refer to appendix D30 for more details.

The same HBLR was performed using HGS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Horsmer and Lemeshow Test, Nagelkereke R^2 and 2-log likelihood. Overall classification accuracy was 97% in both blocks.

Only age at the time of injury showed a significantly association with discharge to a provisional destination in both blocks (p <.05; ORs 1.128 and 1.117). None of the other variables, including HGS, were significant.

Refer to appendix D31 for more details.

Simple linear regressions were carried out for discharge to a provisional destination and both EFS and HGS.

Frail as defined by EFS was significantly (p <.05) associated (OR 3.056) with provisional destination, while HGS was not (appendices D32 and D33).

Individual EFS categories were not assessed due to the low number of patients (n = 16) that were discharged to provisional destinations.

D: Frailty & secondary discharge destinations following short term placements

Secondary discharge destinations following short-term placements at a general rehabilitation unit, a GEM unit, or a provisional destination were: pre-injury homes; new permanent primary residences (advancing to higher care); and further stays at provisional destinations (awaiting placements at higher care settings).

No regression analyses were performed for the group of patients whose primary discharge destination was to a provisional destination. This was due to low numbers (n = 16). All these patients were deemed frail as per post-operative assessments. Their secondary discharge destinations were pre-injury homes (n = 3) and new permanent primary residences providing higher care (n = 13).

Out of 103 patients that permanently changed their primary residence post fracture, only 13 patients were moved to their new homes directly after acute hospitalisation. For the majority, the move happened after a short-term placement. Please refer to the next section (E: Frailty & permanent change of primary residence post fracture) for analyses including all 103 patients, irrespective of pre-injury residence, primary and secondary discharge destination.

In this section, assessments of the relationship between frailty and a) permanent change of primary residence (including 13 patients discharged to another provisional destination) and b) secondary home discharge were presented. This was done separately for patients following rehabilitation and patents following GEM.

Since patients either returned to their pre-injury homes or to a new home, regressions yielded much the same results for both destinations. Only result tables for discharge to a new home were therefore presented in appendix E.

Within the hierarchical models, it was controlled for age and ASA grade. Predictors were added employing a two-step hierarchical approach, adding all confounders to the first block and frailty to the second. All assumptions for HBLR were fulfilled.

Discharge following general rehabilitation

Discharge to a new permanent primary residence was investigated first.

HBLR was performed using EFS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Horsmer and Lemeshow Test, Nagelkereke R2 and 2-log likelihood. Overall classification accuracy only changed from 82% in block one to 83% in block two.

Both age at the time of injury and ASA grade showed a significant association with discharge to a new permanent residence only in block one (p<.05; ORs 1.056 and 2.427, respectively). In block two, EFS was entered and emerged as the sole significant predictor (p<.001; OR 6.335).

HBLR was repeated replacing EFS with HGS as the predictor variable.

Model fit and classification accuracy behaved the same as above, so did age and ASA grade when entered in blocks one (p<.05, ORs 1.058 and 2.394 respectively) and two (non-significant). HGS emerged as the sole predictor in block two (p = .010; OR 6.335).

Refer to appendices E1 and E2 for more details.

Simple linear regressions were carried out using EFS as well as HGS as a binary predictor variable (frail or not-frail). Additionally, all five EFS categories were also used as binary predictors.

Frailty defined by EFS was significantly (p<.001; OR 9.156) associated with discharge to a new permanent residence following general rehabilitation; and so was HGS (p = .001; OR 4.704 (see appendices E3 and E4)

Assessment of individual EFS categories revealed that severe, moderate, and mild frailty were significantly (p<.05) associated with discharge to a new home, with respective ORs of 12.692, 3.489, and 4.056. No association was found with vulnerability; NOT frail showed a significant (p<.001) negative association with a small OR of .110. Refer to appendices E5, E6, E7, E8, and E9.

Home discharge was investigated the same way.

Based on HBLR, frailty determined by EFS was significantly (p>.001) associated with secondary home discharge. Being frail was negatively associated with home discharge (OR .158), and being NOT frail was positively associated with home discharge, with an OR of 6.335 (the same odds as for being frail and moving to a new home). Frailty determined by HGS was also significantly (p = .010) associated with secondary home discharge. Being frail was negatively associated with home discharge (OR .251), and being NOT frail was positively associated with home discharge, with an OR of 3.988.

Unadjusted simple regressions also demonstrated small ORs for the relationship between being frail and home discharge, and larger OR for the relationship between being NOT frail and home discharge.

Individual EFS categories were not assessed in relation to home discharge as no new information would have emerged from it.

Discharge following geriatric evaluation and management

Discharge to a new permanent primary residence was investigated first.

HBLR was performed using EFS as a binary predictor variable (frail or not-frail).

The model fit was good and improved with each block, based on Horsmer and Lemeshow Test, Nagelkereke R2 and 2-log likelihood. Overall classification accuracy was low in both blocks (67% and 69%).

Neither age at the time of injury nor ASA grade showed a significantly association with discharge to a new permanent residence in either block. When EFS was entered in block two, it emerged as a significant predictor (p<.05; OR 5.166).

HBLR was repeated replacing EFS with HGS as the predictor variable.

Model fit was good, classification accuracy low (67% in both blocks). None of the entered predictor variables were significantly associated with discharge to a new permanent residence.

Refer to appendices E10 and E11 for more details.

Simple linear regressions were carried out using EFS as well as HGS as a binary predictor variable (frail or not-frail). Frailty defined by EFS as well as HGS were significantly (p = .006 and p = .037) associated with discharge to a new permanent residence following a stay at a GEM unit, with OR of 7.333 and 10.333 (appendices E12 and E13).

None of the individual EFS categories showed significant associations with discharge to a new permanent residence following a stay at a GEM unit.

Results for the relationship of frailty and secondary home discharge were not presented. As for patents following rehabilitation, being frail was negatively associated with home discharge (small ORs), and being NOT frail was positively associated with home discharge (larger ORs, equivalent to those for being frail and moving to a new home).

E: Frailty & permanent change of primary residence post fracture

The influence of frailty permanent change of primary residence was assessed using HBLR, as well as simple logistic regression.

Within the hierarchical model, it was controlled for age, ASA grade, residing at a RACF pre-fracture, and pre-injury mobility, and DMS. Predictors were added employing a three-step hierarchical approach. Confounders were added in block one (age, ASA grade) and two (residing in a RACF pre-fracture, pre-injury mobility, DMS), frailty in block three.

All assumptions for HBLR were fulfilled.

The first HBLR assessed frailty via the EFS. Model fit was good and improved with each block, based on Nagelkereke R2, Horsmer and Lemeshow Test, and 2-log likelihood. The overall classification also improved with each block, with a maximum of 86%.

Age at the time of injury was significantly (p <.05) associated with change of residence in all three blocks, with ORs just over one. ASA grade was also significant (p <.05) with ORs around 2. RACF pre-fracture was a significant (p >.001) predictor in blocks two and three

with ORs of .033 and .023. Pre-injury mobility was not significantly associated with change of residence. DMS was significantly (p >.05) associated with change of residence in blocks two and three with ORs of 10.427 and 4.830. EFS was entered in block three; it was significant (p <.001) with an OR of 9.414 (appendix F1).

Results from the model where HGS was entered in block three were comparable to those above regarding the confounding variables. HGS was significantly (p <.001) associated with change of residence with an OR of 7.257. See appendix F2 for more detail.

Simple logistic regressions were carried out using EFS, HGS, and individual EFS categories as sole predictor variables.

EFS and HGS were each significantly (p <.001) associated with change of residence, with ORs of 5.198 and 7.728, respectively. See appendices F3 and F4 for more detail.

Severe frailty and vulnerability were not significantly associated with change of residence. Moderate and mild frailty were positively associated with change of residence (p <.001; ORs 3.881 and 4.823), and NOT being frail was negatively associated with change of residence (p <.05; OR .137). Refer to appendices F5, F6, F7, F8, and F9.

Permanent change of primary residence following short term placements specifically were outlined in section D above and appendix E.

F: Frailty & mortality

Mortality was treated as a binary variable; only information of vital status was known, exact dates of death were not available, not allowing for survival analyses.

Three- and 12-months mortality were investigated in relation to frailty.

HBLRs were performed to establish the impact of frailty (binary predictor variable) on three- and 12-month mortality (binary outcome variable) after controlling for age, ASA grade, total number of comorbidity areas, residing at a RACF pre-injury, and pre-injury mobility status. While total number of comorbidity areas and pre-injury mobility were non-significant in all blocks of all four HBLR, their presence improved model fit.

Predictors were added employing a three-step hierarchical approach.

All assumptions for HBLR were fulfilled.

The first HBLR was performed using EFS as a binary predictor variable (frail or not-frail) to establish its relationship with three-month mortality.

The model fit was good and improved with each block, based on Nagelkereke R2 and 2-log likelihood. The Horsmer and Lemeshow test remained non-significant through all blocks but decreased in block three. Overall clarification accuracy was highest in block three.

Age, ASA grade, and total number of comorbidities were entered in block one. Age and ASA grade were significantly (p <.001) associated with three-month mortality. ORs were 1.082 and 3.337, respectively. Age ceased to be significant from block two; ASA grade remained significant with ORs slightly decreasing in each block (3.003 in block two and 2.586 in block three).

Pre-injury mobility status and residing at a RACF pre-injury were added in block two. The latter was significantly (p <.001) associated with three-month mortality in blocks two and three, with ORs of 6.004 and 4.151, respectively.

Frailty measured by EFS was entered in block three; it was significant (p <.05) with an OR of 5.037.
Refer to appendix G1 for more detail.

The second HBLR was performed using HGS as a binary predictor variable (frail or not-frail) to establish its relationship with three-month mortality.

The model fit was good and improved with each block, based on Nagelkereke R2, Horsmer and Lemeshow Test, and 2-log likelihood.

The overall classification accuracy was high without improvements with each block.

From the three variables entered in block one, two (age and ASA grade) were significantly (p = .002 and p <.001) associated with three-month mortality. ORs were 1.072 and 2.768, respectively. Age ceased to be significant in blocks two and three; ASA grade remained significant on a .05 level, with ORs slightly decreasing in each block (2.593 in block two and 2.298 in block three).

Pre-injury mobility status and residing at a RACF pre-injury were added in block two. The latter was significantly (p <.001 and =.002) associated with three-month mortality in blocks two and three, with ORs of 5.138 and 4.644, respectively.

Frailty measured by HGS was entered in block three; it was significant (p <.05) with an OR of 6.676.
Refer to appendix G2 for more detail.

Frailty measured by EFS and HGS were also entered in simple binary logistic regressions as sole predictor variables. Both were significantly (p <.001) associated with three-month mortality; their ORs were 23.555 for EFS and 21.967 for HGS. Overall classification accuracy was 87% for the EFS model and 89% for the HGS model. Refer to appendices G3 and G4.

Twelve-month mortality was assessed in the same way, starting with two HBLRs, followed by simple linear regressions.

Using EFS as the final predictor of a HBLR, the model fit was good and improved with each block, based on Nagelkereke R2, Horsmer and Lemeshow Test, and 2-log likelihood. The overall classification accuracy also improved with each block topping at 80% in block three.

From the three variables entered in block one, two (age and ASA grade) were significantly (p <.001) associated with three-month mortality. ORs were 1.060 and 3.103, respectively. Age ceased to be significant in blocks two and three; ASA grade remained significant on a .001 level, with ORs slightly decreasing in each block (2.829 in block two and 2.553 in block three).

Pre-injury mobility status and residing at a RACF pre-injury were added in block two. The latter was significantly (p <.001) associated with three-month mortality in blocks two and three, with ORs of 5.504 and 4.221, respectively.

Frailty measured by EFS was entered in block three and was significantly (p <.05) associated with twelve-month mortality, with an OR of 2.466.
Refer to appendix G5 for more detail.

The last HBLR was performed using HGS as a binary predictor variable (frail or not-frail) to establish its relationship with 12-month mortality.

The model fit was good and improved with each block, based on Nagelkereke R^2, and Horsmer and Lemeshow test. The 2-log likelihood however increased with each block. The overall classification accuracy improved with each block to a maximum of 81% in block three.

From the three variables entered in block one, two (age and ASA grade) were significantly (p <.001) associated with twelve-month mortality. ORs were 1.058 and 2.799, respectively. Age ceased to be significant in blocks two and three; ASA grade remained significant on a .001 level, with ORs slightly decreasing in each block (2.693 in block two and 2.392 in block three).

Pre-injury mobility status and residing at a RACF pre-injury were added in block two. The latter was significantly (p <.001) associated with twelve-month mortality in blocks two and three, with ORs of 4.466 and 5.217, respectively.

Frailty measured by HGS was entered in block three and was significantly (p <.05) associated with three-month mortality, with an OR of 3.196.

Refer to appendix G6 for more detail.

EFS and HGS were also entered in simple binary logistic regressions as sole predictor variables. They were significantly (p <.001) associated with twelve-month mortality; their ORs were 9.059 and 8.528, respectively. Overall classification accuracies were 74% and 78%. Refer to appendices G7 and G8 for more detail.

4.6.7.4 Gender differences

Selected gender differences are outlined in table 10 below.

Table 10: Exploration of gender differences

	Female N (%) of valid cases	**Male** N (%) of valid cases	**P-value**
Gender	310 (67.09)	152 (32.91)	<0.001
Pre-fracture residence: home alone	83 (26.77)	33 (21.71)	0.238
Pre-fracture residence: home cohabiting	90 (29.03)	66 (43.42)	0.002
Pre-fracture residence: low care	25 (08.06)	15 (09.86)	0.517
Pre-fracture residence: high care	112 (36.12)	38 (25.00)	0.016
Pre-injury mobility (dependent)	74 (23.87)	25 (16.44)	0.042
Mobility on day of discharge (dependent)	271 (87.42)	122 (80.26)	0.039
Frail defined by hand grip strength*	183 (69.06)	98 (69.01)	0.993
Frailty defined by the Edmonton frailty score**	196 (63.43)	80 (53.33)	0.038
Direct home discharge, excl. to RACF	25 (12.65)	21 (18.42)	0.164
Change of permanent residence	65 (21.45)	38 (25.66)	0.316
Osteoporosis diagnosed pre-fracture	98 (31.61)	14 (09.21)	<0.001
Osteoporosis diagnosed at time of fracture	56 (18.06)	26 (17.10)	0.132
Commencement of bone protecting medication during hospitalisation	40 (71.42)	14 (53.85)	0.050
Dementia/Alzheimer's	127 (40.97)	37 (24.34)	<0.001
	Female mean (±SD)	**Male** mean (±SD)	**P-value**
Age (years)	83.39 (09.80)	80.44 (10.74)	0.004
Edmonton frailty score (average)	9.08 (04.36)	7.87 (04.42)	0.005
BMI	23.94 (05.01)	24.63 (04.50)	0.138
Length of hospital stay	7.34 (04.96)	7.73 (05.25)	0.435

* T-score of -2.5 below the gender stratified average; **mild to severely frail (8 to 17 points on score)

Table 11: Association of frailty (defined by EFS) with primary outcome variables

	Adjusted			Un-adjusted		
Outcome variables	N (%)	OR (95% CI)	p-value	N (%)	OR (95% CI)	p-value
In-hospital						
Length of hospital stay[a]	435 (94)	03.684 (01.671-08.122)	.001	459 (99)	02.060 (01.112-03.844)	.022
Discharge mobility[b]	434 (94)	12.884 (03.582-46.343)	<.001	457 (99)	34.587 (12.304-97.228)	<.001
Primary discharge destinations following acute hospitalisation						
Direct home discharge[c]	457 (99)	00.711 (00.192-02.636) (negative association)	.609	459 (99)	03.303 (02.181-05.004)	<.001
Direct home discharge[c] (NOT frail)	457 (99)	01.407 (00.379-05.220)	.609	459 (99)	00.303 (00.200-00.459) (negative association)	<.001
Discharge to general rehabilitation[c]	457 (99)	00.110 (00.059-00.206) (negative association)	<.001	459 (99)	00.108 (00.070-00.167) (negative association)	<.001
Discharge to general rehabilitation[c] (NOT frail)	457 (99)	09.051 (04.851-16.888)	<.001	459 (99)	09.270 (05.991-14.344)	<.001
Discharge to GEM[c]	457 (99)	03.971 (02.023-07.793)	<.001	459 (99)	02.253 (01.253-04.100)	.008
Discharge to GEM[c] (NOT frail)	457 (99)	00.252 (00.128-00.494) (negative association)	<.001	459 (99)	00.444 (00.244-00.808) (negative association)	.008
Discharge to provisional destination[c]	457 (99)	58.060 (04.075-82.310)	.003	459 (99)	10.460 (01.270-79.887)	.024
Secondary discharge destinations following short term placements						
Home discharge following rehabilitation*[d]	160 (95)	00.158 (00.062-00.400) (negative association)	<.001	165 (98)	00.109 (00.046-00.261) (negative association)	<.001
Discharge to a new residence following rehabilitation*[d]	160 (95)	06.335 (02.501-16.051)	<.001	165 (98)	09.156 (03.838-21.843)	<.001
Home discharge following GEM*[d]	54 (83)	00.194 (00.043-00.870) (negative association)	.032	59 (91)	00.136 (00.033-00.564) (negative association)	.006
Discharge to a new residence following GEM*[d]	54 (83)	05.166 (01.149-23.225)	.032	59 (91)	07.333 (01.774-30.312)	.006
Post admission						
Permanent change of residence[e]	424 (92)	09.414 (04.664-19.005)	<.001	449 (97)	05.198 (02.890-09.349)	<.001
3-months mortality[f]	435 (94)	5.037 1.049 24.195	.043	459 (99)	23.555 (05.673-97.809)	<.001
12-months mortality[f]	435 (94)	2.466 1.104 5.508	.028	459 (99)	09.750 (05.059-18.789)	<.001

a: adjusted for age, residing in RACF pre-injury, type of fracture, type of fracture repair, ASA grade.

b: adjusted for age, pre-injury mobility, ASA grade.
c: adjusted for age, residing in RACF pre-injury, discharge mobility.
d: adjusted for age, ASA grade.
e: adjusted for age, ASA grade, residing in RACF pre-injury, pre-fracture mobility, discharge mobility.
f: adjusted for age, ASA grade, comorbidities, residing in RACF pre-injury, pre-fracture mobility.

Associations are positive unless stated otherwise.
Associations are between the outcome variable and being frail unless stated otherwise.

*secondary discharges to new homes or to pre-injury homes are an either-or choice; ORs are therefore applicable for both but in reverse**.**

Table 12: Association of frailty (defined by HGS) with primary outcome variables

	Adjusted			Un-adjusted		
Outcome variables	N (%)	OR (95% CI)	p-value	N (%)	OR (95% CI)	p-value
In-hospital						
Length of hospital stay[a]	387 (84)	02.612 (01.087-06.362)	.032	407 (88)	02.545 (01.204-05.376)	.014
Discharge mobility[b]	387 (84)	03.745 (01.823-07.692)	<.001	407 (88)	09.882 (05.385-18.139)	<.001
Primary discharge destinations following acute hospitalisation						
Direct home discharge[c]	407 (88)	00.806 (00.313-02.076) (negative association)	.655	407 (88)	01.291 (00.824-02.022)	.265
Direct home discharge[c] (NOT frail)	407 (88)	01.240 (00.482-03.195)	.655	407 (88)	00.775 (00.494-01.214) (negative association)	.265
Discharge to general rehabilitation[c]	407 (88)	00.264 (00.141-00.497) (negative association)	<.001	407 (88)	00.308 (00.199-00.475) (negative association)	<.001
Discharge to general rehabilitation[c] (NOT frail)	407 (88)	03.783 (02.013-07.107)	<.001	407 (88)	03.251 (02.103-05.025)	<.001
Discharge to GEM[c]	407 (88)	03.600 (01.578-08.228)	.002	407 (88)	03.554 (01.637-07.715)	.001
Discharge to GEM[c] (NOT frail)	407 (88)	00.278 (00.122-00.635) (negative association)	.002	407 (88)	00.281 (00.130-00.611) (negative association)	.001
Discharge to provisional destination[c]	407 (88)	02.730 (00.519-14.348)	.236	407 (88)	02.766 (00.610-12.545)	.187
Secondary discharge destinations following short term placements						
Home discharge following rehabilitation*[d]	158 (94)	00.251 (00.087-00.722) (negative association)	.010	163 (96)	00.213 (00.082-00.552) (negative association)	.001
Discharge to a new residence following rehabilitation*[d]	158 (94)	06.335 (01.386-11.476)	.010	163 (96)	4.704 1.811-12.217)	.001
Home discharge following GEM*[d]	51 (79)	00.132 (00.014-01.285) (negative association)	.081	56 (86)	00.097 (00.011-00.869) (negative association)	.037
Discharge to a new residence following GEM*[d]	51 (79)	07.578 (00.778-73.773)	.081	56 (86)	10.333 (01.150-92.815)	.037
Post admission						
Permanent change of residence[e]	376 (82)	07.257 (02.888-18.239)	<.001	396 (83)	07.728 (03.457-17.274)	<.001
3-months mortality[f]	387 (84)	06.676 (00.842-52.948)	.042	407 (88)	21.967 (02.988-61.490)	.002
12-months mortality[f]	387 (84)	03.196 (01.246-08.202)	.016	407 (88)	08.528 (03.613-20.128)	<.001

a: adjusted for age, residing in RACF pre-injury, type of fracture, type of fracture repair, ASA grade.

b: adjusted for age, pre-injury mobility, ASA grade.
c: adjusted for age, residing in RACF pre-injury, discharge mobility.
d: adjusted for age, ASA grade.
e: adjusted for age, ASA grade, residing in RACF pre-injury, pre-fracture mobility, discharge mobility.
f: adjusted for age, ASA grade, comorbidities, residing in RACF pre-injury, pre-fracture mobility.

Associations are positive unless stated otherwise.
Associations are between the outcome variable and being frail unless stated otherwise.

*secondary discharges to new homes or to pre-injury homes are an either-or choice; ORs are therefore applicable for both but in reverse.

4.7 Discussion

4.7.1 Discussion of results

4.7.1.1 Hip fracture population characteristics and patient journey

The below is a summative narrative of characteristics observed in the study populations in comparison to other hip fracture cohorts described in the literature; there were similarities but also some differences.

All patients included in this study were admitted to the acute orthopaedic ward via the emergency department. Females significantly outnumbered males (67% versus 33%). This was in line with findings by other researchers, such as Postler et al. (2024), who looked at a German cohort of 734 hip fracture patients consisting of 68% females, or Muller et al. (2020) whose cohort consisted of 67% females. The median age of patients included in this study was comparable to the median age of patients in Postler's cohort (84 and 85 years, respectively). The average age was 81 in the study cohort as well as in a hip fracture cohort form the UK (Mubarak et al. 2020). In the study cohort, the mean age difference between genders was not great (83 versus 80) but statistically significant; not surprisingly, females were older than males.

All patients in the study cohort received a femoral nerve block in the emergency department. Administration of immediate pain relief was in line with the National Institute for Health and Care Excellence (NICE) guideline for hip fracture management as well as the Australian Hip Fracture Clinical Care Standard (AHFCCS). Nerve blocks are recommended as they can reduce the need for opioids and thus avoid opioid related side effects such as drowsiness, delirium, or respiratory complications. (Australian Commission on Safety and Quality in Health Care 2023; NICE 2011)

Irrespective, delirium was present in 44% of patients from this study cohort. This exceeds the 36% reported in a study based on data from the Australian and New Zealand Hip Fracture Registry (ANZHFR) (Oberai et al., 2022). This might be due to the lack of local

delirium prevention strategies (other then administering nerve blocks for pain relief). While delirium has not investigated for its relationship to frailty, recent literature proposes a biological link between the two (Bellelli et al., 2024); clinically, both high frailty index and phenotype were associated with delirium (Deiner et al., 2023).

Patients' overall health status based on ASA grades was assessed pre-operatively. Outcomes for the study cohort were comparable to those found within the cohort observed by Postler et al. (2024) ASA grades 1 – 2 made up 21% of the study cohort, and 22% of Postler's cohort, while ASA grade 3-4 made up 79% and 78%, respectively.

In accordance with best clinical practice (Seong et al., 2020), 94% of study patients were operated within 48 hours of admission to the hospital. This was similar to findings from a hospital in Western Australia, where 95% of patients were operated within 48 hours (Lawless et al., 2020), and better compared to findings from the Irish Hip Fracture Database, where only 75% of patients were operated within 48 hours (Walsh et al., 2023).

Sub-capital fractures were most common in this study population (48%), followed by inter-trochanteric fractures (40%). This pattern was shown in several publications (Alpantaki et al., 2020; Kim et al., 2020).

Percentage choices of types of fracture repair was in concurrence with Postler's (2024) findings: internal fixation was most common, followed by hemi-arthroplasty, and total hip arthroplasty. However, large varieties have been reported in the literature (Werner at al., 2022).

Early mobilisation post fracture was recommended in the NICE guideline as well as the AHFCCS. Mobilisation on day one post-surgery was possible for 80% of study patients (bed exercises or sit out of bed); 29% were able to walk. Tan et al. (2023) observed a Singaporean cohort where also 80% of patients were able to mobilise in some way on day one. In another Australian study (Said et al., 2021), 43% of patients were able to mobilise (step transfer from bed to chair) within 48 hours post-surgery. Data from the ANZHFR

showed that 49% underwent early mobilisation defined as stand and step transfer (Woodcroft-Brown et al., 2024). For this study, people able to do bed exercises or sit out of bed (including step transfer) were grouped together, and people that were able to walk a distance (with or without help) were sorted in a different group. Hence people able to perform step transfer were put in the former group, rather than the latter. This suggest that the findings of this study might well be comparable to the other Australian data.

On the day of discharge, 73% of the study cohort was able to walk (with or without help). It was difficult to compare this finding with data from the literature, as many authors either only reported ORs or had used outcome measures such as the cumulated ambulation score (e.g. Yamamoto et al., 2023; Luck et al., 2024).

Observed length of stay at the acute hospital ward was nine days on average. Eighty-two percent of patients stayed for 10 days or less. In comparison, data from the ANZHFR revealed that patients across Australia and New Zealand spent an average of eight days at the acute ward. (Australia and New Zealand Hip Fracture Registry, 2023) A large American cohort also presented an average stay of eight days (Nikkel et al., 2015).

The prevalence of dementia was 35% in this study cohort, exactly the same as in the cohort observed by Postler et al. (2024). Oberai et al. (2021) found a dementia prevalence of 40%, based on ANZHFR data.

Osteoporosis was another variable of interest. Overall, 24% of the study population had been diagnosed with osteoporosis pre-fracture (significantly more females); out of these, 93% had been receiving pharmacological treatment for bone protection. Eighteen percent of patients were newly diagnosed with osteoporosis as a result of their hip fracture; overall, 66% of these patients commenced pharmacological treatment or were referred on for management. Significantly more newly diagnosed females were started on medication compared to males (71% versus 54%). In comparison, ANZHFR (2023) data showed that 13% of hip fracture patents across Australia and New Zealand had been on bone protection medication pre-fracture, and 31% of patients were discharged with bone

protection medication in Australia (35% in New Zealand). Thus, more patients of the study cohort had already been on medication, but much less were put on medication as a result of their hip fracture, compared to the ANZHFR data. Under-treatment of osteoporosis post hip fracture was demonstrated by a research team from Singapore (Chau et al. 2020), who also highlighted the increased risks of undesirable health outcomes caused by this.

Frailty was measured using the reported EFS (60% prevalence) as well as HGS (69% prevalence). Other authors explored prevalence of frailty in hip fracture patients. Based on a 22-item frailty index, Gandossi et al. (2021) found a 36% prevalence of frailty, while Pizzonia et al. (2020) used a19-item frailty index and detected a prevalence of 77%. The modified Fried frailty index was used by Kistler et al. (2015), showing a prevalence of 51%. Due to the heterogeneity of measures and lack of standardisation, large differences in prevalence can be found and it is not possible to compare these results in a meaningful way. This will be discussed further in chapter 4.7.1.2.

Fifty-nine percent of patients from the study population had been living independently in a private home. ANZHFR (2023) data showed that within their Australian cohort, 73% of patients had been living in a private residence; no information about these patients' independence levels was provided. For this study, people with low dependency were grouped separately. Patients that had been living in a RACF pre-fracture made up 32% of the study cohort and 26% of patients included in the Australian ANZHFR data set. In this study population, significantly more males had been living independently in a private home with someone else, while significantly more females had been living in a RACF. Considering the greater life expectancy in women (Australian Institute of Health and Welfare, 2023), this is not surprising.

The ANZHFR registry report (2023) did not provide information linking pre-injury residence to discharge destination, thus no information regarding home discharge was available. Ryder et al. (2020) used ANZHFR data for their analyses of factors influencing discharge destination; they found that 18% of people that had been living independently in a private

home pre-fracture were discharged home directly, compared to 71% of patients from RACFs.

Analysis of the study population revealed that 40% of patients were directly discharged to their pre-injury homes. Out of all patients that were discharged home 75% had been living in a RACF pre-injury; only 23% of patients that had been living independently in a private residence were discharged home directly. These findings are in vast contrast to the Irish cohort described by Ferris et al. (2022), where 92% of patients that were discharged home had been living in a private residence, and only .2% in a RACF.

The other two frequent discharge destinations for patients from the study cohort were to a rehabilitation unit (37%) and to a geriatric evaluation and management unit (14%). The latter can be classified as a slow-stream rehabilitation; thus, for purpose of comparison, they can be grouped together, bringing discharge to rehab up to 51%. Van Dartel et al. (2021) found it to be 55%, and Ferris et al. (2022) 44%.

Only four study patients previously from a RACF went to rehabilitation. The ANZHFR report (2023) alerted an Australian trend, reporting that numbers of RACF residents attending rehabilitation are declining every year; their data showed it to be 8%, which was still more than the study cohort's 3%, but significantly less than the 29% in New Zealand. The ANZHFR report stated that the reasons for the decline are indistinct and implications on long-term recovery have not been investigated.

It can be speculated that some of the reasons are insufficient numbers of beds in rehabilitation units combined with poorer baseline general health and higher care needs of RACF residents. As rehabilitation places are scarce, they are given to those presumed to benefit most (personally as well as for the health care system).

Twenty-two percent of the study population underwent a permanent change of primary residence as a result of sustaining a hip fracture. Out of these, 11% moved into their new homes directly after their acute hospital stay, while 89% were discharged to short term

placements first. All patents moved due to higher care requirements post fracture. It was apparent that people with a higher independence level pre-fracture were more affected. Ferris et al. (2022) found that 5% of their Irish patients moved to a new home after their acute stay; no information was provided about secondary discharge destinations. As stated before, the 2023 report by the ANZHFR did not link pre-and post-fracture residences, hence no information about change of primary residence was available.

Discharge destinations and permanent change of residence will be discussed further in chapters 4.7.2.5.-7.

Lastly, for this study, in-hospital mortality was 3%, three-month mortality was 13%, and 12-month mortality 26%. Oberai et al. (2021) also reported 3% in hospital deaths (using ANZHFR data); their 12 months mortality was 27%. This is in line with a Danish registry study where they found 27% 12-month mortality; their three-month mortality was 16% (Gundel et al., 2020).

In conclusion, hip fracture patients observed for this study formed a cohort that was, on a narrative level, comparable to many other hip fracture cohorts described in the literature. This was true for most aspects regarding demographics, fracture types and management, as well as overall health. Items such as frailty could not be compared with prior publications in a meaningful way as there was no standardisations of measures and tools. Country/region specific differences in patients' journeys after discharge from the acute hospital ward were apparent.

4.7.1.2 Prevalence of frailty in hip fracture patients and comparability of the selected measures

The prevalence of frailty was statistically significant in the study population, based on the reported EFS (60%) as well as HGS (69%). As stated before, frailty prevalence was reported by many authors, based on multiple different scores. Yan et al. (2022) performed a systematic review that explored the prognostic power of frailty in hip fracture patents. Sixteen of their included studies had reported prevalence, ranging from 22% to 81%, based

on seven different measures. The Clinical Frailty Scale had been used in four studies, but even amongst them the range was wide, with prevalence between 43% and 70%.

While frailty is clearly widespread in hip fracture patients, prevalence is not always significant, depending on cohort and choice of frailty measure.

The wide range of prevalence suggests the obvious: different frailty measures and tools do not inform about the same characteristics.

Two very different frailty measures were used in the presented study. The reported EFS assesses nine domains, aiming to capture the multidimensional aspects of frailty. HGS is a single physical measure. The aim was to assess comparability and possible interchangeability, assuming that HGS was a simpler measure to perform in a clinical setting than the EFS.

A statistically significant relationship was found between HGS frailty and EFS frailty. The R^2 was 39% and the similarity index 73%, demonstrating a moderate overlap. This does not support the idea that the two measures are interchangeable, but results might be comparable.

4.7.1.3 The relationship between frailty measured with EFS and HGS and length of hospital stay

Length of hospital stay was the only variable analysed using linear regression as well as logistic regression.

Linear regression revealed a relationship between LOS and frailty – the frailer the patient the longer the stay. Logistic regressions, hierarchical and simple, looking at frailty and prolonged stay, yielded ORs between 2 and 4. Moderate frailty was linked to prolonged stay (OR 1.204), and NOT being frail was linked to NOT staying at hospital for a prolonged time (OR .249). Severe frailty was not significantly associated with prolonged hospital stay. This was most likely due to severe frailty was most common in RACF residents that tend to get discharged back home as soon as medically stable, assuming that appropriate care

needs can be met there. The negative OR for NOT frail was very small and thus can be assumed clinically negligible.

Correspondingly, prolonged hospital stay has been linked with several frailty measures and tools in the literature: Hospital Frailty Risk Score, Fried Frailty Index, Groningen Frailty Indicator, etc. (Yan et al. 2022). For example, Kistler et al. (2015) found a statistically significant difference in length of hospital stay between frail and non-frail patients using the Fried Frailty Index.

4.7.1.4 Frailty measured with EFS and HGS in relation to discharge mobility

Finding from the presented study demonstrated frailty to be a strong indicator for discharge mobility. Via hierarchical regression, being frail (EFS) created an OR of 12.884 for NOT being independently mobile at discharge. Pre-fracture mobility and age were also indicative of discharge mobility, but with much smaller ORs (2.451 and 1.089, respectively). In the HGS model, frailty yielded a smaller OR of 3.754. Simple regression increased the OR for EFS to 34.587, and for HGS to 9.882. Individual EFS scores showed that the frailer the more likely to not be independently mobile (with or without walking aid) at discharge; OR ranged from 48.031 to 5.207.

Similarly, Gandossi et al. (2021) found an association between frailty (Frailty Index) and poor functional status after hip fracture, and Chang et al. (2021) that weak HGS was an indicator for decreased ambulation capacity. Werner et al. (2024) found frailty to be a independent negative predictor for improvements in the Short Physical Performance Battery from admission to discharge in acute geriatric inpatients.

4.7.1.5 The association of frailty measured with EFS and HGS with primary discharge destinations

As stated before, the main discharge destinations after acute hospitalisation were pre-injury homes, rehabilitation units, GEM, and provisional settings.

Frailty and other factors associated with direct home discharge

Based on hierarchical models, two factors other than frailty were found to be very strong indicators for direct home discharge: residing in a RACF pre-fracture (OR of <1000 in EFS and HGS models), and discharge mobility (OR of 28.934 in EFS model, and OR of 29.917 in HGS model).

No significant association was found between frailty and direct home discharge in any of the two hierarchical models. This was not surprising, as many patients in the study cohort had been residing in a RACF pre-fracture and were directly discharged back home, rather than been given the opportunity of rehabilitation or GEM. The ANZHFR report (2023) stated the same finding and announced the plan to further investigate reasons. It seems however not difficult to speculate on the reasons, based on anecdotal evidence and personal experience: places for rehabilitation and GEM are limited and allocated to those allegedly profiting the most. This means that patients previously living independently at home are given priority, as loss of independence would have more detrimental consequences to them compared to people already living in a high care setting. While many RACF residents might not fulfil the criteria (e.g. not mobile enough) to qualify for rehabilitation or GEM, this is certainly not true for all. It cannot be assumed that most RACFs are able to provide in-service rehabilitation, in which case many patients that would have benefited will miss out. It is to hope that the proposed further investigations in the matter will yield some change, be it more rehabilitation and GEM places or a more formalised home rehabilitation program accessible to all RACF residents. Decline in physical mobility is devastating for older people, irrespective of their place of residence. Mobility was strongly linked to quality of life (La Grow, 2013; Bechtold et al., 2021).

When no confounding factors were considered, frailty as per the EFS was significantly associated with direct home discharge, with an OR of 3.303. There was still no association found between frailty determined by HGS and direct home discharge. Excluding patients from RACFs from the data set changed outcomes expressively, demonstrating a significant

association between NOT being frail and direct home discharge with an OR of 9.300 for EFS, and an OR of 6.364 for HGS.

It must be acknowledged that DMS was very strongly associated with home discharge for people NOT from RACF; if independently mobile, the OR for going home was 64.

The five EFS categories were explored independently, unadjusted, using the full data set. No new insights were gained from this; the frailer the more likely to be discharged home, with home mainly being a RACF. Due to the low number of formerly independent patients that were discharged home directly, it was not viable to investigate individual EFS categories with the exclusion of RACF residents.

Other authors looked at factors related to direct home discharge. Salar et al. (2017) found a multitude of factors significantly associated with the direct home discharge of previously independent living patients. All ORs were under two, except for being younger than 65 years old (OR of 9.2). Ferris et al. (2022) also found younger age (OR of 0.54 for age 60 to 69; OR of 0.22 for age >90) and high mobility status (OR of 2.72), amongst other factors, to be associated with direct home discharge; most ORs stayed well under two.

No further research specifically investigating frailty and direct home discharge could be found.

Frailty and other factors associated with discharge to rehabilitation

As described before, discharge to rehabilitation was explored in hierarchical models. In the EFS model, patients that were NOT frail were significantly more likely to be discharged to rehabilitation (OR of 9.051). Frailty was outranked by DMS (OR of 14.304). The same was true for the HGS model, with lower ORs of 3.783 and 9.234, respectively. Interestingly, adding frailty to the model strengthened the association of DMS and discharge to rehabilitation.

In simple univariate models for both frailties, associations remained much the same. Outcomes of individual EFS categories returned ORs of 5.051 for NOT frail and 5.376 for vulnerable; all other categories were negatively associated with discharge to rehabilitation. That left a difference of .325 between the ORs of NOT frail and vulnerable, CIs were overlapping. While no statistical test was performed to assess if this difference was significant, it did not seem enough to be deemed clinically relevant.

Ryder et al. (2020) assessed factors associated with discharge destinations after hip fracture. They found that the odds to be moved to a rehabilitation unit went up with age; this was however also true for discharge to another hospital/ ward, and to a RACF, therefore not rendering any clinical use. Better mobility was also associated with higher odds to be discharged to a rehabilitation unit, as well as to another hospital. Less mobility was increasing the odds to be discharged to a RACF.

While age was not found to be associated with discharge to rehabilitation in the study cohort, mobility was. While the relationship between mobility and home discharge was stronger, mobility was also an important factor for discharge to rehabilitation.

Frailty and other factors associated with discharge to GEM

In contrast to discharge to rehabilitation, discharge to GEM was significantly associated with being frail (OR of 3.971 in the EFS model; OR of 3.600 in the HGS model). No other factor in the model was stronger associated to discharge to GEM; no other variable remained significant in the EFS model, while age was significant (OR of 1.043) in the HGS model. Simple regressions did not change ORs by much: 2.253 or EFS, and 3.554 for HGS.

Investigation of dividual EFS categories reviled that patients with mild and moderate frailty had the greatest odds to be discharged to GEM (OR of 5.847 and 3.602, respectively). This seemed specific enough to be of clinical interest.

Expectedly, no information about discharge to GEM could be found in the literature. There is not much consistency regarding subgroups of discharge destination. GEM-like

destinations might be called geriatric rehabilitation, or there might not be a distinction between rehab types.

Frailty and other factors associated with discharge to a provisional setting

Frailty defined by EFS was significantly associated with discharge to a provisional destination, with a very large OR of 58.060. No frailty associations were found in the HGS model. Age presented as significant in both models, with a much smaller OR of 1.097 (EFS model) and 1.117 (HGS model).

Less than 20 patients were discharged to a provisional destination, mostly to await permanent admission to a RACF. Unfortunately, this made it impossible to assess its associations with individual EFS categories. However, 50% of these patients were severely frail, and 31% were moderately frail.

Frailty measures for discharge planning following acute hospitalisation - summary

Based on the study findings, NOT being frail (EFS and HGS) and NOT being independently mobile (with or without an aid) indicated rehabilitation to be the most likely discharge destination. Being frail (EFS and HGS), irrespective of DMS, indicated discharge to GEM; most indicative individual EFS categories for discharge to GEM were mild and moderate frailty. Patients with very high frailty scores in conjunction with old age were most likely discharged to a provisional destination.

Frailty measures were not informative about home discharge when looking at the whole study cohort. For people previously form a private residence, NOT being frail was an indicator for home discharge; high levels of discharge mobility were however most indicative.

4.7.1.6 The association of frailty measured with EFS and HGS with secondary discharge destination

After a short-term stay (rehabilitation, GEM, provisional destination) most patients were either discharge to their pre-injury homes, or to a new permanent place of residence providing for higher care needs.

For people from provisional destination, new permanent places of residence were the most common endpoint (81%). As stated before, no further analyses were done due to the low number of patients in this group.

For patient post rehab as well as post GEM, being frail was significantly associated with permanent change of primary residence; conversely, NOT being frail was associated with home discharge.

The odds for moving to a new home based on EFS where higher for patients after rehabilitation than after GEM, with unadjusted ORs of 9.156 and 7.333, respectively. HGS portrayed the opposite - the OR for moving to a new home after rehabilitation was 4.704, and after GEM it was 10.333. Individual EFS categories revealed that, not surprisingly, severe frailty posed the highest odds of moving to a new home (OR of 12.692), compared to mild and moderate frailty (ORs of 3.489 and 4.056, respectively).

Looking at frequencies, the percentage of people moving to a new home after GEM was higher than after rehabilitation. Thirty percent of people that were living independently at home pre-fracture and 41% of patients independently cohabiting changed their home after GEM, versus 23% and 14%, respectively, after rehabilitation. Overall, 56% of patients moved to a new home after GEM, compared to only 19% after rehabilitation. While less people that were cohabiting moved to a permanent new home after rehabilitation, this was not true for people following GEM.

Not much literature could be found on secondary discharge destinations of hip fracture patients. Hayashi et al. (2016) found that the cognition section of the Functional Independence Measure, taken during rehabilitation, was a reliable indicator for secondary

home discharge. For the presented study, no rehabilitation/GEM related data was available, other than type secondary discharge destinations, omitting the possibility to analyse factors post discharge from the acute hospital ward.

Based on findings from the presented study, it can be concluded that being frail decreases the likelihood of secondary home discharge, irrespective of primary discharge destination; an EFS score of 12 or more poses the highest risk of changing residence post rehabilitation.

4.7.1.7 Frailty measured with EFS and HGS in relation to permanent change of primary residence

Permanent change of primary residence affected 22% of patients included in the analyses for the presented study. The less support or company patients had pre-fracture, the higher the occurrence rate: 42% of patients from home alone versus 18% of patients with low dependencies. This is not surprising, as increased care can be more readily provided for people living with someone or people that had already received some level of care pre-fracture.

The hierarchical EFS model presented an OR of 9.414, the HGS model an OR of 7.256; simple models produced a smaller OR of 5.198 for EFS, and a slightly larger OR of 7.728 for HGS. Discharge mobility, ASA grade and age, in decreasing order, were also indicators of risk for change of residence. Analyses of individual EFS categories showed that the odds for moving to a new home were highest for mild to moderately frail people. Since the majority of severely frail people in the study cohort had already been residing in a RACF pre-fracture, this was to expect.

Harrison at al. (2017) produced a systematic review attempting to isolate risk factors for patients' transitions into long term institutional care after acute hospital stays; they were unable to identify any. Chan et al. (2019) presented results from a retrospective cohort study, showing a strong association between pre-admission frailty (measured with the Clinical Frail Scale) and moving into long term care post-discharge (OR of 23). Owodunni

et al. (2021) found that the reported EFS in patients that were unable to return to their pre-injury homes was significantly higher (an average of 7) compared to people that were able to return home (an average of 3); they also found that frailty (EFS >6) was indicative for post-fracture change of residence, with an OR of 6.98.

The findings by Owodunni et al. are the ones that are most comparable to the study findings, as the reported EFS was used to assess frailty. For the presented study, patients with a score of eight or more were classified as being frail; Owodunni considered people with a score of six or more as frail, also including the 'vulnerable' category.

In summary, frailty determined by either EFS or HGS indicated an increased risk for a permanent change of primary residence post fracture. This is directly in line with findings by Owodunni et al. (2021) and relates to findings by Chan et al. (2019).

4.7.1.8 Frailty measured with EFS and HGS and mortality

Ninety-seven percent of patients that passed away within 3 months of hip fracture were frail; 82% severely. Correspondingly, unadjusted regression analyses returned ORs of 23.555 (EFS), 22.967 (HGS), and 10.345 (EFS category: severe frailty). In hierarchical models, frailty measured by EFS and frailty measured by HGS returned different results. Frailty measured by EFS was the strongest indicator for 3-month mortality, followed by residing in a RACF pre-fracture, ASA grade, and age. This was not true for HGS, where the confidence interval crossed one, making residing in a RACF pre-fracture the strongest predictor, followed by ASA grade and age.

Twelve-month mortality was also associated with frailty, but both frequencies and ORs were lower. Frailty by HGS was prevalent in 93% of patients that passed away within 12 months of hip fracture. Ninety percent were frail as per EFS, 77% severely. Unadjusted regression analyses returned ORs of 9.750 (EFS), 8.528 (HGS), and 10.607 (EFS category: severe frailty). In hierarchical models, residing in a RACF pre-fracture was the strongest indicator for 12-month mortality, followed by ASA grade and frailty (EFS) / frailty (HGS) and ASA grade.

This suggest that the effects on mortality post fracture might be strongest closer to the fracture occurrence. This was also concluded in paper by Brown et al. (2021) where survival was observed over six years; mortality was highest in the first year after fracture.

Many authors have linked the presence of frailty to mortality post fracture, using several different measures or tools (e.g. Jorissen et al., 2020 and Forssten et al., 2023, to name a few). Choi et al. (2021) compared the indicative power of HGS and the Multidimensional Frailty Score (MFS). They found the MFS to be superior to HGS in predicting mortality. Factors other than frailty as predictors for mortality were also assessed by many authors; patient-related factors such as frailty and lower BMI appeared to be more important than hospital-related factors (Xu et al., 2019; Postler et al., 2024).

4.7.2 Key findings and resulting clinical recommendations

4.7.2.1 Summarising reflection of key findings

The main objective of this thesis was, after confirming the presence of frailty within a hip fracture cohort, to assess the relationships of clinically relevant outcomes with frailty, measured by HGS as well as EFS. While findings were discussed throughout 4.7.1, this section provides a succinct summarising reflection of key outcomes.

Based on a cohort of 462 hip fracture patients, it can be concluded that frailty is highly prevalent in hip fracture patients, when measured with EFS as well as HGS. This finding has not previously been reported in the available literature, presenting a contribution to the wider knowledge base.

Furthermore, the findings of this study provide new insights in the relationship between HGS and EFS regarding frailty. While 73% similarity was present, the two measures cannot be used interchangeably, as only 39% of variance in the respective dependent variable can be explained by the corresponding independent variable. Hence while they both have merit, they do not provide the same information; however, information can still be considered comparable.

Hierarchical binary logistic regression models found both HGS and EFS to be related to prolonged hospital stay, emerging as the strongest predictors in these models. This is in accordance with findings from the literature, as described in 4.7.1.3. It seems important to note that residing in a RACF pre-fracture was a consistent negative predictor for prolonged hospital stay. This was also found and highlighted by researchers involved in the ANZHFR annual report of 2023 (page 90). It is common practice that patients are discharged back to their RACF very fast under the assumption that rehabilitation services can be provided there, which is unfortunately not guaranteed (ANZHFR, 2023).

Frailty was strongly associated with discharge mobility (EFS > HGS). Pre-fracture mobility status also had a strong association and was equal to HGS. Literature reporting on discharge mobility largely focused on formal outcome measures, making it difficult to compare, as described and referenced in 4.7.1.1 and 4.7.1.4. However, frailty being a negative predictor for functional recovery is well documented. This is not surprising, considering the very nature of frailty (decreased reserve and increased vulnerability to stressors leading to compromised recovery, refer to 2.2.1 at the start of this thesis).

The prime interest was in assessing whether frailty can predict discharge destinations. Following acute hospitalisation, patients were discharged to several destinations – home (according to their pre-injury situations), different forms of rehabilitation, or to a RACF. Discharge mobility (for previously independently living patients) and having resided in a RACF pre-fracture (for previously dependent patients) were relevant factors. The latter corresponds with the finding around length of stay as discussed above as well as in 4.7.1.5.

Frailty had much more bearing when looking at discharge to rehabilitation and GEM; less frailty and moderate mobility for discharge to the former, more frailty irrespective of mobility for discharge to the latter. There was again limited published literature available for direct comparisons. These finding were however relevant for developing clinical recommendations.

Frailty was also indicative of a return to a pre-injury home after rehab / GEM. Overall, more patients went back home after rehab (lower levels of frailty) compared to GEM (higher levels of frailty). Secondary destinations appear less researched, based on available literature, possibly due to difficulties around ongoing follow-ups.

Twenty-two percent of patients had to permanently move to a new home because of their hip fracture. As discussed, limited literature suggested a strong association between frailty and change of residence, which is in line with the findings described in this thesis.

Mortality in relation to frailty was analysed; frailty measured by EFS was associated with 3-months mortality, HGS was not. Neither of these frailty measures were associated with 12-months mortality. Since many solid mortality predictors were reported in the literature, and residing in a RACF pre-fracture, ASA grade, and age were strongly associated with mortality in this cohort, frailty as per EFS and HGS cannot be recommended for clinical use in this instance.

Based on the above summary and preceding discussions, clinical recommendations were formed.

4.7.2.2 Clinical recommendations

The overarching aim of this study was to be able to provide information about the clinical use of frailty measures in the discharge planning of hip fracture patients. The results from this study cannot provide absolute answers. However, the evidence gained through this study can inform a clinical guideline that can be used in conjunction with clinical reasoning for each individual patient, to aid in discharge planning. Due to differences in health care systems around the world, these guidelines may not be applicable in all settings, there is no claim for generalisation.

Guideline for discharge destinations after acute hospital stay, based on study findings:

1. Direct home discharge (for patient that did NOT reside in a RACF pre-fracture): patients that are not frail (EFS >8, HGS above the frailty threshold) AND independently mobile (+/- walking aid).
2. Discharge to rehabilitation: patients that are not frail (EFS >8; HGS is above the frailty threshold) but are NOT independently mobile (+/- walking aid).
3. Discharge to GEM: patients with mild to moderately frailty (EFS 8 to 11; HGS below the frailty threshold), irrespective of DMS.
4. Discharge to a provisional destination: patients that are severely frail (EFS 12 or above) and NOT from a RACF pre-fracture (based on frequencies and ORs).

NOTE: HGS is less indicative of discharge destinations than EFS, due to it having been treated mainly as a binary outcome in this study.

Other clinically relevant findings that could be considered by ward staff for planning and when discussing expectations with patients and family:

- Figure 17 on page 97 illustrates very clearly the decline in frequency of immediate or eventual home discharge with increasing degrees of frailty.
- It is also important to note that only 19% of patients moved to a new permanent home after rehabilitation, versus 56% after GEM. This statistic may be used to set expectations.
- LOS increases with the degree of frailty; DMS is negatively affected by frailty.
- Frail people have an increased mortality risk that decreases with time passed after fracture.

4.7.3 Considerations about risks, ORs, confounders, and clinical significance

Earlier in this thesis, risk factors were discussed in relation to the findings reported in papers included in the systematic review. It was acknowledged that a risk factor is an

exposure that pre-dates an associated outcome (Burt, 2001). However, causality between exposure and outcome cannot be known for certain. While the exposure might have pre-dated the outcome, their relationship might have been linked by factors other than chance and confounding factors were addressed, there is no certainty that the outcome would not have occurred in the absence of the exposure. This is especially true when analyses were based on RCD. The term risk indicator is hence preferable.

The statistical independence of a risk factor (or indicator) is unique to the investigated cohort, based on statistical tests used and confounding factors/co-variables chose. Independence can therefore not be generalised (Brotman et al., 2005).

When reporting study findings, it is important to consider the difference between relative risk and an odds ratio (George et al., 2020). Relative risk reports the probability of an outcome to happen in one group compared to the probability of the same outcome to happen in another group; relative risk can be reported as a percentage. An odds ratio on the other hand reports the association between an exposure and an outcome; it represents the odds of an outcome to occur in the presence of an exposure compared to the odds of the same outcome to occur in the absence of that same exposure. An odds ratio can therefore not be presented as a simple percent increase/decrease of an outcome to occur.

Since a statistically significant odds ratio ($p<.05$ and CI does not cross 1) cannot be reported as a simple percent changes of risk, its magnitude must be interpreted to decide on its clinical significance.

As stated above, statistical independence of a risk indicator is study dependent. Throughout the literature, adjusting for potential confounding factors is strongly recommended (e. g. Lee, 2014 or Groenwold et al., 2021). This might however not be as clear as it appears. Firstly, data cannot be pooled and compared in a meaningful way based on hierarchical models with different covariates. The (additional) reporting of unadjusted data from simple regressions is therefore vital. Secondly, from a clinical

perspective, the simple relationship between two variables might be most meaningful on a practical level.
Additionally, it seems important to remember that data can tell many tales, even when purely looking at frequencies and percentages; important insights to inform day-to-day clinical practice can be gained.

The aim of the observational study presented in this thesis was to produce clinically useful findings. Statistical significance does not inform about clinical relevance. Findings that lead to improved patient care and outcomes can be considered clinically significant (Sharma, 2021). What does that mean for the study results? While causality between exposure and outcome remained uncertain, results provided clinically useful risk indicators. Odds ratios had to be considered individually, and findings based on hierarchical as well as simple regressions were deemed important. Frequencies and percentages also contributed to overall results.

4.7.4 HGS: Which device should we use and what does it actually tell us?

HGS devices - revisited

HGS measurements were described in chapter 2.2.4 of this thesis, written during early stages of this research. Since then, time has passed, more insights were gained and more recent publications are available, meriting another exploration.

The Jamar hydraulic hand dynamometer (figure 19) has been used since the 1950s. It was the first of its kind, developed in California, USA, by Henry **JA**mpol, a physical therapist, **M**orris **A**simow, an engineer, and **R**obert Reiss, a prosthetics mechanist; the idea was allegedly given to them by Charles O. Bechtol, an orthopaedic surgeon (Kushner et al., 2022). Until today, it is considered the gold standard for measuring hand grip strength (Villain et al., 2023). However, as described earlier in this thesis, the device is bulky and heavy to hold, especially for older patients that have just experienced major trauma and surgery. Seated standardised measuring positions are recommended, which can be a challenge for acute hospitalised patients.

Several protocols were proposed over the years, aiming to standardise the way HGS is measured using the Jamar dynamometer, or comparable apparatuses. Some of these protocols were discussed in chapter 2.2.4 of this thesis, along with the recognition that there was no consistency regarding HGS measurement techniques throughout the published literature. Different methods were used, or information about test positions were not described, affecting comparability (Sausa-Santos & Amaral 2017). It was however alleged that accurate test position (sitting upright with bend elbows, wrist supported) was crucial to obtain accurate results. A lighter alternative to the Jamar hydraulic hand dynamometer is the Martin Vigorimeter. Weighing around 200g, the vigorimeter has been used since the 1990's and poses another manual option to measure HGS. Measurements are generated by squeezing a rubber bulb that is connected to a manometer. Although a dynamometer measures static strength (in kg), and a vigorimeter measures dynamic movement (in kPa), high correlations of measurement results between the two tools have been demonstrated. It has been suggested that HGS measurements obtained from a vigorimeter might be less influenced by hand anthropometry than measurements obtained from a dynamometer (De Dobbeleer et al., 2018). A study published in 2015 found that patients suffering from neuropathies preferred using a Vigorimeter over a Jamar hydraulic hand dynamometer (Draak et al., 2015). Sipers et al. (2016) found that a vigorimeter was a more practical tool for measuring HGS in geriatric inpatients compared to the Jamar hydraulic hand dynamometer, while producing reliable, valid, comparable results. Based on its weight, ease to use, and negligible running cost (re-calibration only), it appears to be a good option for use in acute hospital settings.

Figure 19: Jamar hydraulic hand grip dynamometer (photographed by author)

In recent years, electronic and digital HGS measuring devices have gained in popularity. DynX and CAMRY both were assessed against the Jamar hydraulic hand dynamometer with good validity and reliability (Shechtman et al., 2005; Huang et al., 2022). They both are not 'smart' devices, they have no internet connectivity. While the DynX device is designed for professional use, the manufacturer of the inexpensive CAMRY states that it is not recommended for professional use.

More advance technology can be found in devises such as K-force by Kinvent (figure 20) or the Gripwise® by Gripwisetech. Both have been successfully assessed against the Jamar hydraulic hand dynamometer (Nikodelis et al., 2021; Villain et al., 2023). K-force and Gripwise® are very light weight (170g and 215g respectively) compared to the Jamar (1.5kg). They are both very easy to use, have internet connectivity, and, if data is uploaded onto company servers, help gathering global data on HGS. Testing positions for accurate results are also more flexible compared to the Jamar. These devises are however expensive to run as they are requiring a smart device such as an iPad, tablet, or phone to operate.

Ongoing subscriptions to applications are also required. Additionally, if companies want to store and share data online, informed consent must be obtained from patients/clients prior to using the tool. This might be a feasible option of private practices but might not be practical for the use in acute hospital settings.

Figure 20: K-force hand grip strength measurement tool (photographed by author)

HGS – what does it tell us

There is no consensus about frailty definition, diagnosis or measurement. There is no to moderate overlap between outcomes of different types of frailty measures. While HGS moderately correlates with the reported EFS, there is no absolute way to prove that HGS is a measure for frailty, despite the proposal made by Syddall et al. in 2003. Soysal et al. (2021) conducted a meta-analysis based on eight systematic reviews showing HGS to be an indicator for overall health, disability, and mortality. Vaishya et al. (2024) published a

narrative review investigation the question if HGS can be considered a 'vital sign of health'. They concluded that evidence does support HGS to be a key marker for overall health during the lifespan. Frailty is not part of normal aging, as explained previously, but rather a sign of not aging well. Considering this and the findings by Vaishya et al., it does seem justified to consider HGS a frailty measure in its own right.

Irrespective of being considered a frailty marker / measure, HGS was significantly associated with much the same variables as EFS in the study presented in this thesis.

Since HGS was linked to multiple negative health outcomes, in this study and in the wider published literature, various clinical applications should be considered. HGS can provide baseline measurements for ongoing monitoring (outcome measures) or can be used as a single-point assessment tool.

For this study, HGS was used as a single-point assessment tool, employing pre-determined cut-off values. It was used in the same way as part of a test battery to diagnose sarcopenia, and it also comprises part of the test battery for establishing Fried's frailty phenotype, as described earlier. The European consensus on definition and diagnosis of sarcopenia was revised in 2019, where the cut-off values used for this study were confirmed (Cruz-Jentoft et al., 2019), validating the study method.

To use HGS as an outcome measure, access to age and gender specific normative data is helpful, however, it can be useful to just monitor change. There is not a universally accepted minimal clinically important difference for changes in hand grip strength. In a systematic review published in 2019, Richard Bohannon proposed to consider a change between five and six-and-a-half kilograms as clinically important; this was based on only four relevant studies. This proposed change seems large when considering an older population, where women over 80 years of age have an average HGS of between 12 and 19 kilograms (Dodds et al., 2014; Pan et al., 2020; Wiśniowska-Szurlej et al., 2021).

In summary, HGS remains a clinically useful measure with multiple potential applications. It can inform about a person's health (or even frailty) status. There are multiple validated devices available to use for measuring HGS. For geriatric patients, especially in an acute setting, the bulky and heavy Jamar dynamometer is not the best choice, especially as it requires a specific test position to acquire reliable results. Lighter devices that can be used in various test positions are better suited. Depending on available budget, reliable low- and high-tech devices are available. There is definite merit in using HGS as a measure in acute hip fracture patients, as demonstrated in this study and by other authors as well.

As a concluding remark, two things must be noted: Firstly, HGS is a measure that does not solve any other purpose that that of a risk indicator when used in an acute clinical setting; it is a task that health care staff must adopt in addition to their usual duties. Secondly, HGS taken in an acute setting measures the current state of a patient's condition; being a sole test, no aspect of their immediate pre-fracture state can be accounted for, in contrast to the reported EFS that comprises questions relating to the immediate past.

4.7.5 EFS: clinical utility in acute hip fracture patients

The EFS was initially explored in chapter 2.2.4 of this thesis. Some more recent publications provided further relevant insights, many of these were outlined in chapter 4.2.3.

As stated in chapter 4.7.3.1 above, the reported EFS provides information about patients' pre-fracture state, demonstrating a frailty baseline rather than displaying their post-operative form. Its five levels of frailty provide refined information, allowing for specific recommendations. All items on the reported EFS are patient information that should be collected and recorded in their files in any case, irrespective of the EFS being part of routine care. The additional effort can thus be considered negligible, a useful score can be calculated with relative ease.

4.7.6 Limitations

This observational study had several limitations that must be acknowledged.

The use of RCD was explored in the preface (chapter 4.1). The impossibility to gain further information was highlighted as a potential constraint. For this study, this meant that while types of discharge destinations were known, there was no way of verifying whether these destinations were in fact the most appropriate for each patient.

Overall, there was no way to verify the accuracy of patient notes; human error and carelessness had the potential to compromise information. Considering the type of information extracted, and the fact that multiple hospital data sources were used to search for information, this concern is believed to be negligible.

Kim et al. (2023) highlighted the possible inaccuracy of HGS measures in acute hip fracture patients due to pain levels and compromised testing positions. While HGS measurements were standardised at the study hospital, these concerns must be agreed with.

Statistical tests applied for analyses in this study were fairly simple. While this was in favour of preventing statistical misuse, more high-level statistics might have revealed more information. Especially the assessment of statistically significant differences of ORs could have been interesting.

For this thesis, many analyses were performed on the same data set, thus a potential multiple testing problem, arising in false-positive results, should be considered (Steiner at al., 2011; Ranganathan et al., 2016). However, subgroup analyses were limited to retain statistical power; while several end points were considered, only a limited number of different statistical tests were performed. For the proportion estimates in the sample size calculation, findings by Kistler et al. (2015) were considered. In contrast to this study, they had used the Fried Frailty Index to assess frailty. Since it now appears clear that frailty measures are not interchangeable, this might not have been the ideal basis for a

proportion estimate. However, at the time of study planning, Kistler's paper was the best option available.

Subgroup analyses were not considered in the sample size calculations, resulting in possibly under-powered subgroup analyses. In this regard, this study cannot compete with large registry studies.

Findings regarding discharge destinations and arising clinical recommendations must be considered in a local context. This was a single-site study, limiting generalisability. Discharge destinations are also affected by availability at any given time, which might have impacted results.

4.7.7 Strengths

Despite many limitations, this study had obvious strengths.

As stated in the preface, the study design allowed for inclusion of all patients, irrespective of language, cognitive abilities and overall health, avoiding the neglect or under-representation of certain groups.

Data used for this study was collected in a real-life clinical setting. Therefore, only readily available information has been used to establish risk indicators relevant to planning for discharge destinations.

Outcomes were focused on clinical utility rather than just presenting a multitude of associations. A clinical guideline for discharge destinations could be established.

4.7.8 Generalisability

Considering study design and reasoning through findings, no claim could be made that relationships between independent and dependent variables were truly causal. However, internal validity threats relevant for an observational study using RCD were presumed to be negligible. This was since appropriate reporting guidelines were followed (STROBE / RECORD); potential biases were considered; relatively simple statistical test were applied,

omitting the risk of statistical misuse; and confounders were managed through hierarchical statistical models. Single-group and historical threats were also negligible, considering the patient population and the main objectives of this study: the cohort of interest was hip fracture patents only, all objectives were linked to occurrences during the peri-injury phase.

Heterogeneity was found in the literature regarding the choice and use of frailty measures. Therefore, the clinical use of EFS and HGS in the study population was described in much detail, allowing for reproduction of measurements in a different study, if desired.

As presented in chapter 4.7.1.1., the patient cohort observed for this study was deemed comparable to other hip fracture cohorts described in the literature, suggesting no external validity concerns. Thus, findings were likely to apply to other health care settings.

4.8 Conclusion

Based on findings of this study, a discharge guideline based on frailty could be proposed. HGS and EFS were both found to be associated with relevant outcomes in acute hip fracture patients. It appeared that the reported EFS delivered more benefits than HGS cut-offs. This was believed to be because the EFS incorporates more than just the present shape of patients, it also considers their health and capacity immediately prior to the fracture, painting a more holistic picture of individuals' frailty levels. The EFS also allows for sub-classifications of frailty severity, making more specific recommendations possible. While more detailed HGS analyses could possibly yield a sub-classification system in addition to cut-off values, this was not attempted with the study data. This was because such specific subgroup analyses were not considered in the statistical power analyses. Concerns around the accuracy of HGS data (study design as well as tool used) were also a factor, especially as these concerns were shared by the senior physiotherapist responsible for trauma patient care. They advised that time, lack of care, or inexperience were possibly affecting accuracy of measures.

The reported EFS and HGS were routinely administered at the acute ward for hip fracture patients, albeit with inconsistent application. While these measures had been implemented without clear guidance regarding their clinical purpose, the results of this study showed clear clinical utility of such measures. For clinical staff to consistently utilise such measures, robust training should be implemented demonstrating objective benefits.

While the reported EFS appeared to be more useful in the study context, HGS should still be considered a clinically useful and important measure. Its use in acute settings could be refined, as suggested above. Findings by other researchers such as Kunustor et al. (2021), Pratama et al. (2018), or Sirola et al. (2005) imply that HGS may act as a measure of change to track frailty severity in the community. This seems especially relevant as weak HGS has been shown to be a risk factor for sustaining hip fractures; and because frailty is theorised to be reversible.

As stated before, the study findings could not conclusively inform about appropriateness of discharge destinations for individual hip fracture patients. These patients would need to be followed up to verify if their rehabilitation goals could be achieved.

5 FINAL CONCLUSIONS AND FUTURE RESEARCH

To date, hip fractures remain a global health concern (Feng et al., 2024). Frailty is highly prevalent in older hip fracture patients, as shown in the systematic review and observational study presented in this thesis, as well as in the literature (prevalence between 22% and 81%, depending on cohort and setting, as per Yan et al., 2022).

Hip fracture alone poses risks for negative health and life outcomes; the added presence of frailty significantly increases these risks. Considering this, Moloney et al. (2024) conducted an international Delphi consensus study regarding requirements for frailty screening in emergency departments. While this was a great and important attempt, no clinically useful conclusion could be formed.

This reinforces that extensive further research is needed to formalise the concept of frailty, its definition, diagnosis and management/treatment (Doody et a., 2023). This is especially imperative as frailty might be, at least in part, reversible. Considering the vast controversies and incongruities, a more concise, universal definition cannot be expected presently. In the meantime, it is vital to recognise frailty as a state of increased vulnerability that requires detection to provide appropriate care and risk mitigation.

In this thesis, after establishing the presence of frailty in form of decreased HGS in hip fracture patients (systematic review), the use of frailty in an acute setting was investigated (observational study). It was possible to propose a clinical guideline that, in conjunction with clinical reasoning, can aid in discharge planning and expectation management (patients and families/next of kin).

The reported EFS emerged as potentially more useful than HGS in an acute setting. However, HGS was also associated with outcomes in a comparable way. Thus, with reliable measurements and the establishment of subgroups, HGS might be as clinically useful as the EFS. Yet differences between the two types of measure must be considered, since HGS measured in acute post-operative patients informs only about the current state while the

EFS considers pre-fracture capacities. The results from the systematic review conducted for this thesis, amongst other evidence from the literature, highlight that frailty, especially based on HGS, poses a risk for sustaining a hip fracture. Hence, frailty screening in the community may play a role in risk mitigation strategies.

Knowledge and understanding about frailty and the risks it poses to affected patients is crucial. Archibald et al. (2020) found that orthopaedic surgeons, irrespective of years of experience, had little in-depth understanding of frailty; while there was no opposition to frailty screening, there was doubt about its usefulness on an orthopaedic ward. An informal survey conducted amongst 50 nurses working at the local acute orthopaedic ward produced similar results as reported in Archibald's study. This highlights the need for frailty education for all health care providers, including medical, nursing and allied health staff. Frailty is not exclusive, and it negatively affects patients across various medical subgroups.

The aim of the work comprising this thesis was to investigate if most hip fracture patients are indeed frail; resulting implications regarding recovery and change of life circumstances; and the clinical utility of this information. A systematic review of existing literature confirmed a relationship between decreased HGS (a potential indicator of frailty) and hip fracture events. Results from our local retrospective observational study confirmed that frailty was highly prevalent in hip fracture patients, when measured by HGS as well as EFS. Results also confirmed a negative impact of frailty (HGS and EFS) on recovery, functional outcomes, and independence. Clinical recommendations were made, these are likely only locally applicable. However, clinical usefulness of frailty screening can be universally recommended as it is linked to results such as mobility status on discharge, which in any setting will impact discharge decision making.

5.1 Future research

1. HGS should be investigated further, using tools such as the vigiromter or the K-force, to obtain reliable, easily reproducible subgroup data rather than just operating with a single cut-off value. HGS measures the present state of frailty/muscle strength, providing a baseline from which change can easily be tracked.

2. A more comprehensive risk screening tool for permanent change of primary residence (with or without attending any form of rehabilitation) could be developed, taking multiple variables into consideration. The clinical usefulness of such a tool would have to be evaluated first. There are multitudes of risk screening tools published in the literature, including a post-operative delirium risk scoring tool specifically for hip fracture patients by Oberai et al. (2021), or the Hospital Frailty Risk Score (Gilbert et al., 2018). These multi-variable tools are challenging to implement on busy hospital wards, hence a clear benefit that outweighs the extra effort must be demonstrable. The delirium risk score was developed locally and has not been implemented into clinical practice; no evidence could be found in the literature about successful implementation of the Hospital Frailty Risk Score. This clearly demonstrates that it is not enough to base a risk score on statistical findings alone. Practical and clinical benefits must outweigh the extra efforts required to obtain the score results. Machine learning models might be able to self-generate frailty related risk scores based on routinely documented data within electronic patient records, culling the administrative burden. Prediction performance needs further optimisation before machine learning models can be routinely used as clinical decision-support tools (Tarekegen et al. 2020). Machine learning approaches for the detection of frailty rather than negative health outcomes as a result of frailty are still in early development without current clinical application (Oliosi et. al., 2020; Leghissa et al., 2023).

3. Qualitative research formally investigating the knowledge base of health care providers about frailty and its burden is important. Such research should be conducted with a much larger sample than the 15 surgeons in the study by Archibald et al. (2020).

Knowledge about frailty is important for hospital personnel when treating inpatients, but also crucial for health care workers in the community, such as general practitioners, community nurses and physiotherapist. If frailty is falsely regarded as 'normal' aging, vital opportunities are missed to increase healthspan and offload the burden on the health care system. It seems fair to hypothesise that such a qualitative study will highlight massive gaps in knowledge. Proof of this knowledge gap could be the basis for the implementation of broader education on frailty.

4. A prospective study where patients are followed up until discharge from rehabilitation or GEM could inform about the appropriateness of the respective primary discharge destination. This should be based on patient experience but also on the achievement of goals set for patients before and during their stays.

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APPENDICES

Appendix A: Observational study - Frequencies and percentages tables

Appendix A1: Demographics and baseline characteristics – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Demographics			
Number of included patients	462 (100.0)	310 (67.09)	152 (32.90)
Age in years	Range: 50 – 103 Mean: 82 Median: 84	Range: 50 – 103 Mean: 83 Median: 85	Range: 51 – 101 Mean: 80 Median: 83
Type of pre-injury primary residence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Private home – independent alone	116 (25.10)	83 (26.77)	33 (21.71)
Private home - independent cohabiting	156 (33.76)	90 (29.03)	66 (43.42)
Private or institutional home - low dependency	40 (08.65)	25 (08.06)	15 (09.86)
Residential aged care facility - high dependency	150 (32.46)	112 (36.12)	38 (25.00)
Number of morbidities			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Free of morbidities	17 (03.68)	9 (02.90)	8 (05.26)
1 area	53 (11.47)	40 (12.90)	13 (08.55)
2 areas	105 (22.73)	72 (23.23)	33 (21.71)
3 area	131 (28.35)	89 (28.71)	42 (27.63)
4 areas	100 (21.64)	63 (20.32)	37 (24.34)
5 areas	46 (09.96)	29 (09.35)	17 (11.18)
6 areas	10 (02.16)	8 (02.56)	2 (01.32)
Mobility status pre-injury			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Independently mobile	231 (50.00)	145 (46.77)	86 (56.57)
Independent with aid	132 (28.57)	91 (29.35)	41 (26.97)
Physical help or supervision	94 (20.34)	72 (23.22)	22 (14.47)
Bed mobility and sitting only	5 (01.08)	2 (00.64)	3 (01.97)
Cognition and mental health pre-injury			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Dementia/Alzheimer's	164 (35.50)	127 (40.97)	37 (24.34)
Depression	138 (29.87)	105 (33.87)	33 (21.71)
Osteoporosis diagnosis pre-injury and resulting medication			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Diagnosed	112 (24.19)	98 (31.61)	14 (09.21)
Valid cases	*112 (100.0)*	*98 (100.0)*	*14 (100.0)*

On medication	104 (92.86)	91 (92.86)	13 (92.86)
Body mass index			
Valid cases	*439 (100.0)*	*291 (100.0)*	*148 (100.0)*
Underweight	33 (07.52)	25 (08.59)	8 (05.40)
Healthy weight range	235 (53.53)	152 (52.23)	83 (56.08)
Overweight	129 (29.38)	86 (29.55)	43 (29.05)
Obese	42 (09.57)	28 (09.62)	14 (09.46)
Previous hip fracture, corresponding history of falling, resulting osteoporosis diagnosis and medication			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Previous hip fracture	37 (08.01)	33 (10.64)	4 (02.63)
Valid cases	*37 (100.0)*	*33 (100.0)*	*4 (100.0)*
History of falling	31 (83.78)	27 (81.81)	4 (100.0)
Osteoporosis diagnosed	17 (45.94)	14 (42.42)	3 (75.00)
Valid cases	*17 (100.0)*	*14 (100.0)*	*3 (100.0)*
Medication commenced	15 (88.22)	13 (92.86)	2 (66.66)
History of falling – overall, in relation to mobility status, and according to type of residence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Overall	231 (50.00)	165 (53.23)	66 (43.42)
Valid cases	*231 (100.0)*	*165 (100.0)*	*66 (100.0)*
Independently mobile	63 (27.31)	44 (26.66)	19 (28.78)
Independent with aid	84 (36.39)	58 (35.15)	26 (39.39)
Physical help or supervision	80 (34.59)	61 (36.97)	19 (28.78)
Bed mobility and sitting only	4 (01.73)		
Private home, independent, alone	36 (15.58)	26 (15.75)	10 (15.15)
Private home, independent, accompanied	44 (19.05)	26 (15.75)	18 (27.27)
Private or institutional home, dependent, low care	24 (10.39)	18 (10.91)	6 (9.09)
Institutional home, dependent, high care	127 (54.98)	95 (57.57)	32 (48.48)
Dependencies			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Alcohol	35 (07.57)	14 (04.52)	21 (13.82)
Nicotine	102 (22.07)	49 (15.81)	53 (34.87)
Substances	14 (03.03)	7 (02.26)	7 (04.60)
Impairments			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Vision	135 (29.22)	96 (30.97)	39 (25.66)
Hearing	95 (20.56)	63 (20.32)	32 (21.05)
Incontinence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Urinary	228 (49.35)	86 (60.00)	42 (17.63)
Urinary and faecal	56 (12.12)	42 (12.90)	14 (09.12)

Appendix A2: Fracture related details – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Place of occurrence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Institutional home	146 (31.60)	106 (34.19)	40 (26.32)
Public place	60 (12.98)	37 (11.93)	23 (15.13)
Private residence	254 (54.98)	165 (53.23)	89 (58.55)
Hospital ward	2 (00.43)		
Activity when injured			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Getting up from sitting	73 (15.80)	560 (18.06)	17 (11.18)
Standing	26 (05.63)	20 (06.45)	6 (03.93)
Walking	341 (73.80)	224 (72.26)	117 (76.97)
Fall out of bed	4 (00.87)		
Fall off chair	3 (00.64)		
other	13 (02.81)	6 (01.93)	7 (04.60)
Side of fracture			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Left	254 (54.98)	167 (53.87)	87 (57.24)
Right	208 (45.02)	143 (42.13)	65 (42.76)
Fracture type			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Sub-capital	222 (48.05)	149 (48.06)	73 (48.03)
Basic cervical	26 (05.63)	18 (05.81)	8 (05.26)
Per/inter trochanteric	186 (40.26)	128 (41.29)	58 (38.16)
Sub trochanteric	28 (06.06)	15 (04.84)	13 (08.55)

Appendix A3: Peri-operative information – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Analgesics on arrival (ED or ward)			
Valid cases	*462 (100.0)*		
Femoral nerve block	462 (100.0)		
Time to theatre			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Within 24 hours	344 (74.67)	232 (74.84)	112 (73.68)
Within 48 hours	434 (93.93)	294 (94.84)	140 (92.10)
Reasons for delay >48 hours			
Valid cases	*28 (100.0)*		
Medical	22 (78.57)		
Anticoagulants & medical	4 (14.28)		
Organisational	2 (7.14)		
ASA Physical Status Classification System score, pre-operatively			
Valid cases	*438 (100.0)*	*296 (100.0)*	*142 (100.0)*
Grade 1	5 (01.08)	2 (00.65)	3 (01.97)
Grade 2	85 (18.39)	57 (18.39)	28 (18.42)
Grade 3	257 (55.63)	183 (59.03)	74 (48.68)
Grade 4	91 (19.69)	54 (17.42)	37 (24.34)
Surgery (time in minutes)			
Total time in suite	Range: 76 - 431 Mean: 179.61 Median: 175	Range: 76 - 370 Mean: 176.79 Median: 172.5	Range: 87 - 431 Mean: 185.33 Median: 182.5
Time for general anaesthetics	Range: 1-55 Mean: 6.51 Median: 4	Range: 1 - 47 Mean: 6.87 Median: 5	Range: 1-55 Mean: 6.99 Median: 4
Duration of operation	Range: 52 - 303 Mean: 140.12 Median: 138.5	Range: 57 - 267 Mean: 138.4 Median: 135	Range: 52 - 303 Mean: 143.58 Median: 140.5
Time in recovery	Range: 0 - 617 Mean: 157.92 Median: 142	Range: 0 - 617 Mean: 159.80 Median: 143.5	Range: 0 - 503 Mean: 154.10 Median: 140.5
Type of fracture repair			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Hemi-arthroplasty	139 (30.09)	93 (30.00)	46 (30.26)
Total hip replacement	490 (10.60)	37 (11.93)	12 (07.89)
Dynamic hip screw	230 (04.97)	11 (03.55)	12 (07.89)
Short gamma nail	153 (33.11)	106 (34.19)	47 (30.92)
Long gamma nail	530 (11.47)	34 (10.97)	19 (12.50)
Cannulated screws	410 (08.87)	27 (08.71)	14 (09.21)
Other	4 (00.87)	3 (00.97)	1 (00.66)

Appendix A4: In-hospital assessed variables – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Malnutrition Universal Screening Tool (MUST) during admission			
Valid cases	*162 (100.0)*	*115 (100.0)*	*47 (100.0)*
Not at risk	109 (67.28)	77 (66.96)	32 (78.05)
Moderate risk	25 (15.43)	15 (13.04)	10 (21.28)
High risk	28 (17.28)	23 (20.00)	5 (10.64)
Falls risk			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
In-hospital and post discharge falls risk	397 (85.90)	272 (87.74)	125 (82.24)
Mobility status on day one post-surgery			
Valid cases	*461 (100.0)*	*310 (100.0)*	*151 (100.0)*
Independent	0		
Independent with aid	3 (00.64)	1 (00.32)	2 (01.32)
Physical help or supervision	130 (28.13)	78 (25.16)	52 (34.21)
Bed mobility and sitting	237 (51.39)	166 (53.55)	71 (46.71)
Unable to mobilise	91 (19.69)	65 (20.97)	26 (17.10)
Mobility status on day of discharge			
Valid cases	*459 (100.0)*	*308 (100.0)*	*151 (100.0)*
Independent	2 (00.44)	2 (00.65)	
Independent with aid	64 (13.94)	35 (11.36)	29 (19.20)
Physical help or supervision	266 (57.95)	177 (57.47)	89 (58.94)
Bed mobility/exercises and sitting out of bed	108 (23.53)	83 (26.77)	25 (16.56)
Unable to mobilise	19 (04.14)	11 (03.57)	8 (05.29)
Diagnosis of osteoporosis			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
New diagnosis	82 (17.74)	56 (18.06)	26 (17.10)
Valid cases	*82 (100.0)*	*56 (100.0)*	*26 (100.0)*
Commencement of medication	54 (65.85)	40 (71.42)	14 (53.85%)
Prolonged hospital stay			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Acute stay over 10 days	83 (17.96)	52 (16.77)	31 (20.39)
Acute stay over 12 days	60 (12.98)	39 (12.58)	21 (13.82)
Frailty binary			
Valid cases	*407 (100.0)*	*265 (100.0)*	*142 (100.0)*
Frail defined by hand grip strength*	281 (69.04)	183 (69.06)	98 (69.01)
Valid cases	*459 (100.0)*	*309 (100.0)*	*150 (100.0)*
Frailty defined by the Edmonton frail scale**	276 (60.13)	196 (63.43)	80 (53.33)
Frailty: EFS by categories			
Valid cases	*459 (100.0)*	*309 (100.0)*	*150 (100.0)*
Not frail	130 (28.32)	82 (26.53)	48 (32.00)
Vulnerable	52 (11.32)	31 (10.03)	22 (14.66)
Mildly frail	57 (12.41)	36 (11.65)	21 (14.00)
Moderately frail	49 (10.67)	31 (10.03)	18 (12.00)
Severely frail	170 (37.03)	129 (41.71)	41 (27.33)
* T-score of -2.5 below the gender stratified average; **mild to severely frail (8 to 17 points on score)			

Appendix A5: Unplanned events during acute hospital stay – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Adverse events during admission			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
None	218 (47.19)	147 (47.42)	71 (46.71)
Grade 1	74 (16.02)	55 (17.74)	19 (12.51)
Grade 2	135 (29.24)	95 (30.64)	40 (26.31)
Grade 3, 3a and 3B	9 (01.95)	2 (00.64)	7 (04.59)
Grade 4, 4a and 4B	13 (02.81)	8 (02.58)	5 (03.28)
Grade 5 (in-hospital mortality)	13 (02.81)	3 (00.97)	10 (06.58)
Delirium categories			
Valid cases	*460 (100.0)*	*309 (100.0)*	*151 (100.0)*
Not delirious	257 (55.62)	162 (52.43)	95 (61.91)
Confused	166 (36.08)	116 (37.54)	50 (33.11)
Confused and agitated	23 (04.97)	19 (06.15)	4 (02.65)
Confused and drowsy	14 (03.03)	12 (03.88)	2 (01.33)
Delirium yes/no			
Valid cases	*460 (100.0)*	*309 (100.0)*	*151 (100.0)*
Not delirious	257 (55.86)	162 (52.42)	95 (62.91)
Delirious	203 (44.13)	147 (47.57)	56 (37.08)

Appendix A6: Discharge destinations following acute hospital stay – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Home discharge to pre-injury primary residence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	183 (39.61)	131 (42.26)	52 (34.21)
Valid cases	*183 (100.0)*	*131 (100.0)*	*52 (100.0)*
Previously from private home – independent alone	10 (05.46)	3 (02.29)	7 (13.46)
Previously from private home - independent cohabiting	31 (16.94)	20 (15.27)	11 (21.15)
Previously from private or institutional home - low dependency	5 (02.73)	2 (01.53)	3 (05.77)
Previously from residential aged care facility - high dependency	137 (74.86)	106 (80.91)	31 (59.61)
To private home – independent alone			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	10 (02.16)	3 (00.97)	7 (04.60)
Valid cases	*10 (100.0)*	*3 (100.0)*	*7 (100.0)*
Previously from private home – independent alone (home discharge)	10 (100.0)	3 (100.0)	7 (100.0)
To private home - independent cohabiting			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	31 (06.71)	20 (64.52)	11 (07.24)
Valid cases	*31 (100.0)*	*20 (100.0)*	*11 (100.0)*
Previously from private home - independent cohabiting (home discharge)	31 (100.0)	20 (100.0)	11 (100.0)
To private or institutional home – low dependency			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	7 (01.51)	4 (00.13)	3 (01.97)
Valid cases	*7 (100.0)*	*4 (100.0)*	*3 (100.0)*
Previously from private home – independent alone	2 (28.57)	2 (50.00)	0
Previously from private or institutional home - low dependency (home discharge)	5 (71.43)	2 (50.00)	3 (100.0)
To residential aged care facility – high dependency			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	148 (32.04)	114 (36.77)	34 (22.37)
Valid cases	*148 (100.0)*	*114 (100.0)*	*34 (100.0)*
Previously from private home - independent alone	1 (00.67)	1 (00.87)	0
Previously from private or institutional home – low dependency	10 (06.76)	7 (06.14)	3 (08.82)
Previously from residential aged care facility - high dependency (home discharge)	137 (92.67)	106 (92.98)	31 (91.18)
To rehabilitation			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	169 (36.58)	103 (33.22)	66 (43.42)
Valid cases	*169 (100.0)*	*103 (100.0)*	*66 (100.0)*
Previously from private home – independent alone	65 (38.46)	45 (43.69)	20 (30.30)

Previously from private home – independent cohabiting	89 (52.66)	50 (48.54)	39 (59.09)
Previously from private or institutional home – low dependency	14 (08.28)	8 (07.76)	6 (09.09)
Previously from residential aged care facility - high dependency	1 (00.59)	0	1 (01.51)
To temporary care placement			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	14 (03.03)	10 (03.12)	4 (02.63)
Valid cases	*14 (100.0)*	*10 (100.0)*	*4 (100.0)*
Previously from private home – independent alone	5 (35.71)	4 (40.00)	1 (25.00)
Previously from private home - independent cohabiting	4 (28.57)	2 (20.00)	2 (50.00)
Previously from private or institutional home -low dependency	5 (35.71)	4 (40.00)	1 (25.00)
To geriatric evaluation & management unit			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	65 (14.07)	49 (15.81)	16 (10.53)
Valid cases	*65 (100.0)*	*49 (100.0)*	*16 (100.0)*
Previously from private home – independent alone	30 (46.15)	26 (53.06)	4 (25.00)
Previously from private home – independent cohabiting	27 (41.54)	16 (32.65)	11 (68.75)
Previously from private or institutional home – low dependency	5 (07.69)	4 (08.16)	1 (06.25)
Previously from residential aged care facility - high dependency	3 (04.62)	3 (06.12)	0
To care awaiting placement			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	2 (00.43)	1 (00.32)	1 (00.65)
Valid cases	*2 (100.0)*	*1 (100.0)*	*1 (100.0)*
Previously from private home – independent alone	1 (50.00)	1 (100.0)	0
Previously from private or institutional home – low dependency	1 (50.00)	0	1 (100.0)
Hospital transfer			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	3 (00.65)	3 (00.97)	0
Valid cases	*3 (100.0)*	*3 (100.0)*	*0*
Previously from private home - independent alone	1 (33.33)	1 (33.33)	0
Previously from private home – independent cohabiting	2 (66.66)	2 (66.66)	0

Appendix A7: Secondary discharge destinations following any type of short term placement* – frequencies and percentages

	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Valid cases	*244 (100.0)*	*161 (100.0)*	*83 (100.0)*
To private home – independent alone	58 (23.77)	43 (26.71)	15 (18.07)
To private home – independent cohabiting	90 (36.88)	54 (33.54)	36 (43.37)
To private or institutional home – low dependency	32 (13.12)	21 (13.04)	11 (13.25)
To residential aged care facility - high dependency	40 (16.39)	29 (18.02)	11 (13.25)
To temporary care placement	20 (08.19)	11 (06.83)	9 (10.84)
To geriatric evaluation medicine unit	1 (00.41)	1 (00.62)	0
Died during temporary stay	3 (01.23)	2 (01.24)	1 (01.21)
Secondary home discharge	164 (67.21)	106 (65.84)	58 (69.88)
Permanent change of residence	80 (32.78)	55 (34.16)	25 (30.12)

*General rehabilitation, geriatric evaluation and management, temporary care placement, care awaiting placement, other hospital.

Appendix A8: Secondary discharge destinations following specific types of short term placements – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Discharge destinations following general rehabilitation			
Valid cases	*165 (100.0)*	*101 (100.0)*	*64 (100.0)*
To private home – independent alone	48 (29.09)	35 (34.65)	13 (20.31)
To private home – independent cohabiting	77 (46.67)	45 (44.55)	32 (50.00)
To private or institutional home – low dependency	14 (08.48)	7 (06.93)	7 (10.94)
To residential aged care facility - high dependency	12 (07.27)	7 (06.93)	5 (07.81)
To temporary care placement	12 (07.27)	6 (05.94)	6 (09.37)
To geriatric evaluation medicine unit	1 (00.60)	1 (00.99)	0
Died during rehabilitation	1 (00.60)	0	1 (01.56)
Secondary home discharge	134 (81.21)	83 (82.18)	51 (79.69)
Permanent change of residence	31 (29.18.79)	18 (17.82)	13 (20.31)
Discharge destinations following geriatric evaluation & management			
Valid cases	*59 (100.0)*	*45 (100.0)*	*14 (100.0)*
To private home – independent alone	9 (15.25)	7 (15.55)	2 (14.28)
To private home – independent cohabiting	11 (18.64)	7 (15.55)	4 (28.57)
To private or institutional home – low dependency	12 (20.34)	11 (24.44)	1 (07.14)
To residential aged care facility - high dependency	18 (30.51)	14 (31.11)	4 (28.57)
To temporary care placement	8 (13.56)	5 (11.11)	3 (21.43)
Died during stay	1 (1.69)	1 (2.22)	0
Secondary home discharge	26 (44.07)	20 (44.40)	6 (42.86)
Permanent change of residence	33 (55.93)	25 (55.60)	8 (57.14)
Discharge destinations following any provisional destination (including temporary care placement and care awaiting placement)			
Valid cases	*16 (100.0)*		
To private home – independent cohabiting	2 (12.50)		
To private or institutional home – low dependency	6 (37.50)		
To residential aged care facility - high dependency	8 (50.00)		
Secondary home discharge	3 (18.75)		
Permanent change of residence	13 (81.25)		

Appendix A9: Permanent changes of primary residence post fracture and corresponding pre- and post-injury types of residence – frequencies and percentages			
	Combined total N (%) of valid cases	**Female** N (%) of valid cases	**Male** N (%) of valid cases
Change of residence			
Valid cases	*462 (100.0)*	*310 (100.0)*	*152 (100.0)*
Total	*103 (22.29)*	*65 (20.97)*	*38 (25.00)*
From private home – independent alone			
Valid cases	*103 (100.0)*	*65 (100.0)*	*38 (100.0)*
Total	43 (41.75)	33 (50.77)	10 (26.32)
Valid cases	*43 (100.0)*		
To cohabiting	03 (06.98)		
To low care	10 (23.26)		
To high care	16 (37.21)		
To temporary provisional destinations awaiting high care placement	10 (23.26)		
Deceased at initial discharge destination	4 (09.30)		
From private home – independent cohabiting			
Valid cases	*103 (100.0)*	*65 (100.0)*	*38 (100.0)*
Total	32 (31.07)	16 (24.62)	16 (42.11)
Valid cases	32 (100.0)		
To low care	07 (21.87)		
To high care	12 (37.50)		
To temporary provisional destinations awaiting high care placement	09 (28.12)		
Deceased at initial discharge destination	04 (12.50)		
From private or institutional home – low dependency			
Valid cases	103 (100.0)	65 (100.0)	38 (100.0)
Total	19 (18.45)	13 (20.00)	6 (15.79)
Valid cases	19 (100.0)		
To high care	8 (42.10)		
To temporary provisional destinations awaiting high care placement	2 (10.53)		
Deceased at initial discharge destination	9 (47.34)		
From residential aged care facility - high dependency			
Valid cases	*103 (100.0)*	*65 (100.0)*	*38 (100.0)*
Total	9 (08.74)	03 (04.62)	6 (15.79)
Deceased at initial discharge destination	9 (100.0)		

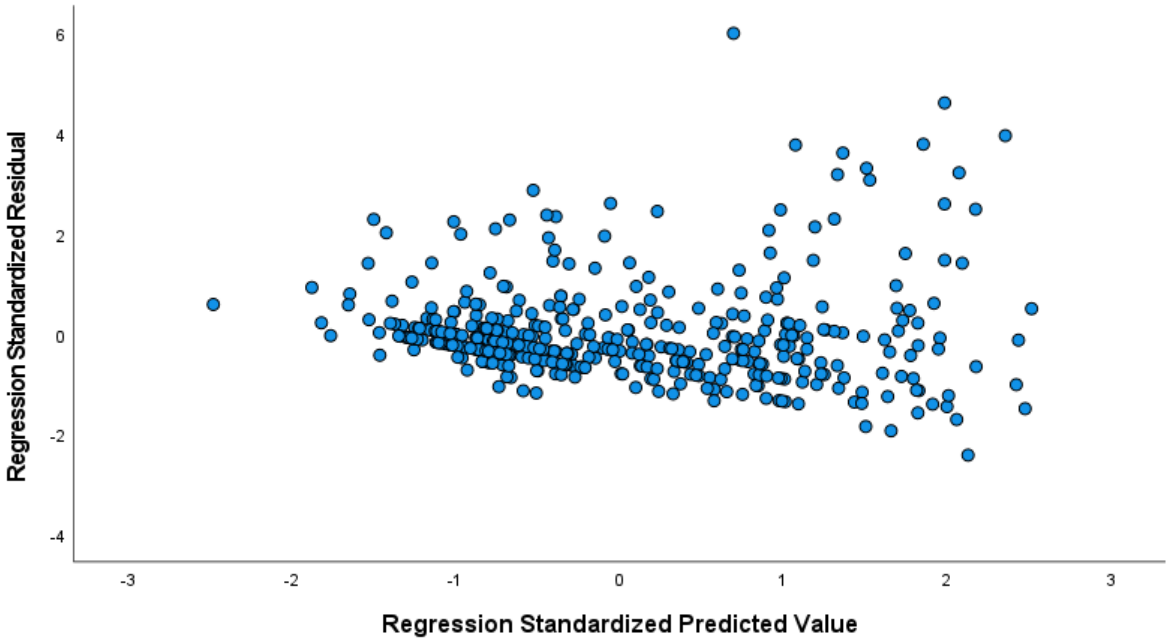
Appendix A10: List of variables collected (observational study)	
1	gender
2	age (time of injury)
3	type of fracture
4	side of fracture
5	repair type
6	femoral nerve block in the emergency department
7	place of occurrence
8	activity when injured
9	pre-injury primary residence type
10	discharge destination 1
11	discharge destination 2
12	permanent change in primary residence
13	pre-injury mobility status
14	mobility status on day one post-surgery
15	discharge mobility status
16	ASA physical status classification system
17	time to theatre in hours (from admission to in-suite)
18	reason for delay of surgery (if applicable)
19	total time in suit in minutes
20	general anaesthetics time in minutes (start op until incision)
21	duration of operation in minutes
22	time in recovery in minutes
23	length of hospital stay in days
24	hand grip strength right (post-surgery)
25	hand grip strength left (post-surgery)
26	maximal hand grip strength
27	Edmonton frail scale points
28	Edmonton frail scale categories
29	malnutrition universal screening tool
30	weight
31	height
32	Body mass index
33	falls risk
34	previous hip fracture
35	history of falling
36	previous osteoporosis drugs
37	new osteoporosis drugs
38	hearing impairment
39	vision impairment
40	alcohol dependency
41	substance abuse
42	smoker
43	comorbidities - musculoskeletal
44	comorbidities – oncological

45	comorbidities – gastro-intestine
46	comorbidities - renal
47	comorbidities – endocrine
48	comorbidities – cardiovascular
49	comorbidities – pulmonary
50	comorbidities – neurological
51	comorbidities – gynaecological
52	Incontinence – urinary and/or faecal
53	depression
54	dementia / Alzheimer's disease
55	comorbidities – mental health (other than depression or dementia)
56	other health problems
57	osteoporosis: diagnosed pre-injury
58	osteoporosis: new diagnosis written in discharge letter
59	osteoporosis: diagnosis post injury – diagnostic tools
60	adverse events during admission (grade)
61	delirium during admission
62	3-months re-admissions
63	3-months mortality
64	12 months mortality

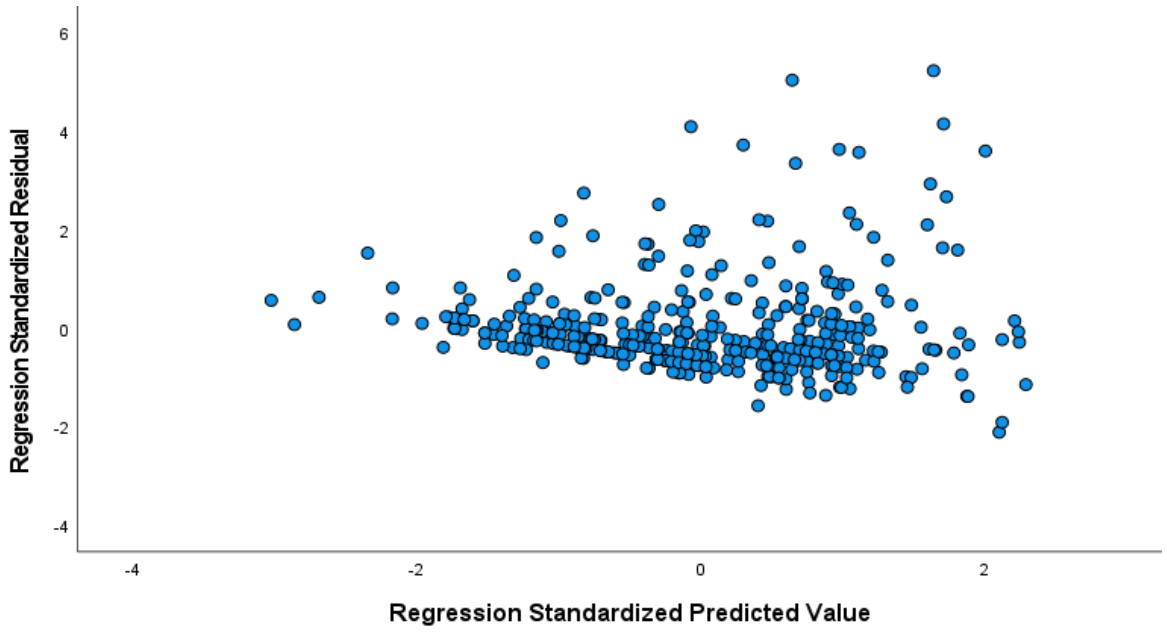
Appendix B: Observational study - Results for frailty and length of hospital stay

Appendix B1: Heteroscedasticity

LOS (outcome variable) and EFS (predictor variable)



LOS (outcome variable) and HGS (predictor variable)



Appendix B2: Association of frailty (defined by EFS) with LOS
Hierarchical multiple linear regression (EFS as continuous predictor, LOS as continuous outcome variable)

Model		B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
1	Constant	2.542	1.989		1.278	.202	-1.367	6.452
	Age	.074	.025	.149	3.003	.003	.026	.123
	Pre-injury RACF	-3.530	.543	-.324	-6.506	<.001	-4.596	-2.464
2	Constant	-.324	2.093		-.155	.877	-4.438	3.791
	Age	.042	.025	.085	1.709	.088	-.006	.091
	Pre-injury RACF	-4.050	.546	-.371	-7.424	<.001	-5.122	-2.978
	Type of fracture	.308	.261	.065	1.179	.239	-.206	.821
	Type of repair	-.190	.159	-.065	-1.195	.233	-.503	.123
	ASA grade	1.878	.367	.249	5.123	<.001	1.157	2.599
3	Constant	3.731	2.058		1.813	.071	-.314	7.777
	Age	-.022	.025	-.045	-.887	.376	-.072	.027
	Pre-injury RACF	-6.940	.654	-.636	-10.614	<.001	-8.226	-5.655
	Type of fracture	.231	.247	.049	.936	.350	-.255	.717
	Type of repair	-.033	.152	-.011	-.218	.828	-.332	.266
	ASA grade	.813	.377	.108	2.158	.031	.073	1.554
	EFS	.586	.082	.513	7.193	<.001	.426	.746

	R^2	F	Sig.
	Model summary		
1	.090		
2	.147	9.500	<.001
3	.239	51.734	<.001
	ANOVA		
1		21.301	<.001
2		14.727	<.001
3		22.347	<.001

N=435 (94.2% of total)
ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frail scale; LOS, length of hospital stay; RACF, residential aged care facility.

Appendix B3: Association of frailty (defined by HGS) with LOS

Hierarchical multiple linear regression (HGS as continuous predictor, LOS as continuous outcome variable)								
Model		**B**	**SE of B**	**Beta**	**t**	**Sig.**	**95% CI Lower**	**95% CI Upper**
1	Constant	2.862	2.102		1.361	.174	-1.271	6.996
	Age	.070	.026	.140	2.652	.008	.018	.121
	Pre-injury RACF	-3.336	.635	-.278	-5.257	<.001	-4.584	-2.088
2	Constant	-.215	2.225		-.097	.923	-4.591	4.160
	Age	.037	.026	.074	1.403	.161	-.015	.088
	Pre-injury RACF	-3.715	.634	-.310	-5.861	<.001	-4.962	-2.469
	Type of fracture	.326	.275	.068	1.188	.236	-.214	.867
	Type of repair	-.205	.171	-.069	-1.202	.230	-.540	.130
	ASA grade	1.976	.390	.258	5.065	<.001	1.209	2.743
3	Constant	5.288	2.609		2.026	.043	.157	10.419
	Age	.001	.027	.002	.038	.970	-.053	.055
	Pre-injury RACF	-4.511	.656	-.376	-6.878	<.001	-5.800	-3.221
	Type of fracture	.257	.271	.053	.949	.343	-.275	.789
	Type of repair	-.119	.169	-.040	-.707	.480	-.452	.213
	ASA grade	1.771	.387	.231	4.577	<.001	1.010	2.532
	HGS	-.118	.030	-.221	-3.861	<.001	-.177	-.058

		R^2	**F**	**Sig.**
	Model summary			
1		.069		
2		.132	9.293	<.001
3		.406	14.904	<.001
	ANOVA			
1			14.125	<.001
2			11.592	<.001
3			12.497	<.001

N=387 (83.8%)
ASA, American Society of Anaesthesiologists physical status classification system; HGS, hand grip strength; LOS, length of hospital stay; RACF, residential aged care facility.

Appendix B4: Association of frailty (defined by EFS) with LOS
Hierarchical multiple linear regression (EFS as binary predictor, LOS as continuous outcome variable)

Model		B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
1	Constant	2.542	1.989		1.278	.202	-1.367	6.452
	Age	.074	.025	.149	3.003	.003	.026	.123
	Pre-injury RACF	-3.530	.543	-.324	-6.506	<.001	-4.596	-2.464
2	Constant	-.324	2.093		-.155	.877	-4.438	3.791
	Age	.042	.025	.085	1.709	.088	-.006	.091
	Pre-injury RACF	-4.050	.546	-.371	-7.424	<.001	-5.122	-2.978
	Type of fracture	.308	.261	.065	1.179	.239	-.206	.821
	Type of repair	-.190	.159	-.065	-1.195	.233	-.503	.123
	ASA grade	1.878	.367	.249	5.123	<.001	1.157	2.599
3	Constant	2.554	2.095		1.219	.224	-1.565	6.672
	Age	.008	.025	.016	.320	.749	-.041	.057
	Pre-injury RACF	-5.428	.586	-.498	-9.260	<.001	-6.581	-4.276
	Type of fracture	.219	.254	.046	.866	.387	-.279	.718
	Type of repair	-.046	.156	-.016	-.296	.767	-.354	.261
	ASA grade	1.277	.372	.169	3.435	<.001	.546	2.008
	EFS	3.257	.600	.316	5.424	<.001	2.077	4.437

		R^2	F	Sig.
	Model summary			
1		.090		
2		.137	9.500	<.001
3		.201	29.422	<.001
	ANOVA			
1			21.301	<.001
2			14.727	<.001
3			17.990	<.001

N=435 (94.2% of total)
ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frail scale; LOS, length of hospital stay; RACF, residential aged care facility.

Appendix B5: Association of frailty (defined by HGS) with LOS
Hierarchical multiple linear regression (HGS as binary predictor, LOS as continuous outcome variable)

Model		B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
1	Constant	2.862	2.102		1.361	.174	-1.271	6.996
	Age	.070	.026	.140	2.652	.008	.018	.121
	Pre-injury RACF	-3.336	.635	-.278	-5.257	<.001	-4.584	-2.088
2	Constant	-.215	2.225		-.097	.923	-4.591	4.160
	Age	.037	.026	.074	1.403	.161	-.015	.088
	Pre-injury RACF	-3.715	.634	-.310	-5.861	<.001	-4.962	-2.469
	Type of fracture	.326	.275	.068	1.188	.236	-.214	.867
	Type of repair	-.205	.171	-.069	-1.202	.230	-.540	.130
	ASA grade	1.976	.390	.258	5.065	<.001	1.209	2.743
3	Constant	1.924	2.257		.853	.394	-2.514	6.362
	Age	.005	.027	.011	.194	.846	-.048	.058
	Pre-injury RACF	-4.149	.633	-.346	-6.554	<.001	-5.394	-2.905
	Type of fracture	.243	.271	.050	.895	.371	-.290	.775
	Type of repair	-.107	.170	-.036	-.630	.529	-.440	.226
	ASA grade	1.564	.398	.204	3.927	<.001	.781	2.347
	HGS	2.367	.619	.214	3.823	<.001	1.150	3.585

		R^2	F	Sig.
	Model summary			
1		.069		
2		.132	9.293	<.001
3		.164	14.613	<.001
	ANOVA			
1			14.125	<.001
2			11.592	<.001
3			12.441	<.001

N=387 (83.8%)
ASA, American Society of Anaesthesiologists physical status classification system; HGS, hand grip strength; LOS, length of hospital stay; RACF, residential aged care facility.

Appendix B6: Association of frailty (defined by EFS) with prolonged hospital stay
Hierarchical binary logistic regression (EFS as binary predictor, prolonged stay as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.029	.016	3.300	.069	1.030	.998	1.062
	Pre-injury RACF	-1.216	.400	9.223	.002	.297	.135	.650
	Constant	-4.027	1.320	9.310	.002	.018		
2	Age	.024	.018	1.745	.187	1.024	.989	1.060
	Pre-injury RACF	-1.501	.437	11.796	<.001	.223	.095	.525
	Type of fracture			1.488	.685			
	Type 1	-.608	.852	.508	.476	.545	.102	2.895
	Type 2	-.272	.842	.104	.747	.762	.146	3.966
	Type 3	-1.061	1.140	.867	.352	.346	.037	3.232
	Type of repair			4.129	.765			
	Type 1	.547	.523	1.093	.296	1.728	.620	4.817
	Type 2	.281	.997	.080	.778	1.325	.188	9.352
	Type 3	.487	.868	.315	.575	1.628	.297	8.931
	Type 4	.807	.981	.677	.411	2.240	.328	15.312
	Type 5	-1.288	1.061	1.475	.225	.276	.034	2.205
	Type 6	1.214	1.402	.750	.386	3.368	.216	52.545
	Type 7	23.622	>100.000	.000	1.000	>100.000	.000	.
	ASA grade	.657	.242	7.364	.007	1.929	1.200	3.100
	Constant	-5.638	1.646	11.731	<.001	.004		
3	Age	.007	.019	.152	.697	1.007	.971	1.045
	Pre-injury RACF	-1.830	.440	17.293	<.001	.160	.068	.380
	Type of fracture			1.977	.577			
	Type 1	-.684	.848	.651	.420	.505	.096	2.660
	Type 2	-.252	.817	.095	.758	.777	.157	3.854
	Type 3	-1.195	1.133	1.113	.291	.303	.033	2.787
	Type of repair			5.710	.574			
	Type 1	.958	.548	3.054	.081	2.607	.890	7.633
	Type 2	.564	.969	.339	.561	1.758	.263	11.743
	Type 3	.675	.846	.637	.425	1.965	.374	10.315
	Type 4	1.011	.965	1.096	.295	2.747	.414	18.220
	Type 5	-.948	1.073	.780	.377	.388	.047	3.177
	Type 6	1.470	1.462	1.011	.315	4.350	.248	76.406
	Type 7	23.886	>100.000	.000	1.000	>100.000	.000	.
	ASA grade	.416	.258	2.609	.106	1.516	.915	2.512
	EFS	1.304	.403	10.456	.001	3.684	1.671	8.122
	Constant	-4.464	1.673	7.123	.008	.012		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.048	.129	.173
2-log likelihood	322.669	302.982	291.664
Horsmer and Lemeshow Test	.552	.821	.889
Overall classification accuracy (%)	87.100	87.400	87.800

N=435 (94.2% of total)
ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frail scale; RACF, residential aged care facility.

Appendix B7: Association of frailty (defined by HGS) with prolonged hospital stay
Hierarchical binary logistic regression (HGS as binary predictor, prolonged stay as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.025	.016	2.433	.119	1.025	.994	1.058
	Pre-injury RACF	-.897	.425	4.457	.035	.408	.177	.938
	Constant	-3.717	1.316	7.982	.005	.024		
2	Age	.019	.018	1.145	.285	1.019	.984	1.056
	Pre-injury RACF	-1.075	.467	5.296	.021	.341	.137	.853
	Type of fracture			1.332	.722			
	Type 1	-.464	.842	.303	.582	.629	.121	3.277
	Type 2	-.244	.853	.081	.775	.784	.147	4.174
	Type 3	-1.049	1.141	.845	.358	.350	.037	3.277
	Type of repair			4.968	.664			
	Type 1	.579	.532	1.185	.276	1.784	.629	5.062
	Type 2	.245	.997	.060	.806	1.278	.181	9.022
	Type 3	.495	.886	.312	.576	1.641	.289	9.322
	Type 4	.866	.984	.775	.379	2.378	.346	16.357
	Type 5	-1.362	1.067	1.629	.202	.256	.032	2.075
	Type 6	1.616	1.517	1.135	.287	5.032	.257	98.345
	Type 7	23.285	>100.000	.000	1.000	>100.000	.000	.
	ASA grade	.666	.247	7.296	.007	1.947	1.201	3.158
	Constant	-5.366	1.645	10.639	.001	.005		
3	Age	.009	.018	.214	.644	1.009	.973	1.046
	Pre-injury RACF	-1.165	.467	6.225	.013	.312	.125	.779
	Type of fracture			1.267	.737			
	Type 1	-.360	.840	.183	.668	.698	.134	3.621
	Type 2	-.188	.859	.048	.827	.829	.154	4.462
	Type 3	-1.015	1.143	.789	.374	.362	.039	3.403
	Type of repair			5.631	.583			
	Type 1	.646	.536	1.450	.229	1.908	.667	5.458
	Type 2	.323	1.002	.104	.747	1.381	.194	9.847
	Type 3	.514	.890	.333	.564	1.672	.292	9.575
	Type 4	.828	.989	.702	.402	2.290	.330	15.903
	Type 5	-1.129	1.074	1.104	.293	.323	.039	2.656
	Type 6	2.413	1.560	2.392	.122	11.173	.525	237.886
	Type 7	23.398	>100.000	.000	1.000	>100.000	.000	.
	ASA grade	.514	.256	4.038	.044	1.672	1.013	2.761
	HGS	.964	.449	4.603	.032	2.621	1.087	6.320
	Constant	-4.805	1.679	8.192	.004	.008		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.027	.117	.139
2-log likelihood	303.320	283.405	298.287
Horsmer and Lemeshow Test	.120	.136	.978
Overall classification accuracy (%)	86.300	86.800	86.800

N=387 (83.8%)
ASA, American Society of Anaesthesiologists physical status classification system; HGS, hand grip strength; RACF, residential aged care facility.

Appendix B8: Association of frailty (defined by EFS) with LOS
Simple linear regression (EFS as continuous predictor, LOS as continuous outcome variable)

	B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
Constant	6.633	.520		12.762	<.001	5.612	7.655
EFS	.094	.053	.082	1.769	.078	-.010	.199

	R^2	F	Sig.
Model summary	.007	3.130	.078

N=459 (99.3%)
EFS, Edmonton frail scale; LOS, length of hospital stay.

Appendix B9: Association of frailty (defined by EFS) with LOS
Simple linear regression (EFS as binary predictor, LOS as continuous outcome variable)

	B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
Constant	6.754	.371		18.193	<.001	6.025	7.484
EFS	1.163	.479	.113	2.428	.016	.222	2.103

	R^2	F	Sig.
Model summary	.013	5.895	.016

N=459 (99.3%)
EFS, Edmonton frail scale; LOS, length of hospital stay.

Appendix B10: Association of frailty (defined by HGS) with LOS
Simple linear regression (HGS as continuous predictor, LOS as continuous outcome variable)

	B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
Constant	8.694	.494		17.614	<.001	7.723	9.664
HGS	-.065	.026	-.122	-2.468	.014	-.117	-.013

	R^2	F	Sig.
Model summary	.015	6.089	.014

N=407 (88.1%)
HGS, hand grip strength; LOS, length of hospital stay.

Appendix B11: Association of frailty (defined by HGS) with LOS
Simple linear regression (HGS as binary predictor, LOS as continuous outcome variable)

	B	SE of B	Beta	t	Sig.	95% CI Lower	95% CI Upper
Constant	6.286	.452		13.913	<.001	5.398	7.174
HGS	1.974	.544	.178	3.631	<.001	.905	3.043

Model summary	**R^2**	**F**	**Sig.**
	.032	13.182	<.001

N=407 (88.1%)
HGS, hand grip strength; LOS, length of hospital stay.

Appendix B12: Association of frailty (defined by EFS) with prolonged hospital stay
Simple logistic regression (EFS as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	.014	2.545	1.204	.022	2.067	1.112	3.844
Constant	<.001	.077		<.001	.089		
Overall classification accuracy (%)			87.400				

N=459 (99.3%)
EFS, Edmonton frail scale.

Appendix B13: Association of frailty (defined by HGS) with prolonged hospital stay
Simple logistic regression (HGS as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	.934	.382	5.989	.014	2.545	1.204	5.376
Constant	-2.565	.346	54.981	<.001	.077		
Overall classification accuracy (%)			86.500				

N=407 (88.1%)
HGS, hand grip strength.

Appendix B14: Association of being severely frail (EFS score ≥12) with prolonged hospital stay
Simple logistic regression (severely frail as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	.156	.283	.304	.581	1.169	.671	2.036
Constant	-1.962	.178	121.452	<.001	.141		
Overall classification accuracy (%)			87.013				

N=462 (100%)
EFS, Edmonton frail scale.

Appendix B15: Association of being moderately frail (EFS score 10-11) with prolonged hospital stay
Simple logistic regression (moderately frail as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	.903	.366	6.084	.014	1.466	1.204	5.053
Constant	-2.029	.154	174.590	<.001	.132		
Overall classification accuracy (%)			87.013				

N=462 (100%)
EFS, Edmonton frail scale.

Appendix B16: Association of being mildly frail (EFS score 8-9) with prolonged hospital stay
Simple logistic regression (mildly frail as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	-.073	.430	.029	.865	.930	.401	2.158
Constant	-1.893	.147	165.128	<.001	.151		
Overall classification accuracy (%)			87.013				

N=462 (100%)
EFS, Edmonton frail scale.

Appendix B17: Association of being vulnerable (EFS score 6-7) with prolonged hospital stay
Simple logistic regression (vulnerable as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	.362	.395	.838	.360	1.436	.662	3.116
Constant	-1.949	.150	169.521	<.001	.142		
Overall classification accuracy (%)			87.013				

N=462 (100%)
EFS, Edmonton frail scale.

Appendix B18: Association of being NOT frail (EFS score ≤5) with prolonged hospital stay
Simple logistic regression (NOT frail as binary predictor, prolonged stay as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT frail	-1.390	.444	9.814	.022	.249	.104	.594
Constant	-1.639	.149	121.413	<.001	.194		
Overall classification accuracy (%)			87.013				

N=462 (100%)
EFS, Edmonton frail scale.

Appendix C: Observational study - Results tables for frailty and discharge mobility status

Appendix C1: Association of frailty (defined by EFS) with DMS
Hierarchical binary logistic regression (EFS as binary predictor, DMS as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.104	.017	39.432	<.001	1.110	1.074	1.147
	PMS	1.706	.424	16.180	<.001	5.505	2.398	12.638
	Constant	-8.697	1.321	43.378	<.001	.000		
2	Age	.099	.017	34.157	<.001	1.104	1.068	1.142
	PMS	1.564	.426	12.471	<.001	4.780	2.073	11.022
	ASA grade	.425	.242	3.071	.080	1.529	.951	2.459
	Constant	-9.310	1.392	44.729	<.001	.000		
3	Age	.085	.018	22.947	<.001	1.089	1.051	1.127
	PMS	.897	.483	3.444	.063	2.451	.951	6.318
	ASA grade	.083	.259	.104	.747	1.087	.655	1.804
	EFS	2.556	.653	15.317	<.001	12.884	3.582	46.343
	Constant	-7.008	1.468	22.780	<.001	.001		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.396	.406	.479
2-log likelihood	255.561	252.413	228.046
Horsmer and Lemeshow Test	.812	.949	.980
Overall classification accuracy (%)	87.1	87.6	87.6

N= 434 (93.9% of total).
ASA, American Society of Anaesthesiologists physical status classification system; DMS, discharge mobility status; EFS, Edmonton frail scale; PMS, pre-injury mobility status.

Appendix C2: Association of frailty (defined by HGS) with DMS
Hierarchical binary logistic regression (HGS as binary predictor, DMS as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.098	.016	36.767	<.001	1.103	1.069	1.139
	PMS	1.599	.430	13.844	<.001	4.949	2.131	11.490
	Constant	-8.138	1.287	39.997	<.001	.000		
2	Age	.093	.017	31.654	<.001	1.098	1.063	1.134
	PMS	1.455	.431	11.386	<.001	4.285	1.840	9.979
	ASA grade	.447	.241	3.444	.063	1.563	.975	2.505
	Constant	-8.805	1.362	41.796	<.001	.000		
3	Age	.080	.017	21.275	<.001	1.083	1.047	1.120
	PMS	1.321	.446	8.783	.003	3.747	1.564	8.939
	ASA grade	.155	.259	.359	.549	1.168	.703	1.939
	HGS	1.320	.367	12.925	<.001	3.745	1.823	7.692
	Constant	-7.404	1.419	27.233	<.001	.001		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.364	.376	.420
2-log likelihood	255.819	252.278	238.789
Horsmer and Lemeshow Test	.550	.689	.986
Overall classification accuracy (%)	85.3	85.5	85.6

N=387 (83.8% of total).
ASA, American Society of Anaesthesiologists physical status classification system; DMS, discharge mobility status; HGS, hand grip strength; PMS, pre-injury mobility status.

Appendix C3: Association of frailty (defined by EFS) with DMS
Simple logistic regression (EFS as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	3.543	.527	45.150	<.001	34.587	12.304	97.228
Constant	.669	.156	18.329	<.001	1.952		
Overall classification accuracy (%)					85.6		

N=457 (98.9% of total)
DMS, discharge mobility status; EFS, Edmonton frail scale.

Appendix C4: Association of frailty (defined by HGS) with DMS
Simple logistic regression (HGS as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	2.291	.310	54.658	<.001	9.882	5.385	18.139
Constant	.452	.183	6.117	.013	1.571		
Overall classification accuracy (%)					83.8		

N=407 (88.1%)
DMS, discharge mobility status; HGS, hand grip strength.

Appendix C5: Association of being severely frail (EFS score ≥12) with DMS
Simple logistic regression (severely frail as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	3.872	1.013	14.614	<.001	48.031	6.598	349.649
Constant	1.246	.141	78.391	<.001	3.477		
Overall classification accuracy (%)				85.621			

N=459 (99.4%)
DMS, discharge mobility status; EFS, Edmonton frail scale.

Appendix C6: Association of being moderately frail (EFS score 10-11) with DMS
Simple logistic regression (moderately frail as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	2.202	1.019	4.666	.031	9.043	1.226	66.685
Constant	1.669	.135	152.385	<.001	5.308		
Overall classification accuracy (%)			85.621				

N=459 (99.4%)
DMS, discharge mobility status; EFS, Edmonton frail scale.

Appendix C7: Association of being mildly frail (EFS score 8-9) with DMS
Simple logistic regression (mildly frail as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	1.650	.733	5.072	.024	5.207	1.239	21.889
Constant	1.664	.136	149.026	<.001	5.281		
Overall classification accuracy (%)			85.621				

N=459 (99.4%)
DMS, discharge mobility status; EFS, Edmonton frail scale.

Appendix C8: Association of being vulnerable (EFS score 6-7) with DMS
Simple logistic regression (vulnerable as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	-.065	.409	.025	.875	.938	.421	2.090
Constant	1.792	.142	159.603	<.001	6.000		
Overall classification accuracy (%)			85.621				

N=459 (99.4%)
DMS, discharge mobility status; EFS, Edmonton frail scale.

Appendix C9: Association of being NOT frail (EFS score 6-7) with DMS
Simple logistic regression (NOT frail as binary predictor, DMS as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT frail	-2.932	.344	72.764	<.001	.053	.027	.105
Constant	3.274	.294	123.937	<.001	26.417		
Overall classification accuracy (%)			85.621				

N=459 (99.4%)
DMS, discharge mobility status; EFS, Edmonton frail scale.

Appendix D: Observational study - Results tables for frailty and discharge destinations

Appendix D1: Association of frailty (defined by EFS) with direct home discharge
Hierarchical binary logistic regression (EFS as binary predictor, direct home discharge as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	-.066	.021	10.320	.001	.936	.899	.974
	RACF pre-injury	6.742	.588	131.232	<.001	846.845	267.228	2683.653
	DMS	3.478	.473	54.086	<.001	32.398	12.822	81.862
	Constant	1.704	1.609	1.121	.290	5.495		
2	Age	-.065	.021	9.759	.002	.937	.900	.976
	RACF pre-injury	6.925	.705	96.357	<.001	1017.067	255.200	4053.383
	DMS	3.365	.512	43.151	<.001	28.934	10.602	78.967
	EFS (NOT frail)	.342	.669	.261	.609	1.407	.379	5.220
	EFS (frail)	-.342	.669	.261	.609	.711	.192	2.636
	Constant*	1.729	1.601	1.166	.280	5.636		

	Block 1	Block 2
R^2 (Nagelkereke)	.784	.785
2-log likelihood	218.217	217.951
Horsmer and Lemeshow Test	.193	.192
Overall classification accuracy (%)	91.700	91.900

N= 457 (98.9% of total).
DMS, discharge mobility status; EFS, Edmonton frail scale; RACF, residential aged care facility.
***reported for the model with EFS (frail)**

Appendix D2: Association of frailty (defined by HGS) with direct home discharge
Hierarchical binary logistic regression (HGS as binary predictor, direct home discharge as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	-.071	.021	11.236	<.001	.931	.893	.971
	RACF pre-injury	6.943	.657	111.642	<.001	1036.006	285.776	3755.767
	DMS	3.462	.473	53.687	<.001	31.896	12.633	80.533
	Constant	2.091	1.638	1.630	.202	8.089		
2	Age	-.069	.022	9.913	.002	.933	.894	.974
	RACF pre-injury	6.988	.667	109.700	<.001	1083.428	293.019	4005.941
	DMS	3.398	.491	47.910	<.001	29.917	11.429	78.314
	HGS (NOT frail)	.215	.483	.199	.655	1.240	.482	3.195
	HGS (frail)	-.215	.483	.199	.655	.806	.313	2.076
	Constant*	2.041	1.643	1.544	.214	7.702		

	Block 1	Block 2
R^2 (Nagelkereke)	.775	.776
2-log likelihood	189.796	189.597
Horsmer and Lemeshow Test	.798	.690
Overall classification accuracy (%)	91.600	92.600

N= 407 (88.1% of total).
DMS, discharge mobility status; HGS, hand grip strength; RACF, residential aged care facility.
***reported for the model with HGS (frail)**

Appendix D3: Association of frailty (defined by EFS) with direct home discharge
Simple logistic regression (EFS as binary predictor, direct home discharge as inary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS (NOT frail)	-1.195	.212	31.807	<.001	.303	.200	.459
EFS (frail)	1.195	.212	31.807	<.001	3.303	2.181	5.004
Constant*	-1.180	.174	45.839	<.001	.307		
Overall classification accuracy (%)					60.800		

N= 459 (99.4% of total)
EFS, Edmonton frailty score.
***reported for the model with EFS (frail)**

Appendix D4: Association of frailty (defined by EFS) with direct home discharge - data set excluding RACF pre-fracture
Simple logistic regression (EFS as binary predictor, direct home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS (NOT frail)	2.230	.538	17.206	<.001	9.300	3.242	26.674
EFS (frail)	-2.230	.538	17.206	<.001	.108	.037	.308
Constant*	-1.204	.176	46.832	<.001	.300		
Overall classification accuracy (%)					85.200		

N= 310 (99.4% of total)
EFS, Edmonton frailty score.
***reported for the model with EFS (frail)**

Appendix D5: Association of frailty (defined by HGS) with direct home discharge
Simple logistic regression (HGS as binary predictor, direct home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS (NOT frail)	-.255	.229	1.242	.265	.775	.494	1.214
HGS (frail)	.255	.229	1.242	.265	1.291	.824	2.022
Constant*	-.802	.193	17.336	<.001	.448		
Overall classification accuracy (%)					65.100		

N= 407 (88.1% of total)
EFS, Edmonton frailty score.
***reported for the model with HGS (frail)**

Appendix D6: Association of frailty (defined by HGS) with direct home discharge - data set excluding RACF pre-fracture
Simple logistic regression (EFS as binary predictor, direct home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS (NOT frail)	1.851	.370	25.012	<.001	6.364	3.081	13.142
HGS (frail)	-1.851	.370	25.012	<.001	.157	.076	.325
Constant*	-.899	.200	20.105	<.001	.407		
Overall classification accuracy (%)					84.900		

N= 304 (97.4% of total)
EFS, Edmonton frailty score.
***reported for the model with EFS (frail)**

Appendix D7: Association of being severely frail (EFS score ≥12) with direct home discharge
Simple logistic regression (severely frail as binary predictor, home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	2.575	.232	122.745	<.001	13.132	8.327	20.710
Constant							
Overall classification accuracy (%)					60.400		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D8: Association of being moderately frail (EFS score 10-11) with direct home discharge
Simple logistic regression (moderately frail as binary predictor, home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	-1.174	.382	9.441	.002	.309	.146	.654
Constant							
Overall classification accuracy (%)					60.400		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D9: Association of being mildly frail (EFS score 8-9) with direct home discharge
Simple logistic regression (mildly frail as binary predictor, home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	-3.101	.727	18.207	<.001	.045	.011	.187
Constant							
Overall classification accuracy (%)					60.400		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D10: Association of vulnerable frail (EFS score 6-7) with direct home discharge
Simple logistic regression (vulnerable as binary predictor, home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	-2.255	.529	18.136	<.001	.105	.037	.296
Constant							
Overall classification accuracy (%)					60.400		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D11: Association of NOT being frail (EFS score ≤5) with direct home discharge
Simple logistic regression (NOT being frail as binary predictor, home discharge as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT being frail	-.581	.221	6.896	.009	.560	.363	.863
Constant							
Overall classification accuracy (%)					60.400		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D12: Association of frailty (defined by EFS) with discharge to general rehabilitation Hierarchical binary logistic regression (EFS as binary predictor, discharge to rehabilitation as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	-.032	.013	5.628	.018	.969	.944	.995
	RACF pre-injury	-5.252	1.014	26.842	<.001	.005	.001	.038
	DMS	1.682	.347	23.578	<.001	5.382	2.728	10.616
	Constant	1.351	.974	1.923	.165	3.861		
2	Age	-.011	.543	.543	.461	.989	.961	1.018
	RACF pre-injury	-4.477	1.021	19.207	<.001	.011	.002	.084
	DMS	2.661	.297	44.910	<.001	14.304	6.569	31.144
	EFS (NOT frail)	2.203	.318	47.917	<.001	9.051	4.851	16.888
	EFS (frail)	-2.203	.318	47.917	<.001	.110	.059	.206
	Constant*	-.059	1.074	.003	.956	.942		

	Block 1	Block 2
R^2 (Nagelkereke)	.463	.570
2-log likelihood	412.732	355.179
Horsmer and Lemeshow Test	.001	.012
Overall classification accuracy (%)	75.055	81.401

N=457 (98.9% of total).
DMS, discharge mobility status; EFS, Edmonton frailty score; RACF, residential aged care facility.
***reported for the model with EFS (frail)**

Appendix D13: Association of frailty (defined by HGS) with discharge to general rehabilitation Hierarchical binary logistic regression (HGS as binary predictor, discharge to rehabilitation as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	-.028	.013	4.445	.035	.973	.948	.998
	RACF pre-injury	-4.924	1.016	23.493	<.001	.007	.001	.053
	DMS	1.661	.344	23.338	<.001	5.267	2.687	10.335
	Constant	1.089	.969	1.264	.261	2.973		
2	Age	-.012	.014	.796	.372	.988	.961	1.015
	RACF pre-injury	-4.797	1.018	22.205	<.001	.008	.008	.061
	DMS	2.224	.349	31.912	<.001	9.234	4.273	19.996
	HGS (NOT frail)	1.330	.322	17.090	<.001	3.783	2.013	7.107
	HGS (frail)	-1.330	.322	17.090	<.001	.264	.141	.497
	Constant*	.243	1.008	.058	.809	1.276		

	Block 1	Block 2
R^2 (Nagelkereke)	.403	.453
2-log likelihood	403.740	484.191
Horsmer and Lemeshow Test	.019	.019
Overall classification accuracy (%)	72.482	73.956

N=407 (88.1% of total).
DMS, discharge mobility status; HGS, hand grip strength; RACF, residential aged care facility.
***reported for the model with HGS (frail)**

Appendix D14: Association of frailty (defined by EFS) with discharge to general rehabilitation
Simple logistic regression (EFS as binary predictor, discharge to rehabilitation as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS (NOT frail)	2.227	.223	99.947	<.001	9.270	5.991	14.344
EFS (frail)	-2.227	.223	99.947	<.001	.108	.070	.167
Constant*	1.121	.156	18.329	<.001	1.952		
Overall classification accuracy (%)					76.035		

N= 459 (99.4% of total)
EFS, Edmonton frailty score.
***reported for the model with EFS (frail)**

Appendix D15: Association of frailty (defined by HGS) with discharge to general rehabilitation
Simple logistic regression (HGS as binary predictor, discharge to rehabilitation as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS (NOT frail)	1.179	.222	28.160	<.001	3.251	2.103	5.025
HGS (frail)	-1.179	.222	28.160	<.001	.308	.199	.475
Constant*	.432	.182	5.652	.017	1.540		
Overall classification accuracy (%)					65.602		

N= 407 (88.1% of total)
HGS, hand grip strength.
***reported for the model with HGS (frail)**

Appendix D16: Association of being severely frail (EFS score ≥12) with discharge to general rehabilitation
Simple logistic regression (severely frail as binary predictor, discharge to a general rehabilitation unit as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	-3.368	.404	69.648	<.001	.034	.016	.076
Constant	.220	.118	3.493	.062	1.246		
Overall classification accuracy (%)					85.900		

N=462 (100%)
EFS, Edmonton frailty score.

Appendix D17: Association of being moderately frail (EFS score 10-11) with discharge to general rehabilitation
Simple logistic regression (moderately frail as binary predictor, discharge to a general rehabilitation unit as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	-.637	.347	3.364	.067	.529	.268	1.045
Constant	-.489	.101	23.264	<.001	.613		
Overall classification accuracy (%)					63.400		

N=462 (100%)
EFS, Edmonton frailty score.

Appendix D18: Association of being mildly frail (EFS score 8-9) with discharge to general rehabilitation
Simple logistic regression (mildly frail as binary predictor, discharge to a general rehabilitation unit as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	.673	.285	5.587	.018	1.960	1.122	3.426
Constant	-.638	.104	37.297	<.001	.528		
Overall classification accuracy (%)					63.600		

N=462 (100%)
EFS, Edmonton frailty score.

Appendix D19: Association of being vulnerable (EFS score 6-7) with discharge to general rehabilitation
Simple logistic regression (vulnerable as binary predictor, discharge to a general rehabilitation unit as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	1.682	.323	27.146	<.001	5.376	2.855	10.122
Constant	-.752	.106	50.410	<.001	.471		
Overall classification accuracy (%)					68.400		

N=462 (100%)
EFS, Edmonton frailty score.

Appendix D20: Association of being NOT frail (EFS score 0-5) with discharge to general rehabilitation
Simple logistic regression (NOT frail as binary predictor, discharge to a general rehabilitation unit as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT frail	1.620	.221	53.518	<.001	5.051	3.273	7.796
Constant	-1.051	.125	70.386	<.001	.350		
Overall classification accuracy (%)					71.200		

N=462 (100%)
EFS, Edmonton frailty score.

Appendix D21: Association of frailty (defined by EFS) with discharge to GEM
Hierarchical binary logistic regression (EFS as binary predictor, discharge to GEM as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.050	.018	7.794	.005	1.051	1.015	1.088
	RACF pre-injury	-3.040	.614	24.473	<.001	.048	.014	.160
	DMS	1.414	.631	5.020	.025	4.112	1.194	14.168
	Constant	-6.688	1.471	20.663	.261	.001		
2	Age	.034	.018	3.441	.064	1.035	.998	1.072
	RACF pre-injury	-3.460	.619	31.210	<.001	.031	.009	.106
	DMS	.820	.661	1.538	.215	2.270	.621	8.297
	EFS (NOT frail)	-1.379	.344	16.063	<.001	.252	.128	.494
	EFS (frail)	1.379	.344	16.063	<.001	3.971	2.023	7.793
	Constant	-4.245	1.558	7.421	.006	.014		

	Block 1	Block 2
R^2 (Nagelkereke)	.403	.275
2-log likelihood	403.740	297.579
Horsmer and Lemeshow Test	.019	.019
Overall classification accuracy (%)	85.777	85.778

N=457 (98.9% of total).
DMS, discharge mobility status; EFS, Edmonton frailty score; RACF, residential aged care facility.
***reported for the model with EFS (frail)**

Appendix D22: Association of frailty (defined by HGS) with discharge to GEM
Hierarchical binary logistic regression (HGS as binary predictor, discharge to GEM as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.057	.019	9.457	.002	.973	.948	.998
	RACF pre-injury	-3.878	1.026	14.291	<.001	.007	.001	.053
	DMS	1.374	.632	4.727	.030	5.267	2.687	10.335
	Constant	-7.230	1.528	22.385	<.001	2.973		
2	Age	.042	.019	4.967	.026	1.043	1.005	1.083
	RACF pre-injury	-4.023	1.026	15.375	<.001	.018	.002	.134
	DMS	1.012	.647	2.443	.118	2.751	.773	9.788
	HGS (NOT frail)	-1.281	.442	9.229	.002	.278	.122	.635
	HGS (frail)	1.281	.442	9.229	.002	3.600	1.578	8.228
	Constant	-6.669	1.547	18.585	<.001	.001		

	Block 1	Block 2
R^2 (Nagelkereke)	.230	.271
2-log likelihood	289.621	278.648
Horsmer and Lemeshow Test	.472	.539
Overall classification accuracy (%)	84.767	84.767

N=407 (88.1% of total).
DMS, discharge mobility status; HGS, hand grip strength; RACF, residential aged care facility.
***reported for the model with HGS (frail)**

Appendix D23: Association of frailty (defined by EFS) with discharge to GEM
Simple logistic regression (EFS as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS (NOT frail)	-.812	.305	7.072	.008	.444	.244	.808
EFS (frail)	.812	.305	7.072	.008	2.253	1.253	4.100
Constant*	-2.345	.262	80.320	<.001	.096		

Overall classification accuracy (%)	85.838

N= 459 (99.4% of total)
EFS, Edmonton frailty score.
***reported for the model with EFS (frail)**

Appendix D24: Association of frailty (defined by HGS) with discharge to GEM
Simple logistic regression (HGS as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS (NOT frail)	-1.268	.395	10.286	.001	.281	.130	.611
HGS (frail)	1.268	.395	10.286	.001	3.554	1.637	7.715
Constant*	-2.700	.365	54.633	<.001	1.952		
Overall classification accuracy (%)					84.767		

N= 407 (88.1% of total)
HGS, hand grip strength.
***reported for the model with HGS (frail)**

Appendix D25: Association of being severely frail (EFS score ≥12) with discharge to GEM
Simple logistic regression (severely frail as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	-1.312	.359	13.377	<.001	.269	.133	.544
Constant	-1.461	.150	95.250	<.001	.232		
Overall classification accuracy (%)					85.900		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D26: Association of being moderately frail (EFS score 10-11) with discharge to GEM
Simple logistic regression (moderately frail as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	1.281	.341	14.160	<.001	3.602	1.848	7.021
Constant	-2.005	.152	173.668	<.001	.135		
Overall classification accuracy (%)					85.900		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D27: Association of being mildly frail (EFS score 8-9) with discharge to GEM
Simple logistic regression (mildly frail as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	1.766	.315	31.354	<.001	5.847	3.151	10.848
Constant	-2.157	.163	175.103	<.001	.116		
Overall classification accuracy (%)					85.900		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D28: Association of being vulnerable (EFS score 6-7) with discharge to GEM
Simple logistic regression (vulnerable as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	.403	.380	1.128	.288	1.497	.711	3.151
Constant	-1.862	.145	165.038	<.001	.155		
Overall classification accuracy (%)					85.900		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D29: Association of being NOT frail (EFS score 0-5) with discharge to GEM
Simple logistic regression (NOT frail as binary predictor, discharge to GEM as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT frail	-1.497	.442	11.466	<.001	.224	.094	.532
Constant	-1.532	.144	113.856	<.001	.216		
Overall classification accuracy (%)					85.900		

N=462 (100%)
EFS, Edmonton frailty score, GEM, geriatric evaluation and management unit.

Appendix D30: Association of frailty (defined by EFS) with discharge to a provisional setting
Hierarchical binary logistic regression (EFS as binary predictor, discharge to a provisional setting as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.112	.040	7.840	.005	1.119	1.034	1.210
	RACF pre-injury	-18.968	3219.858	.000	.995	.000	.000	.
	DMS	.381	.843	.205	.651	1.464	.281	7.638
	Constant	-12.354	3.522	12.302	<.001	.000		
2	Age	.093	.043	4.709	.030	1.097	1.009	1.194
	RACF pre-injury	-19.514	3219.881	.000	.995	.000	.000	.
	DMS	2.839	1.245	5.201	.023	17.106	1.490	96.320
	EFS (NOT frail)	-4.061	1.355	8.978	.003	.017	.001	.245
	EFS (frail)	4.061	1.355	8.978	.003	58.060	4.075	82.310
	Constant*	-14.175	4.117	11.856	<.001	.000		

	Block 1	Block 2
R^2 (Nagelkereke)	.193	.336
2-log likelihood	115.069	96.577
Horsmer and Lemeshow Test	.952	.412
Overall classification accuracy (%)	96.500	95.600

N=457 (98.9% of total).
DMS, discharge mobility status; EFS, Edmonton frailty score; RACF, residential aged care facility.
***reported for the model with EFS (frail)**

Appendix D31: Association of frailty (defined by HGS) with discharge to a provisional setting Hierarchical binary logistic regression (HGS as binary predictor, discharge to a provisional setting as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.121	.044	7.684	.006	1.128	1.036	1.229
	RACF pre-injury	-18.921	3827.078	.000	.996	.000	.000	.
	DMS	.573	.859	.446	.504	1.774	.330	9.549
	Constant	-13.238	3.842	11.870	<.001	.000		
2	Age	.111	.045	6.100	.014	1.117	1.023	1.220
	RACF pre-injury	-19.012	3834.567	.000	.996	.000	.000	.
	DMS	.925	.909	1.036	.309	2.522	.425	14.974
	HGS (NOT frail)	-1.004	.847	1.407	.236	.366	.070	1.925
	HGS (frail)	1.004	.847	1.407	.236	2.730	.519	14.348
	Constant*	-13.227	3.935	11.298	<.001	.000		

	Block 1	Block 2
R^2 (Nagelkereke)	.176	.191
2-log likelihood	102.898	101.246
Horsmer and Lemeshow Test	.855	.633
Overall classification accuracy (%)	96.600	96.600

N=407 (88.1% of total).
DMS, discharge mobility status; HGS, hand grip strength; RACF, residential aged care facility.
***reported for the model with HGS (frail)**

Appendix D32: Association of frailty (defined by EFS) with discharge to a provisional setting
Simple logistic regression (EFS as binary predictor, discharge to a provisional setting as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS (NOT frail)	-2.348	1.037	5.122	.024	.096	.013	.730
EFS (frail)	2.348	1.037	5.122	.024	10.460	1.270	79.887
Constant*	-5.204	1.003	26.934	<.001	.005		
Overall classification accuracy (%)					96.500		

N=459 (99.4% of total)
EFS, Edmonton frailty score.
***reported for the model with EFS (frail)**

Appendix D33: Association of frailty (defined by HGS) with discharge to a provisional setting
Simple logistic regression (HGS as binary predictor, discharge to a provisional setting as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS (NOT frail)	-1.017	.771	1.739	.187	.362	.080	1.640
HGS (frail)	1.017	.771	1.739	.187	2.766	.610	12.545
Constant*	-4.127	.713	33.526	<.001	.016		
Overall classification accuracy (%)					96.600		

N= 407 (88.1% of total)
HGS, hand grip strength.
***reported for the model with HGS (frail)**

E: Observational study - Results tables for frailty and secondary discharge destinations

Appendix E1: Association of frailty (defined by EFS) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Hierarchical binary logistic regression (EFS as binary predictor, new residence as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.055	.026	4.511	.034	1.056	1.004	1.111
	ASA grade	.886	.348	6.492	.011	2.427	1.227	4.796
	Constant	-8.555	2.383	12.899	<.001	.000		
2	Age	.041	.026	2.448	.118	1.042	.990	1.096
	ASA grade	.523	.376	1.931	.165	6.335	2.501	3.524
	EFS	1.846	.474	15.151	<.001	6.335	2.501	16.051
	Constant	-7.083	2.405	8.676	.003	.001		

	Block 1	Block 2
R^2 (Nagelkereke)	.128	.270
2-log likelihood	138.392	122.596
Horsmer and Lemeshow Test	.125	.145
Overall classification accuracy (%)	82.400	83.010

N= 160 (94.7% of total).
ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frailty score.

Appendix E2: Association of frailty (defined by HGS) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Hierarchical binary logistic regression (HGS as binary predictor, new residence as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.057	.026	4.743	.029	1.058	1.006	1.113
	ASA grade	.873	.348	6.296	.012	2.394	1.211	4.734
	Constant	-8.639	2.393	13.037	<.001	.000		
2	Age	.048	.026	3.381	.066	1.050	.997	1.105
	ASA grade	.675	.360	3.518	.061	1.964	.970	3.975
	HGS	1.383	.539	6.579	.010	6.335	1.386	11.476
	Constant	-8.320	2.458	11.455	<.001	.000		

	Block 1	Block 2
R^2 (Nagelkereke)	.130	.201
2-log likelihood	137.490	129.765
Horsmer and Lemeshow Test	.131	.163
Overall classification accuracy (%)	82.278	82.912

N= 158 (93.5% of total).

ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frailty score.

Appendix E3: Association of being frail (EFS) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	2.214	.444	24.918	<.001	9.156	3.838	21.843
Constant	-2.389	.330	52.267	<.001	.092		
Overall classification accuracy (%)			81.212				

N=165 (97.6%)

Appendix E4: Association of being frail (HGS) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	1.548	.487	10.114	.001	4.704	1.811	12.217
Constant	-2.457	.425	33.354	<.001	.086		
Overall classification accuracy (%)			80.981				

N=163 (96.4%)

Appendix E5: Association of being severely frail (EFS score ≥12) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (severely frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	2.541	.864	8.655	.003	12.692	2.335	68.985
Constant	-1.625	.215	57.338	<.001	.197		
Overall classification accuracy (%)			83.030				

N=165 (97.6%)

Appendix E6: Association of being moderately frail (EFS score 10-11) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (severely frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	1.250	.624	4.012	.045	3.489	1.027	11.850
Constant	-1.586	.215	54.293	<.001	.205		
Overall classification accuracy (%)			81.212				
N=165 (97.6%)							

Appendix E7: Association of being mildly frail (EFS score 8-9) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (severely frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	1.400	.460	9.254	.002	4.056	1.646	9.999
Constant	-1.775	.242	53.977	<.001	.169		
Overall classification accuracy (%)			81.212				
N=165 (97.6%)							

Appendix E8: Association of being vulnerable (EFS score 6-7) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (severely frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	-.268	.498	.290	.590	.765	.288	2.029
Constant	-1.406	.223	39.698	<.001	.245		
Overall classification accuracy (%)			81.212				
N=165 (97.6%)							

Appendix E9: Association of being NOT frail (EFS score 0-5) with moving to a new permanent primary residence after a short term placement at a general rehabilitation unit
Simple logistic regression (severely frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT frail	-2.210	.564	15.384	<.001	.110	.036	.331
Constant	-.747	.234	10.229	.001	.474		
Overall classification accuracy (%)			81.212				

N=165 (97.6%)

Appendix E10: Association of frailty (defined by EFS) with moving to a new permanent primary residence after a short term placement at a GEM unit
Hierarchical binary logistic regression (EFS as binary predictor, new residence as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.069	.047	2.135	.144	1.071	.977	1.175
	ASA grade	1.119	.610	3.360	.067	3.060	.925	10.121
	Constant	-9.019	4.628	3.791	.052	.000		
2	Age	.055	.050	1.233	.267	1.057	.958	1.166
	ASA grade	1.001	.653	2.352	.125	2.721	.757	9.777
	EFS	1.642	.767	4.584	.032	5.166	1.149	23.225
	Constant	-8.786	4.983	3.108	.078	.000		
			Block 1					**Block 2**
R^2 (Nagelkereke)			.140					.248
2-log likelihood			68.247					63.117
Horsmer and Lemeshow Test			.715					.843
Overall classification accuracy (%)			66.666					68.591

N= 54 (83.1% of total).
ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frailty score.

Appendix E11: Association of frailty (defined by HGS) with moving to a new permanent primary residence after a short term placement at a GEM unit
Hierarchical binary logistic regression (HGS as binary predictor, new residence as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.066	.047	1.947	.160	1.068	.974	1.172
	ASA grade	1.093	.607	3.245	.072	2.985	.908	9.809
	Constant	-8.644	4.594	3.593	.060	.000		
2	Age	.047	.050	.902	.342	1.048	.951	1.156
	ASA grade	1.000	.648	2.382	.123	2.718	.763	9.679
	HGS	2.025	1.161	3.042	.081	7.578	.778	73.773
	Constant	-8.569	4.911	3.045	.081	.000		

	Block 1	Block 2
R^2 (Nagelkereke)	.140	.231
2-log likelihood	64.098	60.100
Horsmer and Lemeshow Test	.513	.685
Overall classification accuracy (%)	68.627	68.627

N= 51 (78.5% of total).
ASA, American Society of Anaesthesiologists physical status classification system; EFS, Edmonton frailty score.

Appendix E12: Association of being frail (EFS) with moving to a new permanent primary residence after a short term placement at a GEM unit
Simple logistic regression (frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	1.992	.724	7.572	.006	7.333	1.774	30.312
Constant	-1.299	.651	3.979	.046	.273		

Overall classification accuracy (%)	69.491

N=59 (90.8%)

Appendix E13: Association of being frail (HGS) with moving to a new permanent primary residence after a short term placement at a GEM unit
Simple logistic regression (frail as binary predictor, new residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	2.335	1.120	4.348	.037	10.333	1.150	92.815
Constant	-1.792	1.080	2.752	.097	.167		

Overall classification accuracy (%)	66.071

N=56 (86.2%)

Appendix F: Observational study - Results tables for frailty and permanent change of residence

Appendix F1: Association of frailty (defined by EFS) with permanent change of primary residence Hierarchical binary logistic regression (EFS as binary predictor, change of residence as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.029	.013	4.689	.030	1.030	1.003	1.057
	ASA grade	.496	.197	6.305	.012	1.642	1.115	2.418
	Constant	-5.238	1.153	20.626	<.001	.005		
2	Age	.069	.018	14.696	<.001	1.071	1.034	1.110
	ASA grade	1.035	.238	18.903	<.001	2.814	1.765	4.487
	RACF pre-injury	-3.405	.604	31.739	<.001	.033	.010	.109
	Pre-injury mobility	-.708	.665	1.132	.287	.493	.134	1.815
	DMS	2.344	.753	9.691	.002	10.427	2.383	45.619
	Constant	-11.581	1.792	41.779	<.001	.000		
3	Age	.048	.019	6.153	.013	1.049	1.010	1.090
	ASA grade	.650	.266	5.958	.015	1.916	1.137	3.229
	RACF pre-injury	-3.776	.571	43.676	<.001	.023	.007	.070
	Pre-injury mobility	-1.145	.651	3.091	.079	.318	.089	1.140
	DMS	1.575	.800	3.875	.049	4.830	1.007	23.174
	EFS	2.242	.358	39.140	<.001	9.414	4.664	19.005
	Constant	-9.248	1.893	23.865	<.001	.000		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.058	.401	.516
2-log likelihood	427.225	315.949	270.666
Horsmer and Lemeshow Test	.116	.589	.615
Overall classification accuracy (%)	78.300	81.6	86.3

N= 424 (91.8% of total).
ASA, American Society of Anaesthesiologists physical status classification system; DMS, discharge mobility status; EFS, Edmonton frailty score; RACF, residential aged care facility.

Appendix F2: Association of frailty (defined by HGS) with permanent change of primary residence Hierarchical binary logistic regression (HGS as binary predictor, change of residence as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.036	.014	6.607	.010	1.037	1.009	1.066
	ASA grade	.679	.209	10.551	.001	1.973	1.309	2.972
	Constant	-6.289	1.240	25.738	<.001	.002		
2	Age	.072	.019	14.679	<.001	1.074	1.036	1.114
	ASA grade	1.073	.244	19.306	<.001	2.925	1.812	4.720
	RACF pre-injury	-3.140	.661	22.531	<.001	.043	.012	.158
	Pre-injury mobility	-1.009	.881	1.310	.252	.365	.065	2.052
	DMS	2.279	.755	9.110	.003	9.763	2.223	42.875
	Constant	-11.908	1.856	41.156	<.001	.000		
3	Age	.058	.019	8.783	.003	1.059	1.020	1.101
	ASA grade	.870	.257	11.432	<.001	2.388	1.442	3.955
	RACF pre-injury	-3.234	.650	24.742	<.001	.039	.011	.141
	Pre-injury mobility	-1.158	.869	1.776	.183	.314	.057	1.725
	DMS	1.869	.778	5.762	.016	6.479	1.409	29.791
	HGS	1.982	.470	17.770	<.001	7.257	2.888	18.239
	Constant	-11.309	1.946	33.769	<.001	.000		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.097	.388	.457
2-log likelihood	379.657	293.343	269.627
Horsmer and Lemeshow Test	.411	.491	.823
Overall classification accuracy (%)	76.595	80.585	82.713

N= 376 (82.4% of total).
ASA, American Society of Anaesthesiologists physical status classification system; DMS, discharge mobility status; HGS, hand grip strength; RACF, residential aged care facility.

Appendix F3: Association of frailty (defined by EFS) with permanent change of primary residence
Simple logistic regression (EFS as binary predictor, change of residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	1.648	.300	30.279	<.001	5.198	2.890	9.349
Constant	-2.392	.270	78.621	<.001	.091		
Overall classification accuracy (%)					77.321		

N=449 (97.2% of total).
EFS, Edmonton frailty score.

Appendix F4: Association of frailty (defined by HGS) with permanent change of primary residence
Simple logistic regression (HGS as binary predictor, change of residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	2.045	.410	24.829	<.001	7.728	3.457	17.274
Constant	-2.816	.389	52.385	<.001	.060		
Overall classification accuracy (%)					76.515		

N=396 (85.7% of total).
EFS, Edmonton frailty score.

Appendix F5: Association of being severely frail (EFS score ≥12) with permanent change of primary residence
Simple logistic regression (severely frail as binary predictor, change od residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Severely frail	-.153	.234	.427	.513	.858	.542	1.358
Constant	-1.161	.140	68.811	<.001	.313		
Overall classification accuracy (%)					77.162		

N=451 (97.6%).
EFS, Edmonton frailty score.

Appendix F6: Association of being moderately frail (EFS score 10-11) with permanent change of primary residence
Simple logistic regression (moderately frail as binary predictor, change od residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Moderately frail	1.356	.317	18.258	<.001	3.881	2.084	7.230
Constant	-1.399	.125	125.520	<.001	.247		
Overall classification accuracy (%)					77.162		

N=451 (97.6%).
EFS, Edmonton frailty score.

Appendix F7: Association of being mildly frail (EFS score 8-9) with permanent change of primary residence
Simple logistic regression (mildly frail as binary predictor, change od residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Mildly frail	1.573	.304	26.870	<.001	4.823	2.661	8.745
Constant	-1.460	.128	129.773	<.001	.232		
Overall classification accuracy (%)					77.827		

N=451 (97.6%).
EFS, Edmonton frailty score.

Appendix F8: Association of being vulnerable (EFS score 6-7) with permanent change of primary residence
Simple logistic regression (vulnerable as binary predictor, change od residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
Vulnerable	-.515	.403	1.639	.201	.597	.271	1.315
Constant	-1.166	.117	98.556	<.001	.311		
Overall classification accuracy (%)					77.162		

N=451 (97.6%).
EFS, Edmonton frailty score.

Appendix F9: Association of being NOT frail (EFS score 10-11) with permanent change of primary residence
Simple logistic regression (NOT frail as binary predictor, change od residence as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
NOT frail	-1.989	.407	23.847	<.001	.137	.062	.304
Constant	-.861	.122	49.969	<.001	.423		
Overall classification accuracy (%)					77.161		

N=451 (97.6%).
EFS, Edmonton frailty score.

Appendix G: Observational study - Results tables for frailty and mortality (3 and 12 months)

Appendix G1: Association of frailty (defined by EFS) with 3-months mortality
Hierarchical binary logistic regression (EFS as binary predictor, mortality as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.079	.021	14.157	<.001	1.082	1.038	1.127
	ASA grade	1.205	.279	18.653	<.001	3.337	1.931	5.767
	Total comorbidities	.042	.129	.105	.746	1.043	.810	1.342
	Constant	-12.666	1.971	41.278	<.001	.000		
2	Age	.043	.022	3.759	.053	1.044	1.000	1.091
	ASA grade	1.100	.305	12.969	<.001	3.003	1.651	5.463
	Total comorbidities	-.035	.137	.065	.799	.966	.738	1.264
	RACF pre fracture	1.792	.444	16.329	<.001	6.004	2.517	14.321
	Mobility pre fracture	-.163	.398	.167	.683	.850	.390	1.855
	Constant	-9.922	2.038	23.691	<.001	.000		
3	Age	.034	.023	2.207	.137	1.034	.989	1.081
	ASA grade	.988	.310	10.134	.001	2.686	1.462	4.934
	Total comorbidities	-.079	.139	.320	.571	.924	.704	1.213
	RACF pre fracture	1.423	.447	10.132	.001	4.151	1.728	9.971
	Mobility pre fracture	-.198	.391	.256	.613	.820	.381	1.766
	EFS	1.617	.801	4.077	.043	5.037	1.049	24.195
	Constant	-9.759	2.106	21.469	<.001	.000		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.215	.383	.392
2-log likelihood	277.370	253.758	248.402
Horsmer and Lemeshow Test	.834	.838	.611
Overall classification accuracy (%)	87.4	86.4	87.6

N= 435 (94.2% of total).
ASA, American Society of Anaesthesiologists physical status classification system; status; EFS, Edmonton frailty score; RACF, residential aged care facility.

Appendix G2: Association of frailty (defined by HGS) with 3-months mortality
Hierarchical binary logistic regression (HGS as binary predictor, mortality as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.069	.022	9.740	.002	1.072	1.026	1.119
	ASA grade	1.018	.304	11.226	<.001	2.768	1.526	5.022
	Total comorbidities	.072	.145	.245	.620	1.074	.809	1.428
	Constant	-11.431	2.058	30.856	<.001	.000		
2	Age	.034	.023	2.065	.151	1.034	.988	1.083
	ASA grade	.953	.330	8.325	.004	2.593	1.357	4.952
	Total comorbidities	.001	.156	.000	.995	1.001	.737	1.359
	RACF pre fracture	1.637	.488	11.235	<.001	5.138	1.973	13.379
	Mobility pre fracture	.142	.470	.091	.762	1.153	.459	2.894
	Constant	-8.730	2.110	17.126	<.001	.000		
3	Age	.022	.024	.881	.348	1.022	.976	1.071
	ASA grade	.832	.333	6.242	.012	2.298	1.196	4.413
	Total comorbidities	-.023	.158	.022	.883	.977	.716	1.333
	RACF pre fracture	1.536	.488	9.889	.002	4.644	1.783	12.092
	Mobility pre fracture	.041	.469	.008	.931	1.042	.415	2.612
	HGS	1.899	1.057	3.229	.042	6.676	.842	52.948
	Constant	-8.915	2.258	15.588	<.001	.000		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.169	.263	.287
2-log likelihood	228.107	208.123	202.851
Horsmer and Lemeshow Test	.375	.764	.841
Overall classification accuracy (%)	89.4	88.4	89.4

N= 387 (83.8% of total).
ASA, American Society of Anaesthesiologists physical status classification system; status; HGS, hand grip strength; RACF, residential aged care facility.

Appendix G3: Association of frailty (defined by EFS) with 3-months mortality
Simple logistic regression (EFS as binary predictor, mortality as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	3.159	.726	18.917	<.001	23.555	5.673	97.809
Constant	-4.505	.711	40.153	<.001	.011		
Overall classification accuracy (%)				87.1			

N=459 (99.4%)
EFS, Edmonton frailty score.

Appendix G4: Association of frailty (defined by HGS) with 3-months mortality
Simple logistic regression (HGS as binary predictor, mortality as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	3.090	1.018	9.214	.002	21.967	2.988	161.490
Constant	1.739	.167	108.003	<.001	5.690		
Overall classification accuracy (%)				89.4			

N= 407 (88.1%)
HGS, hand grip strength.

Appendix G5: Association of frailty (defined by EFS) with 12-months mortality
Hierarchical binary logistic regression (EFS as binary predictor, mortality as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.058	.015	15.313	<.001	1.060	1.029	1.091
	ASA grade	1.132	.215	27.702	<.001	3.103	2.036	4.731
	Total comorbidities	.167	.099	2.838	.092	1.181	.973	1.434
	Constant	-10.010	1.398	51.292	<.001	.000		
2	Age	.028	.016	3.049	.081	1.028	.997	1.060
	ASA grade	1.040	.236	19.388	<.001	2.829	1.781	4.493
	Total comorbidities	.096	.105	.827	.363	1.100	.895	1.353
	RACF pre fracture	1.705	.345	24.501	<.001	5.504	2.802	10.813
	Mobility pre fracture	-.143	.354	.163	.687	.867	.433	1.735
	Constant	-7.630	1.453	27.588	<.001	.000		
3	Age	.020	.016	1.446	.229	1.020	.988	1.053
	ASA grade	.937	.241	15.112	<.001	2.553	1.592	4.095
	Total comorbidities	.054	.107	.250	.617	1.055	.855	1.302
	RACF pre fracture	1.440	.355	16.435	<.001	4.221	2.104	8.467
	Mobility pre fracture	-.191	.349	.300	.584	.826	.417	1.637
	EFS	.903	.410	4.849	.028	2.466	1.104	5.508
	Constant	-7.044	1.485	22.503	<.001	.001		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.234	.337	.350
2-log likelihood	418.792	381.161	376.034
Horsmer and Lemeshow Test	.378	.131	.390
Overall classification accuracy (%)	76.6	79.3	79.8

N= 435 (94.2% of total).
ASA, American Society of Anaesthesiologists physical status classification system; status; HGS, hand grip strength; RACF, residential aged care facility.

Appendix G6: Association of frailty (defined by HGS) with 12-months mortality
Hierarchical binary logistic regression (HGS as binary predictor, mortality as binary outcome variable)

Block	Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
1	Age	.056	.016	12.710	<.001	1.058	1.026	1.091
	ASA grade	1.029	.230	19.942	<.001	2.799	1.781	4.396
	Total comorbidities	.138	.109	1.592	.207	1.148	.926	1.422
	Constant	-9.557	1.473	42.076	<.001	.000		
2	Age	.028	.017	2.908	.088	1.029	.996	1.063
	ASA grade	.991	.249	15.775	<.001	2.693	1.652	4.391
	Total comorbidities	.067	.116	.330	.566	1.069	.852	1.342
	RACF pre fracture	1.698	.386	19.314	<.001	5.466	2.563	11.658
	Mobility pre fracture	-.275	.423	.422	.516	.760	.331	1.741
	Constant	-7.423	1.515	24.018	<.001	.001		
3	Age	.018	.017	1.077	.299	1.018	.984	1.053
	ASA grade	.872	.253	11.842	<.001	2.392	1.456	3.931
	Total comorbidities	.047	.119	.160	.689	1.049	.831	1.323
	RACF pre fracture	1.635	.390	17.572	<.001	5.127	2.388	11.010
	Mobility pre fracture	-.386	.425	.825	.364	.680	.295	1.564
	HGS	1.162	.481	5.841	.016	3.196	1.246	8.202
	Constant	-7.010	1.552	20.388	<.001	.001		

	Block 1	Block 2	Block 3
R^2 (Nagelkereke)	.169	.294	.316
2-log likelihood	228.107	327.389	320.471
Horsmer and Lemeshow Test	.464	.541	.548
Overall classification accuracy (%)	78.3	80.4	81.4

N= 387 (83.8% of total).
ASA, American Society of Anaesthesiologists physical status classification system; status; HGS, hand grip strength; RACF, residential aged care facility.

Appendix G7: Association of frailty (defined by EFS) with 12-months mortality
Simple logistic regression (EFS as binary predictor, mortality as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
EFS	2.277	.335	46.286	<.001	9.750	5.059	18.789
Constant	-2.750	.311	78.164	<.001	.064		
Overall classification accuracy (%)				74.5			

N=459 (99.4%)
EFS, Edmonton frailty score.

Appendix G8: Association of frailty (defined by HGS) with 12-months mortality
Simple logistic regression (HGS as binary predictor, mortality as binary outcome variable)

Variables	B	S.E. B	Wald	Sig.	Exp (B)	95% CI (lower)	95% CI (upper)
HGS	2.143	.438	23.929	<.001	8.528	3.613	20.128
Constant	-2.996	.418	51.282	<.001	.050		
Overall classification accuracy (%)				77.9			

N= 407 (88.1%)
HGS, hand grip strength.

Appendix H: Reported Edmonton frail scale

Frailty Domain	Item	0 points	1 point	2 points
Cognition	Please imagine this pre-circle is a clock. I would like you to place the numbers in the correct positions, then the hands to indicate a time of `ten after eleven`	No errors	Minor errors	Other errors
General Health Status	In the past year how many times have you been admitted to the hospital? In general how will you describe your health?	0 Excellent/Very good/Good	1-2 Fair	≥2 Poor
Functional Independence	With how many of the following activities do you require help? meal preparation/shopping/transportation/ telephone/housekeeping/laundry/ managing money/ taking medications	0-1	2-4	5-8
Social Support	When you need help, can you count on someone who is willing and able to meet your needs	Always	Sometimes	Never
Medication Use	Do you use five or more different medications on a regular basis? At times, do you forget to take your prescription medications?	No No	Yes Yes	
Nutrition	Have you recently lost weight such that your clothing has become looser?	No	Yes	
Mood	Do you often feel sad or depressed?	No	Yes	
Continence	Do you have a problem with losing control of urine when you don`t want to go?	No	Yes	
Self- Reported Performance	Two weeks ago, were you able to: (1)Do heavy work around the house like washing windows, walls or floors without help (2)Walk up and down stairs to the second floor without help (3)Walk 1km without help	Yes Yes Yes	No No No	

Scoring for Edmonton Frailty scale: (0/18). Not frail: 0-5. Apparently Vulnerable : 6-7. Mildly Frail : 8-9. Moderate frailty : 10-11. Severe Frailty : 12-18.

Appendix I: Ethics approval

Office for Research

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Ward 6C, Room 6A219
Flinders Drive, Bedford Park SA 5042
Tel: (08) 8204 6453
E: Health.SALHNOfficeforResearch@sa.gov.au

Government of South Australia
SA Health
Southern Adelaide Local Health Network

Final Approval for Ethics Application

28 September 2018

Professor Ruurd Jaarsma
Orthopaedic and Trauma Services
Flinders Medical Centre
BEDFORD PARK SA 5042

Katharina.denk@sa.gov.au

Dear Professor Ruurd Jaarsma

OFR Number: 244.18
Project title: The implications of decreased hand grip strength and frailty on acute hip fracture patients
Chief Investigator: Professor Ruurd Jaarsma

Ethics Approval Period: 06 September 2018 – 06 September 2019

The Southern Adelaide Clinical Human Research Ethics Committee (SAC HREC EC00188) have reviewed and provided approval for this application which meets the requirements of the *National Statement on Ethical Conduct in Human Research (2007).*

You are reminded that this letter constitutes **Ethics** approval only. **Ethics approval is one aspect of the research governance process**.

You must not commence this research project at any SA Health sites listed in the application until a Site Specific Assessment (SSA), or Access Request for data or tissue form, has been approved by the Chief Executive or delegate of each site.

Public health sites approved under this Ethics amendment application:

- Flinders Medical Centre

The below documents have been reviewed and approved:

- Audit Based Research Application Form dated 21 August 2018
- Data collection sheet v1a dated 21 August 2018

Terms and Conditions Of Ethics Approval:

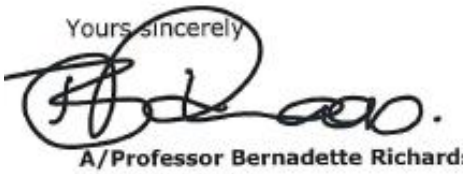
It is essential that researchers adhere to the conditions below and with the *National Statement chapter 5.5.*

Final ethics approval is granted subject to the researcher agreeing to meet the following terms and conditions:

1. The approval only covers the science and ethics component of the application. A SSA will need to be submitted and authorised before this research project can commence at any of the approved sites identified in the application.
2. If University personnel are involved in this project, the Principal Investigator should notify the University before commencing their research to ensure compliance with University requirements including any insurance and indemnification requirements.
3. Compliance with the *National Statement on Ethical Conduct in Human Research* (2007) & the *Australian Code for the Responsible Conduct of Research* (2007).
4. To immediately report to SAC HREC anything that may change the ethics or scientific integrity of the project.
5. Report Significant Adverse events (SAE's) as per SAE requirements available at our website.
6. Submit an annual report on each anniversary of the date of final approval and in the correct template from the SAC HREC website.
7. Confidentiality of research participants MUST be maintained at all times.
8. A copy of the signed consent form must be given to the participant unless the project is an audit.
9. Any reports or publications derived from the research should be submitted to the Committee at the completion of the project.
10. All requests for access to medical records at any SALHN site must be accompanied by this approval email.
11. To regularly review the SAC HREC website and comply with all submission requirements, as they change from time to time.
12. Once your research project has concluded, any new product/procedure/intervention cannot be conducted in the SALHN as standard practice without the approval of the SALHN New Medical Products and Standardisation Committee or the SALHN New Health Technology and Clinical Practice Innovation Committee (as applicable). Please refer to the relevant committee link on the SALHN intranet for further information.

For any queries about this matter, please contact The Office for Research on (08) 8204 6453 or via email to Health.SALHNOfficeforResearch@sa.gov.au

Yours sincerely



A/Professor Bernadette Richards
Chair, SAC HREC