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The association between decreased hand grip strength and hip fracture in older people: A systematic review

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Title:
The association between decreased hand grip strength and hip fracture in older people: a systematic review

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The association between decreased hand grip strength and hip fracture in older people: a systematic review

ABSTRACT

Hip fractures are a global concern, resulting in poor outcomes and high health care costs. They mostly affect people >80 years. Hip fractures are influenced by various (modifiable) risk factors. Emerging evidence suggests hand grip strength (HGS) to be one of several useful tools to identify hip fracture risk. This is the first systematic review that aims to assess the evidence underlying the relationship between hip fracture incidence and HGS. Eleven studies were selected for this review (six case-control and five cohort studies), comprising 21197 participants. Where reported, HGS was significantly decreased in individuals with a hip fracture near the time of injury as compared to controls (p<0.001); HGS was associated with increased hip fracture risk in all included studies. Meta-analysis was not possible.

All studies included in this systematic review confirmed a relationship between decreased HGS and hip fracture incidence. We were not able to quantify the strength of this relationship, due to the heterogeneity of the included studies. HGS merits further investigation as a useful tool for identifying individuals that might be at elevated risk for sustaining a hip fracture.

Key words: Hand grip strength, hip fracture, proximal femur fracture, frailty, risk factor

1. Introduction

Low impact fractures of the proximal femur (hip fractures) are a major worldwide public health concern (Hernlund et al., 2013; Kanis et al., 2012; The World Bank, 2015). They mostly occur in people older than 80 years (Kistler et al., 2015).

As the population ages, hip fractures are predicted to increase by 35% between 2012 and 2022; the annual cost will rise to $1.27 billion in Australia alone (Watts et al., 2013). The current annual hospital cost of hip fractures in the UK has been estimated at £1.1 billion (Leal et al., 2016).

Thus, it is vital to further improve fracture prevention strategies, not only to decrease health care costs, but also to reduce devastating outcomes such as morbidity, disability, dependency, and poor quality of life (Griffin et al., 2015; Parker, 2016).

Many, often modifiable, risk factors need to be considered for hip fracture prevention. Osteoporosis (Kanis, 1994) and falls (Jarvinen et al., 2008) are recognized risk factors for sustaining a hip fracture. Other factors include, but are not limited to, sarcopenia (Oliveira and Vaz, 2015), muscle weakness, physical inactivity, impaired cognition, impaired vision, and chronic health conditions (Marks, 2010).

The current gold standard screening tool to assist in identifying those most at risk of hip fracture 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 bone mineral density (BMD) (The University of Sheffield, 2011). Low BMD, the cardinal sign of osteoporosis, was established as the number one risk factor for sustaining a hip fracture more than two decades ago (Kanis, 1994). However, only between 10% and 44% of fractures occur in people with osteoporosis (Jarvinen et al., 2015; Stone et al., 2003). Hence the value and benefit of FRAX have become a subject of debate. General validity and reliability appear to be higher in women than in men (Sandhu et al.,
When used without BMD, FRAX does not perform any better than only screening for age and previous fracture incidence (Rubin et al., 2013; Sambrook et al., 2011). FRAX does not include variables like activity level, muscle strength and mass, or falls history, and does not differentiate between different types of previous fractures (number, site, severity) (Silverman and Calderon, 2010). Investigating other aspects of hip fracture prevention seems therefore critical when striving for an inclusive evidence based approach.

This review focused on the relationship between hip fracture and hand grip strength (HGS), with the latter being an indicator for overall muscle strength (Hirschfeld et al., 2017; Rantanen et al., 2003) and an important measure for frailty (Syddall et al., 2003), sarcopenia (Chen et al., 2014; Cruz-Jentoft et al., 2010) and osteoporosis (Cheung et al., 2012; Kritz-Silverstein and Barrett-Connor, 1994).

1.1 Hip fracture, hand grip strength, and frailty

It is well recognised that hip fractures affect individuals aged 65 and over, with the majority being older than 80 years (Auais et al., 2013; Kistler et al., 2015). As people age, the likelihood of developing chronic diseases or geriatric syndromes increases. Two of those ageing related conditions are osteoporosis and sarcopenia. They have similar risk factors and often occur simultaneously, then referred to as osteosarcopenia (Hirschfeld et al., 2017).

Osteoporosis is an undisputed major risk factor for sustaining a hip fracture. Decreased BMD makes the proximal femur susceptible to breaking, with no or minimal impact involved (Kanis, 1994). There is somewhat conflicting but mostly positive evidence for a relationship between HGS and systemic BMD (Dixon et al., 2005).

Sarcopenia is a recognized factor in hip fracture risk (Ho et al., 2016; Oliveira and Vaz, 2015; Tarantino et al., 2015). Progressive, generalized loss of muscle strength and mass lead to an increased risk of falls (impaired neuromuscular function) and decreased bone strength (lack of mechanical forces) (Cederholm et al., 2013). The clinical diagnosis of sarcopenia is based on three criteria: decreased muscle mass, poor physical performance (gait speed), and decreased muscle strength (HGS) (Chen et al., 2014; Cruz-Jentoft et al., 2010).

Not surprisingly, Huo et al. (2015) demonstrated gait velocity and HGS to be reduced in patients with osteosarcopenia (p>0.001), and Yoo et al. (2018) found that 28.7% of their 324 hip fracture patients had osteosarcopenia.

Relationships between HGS and postoperative complications, length of hospital stay, discharge destination, disability, multi-morbidity, chronic disease, cognition, mortality, fractures, poor physical performance, and decreased mobility have also been demonstrated (Bohannon, 2008; Cheung et al., 2013; Cheung et al., 2012; Keevil et al., 2013; Lloyd et al., 2009; Rijk et al., 2016; Roberts et al., 2012).

A causal link between HGS and all the aforementioned conditions and outcomes is considered unlikely. Bohannon (2008) suggested the linking factor to be frailty. An operational definition of frailty has not yet been established, (Rodriguez-Manas et al., 2013) but it is generally accepted that genetic and environmental factors of aging are potentially reducing the physiological reserve in several body systems. Together with decreased physical activity and poor nutrition, this leads to increased vulnerability to poor resolution of homeostasis after a stressor event, which causes increased risk of adverse
outcomes (Clegg et al., 2013). Sarcopenia, osteoporosis, and osteosarcopenia can be considered part of frailty (Hirschfeld et al., 2017). Frailty is associated with chronological age (Bassey and Harries, 1993), but Syddall et al. (2003) demonstrated an even stronger association between frailty and (decreased) age and gender stratified HGS. They hence suggested that HGS could possibly be used as a single marker for frailty. Several instruments and scores for diagnosing and monitoring frailty have been developed, and many of them include HGS measures (Buta et al., 2016; de Vries et al., 2011). An example is the currently most cited score, Fried’s Phenotype (Fried et al., 2001). It includes HGS as one of two objective measures, together with gait speed, the same criteria as used for diagnosing sarcopenia (Chen et al., 2014; Cruz-Jentoft et al., 2010).

Frailty measures appear to aid in the prediction of: early complications post hip fracture surgery (Kistler et al., 2015; Kua et al., 2016), adverse outcomes in older inpatients (Hubbard et al., 2017), nursing home placement (Kojima, 2018), falls risk, fracture risk, mortality, length of hospital stay (Ensrud et al., 2007; Khandelwal et al., 2012; Kistler et al., 2015), disability (Vermeulen et al., 2011), and cognitive decline (Godin et al., 2017).

Evidence based cut-off points for identifying low HGS are available from current literature. Dodds et al. (2014) published very well informed normative, age and gender stratified HGS data and suggested cut-off points at 32kg for men and 19kg for women (based on a T-score of -2 or below), measured with a dynamometer. They later conducted a systematic review and meta-analysis to investigate differences in grip strength by world region, which supported the use of their cut-off points across developed regions (Dodds et al., 2016).

The European Working Group on Sarcopenia in Older People (EWGSOP) recommended generic cut-off points at 30kg for men and 20kg for women; they then suggested differentiating further depending on a person’s body mass index (BMI) (Chen et al., 2014).

The Asian Working Group for Sarcopenia (AWGS) provided two sets of cut-off points. Base on Japanese data: 30.3kg for men and 19.3kg for women; base on the recommendations by the EWGSOP, adjusted according to Asian data: >22.4kg for men and >14.3kg for women (Chen et al., 2014).

Many epidemiological studies investigating HGS and its relationship to various parameters have been published over the past few decades. Several systematic reviews have been conducted to summarize this evidence:

Bohannon (2008) looked at HGS as a prognostic tool for negative health outcomes; Norman et al. (2011) established HGS as a marker for nutritional status; den Ouden et al. (2011) related HGS to disability in later life; and Rijk et al. (2016) looked more broadly at the prognostic value of HGS in older individuals.

To our knowledge, no previous review has looked specifically at the relationship between decreased HGS and hip fracture incidence. We believe that HGS is a simple, inexpensive measure that has potential to aid in the identification of individuals at risk of hip fracture. It may support hip fracture prevention strategies and thus help older people to maintain their independence.

1.2 Aim of this review

This paper systematically reviewed the literature about HGS in relation to individuals with hip fracture, pre-injury or at acute presentation, and assessed the strength of the evidence for a relationship between HGS and hip fracture.
2 Methods

2.1 Search strategy
A systematic review of current literature was conducted. (PROSPERO Registration number: CRD42014010080). The reporting of this paper conforms to the process outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009; Moher et al., 2009). A comprehensive computerized database search was performed in Ovid MEDLINE(R), PubMed, Embase, CINAHL, Scopus, and Cochrane Library (both controlled trials and reviews) from each database’s earliest inception data to January 2018. The initial search was performed in Ovid MEDLINE(R), using 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). The key words of HGS and proximal femur fracture were combined to conduct the search. The full search strategy can be found in appendix 1. References of included papers were hand-searched for further relevant studies.

2.2 Inclusion criteria and study identification
The inclusion criteria comprised of: adults aged 50 years or older; that had their HGS measured at least once during the study period; with hip fracture as an outcome. Any study design was included. Publications written in a language other than English were excluded. Studies focusing on recovery after hip fracture were not included. Populations with pathological hip fractures were excluded.

Eligible studies were identified by two reviewers independently (KD and RJ). Titles of all citations identified through database and reference searches were screened for relevance. Selected studies underwent abstract screening, determining aptness based on inclusion criteria. Remaining papers were assessed in full text for confirmation of eligibility and subsequent critical appraisal.

2.3 Critical appraisal, grading of evidence and data analysis
The Joanna Briggs Institute (JBI) Critical Appraisal Checklists (Joanna Briggs Institute, 2016) were used to critically assess methodological quality. JBI checklists were chosen over all other available checklists because a) separate tailored checklists are available for each study type; and b) they are based on extensive research on evidence base health care. (Pearson et al., 2009) Two authors (KD and SL) independently marked all included studies. Each ‘yes’ scored one point; the maximum score was 100%. Where the two reviewers could not reach consensus at any item, a third reviewer (RJ) made the final decision.

Overall evidence was graded using previously published criteria (Brennan et al., 2011; Lievense et al., 2002) with four levels of evidence (no evidence to strong evidence) based on quality, design and number of included studies (appendix 2).

In order to compare HGS measures, values provided in Newton were converted into Kilograms (kg); values provided in Kilopascal (kPa) could not be converted (conversion only possible to Kilogram force per square meter).

3 Results

3.1 Selection of studies
The data base search returned 526 studies; two more studies were identified by hand searching reference lists. Following removal of duplicates using endnote X8, 271 studies
were screened; 79 underwent full-text review. Eleven studies were included in the review (see figure 1). The most common reasons for excluding studies were: populations of children or adolescents; assessing HGS in relation to minimal trauma fractures of all sites combined (vertebra, wrist, hip etc.); exploring the association between HGS and outcomes post hip fracture; correlating HGS with BMD and other outcomes like falls. Only one study was excluded due to language.

[Figure 1 about here]

3.2 Study characteristics

The 11 papers included in this review comprised six case-control studies (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 five cohort studies (Cawthon et al., 2008; Dargent-Molina et al., 1996; Karkkainen et al., 2008; Kauppi et al., 2014; Robbins et al., 2005), published between 1992 and 2014.

Two publications - one by Dargent-Molina et al. (1996), the other by Robbins et al. (2005) - were based on the same data resulting from the EPIDOS study, with different aims. Dargent-Molina et al. (1996) conducted their analyses at an earlier stage of the study with shorter follow up time and with a lower number of hip fractures. They also had a lower total number of participants (7575 versus 7598) which might be due to the exclusion of women that were unable to walk independently. We tried to contact the main author for clarification but did not receive a response. We decided to evaluate both studies independently, but for calculating the total number of participants included in our review, we only added the higher number once.

The cohorts had large sample sizes (average n=4682), but very low hip fracture incidence with an average of only 2.25% (ranging from 0.3% (Karkkainen et al., 2008) to 3.8% (Dargent-Molina et al., 1996; Robbins et al., 2005)). Sample sizes of case-control studies were much smaller (average n=414), but at least 30% of the studied populations were hip fracture cases.

Included studies sought to determine key risk factors for hip fracture or relationships between hip fracture and selected variables. The 11 included studies reported on 74 different variables. None of the studies’ primary objective was to assess the relationship between HGS and hip fracture risk. An overview of all selected studies is presented in table 1.

[Table 1 about here]

3.3 Participant characteristics

The mean age of participants was 59 years in two studies (Karkkainen et al., 2008; Kauppi et al., 2014), and >70 years in the remaining nine papers. The proportion of female participants was considerably higher in nine studies; only one study looked solely at men (Cawthon et al., 2008). This reflects the demography of hip fracture (Dhanwal et al., 2011). Seven studies specifically excluded individuals with cognitive impairments and/or the inability to give written informed consent (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Dargent-Molina et al., 1996; Elliot et al., 1992; Meyer et al., 1995; Robbins et al., 2005); the remaining four studies did not mention the cognitive status of participants (Karkkainen et al., 2008; Kauppi et al., 2014; Lan et al., 2010; Lau et al., 1993).

In five case-control studies participants were age and sex matched (Bean et al., 1995; Coupland et al., 1993; Elliot et al., 1992; Lan et al., 2010; Meyer et al., 1995), one used
random samples (Lau et al., 1993). Controls were either drawn from community samples or from existing longitudinal studies which included aging individuals.

3.4 Methodological quality and strength of evidence

Two authors (KD; SL) independently assessed the quality of the included studies and reached 95% of agreement initially. Disagreement was resolved by discussion. The final overall quality scores for each study and reasons for lost points are shown in appendix 3. Six of the eleven 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) and one study scored below 50% (Lau et al., 1993). The issues for studies scoring low were: confounding factors not addressed, insufficient follow up time, poor reporting, and method for HGS measures not specified (appendix 3).

All studies were observational. Grading of the overall evidence based on Brennan et al. (2011) confirmed strong evidence for a relationship between HGS and hip fracture incidence ("generally consistent findings in multiple high-quality cohort studies"). It was however not possible to comment on the strength of that relationship, as studies were not comparable with regard to design, analyses, populations, primary objectives and dynamometer brands. Pooling data for meta-analysis was therefore also not possible.

3.5 HGS and in relation to hip fracture incidence

The total sample size across the selected studies was 21197, of which 1392 (6.56%) had sustained a hip fracture. All studies described some evidence for a relationship between HGS and hip fracture incidence.

3.6 Statistically significantly decreased HGS in individuals with hip fracture

HGS was significantly decreased in individuals with hip fracture at the time of injury as compared to controls, (p<0.001) (Bean et al., 1995; Elliot et al., 1992; Lau et al., 1993), and at baseline when assessing a cohort (p<0.001) (Kauppi et al., 2014; Robbins et al., 2005). The remaining studies did not report on the sole differences in HGS between study groups and controls/unaffected participants.

3.7 HGS as a risk factor for sustaining a hip fracture

HGS was associated with increased hip fracture risk in all 11 included studies (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Dargent-Molina et al., 1996; Elliot et al., 1992; Karkkainen et al., 2008; Kauppi et al., 2014; Lan et al., 2010; Lau et al., 1993; Meyer et al., 1995; Robbins et al., 2005). The study that looked solely at males found some association between decreased HGS and fracture risk within the lowest HGS group, but did find a much stronger association between the inability to perform the HGS test and fracture risk (Cawthon et al., 2008).

In seven studies, authors aimed to determine if risk factors were independent (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Dargent-Molina et al., 1996; Kauppi et al., 2014; Lan et al., 2010; Lau et al., 1993). HGS remained as an independent risk factor for sustaining a hip fracture in three studies (Bean et al., 1995; Coupland et al., 1993; Lan et al., 2010).

Risks were established using multiple and logistic regressions in case control studies, and Cox regressions in cohort studies. Multivariate models were used to determine the independence of risk factors. Risks were presented as odds ratios, hazard ratios and relative risks. Over all, the risk increase for sustaining a hip fracture based on decreased HGS varied
greatly between the studies. Risk increased as little as 0.7 times in one study (Kauppi et al., 2014) to as much as 49.5 times in another (Coupland et al., 1993).

3.8 HGS values compared to stratified means and cut-off points

HGS for hip fracture cases was provided in five studies:

In the female United Kingdom population examined by Bean et al. (1995) the mean HGS of controls was 2.46% below the age and gender stratified means established by Dodds et al. (2014) (see table 1), and the HGS of cases was 39.1% below the stratified mean. The cases’ mean dominant HGS was well below the 20 kg cut-off point recommended for females by the EWGSOP (Cruz-Jentoft et al., 2010).

In the study by Lau et al. (1993) all Hong Kong participants were below the stratified mean (Dodds et al., 2014) (male controls 35.1%, male cases 60.6%, female controls 43.15%, and female cases 58.9%). Cases’ HGS was well below the 22.4 kg (males) and 14.3 kg (females) cut-off points recommended for Asian populations (Chen et al., 2014).

In the French study reported by Robbins et al. (2005), HGS was recorded in kPa. Cases were significantly weaker than the rest of the cohort but no comparisons with means or cut-off points were possible, as they are presented in kg.

Elliot et al. (1992) and Kauppi et al. (2014) combined males and females; no comparisons with means or cut-off points were possible, as they are gender specific. However, in both studies, cases’ HGS was well below the stratified mean for females, and well below the EWGSOP cut-off point for females.

In the remaining six studies (Cawthon et al., 2008; Coupland et al., 1993; Dargent-Molina et al., 1996; Karkkainen et al., 2008; Lan et al., 2010; Meyer et al., 1995), HGS of all participants was divided into tertiles or quartiles and there was no distinction between HGS of cases and controls/participants without fracture; only the numbers of fractures within each tertile/quartile were stated.

3.9 Measurement of HGS

Baseline measures of HGS taken before the point of fracture were only available for the four cohorts, where recruitment had occurred prior to the hip fracture; the length of time from measurement to fracture was not provided. For the case-control populations, HGS had been measured either within 72 hours of the hip fracture or between 72 hours and two weeks post fracture. A variety of different dynamometer devices was used to measure HGS, ranging from a custom-built strain gauge (Bean et al., 1995) to a Jamar device (Cawthon et al., 2008); three studies did not specify the brand (Coupland et al., 1993; Dargent-Molina et al., 1996; Lau et al., 1993; Robbins et al., 2005). Methods of HGS measurements also varied greatly between studies. In five studies both hands were measured (Bean et al., 1995; Cawthon et al., 2008; Coupland et al., 1993; Dargent-Molina et al., 1996; Lau et al., 1993; Robbins et al., 2005), in three studies the dominant (Elliot et al., 1992; Karkkainen et al., 2008; Lan et al., 2010), and in one study the non-dominant hand (Meyer et al., 1995). The number of measurements diverged widely from the best of two attempts (Cawthon et al., 2008; Kauppi et al., 2014), to best of six attempts (Bean et al., 1995). No information about the method of measurement was provided for publications resulting from the EPIDOS study (Dargent-Molina et al., 1996; Robbins et al., 2005).

4 Discussion

4.1 Summary of findings
This systematic review aimed to assess the evidence for a relationship between HGS and hip fracture incidence. Our findings confirm an association between decreased HGS and hip fracture incidence. The retrieved evidence conclusively confirms: a) patients with hip fracture have decreased HGS at the time of hip fracture; b) decreased HGS is a risk factor for sustaining a hip fracture.

Previously published systematic reviews investigated HGS and frailty, and their prognostic value for several variables: HGS has predictive power for mortality, decreased mobility, and cognitive decline in older people (Rijk et al., 2016). HGS is an important factor of frailty (Chainani et al., 2016; Syddall et al., 2003), and frailty is a predictor/risk factor for falls in older people (Cheng and Chang, 2017; Kojima, 2015). This is the first systematic review to objectively confirm the relationship between decreased HGS and hip fracture in older people.

None of the studies included in this review exclusively assessed the relationship between HGS and hip fracture. The 11 included studies reported on 74 different variables. We had targeted our comprehensive data base search towards finding papers about HGS. Thus, only some variables were considered in more than one study. Amongst the most mentioned variables related to hip fracture were low BMD (considered in six studies (Cawthon et al., 2008; Dargent-Molina et al., 1996; Elliot et al., 1992; Lan et al., 2010; Lau et al., 1993; Robbins et al., 2005) with significant results in four (Dargent-Molina et al., 1996; Lan et al., 2010; Lau et al., 1993; Robbins et al., 2005)) and falls (considered in five studies (Cawthon et al., 2008; Elliot et al., 1992; Lan et al., 2010; Meyer et al., 1995; Robbins et al., 2005) with significant results in two (Lan et al., 2010; Robbins et al., 2005)). Even though we did not aim to search for risk factors other than HGS, our review highlights the dominance of low BMD and falls as perceived main factors for hip fracture. On the other hand, the large number of other variables investigated in the 11 studies also shows that the pathogenesis of hip fractures is complex, far beyond just BMD and falls.

Frailty was briefly mentioned in the discussion of four papers (Cawthon et al., 2008; Dargent-Molina et al., 1996; Karkkainen et al., 2008; Lan et al., 2010), but one of the included papers discussed the concept of frailty; this might be because most papers’ publication date pre-dates the wider recognition of frailty as a concept, starting with Fried et al. (2001) and Rockwood (2005).

4.2 ‘Risk factor’, what does that mean?

All included studies talked about risk factors or correlations. There is consensus in the literature that a risk factor is an exposure that pre-dates and is in some way related to an outcome. There is no certitude on how strong the association between exposure and outcome has to be for the former to become a risk factor, or if the exposure must be causal (Burt, 2001).

Five out of the 11 included studies were longitudinal and exposure clearly pre-dated outcome. The remaining six studies were case control studies, where it is impossible to prove that the exposure pre-dated that outcome; Burt (2001) suggested using the term ‘risk indicator’ rather than ‘risk factor’ if relationships are based on prevalence data.

HGS was reported as an independent risk factor in three out of seven studies included in this review. The clinical relevance of establishing the independence of a risk factor is debated: Brotman et al. (2005) explained that independence is a statistical paradigm that depends on which variables are included in each model, and it does not inform about causality. They
pointed out that the same variable may remain an independent factor in one study but not in another; this is due to differences in populations, choice of statistical methods, and selection of co-variables. An independent risk factor may thus be less clinically relevant than another factor that did not reach statistical independence.

Common sense does not suggest that decreased HGS would be a causal risk factor for sustaining a hip fracture; it is much more likely that they both are related to a third variable such as osteosarcopenia that might be causal.

4.3 The link between HGS and hip fracture
In the introduction, we explored the link between HGS and hip fracture incidence through the concept of frailty, including sarcopenia, osteoporosis and osteosarcopenia. Lan et al. (2010) discussed the possibility of a chain reaction in muscle recruitment to be the link between HGS and fracture incidence: the activation of arm and shoulder muscles through strong grip might trigger stabilizing trunk muscle activity, which further triggers muscle contraction forces directly at the hip. Two other papers support this theory: Firstly, Martelli et al. (2014) concluded in a biomechanical paper that hip extensor contractions improve femoral neck bone strength (not density). Secondly, Sherrington and Henschke (2013) pointed out that in an older, falls prone population, the importance of exercise training lies with the stimulation of central and peripheral neurological factors, which are crucial for falls and fracture prevention; inter-muscular coordination, motor control, and cognition are the key. In a previous paper, Sherrington and Lord (2005) found HGS to be an indicator for hip muscle strength. Weakness due to neuro-degeneration, malnutrition, low physical activity, and falls are important factors of sarcopenia which is a core aspect of frailty (Martin, 2017).

4.4 Limitations
Only English language papers were finally included in this review, which might have led to bias. However, despite not limiting our data base searches to English language, we excluded only one study due to language (Chinese).

A further limitation was that pooling of data was not possible due to varied populations, objectives, methods, analyses, as well as different dynamometer brands and different measurement techniques to establish HGS.

In six of the 11 included studies, individuals with cognitive impairments were excluded; as delirium and dementia are very common in the hip fracture population, this might introduce bias to the sample.

A last limitation was that hip fracture rates were very low in all four cohort studies with an average of only 2.25% of participants having sustained a hip fracture during the study period.

4.5 Clinical implications
HGS is an accessible, cost effective, and simple measure that can be easily conducted in the community, a doctor’s office, aged care facility, or hospital.

In line with Rijk et al. (2016), we suggest using HGS measures more broadly in the assessment of older individuals. Although HGS measures alone are unlikely to be sufficient to prevent hip fractures, our results suggest that HGS measures may be useful for identifying individuals that might be at elevated risk of hip fracture. Normative age and gender stratified HGS data as well as cut-off points suggested in the literature (e.g. Dodds et al. (2014): 32kg for men and 19kg for women) can be used as reference values.

4.6 Conclusion
This systematic review confirmed an association between decreased HGS and low impact hip fracture. We were not able to quantify the strength of this relationship, due to the heterogeneity of the included studies. Nevertheless, our results suggest that HGS merits further investigation as a useful tool for identifying individuals that might be at elevated risk for sustaining a hip fracture.

REFERENCES:


Table 1: Overview of selected studies

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Study design/ numbers</th>
<th>Mean age in years (SD)</th>
<th>Gender female%</th>
<th>Relevant results – HGS</th>
<th>HGS values in kg</th>
<th>Normative HGS values in kg for age and gender (Dodds et al., 2014)</th>
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</thead>
<tbody>
<tr>
<td>(Bean et al., 1995) UK</td>
<td>Case control</td>
<td>Age matched +/- 3 years, 1:1</td>
<td>Cases 79.5 (8.4) Controls 79.6 (7.7)</td>
<td>100</td>
<td>T-test: HGS weaker in cases p&lt;0.001 Stepwise multiple regression: Multiple R=0.59 R²=0.35 p&lt;0.0001</td>
<td>Females with # =11.63 (mean) Females without # =18.63 (mean)</td>
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<tr>
<td></td>
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<td></td>
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<td>Females: 19.1 (80)</td>
</tr>
<tr>
<td>(Cawthon et al., 2008) USA</td>
<td>Retrospective cohort</td>
<td>Total: n=5902 Hip fractures: n=77 Mean follow-up: 5.3 years ≥85 (71.9 to 77.2)</td>
<td>0</td>
<td>Cox regression: HR (95% CI) of hip fracture (multiple adjusted): worst quartile: HR 1.63(0.65-4.14) unable: HR 4.50 (1.32-15.35) p for trend=0.184</td>
<td>Worst quartile: Male &lt;36</td>
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<tr>
<td></td>
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<td></td>
<td>Males: 39.1 (70) Females: 21.4 (75)</td>
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<tr>
<td>(Coupland et al., 1993) UK</td>
<td>Case control</td>
<td>Age and sex matched, 1:2</td>
<td>Cases 79.1(1.0) Controls 78.4(0.7)</td>
<td>78</td>
<td>T-test: HGS weaker in cases p&lt;0.001 Logistic regression: p=0.003 (coefficient=0.14)</td>
<td>Females and males combined with # =11.4 (mean) Females and males combined without # =19.2 (mean)</td>
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<tr>
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<td>Males: 35.6 (75) Females: 19.1 (80)</td>
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<tr>
<td>(Elliot et al., 1992) NZ</td>
<td>Case control</td>
<td>Age and sex matched, 1:2</td>
<td>Cases 74.29(7.92) Controls 66.08(8.11)</td>
<td>58.87</td>
<td>T-test: HGS weaker in cases p&lt;0.0001 HR (95% CI) of hip fracture (multiple adjusted): HR 0.70 (0.45-1.08) p for trend=not provided</td>
<td>Females and males combined with # =25.0 (mean) Females and males combined without # =32.4 (mean)</td>
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<td>(Karkkainen et al., 2008) FI</td>
<td>Retrospective cohort</td>
<td>Total: n=2928 Hip fractures: n=8 Mean follow-up: 8.3 years 59(2.8)</td>
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<td>Cox regression: HR (95% CI) of hip fracture (multiple adjusted): HR: 1.046 (1.005-1.088); p for trend=0.026</td>
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<td>58.1(7.9)</td>
<td>T-test: HGS weaker in cases p&lt;0.001 HR (95% CI) of hip fracture (multiple adjusted): HR 0.70 (0.45-1.08) p for trend=not provided</td>
<td>Females and males combined with # =25.0 (mean) Females and males combined without # =32.4 (mean)</td>
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<td>(Lan et al., 2010) TW</td>
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<td>Age and sex matched 1:1 or 1:2</td>
<td>Cases: 71.5 Controls: 69.4</td>
<td>80.1(7.9)</td>
<td>Logistic regression: OR (95% CI) of hip fracture (adjusted): best tertile: OR males (group adjusted):</td>
<td>Worst tertile: Male ≤15 Females</td>
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<td>Gender</td>
<td>HGS Measurement</td>
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<td>Lau et al., 1993</td>
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<th>HGS Measurement</th>
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<th>RR (95% CI) of Hip Fracture</th>
<th>p for Trend</th>
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<td>Rest of cohort 80.4(3.7)</td>
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<td>OR: 0.82(0.73-0.93); p=0.001</td>
<td>left: HR: 0.77(0.68-0.87); p&lt;0.001</td>
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<td>Rest of cohort 80.4(3.7)</td>
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</table>

HGS= handgrip strength; HR=hazard ratio; OR=odds ratio; RR=relative risk; #=fracture
Figure 1: Flowchart of inclusion

Records identified through multiple database searching (n = 526) → Records after duplicates removed (n = 271) → Records screened (n = 271) → Full-text articles assessed for eligibility (n = 79) → Studies included in qualitative synthesis (n = 11) → Additional records identified through other sources (n = 2) → Records excluded based on titles and abstracts (n = 192) → Full-text articles excluded (n = 67 – not relevant) (n = 1 – full text not in English)
<table>
<thead>
<tr>
<th>Appendix 1. Search Strategy for Ovid MEDLINE(R)</th>
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</thead>
<tbody>
<tr>
<td>1. Hand Strength/</td>
</tr>
<tr>
<td>2. &quot;grip strength&quot;.mp.</td>
</tr>
<tr>
<td>3. (hand* adj3 (strength* or grip* or grasp*)).mp.</td>
</tr>
<tr>
<td>4. Muscle Strength Dynamometer/ or dynamom*.mp</td>
</tr>
<tr>
<td>5. 1 or 2 or 3 or 4</td>
</tr>
<tr>
<td>6. Hip fractures/ or femoral neck fractures/ or proximal femur fracture</td>
</tr>
<tr>
<td>7. Femoral Fractures/ and (Femur Head/ or Femur Neck/)</td>
</tr>
<tr>
<td>8. (&quot;femoral neck&quot; or &quot;femoral head&quot; or &quot;femur neck&quot; or &quot;femur head&quot; or trochant* or intertrochant* or &quot;inter-trochant*&quot; or subtrochant* or &quot;sub-trochant*&quot; or intratrochant* or &quot;intra-trochant*&quot; or peritrochant* or &quot;peri-trochant*&quot;) and fracture*.mp.</td>
</tr>
<tr>
<td>9. 6 or 7 or 8</td>
</tr>
<tr>
<td>10. 5 and 9</td>
</tr>
<tr>
<td>Level of evidence</td>
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<tr>
<td>Strong evidence</td>
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<td>Conflicting evidence</td>
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## Appendix 3. Critical appraisal and quality rating

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<th>Author (year)</th>
<th>Score</th>
<th>Factor(s) that reduced quality</th>
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<tbody>
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<td>Bean et al. (1995)</td>
<td>77.7%</td>
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<tr>
<td>Cawthon et al. (2008)</td>
<td>100%</td>
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<tr>
<td>Coupland et al. (1993)</td>
<td>100%</td>
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<tr>
<td>Elliot et al. (1992)</td>
<td>90%</td>
<td>Insufficient follow up time</td>
</tr>
<tr>
<td>Karkkainen et al. (2008)</td>
<td>100%</td>
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</tr>
<tr>
<td>Kauppi (2014)</td>
<td>100%</td>
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<tr>
<td>Lan et al. (2010)</td>
<td>100%</td>
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<tr>
<td>Lau et al. (2003)</td>
<td>30%</td>
<td>Poor reporting through out</td>
</tr>
<tr>
<td>Meyer et al. (1995)</td>
<td>100%</td>
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<tr>
<td>EPIDOS study</td>
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<tr>
<td>Dargent-Molina (1996)</td>
<td>90.91%</td>
<td>Measurement of outcome (HGS) not specified</td>
</tr>
<tr>
<td>Robbins et al. (2005)</td>
<td>90.91%</td>
<td>Measurement of outcome (HGS) not specified</td>
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</table>
Highlights

- Hand grip strength is decreased in individuals with hip fracture near the time of injury.
- Decreased hand grip strength is associated with increased risk of sustaining a hip fracture.
- Hand grip strength might be a useful tool for identifying individuals at risk of sustaining a hip fracture.