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Social and regional inequalities in the incidence of and outcomes after hip fracture in England

Social and Regional Inequalities in the Incidence of and Outcomes after Hip Fracture in England

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ABSTRACT

Background
Hip fracture risk varies by levels of deprivation and geography; however, it is not known whether social inequalities in hip fracture incidence have changed over time in England. Furthermore, the impact of deprivation on clinical outcomes after hip fracture is not established. I examined the effect of area-level social deprivation on hip fracture incidence and outcomes among older men and women in England.

Methods
In the incidence study, hip fractures were identified using Hospital Episode Statistics (HES) (2001/02-2014/15) and Office for National Statistics (ONS) mid-year population estimates (2001-2014). The Index of Multiple Deprivation (IMD) was used to measure area-based deprivation (Q1 - least deprived; Q5 - most deprived). Age-adjusted incidence rate ratios (IRR) were calculated, stratified by gender, deprivation quintiles and region.

In the outcomes study, hip fractures were identified using HES data linked to the National Hip Fracture Database (04/2011-03/2015) and ONS mortality data. Deprivation was measured using the IMD. Associations between deprivation and 30-day mortality and emergency 30-day readmission were examined, adjusted for age, gender and comorbidity. Mean length of stay (LOS) in NHS acute and rehabilitation hospitals (‘superspell’) and total NHS bed occupancy within 1-year post-fracture were calculated.

Results
Over 14 years, 747,369 index hip fracture admissions were identified. Incidence was higher in more deprived areas, particularly among men: IRR Q5 vs. Q1 1.50 [95% CI 1.48,1.52] in men, 1.17 [1.16,1.18] in women. Age-standardised incidence increased for men across all deprivation quintiles from 2001-2014. Among women, incidence fell more amongst those least deprived compared to most deprived (year by deprivation interaction $p<0.001$). Age-standardised hip fracture incidence was highest in the most deprived areas in the North of England compared to the Midlands and the South for both women and men.

Over 4 years, 218,907 index hip fracture admissions were identified. Greater deprivation was associated with higher 30-day mortality (adjusted OR 1.23 [1.17,1.30], $p<0.001$). Among survivors, mean superspell LOS was longer in the most deprived versus least deprived quintile (Q5: 24.4 [SD 21.7] days, Q1: 23.3 [22.1], $p<0.001$). Emergency 30-day readmission was higher in those most deprived compared to least deprived (adjusted OR 1.27 [1.22,1.32], $p<0.001$). A similar trend was observed when assessing mean total NHS bed occupancy.

Conclusions
Deprivation is a stronger relative predictor of hip fracture incidence in men than women. Absolute inequalities in hip fracture incidence are greatest in the North of England. Furthermore, increasing deprivation is associated with higher 30-day mortality and, among those who survive, greater healthcare utilisation after hip fracture. These study findings highlight the need for greater focus on addressing social inequalities in hip fracture care in England.

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AUTHOR'S DECLARATION

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's *Regulations and Code of Practice for Research Degree Programmes* and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

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AUTHOR CONTRIBUTIONS TO JOURNAL PUBLICATIONS

Two articles have been published in peer-reviewed journals, one in Osteoporosis International and one in Public Health, as listed below and presented in Appendix 13.1. These articles are based on analyses presented in Chapters 7 and 8 of this thesis. I conducted the statistical analyses, generated the tables and figures, and drafted the manuscripts for both journal articles. Dr Celia Gregson, Prof Yoav Ben-Shlomo and Dr Jenny Neuburger, my PhD supervisors, provided guidance on the development of these analyses and comments on the manuscripts. Dr Timothy Jones provided me with the HES data extracts for analysis and commented on the manuscripts. Susan Charman provided me with the Stata code that she developed to calculate the Royal College of Surgeons of England's Charlson comorbidity score.

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Bhimjiyani A, Neuburger J, Jones T, Ben-Shlomo Y, Gregson CL. Inequalities in hip fracture incidence are greatest in the North of England: regional analysis of the effects of social deprivation on hip fracture incidence across England. Public Health. 2018;162:25-31.

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LIST OF ABBREVIATIONS

Abbreviation	In Full
ADLs	Activities of Daily Living
AMTS	Abbreviated Mental Test Score
AOD	Anti-Osteoporosis Drugs
APC	Admitted Patient Care
ASA	American Society of Anaesthesiologists
ASBMR	American Society for Bone and Mineral Research
BMI	Body Mass Index
BMC	Bone Mineral Content
BMD	Bone Mineral Density
BPT	Best Practice Tariff
CCI	Charlson Comorbidity Index
CHD	Coronary Heart Disease
CI	Confidence Interval
CINAHL	Cumulative Index to Nursing and Allied Health
COPD	Chronic Obstructive Pulmonary Disease
CPRD	Clinical Practice Research Datalink
CRF	Clinical Risk Factor
CVD	Cardiovascular Disease
DA	Dissemination Area
DHS	Dynamic Hip Screw
ED	Emergency Department
EU	European Union
FCE	Finished Consultant Episode
FFFAP	Falls and Fragility Fracture Audit Programme
FLS	Fracture Liaison Service
FRAX	Fracture Risk Assessment Tool
GOR	Government Office Region
GP	General Practitioner
HES	Hospital Episode Statistics
HI	Health Insurance
HR	Hazard Ratio
HRT	Hormone Replacement Therapy

Abbreviation	**In Full**
HSE	Health Survey for England
ICD-9	International Classification of Diseases, Ninth Revision
ICD-10	International Classification of Diseases, Tenth Revision
IDAOPI	Income Deprivation Affecting Older People Index
IM	Intramedullary
IMD	Index of Multiple Deprivation
IQR	Interquartile Range
IRR	Incidence Rate Ratio
IRSD	Index of Relative Social Disadvantage
KM	Kaplan-Meier
LOCF	Last Observation Carried Forward
LOS	Length Of Stay
LRT	Likelihood Ratio Test
LSOA	Lower Super Output Area
MOF	Major Osteoporotic Fracture
MYPE	Mid-Year Population Estimates
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
N-OS	Newcastle Ottawa Scale
NHFD	National Hip Fracture Database
NR	Not Reported
ONS	Office for National Statistics
OR	Odds Ratio
PD	Parkinson’s Disease
PHS	Population Health Sciences
PMW	Postmenopausal Women
RA	Rheumatoid Arthritis
RCS	Royal College of Surgeons of England
Ref	Reference category
ROS	Royal Osteoporosis Society
RR	Relative Risk
SD	Standard Deviation
SEP	Socioeconomic Position

Abbreviation	In Full
SES	Socioeconomic Status
SHA	Strategic Health Authority
SHS	Sliding Hip Screw
SUS	Secondary Uses Service
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
TDI	Townsend Deprivation Index
THA	Total Hip Arthroplasty
UoB	University of Bristol
UK	United Kingdom
US	United States
USA	United States of America
WHiTE	World Hip Trauma Evaluation
WHO	World Health Organisation

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CHAPTER 1. EPIDEMIOLOGY OF HIP FRACTURES

This chapter describes the classification and management of hip fractures, and their epidemiology, focusing on geographic variation and secular trends in hip fracture incidence. Osteoporosis, an important cause of hip fractures in older people, and other factors associated with increased hip fracture risk are discussed, and published literature on clinical outcomes after hip fracture are reviewed. National and international policies that aim to improve care after hip fracture and reduce the occurrence of subsequent fractures are discussed.

1.1. Classification

Hip fractures, also known as proximal femoral fractures, are fractures that occur between the hip joint and 5 cm below the distal part of the lesser trochanter, and are classified as intracapsular or extracapsular depending on the site of the fracture in relation to the capsule of the hip joint (1). Intracapsular hip fractures, or femoral neck fractures, are those that occur above the insertion of the capsule (1), whilst fractures that occur below the insertion of the capsule are termed extracapsular hip fractures, and can be further subdivided into pertrochanteric and subtrochanteric depending upon their relationship to the lesser trochanter (2). Classification of hip fractures as intracapsular and extracapsular has implications for the surgical approach to fracture management, as discussed in section 1.2, page 19. Blood vessels that pass along the femoral capsule may be damaged by an intracapsular fracture, particularly when displaced (2), thus disrupting the blood supply to the femoral head with the subsequent risk of avascular necrosis (3).

1.2. Management

Conservative management of hip fractures results in a painful, immobile hip and so the vast majority of these fractures are treated surgically (1), with the aim of restoring pre-fracture mobility and function (4). Whilst undisplaced intracapsular fractures can be treated conservatively, the risk of subsequent displacement is high and therefore surgical management is preferred (1). The incidence of non-union and avascular necrosis is high among patients with displaced intracapsular fractures managed with internal fixation (5), and therefore surgical options include hemiarthroplasty (only the femoral head is replaced) and total hip arthroplasty (THA) (both the femoral head and acetabulum are replaced) (6). Extracapsular hip fractures, historically treated with external traction, are now managed with a sliding hip screw (SHS) owing to the prolonged period of immobilisation required with external traction (1). Intramedullary (IM) nailing is recommended for subtrochanteric fractures as part of clinical guidance in the United Kingdom (UK) (6).

1.3. Geographic variation in hip fracture incidence

In 1990, there were an estimated 1.3 million hip fractures among men and women worldwide (7). The global burden of hip fractures is projected to increase to 2.6 million in 2025 and 4.5 million by 2050 owing to a growing older population (7). Whilst, in 1990, approximately 50% of global hip fractures in women aged 65+ years occurred in Europe and North America, about three-quarters of these fractures are projected to occur in Asia, Latin America and Africa by 2050 due to rapid population ageing in these regions (8).

Worldwide, there is considerable geographic variation in hip fracture incidence, with the highest rates reported in North America and Europe, and the lowest in Latin America and Africa (9). Hip fracture incidence in high-income countries has been studied extensively; however, comparatively little is known about the burden of hip fractures in certain geographic regions (e.g. the Middle East, Africa and Latin America) (10, 11). Kanis et al systematically reviewed studies published between 1950 and 2011 with data available for sixty-three countries; age-standardised hip fracture incidence varied by greater than 10-fold between countries in both men and women, and was approximately 50% lower among men than women (12). Age-standardised hip fracture incidence was highest among women in Denmark (574 per 100,000 population) and Norway (563/100,000), and lowest among women in Nigeria (2/100,000). A hospital-based cross-sectional study conducted in a single region in South Africa reported that, among Black Africans aged 60+ years, hip fracture incidence was ten-fold higher than previous estimates (13), suggesting that hip fractures may be more prevalent among Africans than previously considered. Ethnic variation in bone structure and geometry, and thus resistance to fracture, may partly explain the observed geographic differences in hip fracture incidence (discussed further in section 1.6.4, page 27).

1.4. Secular trends in hip fracture incidence

Studies conducted in high-income countries have consistently demonstrated that hip fracture incidence has plateaued or declined over the last few decades. Secular trends in hip fracture incidence in North America, the UK and Oceania are discussed below.

1.4.1. North America

Secular analysis of hip fracture incidence over a 65-year period (1928-1992) in the United States of America (USA) has demonstrated that, among residents of Rochester, Minnesota, age-adjusted incidence rates rose in women until 1950 and in men until 1980, after which rates declined in both sexes (14). Subsequent studies conducted in Canada and the USA have similarly reported declining rates in hip fracture incidence in both men and women, with more marked declines observed in women than men (15, 16). A more recent US analysis conducted among women aged 65+ years has shown that whilst age-adjusted hip fracture incidence declined at a rate of 1.8% per year between 2002 and 2012, incidence rates stabilised at higher than projected levels between 2013 and 2015 (17), possibly explained in part by a decline in the prescribing of anti-osteoporosis medications (18).

1.4.2. United Kingdom

Most UK studies examining secular trends in hip fracture incidence have been conducted in England, with no published data available for Scotland and Wales individually. The earliest known English study showed, using hospital administrative data, that age-standardised hip fracture incidence had increased between 1968 and 1986 in both men and women, with a more marked increase observed in women (19). Other studies analysing English hospital administrative data have since shown that overall hip fracture incidence has plateaued over the last few decades (20, 21). Wu et al reported that age-standardised hip fracture incidence remained relatively stable over the period 1998 to 2009 (20), whilst another English study similarly showed that age- and sex-standardised hip fracture admission rates had plateaued between 2001 and 2011 (21).

Studies examining gender-specific trends in hip fracture incidence have reported inconsistent findings, possibly explained by the differing time periods and data sources analysed. Balasegaram et al showed, using English hospital administrative data, that age-standardised hip fracture incidence was stable in men and women between 1989 and 1998 (22), whilst other studies have reported contrasting gender-specific trends (23, 24). Analysis of English hospital administrative data showed that hip fracture incidence rose amongst men aged 85+ years, but declined amongst women aged 75+ years, over the period 2003 to 2013 (23). Van der Velde et al reported, using UK General Practitioner (GP) practice records, that hip fracture incidence remained stable in women between 1990-1994 and 2008-2012, although these analyses were not age adjusted, and increased in men over the same period (24).

1.4.3. Oceania

In Australia, age-standardised hip fracture incidence decreased in both men and women between 1997 and 2007, with a more marked decline observed in women than men (20% *vs*. 13% over this ten-year period) (25). Langley et al demonstrated, using national hospital discharge data for New Zealand (1974-2007), that age-adjusted hip fracture incidence increased in men over the entire study period and in women until 1987, but declined in women thereafter (26).

1.5. Osteoporosis

Osteoporosis is defined as *"a systemic skeletal disease characterised by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture"* (27). The importance of osteoporosis lies in the fractures that can ensue, and their associated morbidity and mortality (28). Osteoporotic fractures commonly occur at the hip, wrist, spine and shoulder (termed major osteoporotic fractures (MOF)), of which hip fractures have the most serious consequences (28). In the UK, mortality after hip fracture is high with 29.7% of individuals dying within the year after hip fracture (29) and among survivors, less than one-third recover to pre-fracture levels of independent mobility (30). Hip fracture patients spend on average 21 days in hospital (30), with considerable financial implications for the health service at an estimated cost of £1.1 billion per year (31).

Osteoporosis arises because of age-related bone loss or secondary to other diseases. Bone mass increases during childhood and adolescence, reaches a peak during the third decade of life and decreases thereafter with increasing age (32). Peak bone mass, the amount of bone tissue present upon completion of skeletal maturation (32), is higher in men than women (27) and is influenced by genetics, environmental factors (e.g. calcium, vitamin D and protein intake) and physical loading from exercise (32). Bone mass decreases with increasing age in both men and women at a rate of approximately 1% per year, with the most marked decline occurring in women during the early postmenopausal period (about 3-5% per year) (27). Other determinants of increased bone loss include genetic factors, lifestyle risk factors (e.g. alcohol abuse and cigarette smoking), diseases such as hyperthyroidism and certain drugs (e.g. glucocorticoids) (27). Osteoporosis, and the subsequent risk of fractures, occurs because of attainment of low peak bone mass in early life and/or excessive bone loss later in life (33).

In 1994, the World Health Organisation (WHO) operationalised a definition of osteoporosis that is based purely on the measurement of bone mineral density (BMD) (34). Dual-energy X-ray absorptiometry, a two-dimensional assessment of bone mineral content (BMC) at a specific skeletal site, is used to quantify areal BMD by dividing the value for

BMC by the area measured (28). BMD is compared to that of a young healthy adult and converted to a T-score that denotes the difference in standard deviations (SD). Normal BMD is less than 1 SD below the mean value of a young adult, whilst osteoporosis is defined by the WHO as a T-score of 2.5 SD or more (34). Osteopenic individuals (defined as a T-score between 1 to 2.5 SD below the mean value of a young adult) represent a population in whom prevention of bone loss can also be beneficial (34). However, it is to be noted that a considerable proportion of individuals with a hip fracture do not have a BMD T-score that meets the WHO criteria for osteoporosis. Wainwright and colleagues showed, among a prospective multicentre cohort of 8,065 US women aged 65+ years, that 54% of women with an incident hip fracture did not have a total hip BMD T-score greater than or equal to -2.5 SD at the start of the five-year study duration (35). Changes in bone structure and composition with older age due to imbalances in bone remodelling affect bone quality, thus contributing to fragility fracture risk (36).

Fragility fractures are defined as fractures occurring because of low-impact trauma such as a fall from standing height or less (37), and commonly occur at the hip, spine, shoulder and wrist. A population-based study analysing data from a hospital injury register (1993-2004) reported that, among men and women aged 50+ years in Umea, Sweden, 53% of all fractures were due to low-energy trauma (38). The proportion of all fractures that occurred because of low-energy trauma increased with age, from fewer than 30% in those aged 50-59 years to greater than 80% in individuals aged 90+ years (38).

1.6. Clinical risk factors for hip fracture

Several clinical risk factors (CRFs) are known to increase hip fracture risk; they include non-modifiable risk factors such as age, gender and ethnicity, and modifiable lifestyle risk factors (e.g. smoking and alcohol consumption). This section describes the relationship between key modifiable and non-modifiable CRFs and hip fracture risk.

1.6.1. Bone mineral density

Low BMD is associated with an increased risk of hip fracture, as described in section 1.5, page 22. The lifetime risk of hip fracture increases as hip BMD decreases (39). A meta-analysis of eleven prospective cohort studies reported that, among older women, a 1 SD decrease in BMD measured at the hip was associated with a 2.6-fold increased risk of hip fracture (40). Another meta-analysis, conducted using prospective cohort data for both men and women, showed that a 1 SD decrease in femoral neck BMD was associated with a 2.07-fold increased risk of hip fracture (41). The strength of the relative association between low BMD and hip fracture risk was similar in men and women but lessened with age in both sexes; however, the absolute risk of hip fracture increased with age for any given BMD value (41). The Study of Osteoporotic Fractures (SOF), a large prospective cohort study conducted among community-dwelling women aged 65+ years from four areas in the USA (1986-1988), showed that BMD measured at the hip compared to the spine and radius was a better predictor of hip fracture risk (42). Age-adjusted hip fracture risk increased 2.6 times and 1.5 times for each SD decrease in BMD measured at the femoral neck and distal radius respectively.

1.6.2. Age

The lifetime risk of hip fracture increases exponentially with age in both men and women. Kanis et al estimated that, among men and women from Malmo, Sweden, the mean ten-year hip fracture probability increased from 0.5% in men aged 45 years to 7.1% in men aged 85 years, and in women, from 0.4% to 16.1%. (43). Whilst BMD decreases with increasing age and low BMD is associated with increased hip fracture risk (see section 1.6.1, page 25), age also predicts hip fracture risk independent of BMD (44). The SOF study, described earlier in section 1.6.1, showed that a 10-year increase in age was associated with a 2.09 increased risk of hip fracture after adjustment for BMD measured at the calcaneus, proximal radius and distal radius (45).

1.6.3. Gender

The lifetime risk of hip fracture is greater in women than men. Melton et al estimated that, over the period 1950 to 1982, the lifetime risk of hip fracture was 17.5% in White women and 6.0% in White men from Rochester, Minnesota (USA) (46). Similar gender-specific patterns in hip fracture risk have been reported in the UK. Using GP practice records for England and Wales (1988-1998), Van Staa et al estimated that ten-year hip fracture risk was 0.2% in men and 0.3% in women aged 50 years, increasing to 2.9% and 8.7% in men and women aged 80 years (47). Gender differences in BMD are likely to account for some of the observed patterns in hip fracture risk. Peak bone mass attainment is lower in women than men, and age-related bone loss is more marked among women as compared to men, particularly during the first five years after the menopause (27). However, gender also predicts hip fracture risk independent of BMD. Cummings et al showed, analysing data from two large prospective cohorts of older US men and women, that non-vertebral fracture risk was higher in women than men independent of BMD and weight (48).

1.6.4. Ethnicity

Hip fracture risk differs according to ethnicity, with the highest risk being in White individuals. Analysis of hospital discharge data for the state of California, USA (1983-1984) showed that age-adjusted hip fracture incidence was highest in White women and lower in Hispanic, Black, and Asian women; a similar pattern was observed in men (49). A recent analysis of UK Clinical Practice Research Datalink (CPRD) data (1988-2012) similarly showed that hip fracture incidence was highest in White individuals, being 2.7 times higher in White men versus Black men and 5 times greater in White women compared with Black women (50). Differences in bone density, structure and geometry may contribute to ethnic variation in hip fracture risk. A US analysis of nationally-representative survey data (2005-2006) found that the age-adjusted prevalence of osteoporosis was higher in White women compared to Black women (51), whilst a regional study conducted in Manchester, UK showed that Black men had greater cortical thickness, cortical area and bending strength than White men (52), possibly explaining the lower fracture risk in individuals of Black ethnicity residing in high-income countries.

1.6.5. Previous history of fracture

Among men and women aged 50+ years from Canada, Sweden, the UK and USA, prior history of fracture has been associated with an increased risk of subsequent hip fracture, with low BMD accounting for 22% of the increased hip fracture risk (53). Changes in bone microarchitecture following a previous fracture may impair resistance to the mechanical force of injury, possibly explaining the increased risk of subsequent fractures (53). The highest risk of a further fracture is in the first year after an index hip fracture and decreases with time; 45% of subsequent fractures occurred within one year of the index hip fracture in a prospective cohort of men and women resident in Reykjavik, Iceland (54).

1.6.6. Family history of fracture

It has previously been demonstrated using twin and family studies that bone density is highly heritable (55). A meta-analysis of seven prospective cohort studies reported that, among men and women, parental history of any fracture (i.e. not limited to hip fracture) was associated with an 63% increased risk of hip fracture, whereas parental history of hip fracture was associated with a 127% increased risk of hip fracture; both associations were not explained by adjustment for BMD (56). A large genome-wide association study analysing UK Biobank data (n=142,487 individuals) identified 207 loci associated with heel BMD that had also been associated with osteoporosis, of which 12 predicted fracture risk (57). The relationship between family history of fracture and hip fracture risk independent of BMD may be explained by family history of falls and skeletal factors other than BMD such as bone size, shape or microarchitecture (56).

1.6.7. Smoking

Current smokers and ex-smokers versus non-smokers have an increased risk of hip fracture, with the magnitude of this association being strongest for current smokers (58). A meta-analysis conducted using prospective cohort data for men and women aged 50+ years found that hip fracture risk was 84% higher in current smokers compared with non-smokers; this association was partially attenuated after adjustment for age and BMD (adjusted relative risk (RR) 1.60 95% confidence interval (CI) [1.27,2.02]) (58). Whilst

BMD explains some of the association between smoking and hip fracture risk, bone microarchitecture is also impaired among current smokers (59), which has been associated with an increased risk of hip fracture (60).

1.6.8. Alcohol

Higher levels of alcohol consumption are associated with increased hip fracture risk. Among men and women from Australia, Canada and the Netherlands, alcohol intake of >2 units per day versus 0-2 units per day was associated with an 68% increased risk of hip fracture that was not explained by smoking, body mass index (BMI) or BMD (61). Greater risk of falls among heavy alcohol drinkers may explain some of the relationship between alcohol and hip fracture risk. Heavy alcohol intake (>1000 grams per month) was associated with a 3.05 times increased risk of fall-related injury in a prospective cohort of individuals aged 20+ years from four Finnish regions who were hospitalised with or died from a fall-related injury (62).

1.6.9. Body mass index

Low BMI is associated with an increased risk of hip fracture, that is partly explained by BMD. A meta-analysis, conducted using data from twelve prospective cohort studies, showed that a stronger relationship between BMI and hip fracture risk existed at lower BMI values (63). In men and women aged 50+ years, low BMI (15 kg/m^2) compared with normal BMI (25 kg/m^2) was associated with a 4.48 times increased risk of hip fracture; this association was partially attenuated after adjustment for BMD (RR 2.16 [1.42,3.28]) (63). Obesity (BMI 30 kg/m^2) compared with normal BMI was associated with a 17% decreased risk of hip fracture (63), possibly explained by soft-tissue padding over the greater trochanter protecting against hip fracture (64). However, this relationship did not persist after adjustment for BMD (63), suggesting that the effect of obesity on hip fracture risk may be mediated by higher BMD due to loading on weight-bearing bones (65).

1.6.10. Comorbidity

A wide range of comorbid conditions are associated with an increased risk of osteoporosis and/or fracture, as highlighted in the National Osteoporosis Guideline Group (NOGG) clinical guideline on the prevention and treatment of osteoporosis (discussed later in section 1.9.7, page 48) (66). Secondary causes of osteoporosis include diabetes, chronic obstructive pulmonary disease (COPD) and Parkinson's disease (PD). Both type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) are associated with an increased risk of hip fracture, with the risk being higher among those with T1DM than T2DM. (67). Although hip fracture risk has not been studied in individuals with COPD (68), airflow obstruction has been associated with 90% increased odds of osteoporosis, that was not explained by oral corticosteroid therapy, in a population-based sample of US individuals aged 50+ years (69). The SOF study, described earlier in section 1.6.2 (page 25), found that the age-adjusted risk of incident hip fracture was 2.6 times higher among older US women with PD compared to those without PD (70). Similar findings have been reported by a primary care-based, longitudinal study conducted among older women in Australia, Europe and the USA (The Global Longitudinal Study of Osteoporosis in Women); the age-adjusted hazard ratio for any incident fracture was 2.2 times higher among women with PD compared to without PD (71).

1.6.11. Falls

Falls history is an independent predictor of hip fracture risk. Harvey et al demonstrated that, among community-dwelling men aged 65+ years from Sweden, Hong Kong and the USA, falls history in the previous 12 months was associated with a 54% increased risk of hip fracture that was independent of BMD and other CRFs (72). A positive association between falls history and hip fracture risk has also been observed among community-dwelling, older White women in the US; however, this relationship was explained by adjustment for the inability to rise from a chair, standing for four hours or less per day, and poor self-rated health (73). Slower gait speed, difficulty in doing a heel-to-toe walk and reduced visual acuity are all associated with increased hip fracture risk (74), possibly explaining in part the positive relationship between falls and hip fracture risk.

1.7. Risk prediction models

Risk assessment tools estimate fracture probability in individuals considered to be at high risk of fracture, thus aiding clinical decision-making and targeted initiation of fracture prevention strategies. Risk prediction models based on both BMD and CRFs provide a better estimate of hip fracture risk than do models based on either BMD or CRFs alone (75). In the UK, national clinical guidelines recommend the use of the Fracture Risk Assessment Tool (FRAX) or QFracture risk calculator (76). Both tools predict fracture risk based on many of the CRFs discussed earlier in section 1.6, page 24; however, they differ with respect to the specific risk factors included and their categorisations.

1.7.1. Fracture Risk Assessment Tool

FRAX predicts the ten-year probability of hip fracture and MOF in men and women aged 40 to 90 years based on population-based cohort data from Europe, North America, Asia and Australia (77). Country-specific FRAX algorithms have been developed for different geographic regions (78).

FRAX includes lifestyle risk factors for fracture (e.g. BMI, smoking and alcohol consumption) and other known risk factors such as previous history and family history of fracture, rheumatoid arthritis, secondary osteoporosis and glucocorticoid use (77). FRAX was developed using femoral neck BMD data, and T-scores and Z-scores vary depending on the site at which BMD is measured (78). It is therefore recommended that BMD measured at the femoral neck is used to estimate fracture probability with FRAX (78).

Certain limitations of FRAX are recognised. Smoking and alcohol are categorised as binary exposures assuming average exposure to these risk factors (77); fracture risk may therefore be underestimated in individuals with high levels of exposure given their dose-dependent effect on fracture risk (58, 61). Whilst FRAX takes account of previous fracture history, fracture risk may be underestimated in individuals with a previous history of hip fracture, clinical vertebral fracture or multiple fractures, all of which are strong predictors of fracture risk (78).

1.7.2. QFracture

The QFracture risk calculator was specifically developed for use in primary care settings, and predicts the ten-year absolute risk of hip fracture and osteoporotic fracture (hip, wrist and vertebral fractures) in men and women aged 30 to 85 years (79). The QFracture algorithm, first published in 2009, has since been updated to include assessment of fracture risk in older individuals (up to 99 years of age) and additional risk factors such as ethnicity and previous history of fracture (80).

Whilst the QFracture algorithm is based on many of the risk factors included in FRAX, additional variables include falls history, specific comorbidities, and hormone replacement therapy (HRT) use (79). The QFracture algorithm does not take account of BMD because this information is not routinely collected in primary care records (81).

1.8. Clinical outcomes after hip fracture

This section reviews published literature on three key clinical outcomes after hip fracture: mortality, hospital length of stay (LOS) and hospital readmission. Patient characteristics such as male gender, older age, comorbidity and dementia are associated with poor clinical outcomes after hip fracture as described below.

1.8.1. Mortality

Hip fractures are associated with increased mortality risk. The National Hip Fracture Database (NHFD), a national clinical audit of hip fracture care in England, Wales and Northern Ireland (discussed later in section 1.9.4, page 44), reported that in 2017 6.9% of patients aged 60+ years died within 30-days of hospital admission for hip fracture (82). This is a considerable improvement on the earliest English study of secular trends in mortality after hip fracture, which reported that in 1968 approximately 20% and 50% of patients died within 30-days and 365-days of hip fracture respectively (83). Mortality risk among hip fracture patients is approximately double that of control populations (84), a concept known as excess mortality in which mortality attributable to the hip fracture is determined (85). Excess mortality up to 365-days post-hip fracture varies from 8.4% to 36% (86). The highest risk of all-cause mortality is in the first year after hip fracture, particularly during the first 3-months (87). Although the excess risk of death decreases over time, it remains elevated at ten-years after fracture when compared to age- and sex-matched control participants without fracture from Australia, Europe, the USA and Thailand (87).

The increased mortality risk after hip fracture has been attributed to the fracture event and the considerable burden of comorbidity among hip fracture patients. A Swedish study that examined excess mortality up to five years after hip fracture (1987-1996) reported that approximately one-quarter of deaths associated with hip fracture were related to the fracture itself, with the remaining increased mortality risk beyond that of the general population possibly explained by comorbidity (88). Mortality attributable to hip fracture is greatest during the initial period after fracture, with 70.8% of deaths during the first 30-days after hip fracture being due to fracture-related complications, decreasing thereafter to 7.6% (89).

Age

Mortality risk after hip fracture increases with advancing age. A population-based case-control study conducted in south-central Sweden (1993-1995) reported that mortality at 365-days after hip fracture was 5.6% in women aged 50-70 years, increasing to 13.6% among women aged 76-81 years, whilst among age-matched control participants, 365-day mortality rates were considerably lower at 0.2% and 4.3% respectively (90). Kannegaard et al similarly showed, using Danish hospital discharge data (1999-2002), that 365-day mortality was highest in older patients for both men and women (91). The higher rates of mortality among older individuals may, in part, be explained by differences in the incidence of postoperative complications. Roche et al demonstrated, among a prospective cohort of patients admitted to a single hospital in Nottingham, England (1999-2003), that 30-day mortality risk was 3 times higher in patients aged 90+ years versus 60-69 years after adjustment for gender and comorbidity (92); however, this relationship did not persist after further adjustment for the presence of postoperative complications. Vestergaard et al further showed, using Danish hospital discharge data (1977-2001), that mortality related to post-fracture complications was 7.5% in hip fracture patients under 65 years of age, increasing to 21.9% in patients aged 85+ years (89).

Gender

Analysis of Scottish hip fracture audit data (1998-2005) has shown that 30-day and 120-day mortality rates are higher in men than women, and mortality at 120-days increases with older age, more markedly in men than women (93). Similar gender differences in mortality have been observed at 365-days post-hip fracture; the Danish study by Kaanegaard et al reported that 365-day mortality was 37.1% in men and 26.4% in women (91). The higher rates of mortality in men compared to women may partly be explained by differences in the prevalence of comorbidity and postoperative complications. The American Society of Anaesthiologists' (ASA) classification of physical status is an assessment of a patient's preoperative health status based on five classes from ASA grade I (healthy patient) to ASA grade V (moribund patient) (94). Male hip fracture patients have a greater burden of comorbidity (91) and higher prevalence of ASA grade III and above compared with women, despite being of younger age (93), indicating poorer pre-fracture health status. Both greater comorbidity and higher ASA grade predict 365-day mortality (95), which may account for some of the gender differences in mortality. Unsurprisingly, the presence of postoperative complications predicts reduced survival at both 30-days and 365-days post-hip fracture (92, 96), with the incidence of pneumonia, delirium and pulmonary embolism all reported to be higher in men than women (96). Male gender itself is a risk factor for mortality after hip fracture; men have approximately double the risk of death at 30-days and 365-days compared with women, independent of age, comorbidity and postoperative complications (92).

Comorbidity

Number of comorbid conditions predicts mortality risk at 30-days post-hip fracture. Roche et al reported that 30-day mortality rates increased with greater comorbidity corresponding to a 2.4 times increased risk of death in hip fracture patients with 3+ comorbid conditions compared with no comorbidity; this relationship persisted after adjustment for age and gender (92). Specific comorbid conditions such as cardiovascular disease (CVD), COPD, diabetes and dementia are associated with increased mortality risk after hip fracture (89), all of which are prevalent among hip fracture patients (89, 92). Vestergaard et al showed that mortality risk after hip fracture was highest in patients with renal disease and dementia; the risk of death was 71% higher in hip fracture patients with dementia compared to those without dementia, with similar hazard ratios reported for renal disease (89). A single-site prospective cohort study conducted in New York, USA (1996-1998) reported that 6-month mortality was 55% in hip fracture patients with end-stage dementia and 12% in patients without cognitive impairment (97). Mortality risk within 6-months post-hip fracture was approximately 6 times higher in patients with end-stage dementia compared to patients with intact cognition, albeit with wide confidence intervals around the point estimate due to the small sample size (n=97), adjusted for age, comorbidity, level of mobility and pre-admission nursing home residence (97).

1.8.2. Hospital length of stay

Superspell LOS represents the total amount of time spent in National Health Service (NHS) care following hip fracture and captures hospital LOS for acute, post-acute and rehabilitation care (98), which may include transfers of care to different hospital trusts. Most hip fracture patients are admitted to hospital as an emergency via the Emergency Department (ED) and thereafter are transferred to an Orthopaedic ward for the surgical management of their hip fracture, thus capturing the acute period of hospital care after hip fracture. Post-acute care captures the transfer of care to a Consultant Orthogeriatrician for the ongoing management of medical issues, and rehabilitation care describes the transfer of care for ongoing rehabilitation to restore mobility and function. Figure 1 below depicts the care pathway of a 'typical' hip fracture patient.

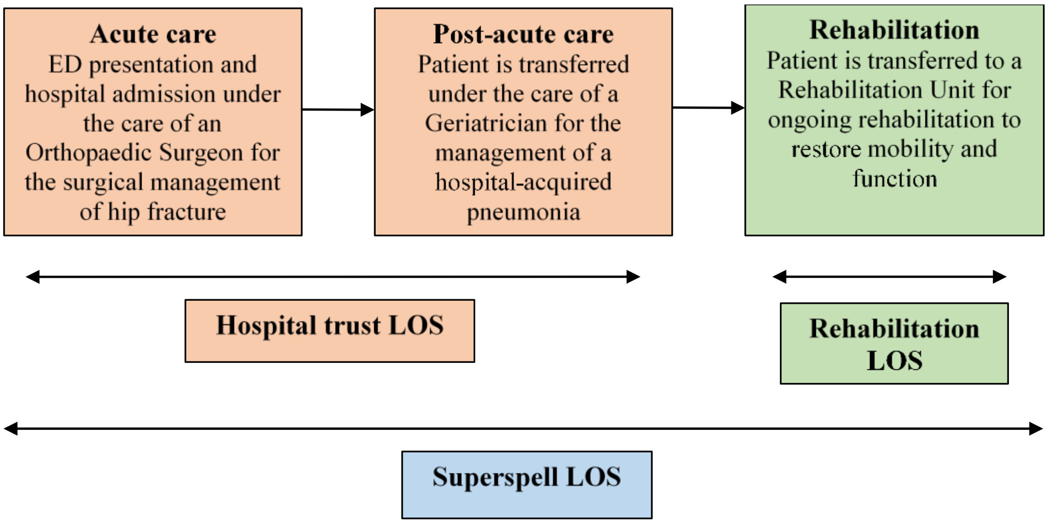

Figure 1: An example of a care pathway of a hip fracture patient (LOS – length of stay)

Since 2013, the NHFD has routinely reported on hospital LOS after hip fracture in England. Mean total trust LOS (acute and post-acute LOS) has remained relatively stable in England since this time; mean hospital LOS was 19.8 days in 2013 and decreased slightly to 19.2 days in 2017 (82, 99). The NHFD also uses English hospital administrative data to report on superspell LOS. Superspell LOS, also known as continuous inpatient spells, provides a more accurate estimate of hospital LOS; methodological approaches that do not take account of hospital transfers and rehabilitation care underestimate the total amount of time spent in hospital after hip fracture (100). In 2014, mean superspell LOS was 22.7 days for hip fracture patients in England, of which 15.6 days corresponded to the time spent in acute care, 3.9 days in post-acute care and 3.2 days in rehabilitation care (99).

Male gender, older age and comorbidity are all predictors of prolonged hospital stay after hip fracture. Basques et al analysed national surgical quality improvement data (2011-2012) for 8,434 US hip fracture patients aged 70+ years reporting that men spent on average 0.80 days longer in hospital than women after adjustment for ASA grade, specific comorbidities and perioperative factors (e.g. time to surgery and procedure type) (101). Castelli et al similarly showed, using English hospital administrative data for hip fracture patients aged 18+ years (2009-2010), that hospital LOS was 0.29 days longer in men than women, and increased by 0.28 days for each year of increased age (102). The presence of comorbid conditions such as CVD, COPD and renal disease all increased hospital LOS, with the longest hospital stays observed among hip fracture patients with paralysis, neurological disorders, peptic ulcer disease and diabetes with complications, ranging from an extra 4 to 7 days.

Discharge destination influences hospital LOS after hip fracture. An analysis of English hospital administrative data (2008) for hip fracture patients aged 65+ years admitted from home found that hospital LOS was longer among older individuals, particularly those who returned home (103). Among patients discharged home, hospital stays after hip fracture were 32% longer in patients aged 85+ years compared with 65-74 years, and hospital LOS was 12% longer in older patients discharged to a care home. Hospital LOS was similar in men and women who returned home, and 7% longer in men than women discharged to a care home.

1.8.3. Hospital readmission

Hospital readmission after hip fracture is associated with poor patient outcomes and has significant implications for the healthcare system. After adjustment for patient case-mix, hospital readmission rates are used to monitor hospital performance and provide an indication of the quality of care received during the index hospital admission (104), with particular emphasis on reducing preventable readmissions through investment in better discharge planning and post-discharge service provision (105). Hospital readmissions after hip fracture are costly; a US study reported that the cost of a hospital readmission post-hip fracture was similar to that for the index hip fracture admission itself (106).

In England, over the period 2003 to 2008, 11.9% of hip fracture patients aged 65+ years were readmitted within 28-days of discharge (104). Analysis of English hospital administrative data has shown that age- and sex-standardised 28-day readmission rates increased by 41.3% between 2001 and 2010, from 80.3 to 113.4 readmissions per 1000 admissions (21).

Mortality is higher among hip fracture patients readmitted to hospital. Kates et al analysed hospital registry data for 1,081 older hip fracture patients admitted to a single trauma centre in the USA (2005-2010) (106). In-hospital mortality was 19% for patients readmitted within 30-days of discharge versus 2.8% during the index hip fracture admission, and one-year mortality was considerably higher in those readmitted compared to those not readmitted (56.2% *vs*. 21.8%) (106). Medical causes are the most common reason for hospital readmission after hip fracture (107), with approximately one-third of readmissions being for pneumonia (108, 109).

Age

Kates et al further showed that older age was an independent predictor of hospital readmission; 30-day readmission rates were 4.7% and 16.3% in hip fracture patients aged 60-69 years and 90+ years (108), corresponding to 58% higher odds of readmission in patients aged 85+ years versus 60-85 years after taking account of patient characteristics, time to surgery and in-hospital complications (106). Similarly, Basques et al reported that the odds of 30-day readmission were 35% higher in hip fracture patients aged 90+ years versus 70-80 years after adjustment for patient characteristics such as gender, comorbidity and functional status (101).

Gender

Studies conducted in England, Denmark and the USA have all shown that readmission rates after hip fracture are higher in men than women (101, 110, 111). Analysis of English hospital administrative data (2002-2011) showed that, among hip fracture patients of all ages, indirectly age-standardised emergency 28-day readmission rates were approximately one-third higher in men than women (15.0% in males *vs.* 11.8% in females) (110). A population-based cohort study analysing Danish hip fracture registry data (2010-2013) found that 21.6% of men and 16.4% of women were readmitted within 30-days of hospital discharge, corresponding to 38% higher odds of readmission in men compared with women (111). Basques et al similarly reported that the adjusted odds of 30-day readmission after hip fracture were 40% higher in men than women (101).

Comorbidity

Both preoperative health status and the presence of specific comorbidities are predictors of hospital readmission after hip fracture. Khan et al found that, among 467 hip fracture patients aged 16+ years admitted to a single hospital in Hull, England (2009-2010), 28-day readmission rates were 3.8% in patients with ASA grade I and 52.8% with ASA grade III (112). Basques et al observed a similar relationship among older hip fracture patients in the USA reporting that the odds of 30-day readmission were 90% higher in patients classified as ASA grade IV compared with ASA grades I-II (101).

The presence of specific comorbidities such as COPD, cardiac and renal disease, and diabetes are all associated with increased readmission risk after hip fracture (109). Analysis of national health insurance claims data for older US veterans (1999-2002) showed that the odds of 30-day readmission were 33% higher in hip fracture patients with COPD and 43% higher in those with renal disease (109). Whilst Kates et al found that dementia was associated with 61% higher odds of 30-day readmission after hip fracture (106), Radcliff et al did not find evidence in support of a similar association among 5,683 male veterans aged 65+ years admitted to a single US hospital (113). Both studies adjusted their analyses for different covariates and used different definitions where the same covariates were included, possibly explaining the conflicting findings reported. Whilst both studies controlled for the effect of age, functional status and comorbidity, these patient characteristics were defined differently in both studies. Radcliff et al additionally adjusted their analyses for mode of anaesthesia and need for blood transfusion (113). Whilst limited evidence exists on the relationship between perioperative factors and hospital readmission after hip fracture, the need for blood transfusion, for example, may indicate poorer preoperative health status and thus higher readmission risk.

1.9. National policies and initiatives

This section describes key national policies and initiatives implemented in the UK over the last decade that aim to improve hip fracture care, including the Blue Book, Best Practice Tariff (BPT) and National Hip Fracture Database (NHFD). Whilst not described in this section, national clinical guidelines have been developed that are of relevance to older people with hip fractures such as the Department of Health's 'Prevention Package for Older People' and Public Health England's 'Falls and fracture consensus statement'.

1.9.1. Blue Book

The Blue Book was published in 2007 as a joint collaboration between the British Orthopaedic Association and the British Geriatric Society, with the aim of providing guidance on good standards of care for individuals with fragility fractures and for the secondary prevention of fragility fractures (114). The Blue Book recognises that compliance with the six standards of hip fracture care that constitute the BPT, discussed further in section 1.9.2, page 43, results in better quality of hip fracture care and outcomes post-hip fracture, and reduces costs. The Blue Book promotes joint orthopaedic and orthogeriatric involvement in the care of hip fracture patients, prompt preoperative medical assessment, early surgery, and early postoperative multidisciplinary rehabilitation.

Fracture Liaison Services (FLSs) are recommended for the identification of individuals at-risk of future fractures who may benefit from bone protection and falls assessment.

1.9.2. Best Practice Tariff

The BPT for fragility hip fractures, introduced on 1st April 2010, was based on the six standards of care outlined in the Blue Book (described earlier in section 1.9.1, page 42), and aims to promote best practice in acute hip fracture care for older adults (115). Since its introduction, the BPT criteria for hip fracture care have been revised; current criteria for the period 2017 to 2019 are presented below (116).

The NHFD, described later in section 1.9.4, page 44, regularly collects data and reports on compliance against the BPT criteria. The pricing structure of the BPT incentivises the provision of high-quality hip fracture care; a base price is payable for all hip fracture care provided and an additional payment is received conditional upon achieving the BPT criteria (116).

1. Time to surgery within 36 hours measured from the time of arrival in an ED, or from the time of diagnosis if already an in-patient, to the start of anaesthesia
2. Perioperative assessment by a geriatrician (within 72 hours of admission)
3. Assessment of fracture prevention, including falls risk and bone health
4. AMTS conducted preoperatively and recorded in the NHFD
5. Nutritional assessment performed during the hospital admission
6. Delirium assessment performed during the hospital admission, using the 4AT screening tool
7. Assessment by a physiotherapist, either on the day of surgery or the following day

1.9.3. Falls and Fragility Fracture Audit Programme

The Falls and Fragility Fracture Audit Programme (FFFAP) is a national clinical audit managed by the Royal College of Physicians (RCP) that aims to monitor the quality of hospital care among patients with fragility fractures and in-hospital falls, and improve patient outcomes after hip fracture (117). The FFFAP is comprised of three audits: NHFD, Fracture Liaison Service Database (FLS-DB) and National Audit of Inpatient Falls (NAIF) (117). The NHFD and FLS-DB audits are discussed further below. The NAIF audit aims to monitor compliance against national best practice standards for the reduction of falls risk in secondary care (117).

1.9.4. National Hip Fracture Database

The NHFD is a clinical audit of hip fracture care that was established in 2007 and provides a mechanism by which hospitals can monitor compliance with the standards of care outlined in the Blue Book (118). The NHFD routinely collects data through a web-based tool and reports on these data through annual publications, real-time monitoring via online run charts, benchmark tables and dashboards (119). NHFD data are collected and input into the web-based tool by clinical staff in the majority of hip fracture units, and follow-up data are collected by administrative and audit staff in less than 50% of units (30). The NHFD web tool has a number of data quality checks to ensure that correct data are entered and unlikely combinations are identified (120).

Patient audit

The first NHFD annual report, published in 2009, provided details of case-mix, care and outcomes among hip fracture patients admitted to 64 hospitals in England, Wales and Northern Ireland between 1st October 2007 and 30th September 2008 (121). Since this time, participation in the NHFD has increased considerably with all 175 eligible hospitals in England, Wales and Northern Ireland regularly uploading data in 2017 (82).

The NHFD collects patient-level data on indicators that reflect national standards of hip fracture care such as those outlined as part of the BPT for hip fracture care (section 1.9.2, page 43) and NICE quality standards (section 1.9.6, page 48). Clinical audit data are captured for all hip fracture patients aged 60+ years based on International Classification of Diseases version 10 (ICD-10) codes for fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1), and subtrochanteric fracture (S72.2) (120). NHFD data collection is restricted to the primary hip fracture event (i.e. first hip fracture admission), and does not include hip fractures occurring because of high-impact trauma (e.g. motor vehicle accidents) (120).

Facilities audit

The NHFD facilities audit provides an overview of hospital-level provision of hip fracture care (120), and collects hospital-level data on parameters that relate to the organisation of hip fracture care, including staffing levels, orthogeriatric input and BPT attainment criteria (30, 82). Facilities audit data have been collected since the first NHFD annual report published in 2009, with the most recent audit in 2017 reporting on data from 99% of the 175 eligible hospitals, thus allowing hip fracture care provision to be monitored over time and potential areas for improvement to be identified (82).

Anaesthesia Sprint Audit of Practice

The Anaesthesia Sprint Audit of Practice (ASAP) was conducted in 2014 to assess hospital-level compliance with perioperative standards of hip fracture care developed by the Association of Anaesthetists of Great Britain and Ireland (122). The ASAP demonstrated that considerable hospital-level variation existed in the anaesthetic management of hip fracture patients undergoing surgery, and made recommendations for standardised protocols to be developed for spinal anaesthesia administration and for perioperative nerve blocks to be considered in all hip fracture patients.

Physiotherapy Hip Fracture Sprint Audit

In 2017, the Physiotherapy Hip Fracture Sprint Audit (PHFSA) was conducted as a collaboration between the NHFD and Chartered Society of Physiotherapy (123). The PHFSA documents postoperative rehabilitation at all stages of the hip fracture care pathway, from the acute hospital to rehabilitation wards and home rehabilitation, and makes recommendations for early mobilisation, intensive rehabilitation and continuity of care upon return home.

1.9.5. Fracture Liaison Service Database

The FLS-DB is a national clinical audit of secondary fracture prevention in England and Wales that examines the assessment and treatment of osteoporosis and falls (124). Whilst the NHFD focuses on hip fractures, the FLS-DB includes all fragility fractures (125).

Patient audit

The FLS-DB patient audit collects information on fragility fractures in patients aged 50+ years systematically identified or managed by a FLS (125). The first FLS-DB patient audit report published in 2017 highlighted that national coverage of FLSs was low, with considerable variability in the performance of FLSs against eight clinical standards of secondary fracture prevention (125). The second FLS-DB clinical audit report demonstrated an improvement in the quality of data collection and case ascertainment with participation from additional FLS sites (126). Considerable regional variation exists in the number of established FLSs across England (127); the South West has the highest number of FLSs (n=9), whilst the North West and Yorkshire and the Humber regions both have the fewest (n=2) (127).

Facilities audit

The FLS-DB facilities audit assesses the quality of existing FLSs against national and international best practice standards (128). In 2014, facilities data were collected from acute NHS trusts in England and Wales, regardless of whether they had an established FLS (128). Fewer than 50% of eligible sites in England participated in the audit, of which 65% (48/74) reported having a dedicated FLS; considerable variation in the identification, investigation, treatment and monitoring of patients with a fragility fracture was demonstrated.

1.9.6. National Institute for Health and Care Excellence

The National Institute for Health and Care Excellence (NICE) is a national independent organisation that provides evidence-based guidance and recommendations with the aim of improving the quality of health and social care in England (129). NICE have published two clinical guidelines that are of relevance to individuals with or at-risk of a hip fracture.

In 2011, clinical guidance on the management of hip fractures in adults made recommendations for prompt preoperative medical optimisation, early surgery, early postoperative mobilisation and multidisciplinary team involvement (6). This clinical guideline was updated in 2017 to highlight the role of replacement arthroplasty for the management of displaced intracapsular hip fractures, and specifically THA as opposed to hemiarthroplasty if certain criteria are met (6).

Clinical guidance on fragility fracture risk assessment in adults recommends that absolute fracture risk be assessed in population groups at high-risk of fragility fracture, using FRAX or QFracture risk prediction tools (see section 1.7, page 31) (76). Fracture risk assessment is recommended in men aged 75+ years and women aged 65+ years, and in men and women below these age thresholds with the presence of specific CRFs (discussed earlier in section 1.6, page 24). Measurement of BMD is recommended in those individuals with a fracture risk that is within the intervention threshold.

1.9.7. National Osteoporosis Guideline Group

In the UK, national guidelines on the prevention and treatment of osteoporosis have been developed since 2008; the most recent update of this guidance was published in 2017 (66). The NOGG clinical guideline provides guidance on fracture risk assessment in postmenopausal women and men aged 50+ years, makes lifestyle and pharmacological recommendations for the management of osteoporosis, and recommends systematic identification of fragility fractures through FLSs.

1.9.8. Royal Osteoporosis Society

The Royal Osteoporosis Society (ROS) is a registered charity that works with patients, healthcare professionals and academics, with the aim of improving bone health and preventing osteoporosis (130). Key activities of the charity include patient advocacy, encouraging health service development and quality improvement through published clinical guidance, and promoting research and development in the field of osteoporosis.

1.10. International initiatives

An osteoporosis ‘treatment gap’ exists such that individuals with an osteoporotic fracture are not always receiving anti-osteoporosis medication for the risk reduction of future fractures. In Europe, it was estimated that in 2010 more than 50% of men and women with a fracture risk above an intervention threshold did not receive osteoporosis treatment (131). Klop et al showed, using UK GP practice records, that although anti-osteoporosis drug prescribing rates had increased from 7.4% to 45.5% between 2000 and 2010, more than 50% of hip fracture patients did not receive treatment for osteoporosis in 2010 (132). An osteoporosis ‘treatment gap’ similarly exists in the USA, and of concern is that the probability of receiving osteoporosis treatment has decreased over time. Solomon et al analysed US administrative health insurance claims data (2002-2011) demonstrating that the probability of osteoporosis medication use in the year after hip fracture was 28.5%, and had declined from 40.2% in 2002 to 20.5% in 2011 (133).

Several international initiatives have been developed that aim to address the osteoporosis 'treatment gap' and reduce secondary fracture occurrence. The International Osteoporosis Foundation's 'Capture the Fracture' programme promotes the implementation of FLSs based on an internationally-recognised best practice framework (134). Whilst FLSs have been established in all geographic regions except for Africa, most of these are in Europe (135). The Fragility Fracture Network's 'Global Call to Action', supported by eighty-one organisations from a range of disciplines, promotes orthogeriatric models of fragility fracture care and FLSs for secondary fracture prevention (136). The American Society for Bone and Mineral Research's 'Secondary Fracture Prevention Initiative' makes clinical recommendations for the multidisciplinary management of individuals with a hip or vertebral fracture, including secondary fracture prevention through FLSs (137).

1.11. Economic impact of hip fractures

The financial cost of hip fractures to the health and social care system is substantial; the worldwide annual direct and indirect cost of hip fractures was estimated to be US$34.8 billion in 1990 and predicted to increase considerably over the next 50 years (138).

In the UK, the total cost of hip fractures was estimated to be £2.0 billion in 2010 (139), whilst Leal et al, using hospital administrative data for one English region (2003-2013), estimated that the total annual hospital costs associated with incident hip fractures was £1.1 billion for the UK (31). Leal et al further estimated that the total hospital cost within the first year after hip fracture was £14,264, of which the index hip fracture admission accounted for 61% (£8,663) of the total one-year cost. Hospital costs in the year after hip fracture were £10,964 higher than in the year prior to the fracture event, including

ED attendances, inpatient care and outpatient care. Male gender, older age, greater comorbidity, income deprivation and surgical complications were all predictors of higher hospital costs.

Studies conducted in the USA have similarly shown that the financial impact of hip fractures is high. It has been estimated, using national healthcare survey data for individuals aged 45+ years, that 63% ($8.7 billion) of the total healthcare expenditure on osteoporotic fractures in 1995 was due to osteoporotic hip fractures (140). Hospitalisation (64%) and nursing home care (32%) accounted for most of the total expenditure on hip fractures across different healthcare settings. Braithwaite et al estimated that, among a hypothetical cohort of community-dwelling hip fracture patients aged 80 years in the USA, one-third of the lifetime cost attributable to hip fractures occurred within the first six months of the index hip fracture admission and just less than half was related to the provision of nursing care (141).

1.12. Summary

Hip fractures are an important public health problem worldwide. Whilst hip fracture incidence has declined or plateaued over the last few decades in many high-income countries, incidence rates are rising in certain countries and among specific population groups. Several clinical risk factors are known to increase hip fracture risk, including low BMD, older age, female gender and lifestyle risk factors. Hip fractures are associated with poor clinical outcomes, including higher mortality and greater healthcare utilisation, and pose a considerable financial burden on healthcare systems. National and international policies and initiatives that aim to improve the care of patients with a hip fracture emphasise the importance of a multidisciplinary approach to hip fracture management and secondary fracture prevention through coordinator-based systems.

The next chapter provides an overview of social inequalities in health, and describes commonly used individual-level and area-based measures of deprivation, and their relationship with health.

CHAPTER 2. SOCIAL INEQUALITIES IN HEALTH

This chapter provides an overview of social inequalities in health. Commonly used individual-level indicators of socioeconomic position (SEP) and area-based measures of deprivation, and their relationship with health, are described. The effect of individual-level characteristics on the relationship between social disadvantage and health are then discussed. Finally, key national reviews that have examined health inequalities in England over the last few decades are described.

2.1. Social determinants of health

Several factors influence the distribution of health, including age, sex and social status (142). There exists a social gradient in health, with more disadvantaged individuals experiencing poorer health for many, but not all, outcomes (143, 144). The term 'health inequality' describes differences in health outcomes among individuals of different social groups, whilst 'health inequity' relates to fairness in the distribution of health and thus implies a moral judgement (145).

Different models have been used to explain social inequalities in health, all of which emphasise the role of material circumstances, lifestyle health behaviours and broader determinants of health (142, 144, 146). The Black Report, described in detail in section 2.7.1, page 71, suggested that social selection, material circumstance and behavioural factors may explain social differences in health (144). Bartley and Blane further proposed that, in addition to behavioural and materialist factors, psychosocial and life course factors may account for health inequalities (146). The Dahlgren and Whitehead model uses a ‘layers of influence’ approach to describe modifiable (e.g. lifestyle behaviours) and non-modifiable factors such as age, gender and genetics that determine health, and their inter-relationship with social networks and environmental conditions that includes availability of good-quality housing, education and health care services (142).

2.2. Measurement of social inequalities in health

Different approaches have been used to define and measure social differences in health, all of which stratify individuals into groups that share common social and economic characteristics that influence their structural position in society (147). Social stratification can be defined, and thus measured, according to individual-level and/or area-based characteristics, both of which are described in detail later (see section 2.3, page 55 and section 2.5, page 61).

Furthermore, health inequalities can be expressed in both absolute and relative terms, and are often used to describe health differences between two extreme groups (148). Absolute measures express the absolute rate difference in morbidity or mortality between the lowest and highest social groups, whilst relative measures describe the morbidity or mortality rate of the most disadvantaged group as a ratio to the least disadvantaged group (148).

2.3. Individual-level measures of socioeconomic position

Various terms have been used to describe the social position held by an individual in the structure of society, including social class, socioeconomic status (SES) and SEP (149). Krieger et al distinguishes between these terms suggesting that SEP captures both resource-based and prestige-based aspects (i.e. material resources and social status), whilst the term SES is not considered to adequately distinguish between both aspects of social hierarchy (149). Social class relates to social relationships arising from the economic structure of society such as the employer-employee relationship (149), and is usually based on an occupational classification system.

Commonly used indicators of individual-level SEP include education, income and occupation, all of which influence health status (150-153). Whilst all three indicators capture an individual's position in the social hierarchy, each indicator is likely to capture additional specific effects on health (147). Education and income reflect an individual's knowledge-related and material resources and also future opportunities, whilst occupation captures prestige and social standing (147). The indicator used to measure SEP should therefore be determined by the hypothesised relationship between SEP and health (147). Country context and availability of data are also likely to influence the choice of indicator; education and income are more commonly used as indicators of SEP in the USA, whilst social class has historically been used in the UK.

2.3.1. Education

Education is a measure of early life SEP that is usually assessed at a single time point in the life course, that is, at the transition from adolescence to young adulthood when education is usually completed (147). Whilst education is commonly measured based on the number of years in education or educational attainment (154), such measures do not capture information on the quality of education received (147).

Studies have consistently demonstrated that higher education is associated with better health outcomes (150, 155, 156). Analysing data from European populations, Mackenbach et al showed that higher educational attainment was associated with decreased morbidity (self-reported health status, long-term disability and chronic conditions) and mortality (150, 155). Similar findings were reported using national health survey data for US adults; greater time spent in education was associated with decreased risk of five-year mortality and chronic diseases such as coronary heart disease (CHD) and diabetes (156).

Several factors may account for the positive relationship between education and health, including work and economic conditions, social and psychological resources, and lifestyle behaviours (157). Greater time spent in education is associated with increased likelihood of full-time employment and engaging in healthy lifestyle behaviours, and greater personal control and social support, all of which are positively associated with good self-reported health (157). Education also influences health through knowledge and skills gained, thus enabling access to health-promoting information and appropriate health services (157), known as ‘health literacy’. Lower educational attainment (based on high school completion) is associated with a higher prevalence of low health literacy (158), and worse health outcomes such as poor health status and higher morbidity have been reported among individuals with low health literacy (159).

2.3.2. Income

Income is a measure of material circumstance that can be determined for individuals or households (154). Measurement of household income based on the head of household, main earner or adjusted for family size (equivalised household income) can be useful when income status may be difficult to determine such as for women who have a role as 'home makers' (154). Obtaining accurate self-reported information on absolute income may be difficult owing to an unwillingness to disclose such sensitive information; however, the use of predefined categories, for example, can be used to overcome this (154).

Most epidemiological studies measure income at a single time point; however, this does not take account of variability in income across the life course (147). McDonough et al demonstrated that, among a nationally-representative sample of US individuals and households (1968-1989), 12% of the population sample experienced income instability (one or more income drops of 50% or more) over a five-year period, and income instability was associated with higher odds of mortality (160).

Increasing absolute income is associated with better health outcomes (mortality, respiratory function and limiting long-term illness), although health gains are less marked at high levels of income (151, 161). An individual's rank in the income distribution also has important effects on health (145). Wilkinson and Pickett reviewed 155 published studies, most of which reported that greater income inequality was associated with poorer population health (152).

Higher income has a direct effect on absolute material living standards, and in turn health outcomes, through the ability to obtain better quality housing and food, and access medical care (147). Psychosocial pathways have an indirect effect on the relationship between income inequality and health through weak social relationships and lack of workplace autonomy (162). Although poor health status can influence income potential ('reverse causality') with downward social mobility (163), there may be limited opportunity to assess this in epidemiological studies that measure income at a single time point.

2.3.3. Occupation

Historically, occupation-based classification systems have been used to measure SEP in the UK. The Registrar General's classification of occupations, known as social class, was introduced in 1913 as a hierarchical grading of six groups based on the social ranking of an occupation in society (164, 165). The occupational structure of society has changed over time; manual roles have declined with a predominance towards service-based occupations (154). An updated classification system was introduced in 2001, the National Statistics Socio-Economic Classification system, that describes the employment relations and working conditions of eight broad occupational groups (166).

Occupational status is likely to vary across the life course and therefore is usually measured based on current or longest held occupation (154). Certain population groups such as women who have a role as 'home makers' and retired individuals may be excluded from occupation-based analyses of SEP, thus underestimating the true association between SEP and health (167). For women in paid employment, current national classification systems that are likely to be based on male-dominated roles may not accurately reflect differences in social stratification (168), particularly as occupational roles are known to differ in men and women (169).

Higher occupational grade predicts better health outcomes. The Black Report demonstrated, using occupational mortality data for England and Wales (1970-1972), that premature mortality rates in unskilled men (social class V) were approximately double that of professional men (social class I) (see section 2.7.1, page 71 for further discussion of the Black Report) (144). Marmot et al observed similar findings as part of the Whitehall Study conducted among British civil servants; men in the lowest (unskilled manual workers) versus highest occupational grades (administrators) had higher rates of all-cause mortality and cause-specific mortality from CVD, respiratory disease and lung cancer amongst others (153).

Whilst occupation has a direct effect on income potential and thus health (170), other mechanisms may contribute to the relationship between occupation and health. Firstly, occupation reflects prestige and social standing, which has been associated with lower mortality risk (171). Furthermore, occupations differ in their job demands and decision autonomy, which has been shown to influence health outcomes (172). Finally, occupation-based measures of SEP may reflect workplace conditions and occupation-specific environmental exposures that negatively impact on health (154); for example, construction workers exposed to asbestos have an increased risk of developing mesothelioma.

2.4. Life course approach to individual-level socioeconomic position and health

Early life exposure to adverse socioeconomic conditions influences the development of disease later in life (173). Davey Smith et al demonstrated, among a prospective cohort of men aged 35-64 years in the west of Scotland, that men exposed to social disadvantage in childhood, based on father's occupation (manual *vs.* non-manual), had an increased risk of mortality from stroke, CHD, respiratory disease and stomach cancer independent of adult SEP (174).

Various models have been described that conceptualise the mechanism by which life course SEP influences health status (175). Exposure to adverse social circumstances during a specific developmental period alters the structure and function of body systems with associated longer-term effects on disease risk (critical period model) (175). The foetal origins of adult disease hypothesis is an example of a critical period model; low birthweight due to poor prenatal nutrition is associated with the development of CHD in adulthood (176). The ‘sensitive period model’ is similar to the critical period model, except that the risk of later disease development is greater when exposed to adverse social conditions during a specific time period (175). Cumulative exposure to poor socioeconomic conditions across the life course has an additive effect on later disease risk that is related to the number, duration and severity of exposure periods (accumulation of risk model) (175). CVD is an example of such a model; cumulative social disadvantage over the life course increases CVD risk (177).

Specific indicators may be better measures of individual-level SEP at different stages of the life course. Education is a measure of early life SEP that is usually completed by early adulthood, whilst occupation and income measure material circumstance and are likely to vary across the life course, as described in section 2.3, page 55 (154). While education influences occupational status and thus income level (170), the correlation between education and income is not strong enough for them to be considered appropriate proxy measures for one another (178). Rather, European studies have shown that education, occupational status and income all have independent effects on health (170, 179), and the magnitude of this effect depends on the health outcome being assessed (179). Geyer et al showed, analysing national administrative data for adults in Germany and

Sweden, that education had the strongest effect on diabetes prevalence and income on all-cause mortality risk (179). Hence, Davey Smith et al recommend measuring SEP at different stages of the life course to fully capture the effect of SEP on health (180).

2.5. Area-based measures of deprivation

Area-based measures are used to describe the socioeconomic conditions of a geographical area, and can be used to inform resource allocation (164). They can be used to describe the characteristics of individuals residing in an area such as the proportion with low income (collective effects) and can also be used to characterise the area itself (contextual effects) (145, 181). Contextual area effects may influence health outcomes through the physical and environmental attributes of an area, availability of local services or the socio-cultural features and reputation of an area (182). Area-based measures, although ecological, are also used as proxy measures, when individual-level SEP data are not available, based on area of residence through linkage with census or administrative databases (183). Area-based measures provide valid estimates of the relationship between individual-level SEP and health outcomes (184), albeit with weaker associations than if individual-level indicators were used (185, 186).

Geographical areas are commonly defined based on administrative geographies, particularly when national or census databases are used (183). Smaller geographical areas are likely to be used for analyses that approximate neighbourhoods and larger geographical areas for county-level studies (183). Area-level measures can be defined based on a single indicator or combination of several indicators (i.e. a composite index) (21). Townsend described the concept of deprivation as a lack of material resources and social conditions relative to the societal unit to which an individual belongs; this is distinct from poverty which is described as the absolute level of material resources needed to maintain a certain standard of living (187).

Greater area-based deprivation is associated with poorer health outcomes independent of individual-level SEP (188, 189). Diez Roux et al demonstrated, among individuals residing in four US states, that individuals living in the most deprived compared with least deprived areas (based on a composite deprivation score) had a higher incidence of CHD; this association remained after adjustment for individual-level SEP (income, education and occupation) and cardiovascular risk factors (190). Multilevel methods allow simultaneous assessment of the effect of individual-level SEP and area-based deprivation on health so that one can estimate the influence of area deprivation over and above individual-level factors (185), providing such data are available.

2.5.1. Townsend Deprivation Index

The Townsend Deprivation Index (TDI) is a composite measure of material deprivation for small geographical areas that was developed by Peter Townsend and colleagues in 1987 (191). The TDI is constructed using census data for four variables: car ownership, housing tenure, overcrowding and employment status. Standardised scores for each variable are weighted equally and summated to generate an overall TDI score; higher TDI scores reflect greater levels of material deprivation (192). Whilst the TDI is relatively easy to construct requiring data on four census variables, it may not provide an up-to-date picture of deprivation given that census data are only collected every ten years.

Greater area-based deprivation (as indicated by higher TDI scores) is associated with higher morbidity and mortality (189, 193). Ben-Shlomo et al demonstrated, using 1981 census data for electoral wards in England, that increasing area-based deprivation was associated with higher rates of all-cause premature mortality (189). Similar patterns were reported for morbidity measures (temporary and permanent sickness), using 1981 census data for small areas in Scotland (193).

2.5.2. Carstairs Score

The Carstairs score was developed by Carstairs and Morris as a measure of material deprivation for small areas in Scotland (194), using a similar methodological approach to that employed by Townsend et al. Four census variables are standardised and combined to construct an unweighted measure of area-based deprivation. Both the TDI and Carstairs score differ slightly with respect to the variables selected. Although both indices are based on census variables for car ownership, household overcrowding and employment status, the Carstairs score includes low social class instead of home ownership because low social class was considered to *"place families in a position of poor access to material resources"* (194). As for the TDI, onerous amounts of data are not required to construct the Carstairs score given that it is based on four census variables; however, scores can only be generated every ten years as updated census data become available.

Higher Carstairs scores indicate greater material deprivation. Carstairs and Morris demonstrated, analysing mortality data from a 10% sample of the Scottish population (1980-1982), that greater area-based deprivation was associated with higher age-standardised mortality among Scottish men aged 20-64 years (194). Similar patterns have been observed for morbidity outcomes (temporary and permanent sickness), using 1981 census data for Scotland (193).

2.5.3. Index of Multiple Deprivation

The Index of Multiple Deprivation (IMD) is a multi-dimensional measure of relative deprivation for small areas in England (195). Small areas, termed lower super output areas (LSOAs), are geographical areas of a similar population size (average 1,500 residents) with stable census boundaries; only 2.5% of LSOAs changed between the 2001 and 2011 census, increasing the total number of LSOAs from 32,482 to 32,844 (195, 196). Greater area-based deprivation, based on the IMD, predicts adverse health outcomes among different disease populations in England, including those with CVD, diabetes and cancer (197-199).

The IMD, first introduced in 2000, has been updated every three to five years based on broadly similar methodology but using more up-to-date data (195). There is considerable stability in the distribution of deprivation at the extremes across IMD versions; 81% of the least deprived LSOAs and 83% of the most deprived LSOAs remained in the same deprivation decile between IMD 2010 and IMD 2015 versions (200).

The IMD is based on thirty-eight indicators across seven domains of deprivation: income; employment; education, skills and training; health deprivation and disability; crime; barriers to housing and services; and living environment (195). Two supplementary indices measure income deprivation in children under the age of 15 years (Income Deprivation Affecting Children Index) and older people aged 60+ years (Income Deprivation Affecting Older People Index) (195). Each domain, and its constituent indicators, measure a different aspect of deprivation experienced by individuals residing in LSOAs, using nationally-available administrative data. The IMD was specifically designed to measure deprivation, not affluence, and this is reflected in the indicators used to construct the index (195). For example, the income domain measures low-income families as determined by receipt of benefits, whilst the housing domain captures poor quality and unaffordable housing.

Each LSOA is assigned a score and a rank for each deprivation domain (195). A weighted sum of the ranks for each domain is used to calculate an overall IMD score based upon which LSOAs are then ranked nationally. The IMD can therefore only be used to examine the extent to which deprivation for an LSOA has changed over time relative to other LSOAs, as opposed to absolute changes in the level of deprivation (195).

2.6. Influence of individual-level characteristics on social inequalities in health

The relationship between social disadvantage and health differs according to individual-level characteristics such as age, gender and ethnicity amongst others. The effect of each of these factors on social inequalities in health are discussed below.

2.6.1. Age

Social inequalities in health differ according to age and are largest in early adulthood through to middle-age, diminishing thereafter (156, 201). Analysing longitudinal data from eight western European countries, Huisman et al demonstrated that all-cause mortality was 28% higher among men aged 45-59 years with low versus high education, decreasing to 21% in men aged 75+ years (202). Similar patterns were observed in women, albeit with weaker associations. Other mortality studies have reported similar findings for area-based measures of deprivation (193, 203, 204). Woods et al analysed Office for National Statistics mortality data for England and used the IMD 2000 income domain to measure area-based deprivation at the electoral ward level (203). Mortality rates in the most deprived areas were approximately twice that of the least deprived areas for men up to 60 years of age and up to 50 years for women. The effect of deprivation on mortality decreased with older age; mortality rates were about 1.15 and 1.25 times higher in the most deprived versus least deprived areas for men and women aged 85+ years.

The diminishing effects of social disadvantage on health with increasing age may partly be explained by 'survival bias' (201). Beckett tested this hypothesis using longitudinal data from a nationally-representative sample of US adults; the association between education and health status and functional impairment declined with age after taking account of selective survival suggesting that selection bias does not explain the smaller health inequalities observed in later life (205). Secondly, the health impact of SEP and associated risk factors may be greater among younger individuals owing to *"biological robustness"*, whilst frailty and access to social welfare programmes in older age may minimise the influence of SEP on health (206).

2.6.2. Gender

Gender differences in health outcomes have been widely reported, with higher rates of mortality observed in men and higher morbidity rates in women (207, 208). Gender-specific patterns in the prevalence of, and risk factors for, chronic diseases may account for these findings. The burden of non-fatal chronic conditions and healthcare use is higher in women, whilst life-threatening chronic diseases, particularly smoking-related diseases, are more prevalent in men (207). Smoking is a more important determinant of excess mortality in men and psychosocial factors have a greater influence on the excess morbidity observed in women (209).

Socioeconomic inequalities in health are more marked in men than women (202). Mackenbach and Kunst showed that, among men and women from seven European countries, both absolute and relative inequalities in all-cause mortality were larger in men, based on low and high educational attainment (210). Differing cause-specific mortality patterns in men and women may partly account for these inequalities; diseases with large socioeconomic differentials such as lung cancer, respiratory diseases, and accidents and violence are more common in men than women (210, 211).

2.6.3. Ethnicity

Ethnic variation in health outcomes exists, with poorer health outcomes reported among Black compared with White individuals (212). Whilst social disparities in health may explain some of this association, ethnic differences in genetics, psychosocial factors and lifestyle risk factors may partly account for the patterns observed (213).

Sorlie et al demonstrated that, among a large prospective sample of US men and women, age-adjusted premature mortality was approximately 1.5- to 2-fold higher among Black compared with White individuals; these relationships persisted, albeit of weaker magnitude, after adjustment for socioeconomic factors (education, income and employment status), marital status and household size (214). Another US study further showed that education and income inequalities in self-reported health status and mortality were more marked among Black compared with White individuals (215).

2.6.4. Comorbidity

Comorbidity has been defined as "*any distinct additional clinical entity that has existed or that may occur during the clinical course of a patient who has the index disease under study*" (216), whilst multimorbidity is recognised as a distinct concept that describes the co-occurrence of two or more chronic diseases in the same individual, i.e. without reference to an index disease (217). Regardless of the definition used, the presence of two or more diseases in the same individual is associated with poor health outcomes (218, 219). Gijsen et al systematically reviewed eighty-two studies reporting that greater comorbidity was associated with increased mortality risk, poorer functional status and quality of life, and greater healthcare utilisation (218).

Different approaches have been used to measure comorbidity burden. Most studies have constructed a single summary measure (index) that takes account of the number and severity of comorbid diseases (220); however, predefined criteria for disease selection are often not specified and therefore, unsurprisingly, there is considerable variability in the number and type of diseases included in existing indices (218). Other studies have simply counted the number of comorbid diseases present in an individual, albeit using different criteria to define a disease as comorbid (220).

The Charlson Comorbidity Index (CCI) is the most widely used comorbidity index (220). It was developed in 1984 among a cohort of 559 medical patients admitted to a single hospital in New York, USA and was shown to predict one-year mortality (221). It is based on nineteen conditions that were identified from patient medical records and is weighted according to disease severity (221). The CCI has since been adapted for use with hospital administrative databases in Australia, Canada and the USA that record clinical diagnoses using ICD-9 and ICD-10 coding systems (222-225).

Several risk factors predict multimorbidity, including female gender, older age and higher deprivation levels (219). Analysing primary care records for about one-third of the Scottish population, Barnett et al reported that more than half of the study population were multimorbid by the age of 65 years and the burden of multimorbidity was higher in women than men (26.2% *vs*. 20.1%) (226). Furthermore, the prevalence of multimorbidity increased with greater deprivation and individuals residing in the most deprived areas became multimorbid 10-15 years earlier than those living in the least deprived areas (226).

2.6.5. Lifestyle risk factors

The relationship between SEP and mortality is explained, in part, by the differential distribution of lifestyle risk factors (227-230), and therefore lifestyle factors may be conceptualised as potential mediators. There is a social gradient in the prevalence of lifestyle behaviours, with rates of smoking, heavy alcohol consumption and obesity all reported to be higher among more deprived individuals (231-233). The Whitehall II longitudinal study, conducted among male and female British civil servants aged 35-55 years, found that all-cause mortality risk was 1.6 times higher among individuals with low versus high SEP (based on occupational grade); this association was attenuated by 42% after adjustment for health behaviours that was largely explained by smoking (227). Similar findings have been reported by studies conducted in Finland, the Netherlands and USA examining the effect of lifestyle behaviours on the association between individual-level education or income and all-cause mortality (228-230).

2.6.6. Region

There is a well-documented 'North-South divide' in health outcomes across England, which may be explained, in part, by regional differences in deprivation levels. Morbidity and mortality burden is higher in northern regions compared to the average for England, with the reverse pattern seen in southern regions (234). In 2010, 22% of small areas (LSOAs) in the North West of England were in the most deprived IMD quintile compared with 4% in the South West (235).

Social inequalities in premature mortality exist in all English regions; however, these are more marked in northern regions (236). Regional variation in lifestyle risk factors may account for some of this observed relationship. Recent analyses published as part of the Global Burden of Disease Study (1990- 2016) showed that, for most lifestyle risk factors, the attributable burden of age-standardised all-cause premature mortality increased with greater area-based deprivation in England (using the IMD 2015); however, this relationship was more marked in the North West compared with London or the South West (237).

2.7. Key national reviews on health inequalities in England

Several key national reviews on health inequalities in England have been conducted over the last few decades with the aim of identifying policy interventions. Each of these national reviews are described below.

2.7.1. Black report

The Labour Government convened a working group in 1977 that was tasked with reviewing information on social gradients in health, and suggesting possible explanations and implications for policy (144). The findings of the working group, chaired by Sir Douglas Black, were summarised in the ‘Black Report’. Social class differences in mortality were observed among both men and women, with mortality rates being higher among lower social classes, and these inequalities had widened over time (see section 2.3.3, page 58 for further description of the Registrar General’s classification system of social class). It was further reported that inequalities in the use of healthcare services existed in England, particularly preventative services, with decreased utilisation observed among lower social classes.

The Black Report described four possible explanations for the observed social inequalities in health (144). Firstly, numerator-denominator bias may have accounted for the observed patterns if occupation was recorded differently on the death certificate (numerator data) and at the time of the census (denominator data) (144). Similar mortality gradients were observed by longitudinal studies conducted since the Black Report that took account of numerator-denominator bias suggesting that measurement artefact does not explain the findings of the Black report (238, 239). Secondly, poor health status influencing downward drift in social status (social selection) was suggested as a possible explanation on the basis that low social class identifies frail individuals at increased risk of death (144). The differential distribution of poverty (material circumstances) and unhealthy lifestyle behaviours (behavioural factors) were further proposed as possible explanations for the higher mortality rates observed among individuals in lower social classes (144).

Thirty-seven policy recommendations were made to address these social inequalities in health (144). Particular emphasis was placed on increased investment in health and social care services, and interventions that focused on broader determinants of health such as early life circumstances (e.g. child benefits and school meals) and better working conditions. Importantly, the Black Report highlighted the Government's role in encouraging healthy lifestyle behaviours through population-level prevention initiatives based on legislation, fiscal measures and social policies.

2.7.2. Acheson report

In 1997, the Labour Government commissioned an independent inquiry that was tasked with reviewing the most recent evidence on health inequalities in England and developing policy recommendations (240). The inquiry, chaired by Sir Donald Acheson, reported that despite overall declines in mortality between the early 1970s and 1990s, health inequalities persisted in England with a greater decline observed among individuals in higher versus lower social classes. The Acheson Inquiry further demonstrated that social inequalities in morbidity existed that favoured more advantaged individuals; the prevalence of self-reported long standing illness was lower among those in higher social classes.

The Acheson Inquiry used the Dahlgren and Whitehead model of social determinants of health to propose key policy development areas based on individual characteristics, social and community networks, and wider determinants of health (see section 2.1, page 53). Thirty-nine policy recommendations were made that focused on broader determinants of health (upstream policies) and narrower impacts such as health behaviours (downstream policies) (240). Of the thirty-nine recommendations, three key priority areas were identified. The Inquiry firstly recommended that health impact assessment should be undertaken for all policies that may impact on inequalities in health and secondly, recommended that the health of women and children should be improved given the relationship between early life exposure to social disadvantage and associated health consequences in later adulthood. Finally, particular importance was placed on reducing income inequalities and improving living standards for the poorest households through better quality education and jobs, and greater availability and uptake of social support.

2.7.3. Fair Society, Healthy Lives – Marmot Review

In 2008, Professor Sir Michael Marmot chaired an independent review that summarised existing evidence on health inequalities in England and proposed evidence-based policy interventions to address them (143). The Marmot Review reported that health inequalities continue to persist in England; higher mortality rates were observed among individuals in lower social classes, particularly those residing in the North of England. It was further highlighted that reducing social gradients in health requires interventions targeted to all segments of society, although the intensity of such actions should be determined by the level of disadvantage, a concept termed ‘proportionate universalism’.

Recognising the importance of social determinants of health and their effects on health across the life course, the review recommended evidence-based strategies based on six policy areas (143). Greatest emphasis was placed on reducing exposure to social inequalities during the prenatal period and early childhood through access to high-quality maternity services and increased investment in early childhood programmes. Other policy recommendations included education and skills development for young people and adults, fair employment opportunities, and greater investment in disease prevention and health promotion activities. The implementation of these policy objectives, many of which extend beyond the health sector, requires engagement from a wide range of stakeholders, including central and local Governments, non-governmental organisations, the private sector, and individuals and communities.

2.8. Summary

It is well-established that a social gradient in health exists, with more disadvantaged individuals experiencing poorer health outcomes. These patterns have been observed using individual-level indicators of SEP and area-based measures of deprivation, and differ according to individual-level characteristics. Key policy reviews conducted over the last few decades have demonstrated that social inequalities in health continue to persist in England.

The last two chapters have described the epidemiology of hip fractures and measurement of social inequalities in health. The next chapter systematically reviews existing literature examining the effect of social disadvantage on fragility fracture risk.

CHAPTER 3. SYSTEMATIC REVIEW OF THE EFFECT OF SOCIAL DISADVANTAGE ON INCIDENCE OF FRAGILITY FRACTURES

3.1. Introduction

The epidemiology of hip fractures was described in detail in Chapter 1 highlighting their substantial impact on individuals and healthcare systems. Different individual-level and area-based measures of social disadvantage, and their effect on health outcomes, were discussed in Chapter 2. This current chapter synthesises the findings of published studies examining the relationship between individual-level SEP and/or area-based measures of deprivation, and risk of fragility fractures.

As described in Chapter 1.5, fragility fractures occur following a fall from standing height or less (i.e. low-energy trauma) (37); common sites of occurrence include the hip, spine, shoulder and wrist. Fragility fractures are a global public health problem. It has been estimated that worldwide approximately 9 million incident osteoporotic fractures occurred in the year 2000, of which 1.6 million were at the hip, 1.7 million at the wrist and 1.4 million were symptomatic vertebral fractures (241). In the USA, the lifetime risk of experiencing a fragility fracture has been estimated to be 13% for men and 40% for women aged 50 years (46).

Of all fragility fractures, hip fractures are associated with the most serious consequences with nearly all individuals requiring hospitalisation (242). Approximately one-third of individuals die within one year of hip fracture (29), and among those who do survive, hip fractures are associated with a decline in mobility and greater need for institutionalisation (30, 243). Vertebral fractures are the most prevalent type of fragility fracture (244), although it is difficult to obtain accurate figures given that only an estimated one-third are clinically detected (245). Vertebral fractures are associated with functional limitations, decreased health-related quality of life and an increased risk of subsequent mortality (246). Other types of fragility fractures have been less extensively studied. Osteoporotic fractures have a considerable financial impact on healthcare systems, with the annual direct cost of incident and prevalent fragility fractures estimated to be €37 billion for the EU in 2010 (131).

Several factors are associated with an increased risk of fragility fractures, including older age, female gender, low BMD and previous history of fracture (247). A social gradient in health exists for diseases such as CVD, diabetes and cancer (198, 248-251); however, less is known about the effect of social disadvantage on fragility fracture risk. Brennan et al systematically reviewed twelve studies published prior to 2007 that assessed the relationship between individual-level SEP and fragility fracture risk, with conflicting findings reported by studies that used education and income to define SEP (252). There has been growing interest in the role of social disadvantage on fragility fracture risk over the last decade as demonstrated by the increasing number of studies published in this area. Although the review by Brennan et al was limited to individual-level SEP measures, several studies have examined the association between area-based deprivation and risk of fragility fractures. As discussed in Chapter 2.5, area-based measures may be used as a proxy where individual-level SEP data are not available; however, they can also be used to describe the socioeconomic characteristics of an area itself (145) (see page 61).

Furthermore, area attributes have an independent effect on health outcomes after controlling for individual-level SEP (185).

3.2. Aims of this Chapter

The aims of this systematic review were firstly to update the existing review by Brennan et al on the association between individual-level SEP and fragility fracture risk, and secondly to synthesise the literature examining the effect of area-based deprivation on fragility fracture risk, among men and women aged 50+ years.

3.3. Methods

3.3.1. Protocol and registration

PROSPERO is an international prospective register of systematic reviews for which a health-related outcome is studied and covers a range of research areas, including health and social care, public health, education and crime (253). The study protocol for this systematic review was registered on PROSPERO and can be accessed using the following registration number: 42016032866 (Appendix 13.2, page 413).

3.3.2. Search strategy

A systematic search strategy was developed using Medical Subject Headings and keyword terms based on the following three key concepts: anatomical site of fracture (to identify the relevant study population), individual-level and area-based measures of deprivation (study exposure), and fracture occurrence (study outcome). The detailed systematic search strategy is presented in Appendix 13.2, page 413.

Two electronic medical databases were searched (MEDLINE and Embase) and the following electronic social science databases were searched: Web of Science, PsycINFO and Cumulative Index to Nursing and Allied Health (CINAHL). All electronic databases were searched from their date of commencement to April or July 2016 depending on the specific database. Systematic searches of MEDLINE, Embase and PsycINFO were updated in October 2018. Snowballing methods were used to identify additional studies eligible for inclusion.

3.3.3. Study selection

Two reviewers (myself and AH) independently conducted title and abstract screening of search results. Study eligibility was assessed using the inclusion criteria summarised below, and described in detail in this section. Study authors were contacted for additional information to determine eligibility for inclusion, where further clarification was required.

Studies that met the following inclusion criteria were included in this review:

1. Observational epidemiological study, including cohort, case-control, cross-sectional and ecological studies
2. Identified individuals aged 50+ years with a fragility fracture occurring at the hip, spine, forearm or shoulder
3. Measured social disadvantage using an individual-level and/or area-based measure

4. Compared lower or less affluent SEP with higher SEP, or greater area deprivation with less deprived areas
5. Reported absolute fracture incidence and/or relative measures of association for MOFs combined, or stratified by fracture type

Types of studies

Observational epidemiological studies of the following study designs were included in this review: prospective and retrospective cohort studies, case-control studies, cross-sectional studies (including registry and database studies), and ecological studies. Case reports, case series, qualitative studies and review articles were excluded. Editorials, commentaries, letters and conference abstracts were reviewed to identify relevant articles eligible for inclusion.

PICO criteria

The PICO (Participants, Intervention/Exposure, Comparator and Outcome) criteria were used to identify studies that met the review inclusion criteria. Studies conducted in all geographical contexts and published in any language were included; studies published in a foreign language were translated by departmental colleagues or using web-based tools.

Participants

The study population for this review was individuals aged 50+ years with a fragility fracture occurring at the hip, spine, forearm or shoulder. Whilst fractures occurring at other sites account for a considerable proportion of fragility fractures (241), this review was restricted to the commonly occurring fragility fractures for which the greatest body of literature is available. Individuals below the age of 50 years were excluded as fractures occurring in this age group are mainly due to high-impact trauma (e.g. road traffic accidents) (254).

Exposure

The study exposure for this review was lower or less affluent SEP as measured by one or more individual-level measures and/or an ecological measure of area deprivation that is usually based on routine census data. Individual-level SEP measures commonly included education level, income, occupation and housing/residential status, whilst area-based deprivation measures included country-specific indices.

Comparator

The comparator was higher or more affluent individual-level SEP, or less deprived areas, thus allowing the effect of lower SEP or greater area deprivation on the study outcome to be estimated.

Outcome

The study outcome for this review was the occurrence of an incident fragility fracture. Studies that presented absolute fracture incidence and/or relative measures of association for MOFs combined, or stratified by fracture type, were included.

3.3.4. Data extraction

An excel-based data extraction tool was developed and piloted on approximately 10% of included studies. The tool was subsequently updated and used to extract data from all included studies. The final data extraction tool is presented in Appendix 13.2, page 413. Data extraction was conducted independently by myself and AH.

3.3.5. Methodological quality appraisal

Several tools are available that can be used to critically appraise observational epidemiological studies; however, the methodological approaches employed differ across tools, including domains and component indicators selected and methods used to summarise assessments (e.g. scales and checklists) (255).

The Newcastle-Ottawa Scale (N-OS) was developed to assess the methodological quality of non-randomised studies included in systematic reviews and meta-analyses (256). The N-OS is a simple and convenient tool that can be used to assess the quality of case-control and cohort studies based on the following three criteria: selection, comparability of exposed/unexposed participants, and ascertainment of study exposure or outcome. The N-OS collaborative group did not develop a critical appraisal tool for use with cross-sectional studies; however, other researchers have adapted existing N-OS tools to meet the methodological criteria for cross-sectional studies (257).

No widely accepted quality appraisal tool exists for ecological studies and therefore based on expert guidance sought from the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care West, the quality of ecological studies was not assessed as part of this review (J. Savovic, personal communication, 19/01/2016). Although, for completeness, ecological studies that met the review eligibility criteria were included.

One reviewer (GV) critically appraised the quality of included studies using N-OS tools for case-control and cohort studies, and the modified N-OS tool for cross-sectional studies (see Appendix 13.2, page 413). Scores assigned across the three quality domains were summed following which studies were graded as being of poor, moderate or good methodological quality based on the overall score.

3.3.6. Data synthesis of results

It was decided that it was not sensible to perform a meta-analysis due to considerable methodological heterogeneity across studies. Instead, a narrative approach was used to synthesise the findings of studies included in this review. Data were synthesised separately for each study exposure (i.e. individual-level and area-based measures), and if available, data were further described according to age and gender.

3.4. Results

3.4.1. Search results

Systematic searches of five electronic medical and social science databases conducted in 2016 yielded 6,425 articles and a further 26 articles were identified using snowballing methods. 1,389 articles were duplicate results. Titles and abstracts of the remaining 5,062 articles were screened against the inclusion criteria described in section 3.3.3 to determine eligibility for inclusion. Full-text review was conducted for 46 articles, of which 26 articles met the inclusion criteria for this review (Figure 2). Studies that did not meet the sample population criteria (i.e. study population was not restricted to individuals aged 50+ years or those with only fragility fractures) or for which the study exposure or outcome measure was not relevant to this review (e.g. did not examine fracture incidence) were excluded.

A further 1,208 articles studies were identified as part of an updated search of three electronic databases (MedLine/Embase/PsychInfo) that was conducted for the period January 2016 to October 2018; one additional article was identified using snowballing methods. Title and abstract screening were conducted for 1,050 articles; full-texts were reviewed for 26 of these articles (Figure 3). 3 articles met the inclusion criteria for this review. As described for the 2016 literature search, studies that did not meet the sample population criteria, or the study exposure/outcome criteria were excluded. Furthermore, several duplicate articles were excluded that had previously been identified as part of the 2016 literature search. Analyses conducted as part of this thesis that examine the effect of area-based deprivation on hip fracture incidence among older adults in England were published in the journal Osteoporosis International in 2018 (258). This journal article was identified as part of the 2018 literature search; however, given that these findings are described in detail in Chapter 7 of this thesis, this study has been excluded from this review.

29 articles met the inclusion criteria for this review as identified from systematic searches conducted in 2016 and 2018. 2 of these articles were conducted among the same study population (259, 260); of these, the most recently published article identified as part of the 2018 literature search that presented more up-to-date data was included. A total of 28 articles were included in this systematic review.

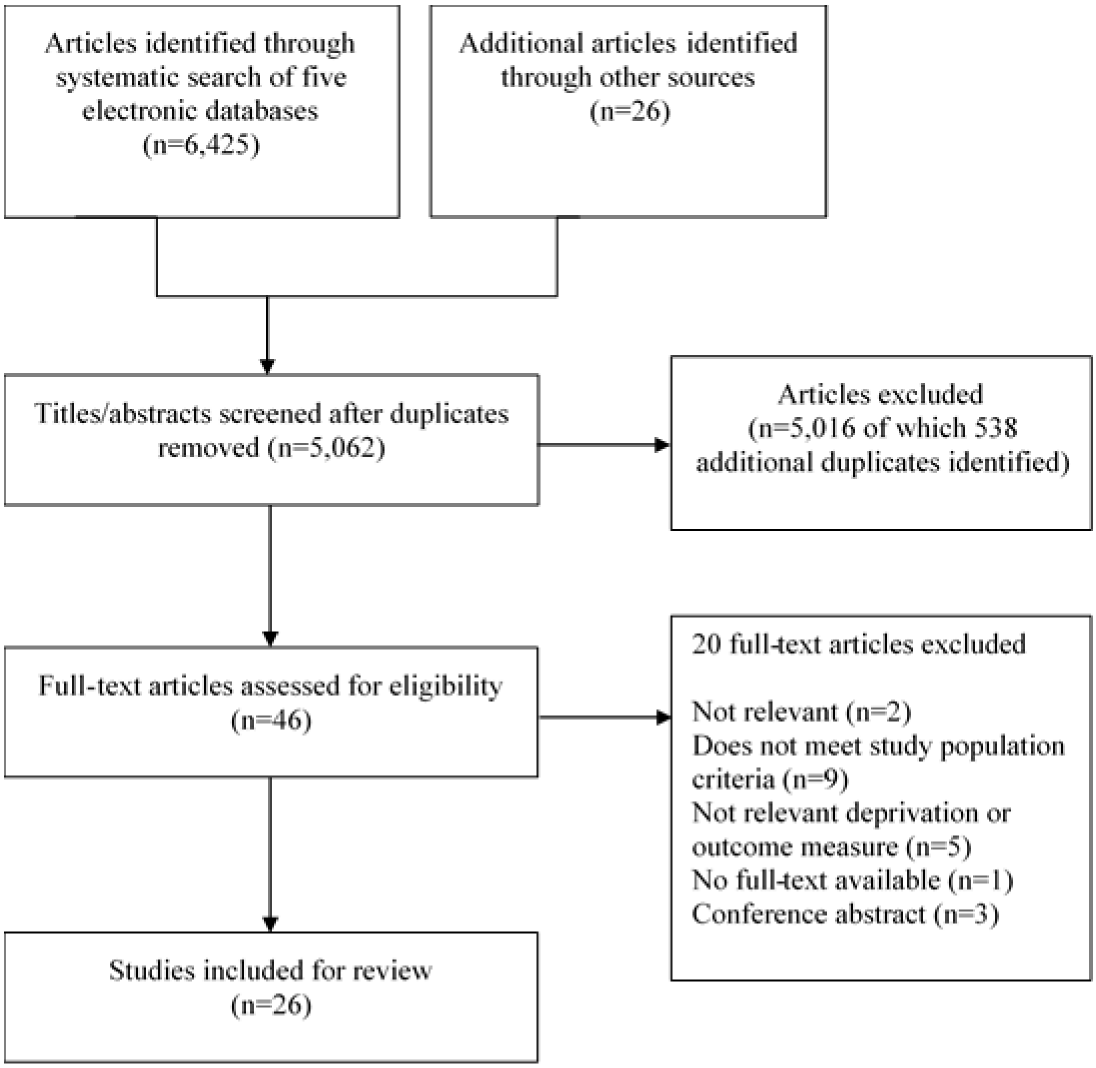

Figure 2: Flow diagram summarising the results of systematic searches of five electronic medical and social science databases conducted in 2016

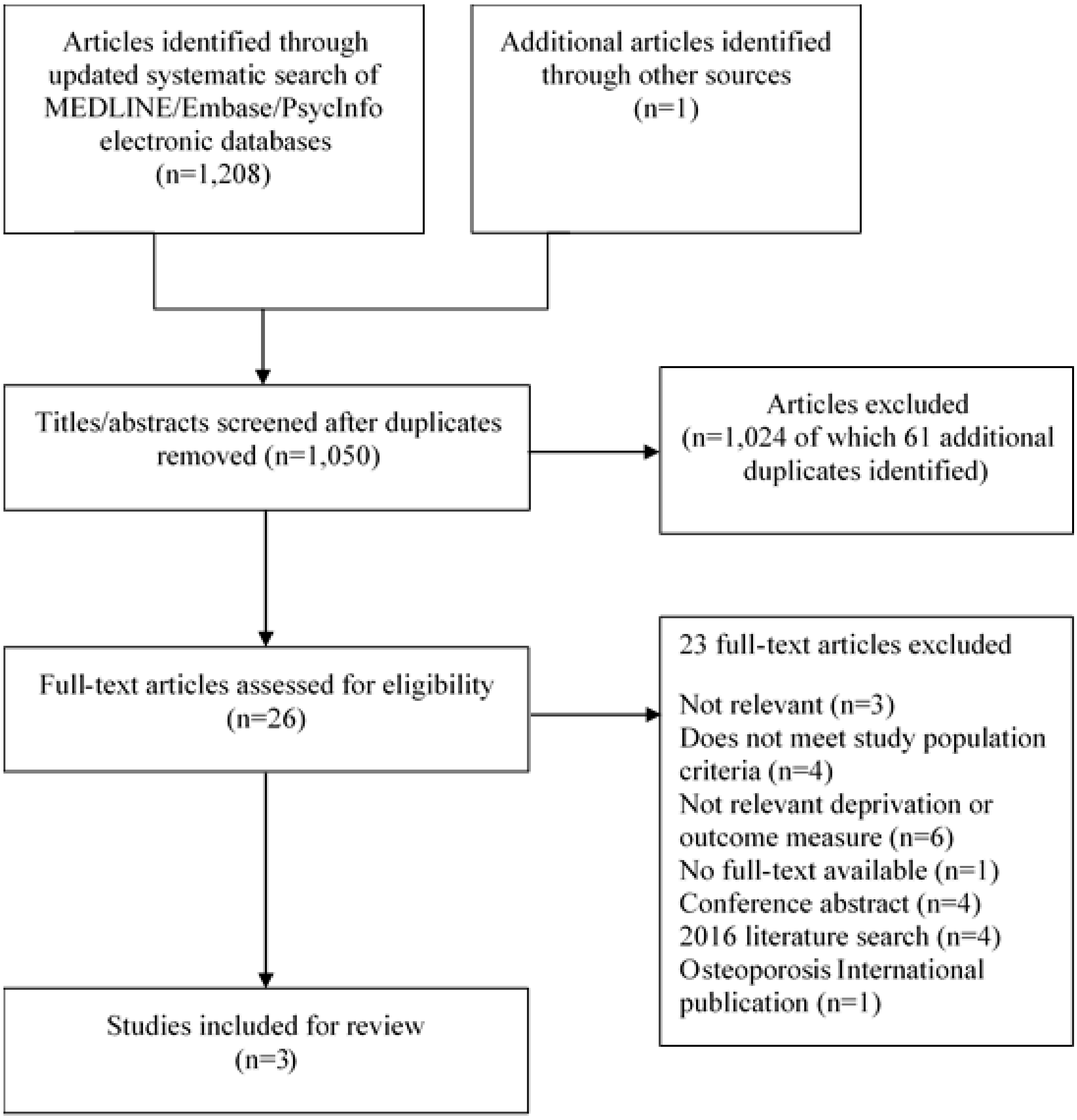

Figure 3: Flow diagram summarising the results of systematic searches of three electronic medical and social science databases for the period January 2016 to October 2018

3.4.2. Description of studies

Study characteristics of the twenty-eight studies included in this review are summarised according to study design and site of fracture occurrence in Table 1 to Table 4 below. Twenty-six studies were conducted among hip fracture populations, of which four were cohort studies (261-264), seven were case-control in design (259, 265-270), ten were cross-sectional studies (21, 50, 271-279) and five were ecological studies (280-284). Six studies were conducted among individuals with a MOF (50, 262, 263, 267, 273, 285), of which five studies presented analyses stratified by fracture type (50, 263, 267, 273, 285).

Most studies were conducted in high-income countries, except for two studies conducted in Iran and Taiwan (259, 276). Studies analysed data for the period 1988 to 2016, albeit of varying durations. The longest study was conducted by Curtis et al over a 24-year period (50). Study populations ranged in size from 100 to 1,210,781 individuals with a fragility fracture. As expected, most studies were conducted primarily among women (range 53.5% to 100%). All studies were conducted among older adults as per the review inclusion criteria except for one study by Icks et al that included individuals of all ages (281); however, age-stratified analyses were presented for individuals aged 70+ years.

Ten studies measured individual-level SEP (259, 261, 264-270, 275), primarily using self-reported data; education and income were most commonly studied. The remaining eighteen studies measured area-based deprivation, of which seven studies were defined based on income (262, 263, 271, 273, 274, 279, 281), seven used country-specific indices (21, 50, 272, 277, 283-285) and five studies used other constructs of deprivation (276, 278, 280-282). The majority of area-based studies used national statistics or census data to measure deprivation. Most studies identified cases of fragility fracture from hospital admissions databases or hospital medical records, except for four studies that used a primary care database (50), hospital claims database (263) or self-reported data (261, 264).

Table 1: Descriptive characteristics of *cohort studies* included in the review

Author, year	Study period	Country	Follow-up period (years)	Type of deprivation measure	Deprivation measure	No. of study participants	Sample characteristics (age in years, % female)
Hip fracture							
Benetou, 2015 (261)	NR	Germany, Greece, Norway, Sweden, USA	11.1-15.2	Individual	Education	4,185	60+ years, 79.0%
Brennan, 2014 (262)	1996-2011	Canada	6.2	Area	Income	1,027	50+ years, 100.0%
Taylor, 2011 (263)	2000-2005	USA	4.2	Area	Income	60,354	65+ years, 58.4%
Wilson, 2006 (264)	1993-1995	USA	2.0	Individual	Education, income, HI status, type of residence	102	70+ years, 64.9%
MOF							
Brennan, 2014 (262)	1996-2011	Canada	6.2	Area	Income	MOF 3,723	50+ years, 100.0%
Taylor, 2011 (263)	2000-2005	USA	4.2	Area	Income	Spine 44,075 Wrist 24,655 Humerus 19,393	65+ years, 58.4%

NR – not reported; HI – health insurance; MOF – major osteoporotic fracture

Table 2: Descriptive characteristics of *case-control studies* included in the review

Author, year	Study period	Country	Type of deprivation measure	Measure of deprivation	No. of study participants	Sample characteristics (age in years, % female)
Hip fracture						
Cano, 1993 (265)	1988-1989	Spain, Turkey	Individual	Education	519 cases 808 controls	50+ years, 100%
Chen, 2018 (259)	2014-2016	Taiwan	Individual	Education	100 cases 100 controls	PMW, 100%
Farahmand, 2000 (266)	1993-1995	Sweden	Individual	Education, income, occupation, type of residence	1,327 cases 3,262 controls	50-81 years, 100%
Hansen, 2018 (267)	1995-2011	Denmark	Individual	Income	37,500 cases 37,500 controls	60+ years, 68.8%
Meyer, 1995 (268)	1992-1993	Norway	Individual	Education	246 cases 246 controls	50+ years, 77.8%
Peel, 2007 (269)	2003-2004	Australia	Individual	Income	126 cases 261 controls	65+ years, cases 81.7% controls 82.0%
Suen, 1998 (270)	1990-1991	Australia	Individual	Occupation	209 cases 207 controls	65+ years, 75%
MOF						
Hansen, 2018 (267)	1995-2011	Denmark	Individual	Income	Wrist 106,736 cases 106,736 controls Humerus 45,602 cases 45,602 controls	60+ years, 73.8-79.5%

PMW – postmenopausal women; MOF – major osteoporotic fracture

Table 3: Descriptive characteristics of *cross-sectional studies* included in the review

Author, year	Study period	Country	Type of deprivation measure	Measure of deprivation	No. of study participants	Sample characteristics (age in years, % female)
Hip fracture						
Bacon 2000 (271)	1989-1991	USA	Area	Income	5,161	50+ years, 78.2%
Brennan, 2011 (272)	2006-2007	Australia	Area	IRSD	495	50+ years, 67.9%
Brennan, 2015 (273)	2000-2007	Canada	Area	Income	4,736	50+ years, 71.4%
Curtis, 2016 (50)	1988-2012	UK	Area	IMD	29,666	50+ years, 76.6%
Guilley, 2011 (274)	1991-2000	Switzerland	Area	Income	2,454	50+ years, 74.4%
Hokby, 2003 (275)	1993-1995	Sweden	Individual	Type of residence	9,420	65+ years, 75.5%
Maharlouei, 2014 (276)	2008-2010	Iran	Area	Other	1,923	50+ years, 53.5%
Quah, 2011 (277)	1999-2009	England	Area	IMD	7511	65+ years, NR
Reimers, 2007 (278)	1993-1995	Sweden	Area	Other	7,748	65+ years, NR
Smith, 2013 (21)	2001-2011	England	Area	IMD	504,351	>65+ years, NR
Zingmond, 2006 (279)	1996-2000	USA	Area	Income	116,919	50+ years, 74.0%
MOF						
Brennan, 2015 (285)	2006-2007	Australia	Area	IRSD	1,869	50+ years, 70.9%
Brennan, 2015 (273)	2000-2007	Canada	Area	Income	Spine 1,979 Forearm 5,367 Humerus 3,012	50+ years, 71.4%
Curtis, 2016 (50)	1988-2012	UK	Area	IMD	Spine 9,307 Wrist 32,719	50+ years, 76.6%

NR – not reported; MOF – major osteoporotic fracture; IRSD – Index of Relative Social Disadvantage; IMD – Index of Multiple Deprivation

Table 4: Descriptive characteristics of *ecological studies* included in the review

Author, year	Study period	Country	Type of deprivation measure	Measure of deprivation	No. of study participants	Sample characteristics (age in years, % female)
Bugeja, 2018 (280)	2015-2016	Maltese Islands	Area	Other	454	50+ years, 72.7%
Icks, 2009 (281)	1995-2004	Germany	Area	Income, Other	1,210,781	All ages, NR (age-specific analyses for 70+ years)
Oliveira, 2015 (282)	2000-2010	Portugal	Area	Other	96,905	50+ years, 77.3%
Turner, 2009 (283)	1998-2004	Australia	Area	IRSD	NR	65+ years, NR
West, 2004 (284)	1992-1997	England	Area	TDI	17,390	75+ years, NR

NR – not reported; TDI – Townsend Deprivation Index; IRSD – Index of Relative Social Disadvantage

3.4.3. Individual-level measures of SEP and hip fracture incidence

Ten studies examined the association between individual-level SEP and hip fracture risk. The findings of these studies are summarised below according to the following study exposures: education, income, occupation and type of residence. Education and income were most commonly studied; six studies defined individual-level SEP based on educational status and five studies used income level.

Education

Of the six studies that assessed the relationship between education and hip fracture risk, four studies were case-control in design (259, 265, 266, 268) and two were prospective cohort studies (261, 264). Studies were conducted in Europe, North America and Asia. Most studies used self-reported information on education (259, 261, 264, 265, 268), except for one study that additionally obtained national census data (266). Two studies defined education based on the number of years in education (265, 268), whilst the remaining four studies were based on educational attainment, albeit using different categorisations (259, 261, 264, 266).

Three studies showed that, among men and women, higher education was associated with lower hip fracture risk, although different approaches were used to define education (Table 5). Meyer et al reported that longer periods in education were associated with lower odds of hip fracture among older adults in Oslo, Norway (268). Benetou et al similarly showed, among a large prospective sample of men and women aged 60+ years from seven cohorts in Europe and the USA, that higher educational attainment compared with low educational attainment was associated with lower hip fracture risk, although the effects were stronger in women than men (261). However, evidence in support of a gender by education interaction was found for only one of the four study cohorts that included both men and women (Swedish cohort p=0.02) (261). Wilson et al found that having no high-school diploma compared with a college education was associated with higher adjusted odds ratio of hip fracture among a prospective sample of nationally-representative US individuals (OR 2.5 [1.03,6.12]) (264). The wide confidence intervals reflect the small number of hip fractures over the two-year study period (n=102 hip fractures).

Three case-control studies were conducted among women only, of which two studies reported a negative association between education and hip fracture risk. Cano et al showed that, among both Spanish and Turkish women, longer periods in education were associated with lower hip fracture risk after adjustment for age and BMI (265). Chen and colleagues found that higher levels of education (defined as primary schooling and secondary schooling or higher *vs*. no schooling) were associated with lower odds of hip fracture among postmenopausal women in Taiwan (259). In contrast, Farahmand et al did not observe an association between educational attainment and hip fracture risk in a population-based case-control study conducted among postmenopausal women in south-central Sweden (266), possibly explained by universal access to a basic level of education in Sweden (286). Although all three studies were case-control in design and thus may have been prone to recall bias (259, 265, 266), Farahmand et al used both national census data and self-reported information to determine level of education which is likely to have minimised recall bias (266).

Table 5: Summary of findings reported by studies examining the association between *individual-level educational status* and *hip fracture risk*

Author, year (country)	**Measurement of exposure**	**Ascertainment of outcome**	**Main findings presented for hip fracture**	**Summary**
Benetou, 2015 (261) (Germany, Greece, Norway, Sweden, USA)	Questionnaire and interview	Questionnaire, interview and national inpatient or fracture registries	Ref – low (less than primary school) Medium (high school)/high (college/university degree) Overall HR 0.84 (0.72,0.95) Males HR 0.97 (0.82,1.13); Females HR 0.75 (0.65,0.85)	Decreased hip fracture risk among those with high vs. low education
Cano, 1993 (265) (Spain, Turkey)	Questionnaire and interview	National registers	*Spain* (ref – 0-3 years) 4-6 years RR 0.6 (0.3,1.2); 7-9 years RR 0.2 (0.1,0.6) ≥10 years RR 0.1 (0.0,0.5) *Turkey* (ref – 0-3 years) 4-6 years RR 0.7 (0.3,1.7); 7-9 years RR 0.2 (0.1,0.6) ≥10 years RR 0.3 (0.1,0.8)	Reduced risk of hip fracture with increased education
Chen, 2018 (259) (Taiwan)	Questionnaire and interview	Hospital admission for hip fracture	Ref – unschooled primary school OR 0.25 (0.11,0.59) secondary or higher education OR 0.34 (0.13,0.89)	Reduced odds of incident hip fracture among educated vs. uneducated women
Farahmand, 2000 (266) (Sweden)	National census databases	Hospital records, radiological reports, national inpatient register	Ref – low (elementary school) Medium (secondary school) OR 1.05 (0.89,1.25) High (university) OR 1.15 (0.86,1.55)	No association between education and hip fracture

HR – hazard ratio; OR – odds ratio; RR – relative risk; ref – reference category

Table 5: Summary of findings reported by studies examining the association between *individual-level educational status* and *hip fracture risk* (contd.)

Author, year (country)	**Measurement of exposure**	**Ascertainment of outcome**	**Main findings presented for hip fracture**	**Summary**
Meyer, 1995 (268) (Norway)	Questionnaire and interview	Hospital records	Ref – >=11 years 8-10 years OR 1.58 (0.90,2.77) ≤ 7 years OR 2.66 (1.45,4.89)	Higher odds of hip fracture with decreased education
Wilson, 2006 (264) (USA)	Interview	Interview	Ref – college High school OR 2.0 (0.84,5.01) No high school diploma OR 2.5 (1.03,6.12)	Higher odds of hip fracture among those with no high school vs. college education

HR – hazard ratio; OR – odds ratio; RR – relative risk; ref – reference category

Income

Four studies conducted in Europe and the USA examined the effect of income on hip fracture risk (264, 266, 267, 269) (Table 6). Three studies obtained data on individual-level income, albeit using different currencies (264, 266, 267). Two studies used health insurance coverage (264, 269), which may be considered a proxy for income status (287). Information on income level was obtained from national records, questionnaires and interviews.

Two of the three studies that analysed personal income data reported that higher income was associated with lower hip fracture risk (266, 267). Both studies were case-control in design; however, the use of routinely collected income data is likely to have avoided the risk of recall bias (266, 267). The age- and sex-matched case control study by Hansen et al showed, using income data recorded on the latest annual tax return before fracture (in Danish kroner), that individuals in the highest income quintile had 22% lower odds of hip fracture compared to those in the average income group (quintile 3); an association was not observed for the other income groups (267). Farahmand et al similarly showed, using household income data from national census databases, that a high or medium income compared with a low income was associated with reduced hip fracture odds among postmenopausal women in south-central Sweden after adjustment for age, lifestyle behaviours, marital status and socioeconomic factors (education, occupation and housing type) (266). In contrast, the prospective cohort study by Wilson et al used self-reported information on employment, retirement benefits and investments to determine annual household income in US dollars, and found no evidence of a relationship between household income and hip fracture risk (264). Accurate self-reported information on absolute income may be difficult to obtain owing to an unwillingness to disclose such sensitive information (154), possibly explaining in part the lack of association between income and hip fracture risk in this study.

Two studies showed that health insurance coverage was associated with lower hip fracture risk (264, 269). An age- and sex-matched case control study conducted by Peel et al found that having private health insurance was associated with 51% lower odds of hip fracture among older individuals in Brisbane, Australia after taking account of comorbidity, functional limitations and previous hip fracture (269). Interestingly, despite not finding evidence of a relationship between household income and hip fracture risk in older US men and women as described earlier, Wilson et al showed that having health insurance (Medicare part B) was associated with reduced odds of hip fracture (264). Medicare part B is a Government-managed national health insurance scheme that covers essential medical services and preventative services in the USA (288). Whilst income status and health insurance coverage are both indicators of material circumstance, the more sensitive nature of obtaining information on personal income, rather than health insurance status, may partly account for the inconsistent findings reported by Wilson et al.

Table 6: Summary of findings reported by studies examining the association between *individual-level income status* and *hip fracture risk*

Author, year (country)	**Measurement of exposure**	**Ascertainment of outcome**	**Main findings presented for hip fracture**	**Summary**
Farahmand, 2000 (266) (Sweden)	National census databases	Hospital records, radiological reports, national inpatient register	Ref – low household income (based on distribution of controls) Medium OR 0.82 (0.69,0.98) High OR 0.74 (0.60,0.90)	Lower odds of hip fracture with increasing household income
Hansen, 2018 (267) (Denmark)	Individual income on latest annual tax return before fracture (Danish Kroner)	National hospital inpatient and outpatient register	Ref – quintile 3 (average group) Q5 (highest income) OR 0.78 (0.72,0.85)	Lower odds of hip fracture among individuals in highest vs. average income group
Peel, 2007 (269) (Australia)	Questionnaire and interview	Hospital admission for hip fracture	Ref – no private HI Private HI OR 0.49 (0.27,0.90)	Lower hip fracture odds among individuals with private HI
Wilson, 2006 (264) (USA)	Interview	Interview	Ref – HI coverage No HI coverage OR 2.4 (1.53,4.11) Ref – annual household income US$ ≥25,000 US$ 12,000-24,999 OR 1.1 (0.64, 2.01) US$ <12,000 OR 1.6 (0.91, 2.81)	Hip fracture odds higher among those without HI coverage but not associated with level of annual household income

HI – health insurance; OR – odds ratio; US$ - United States dollars; ref – reference category

Occupation

Two case-control studies examined the association between occupation and hip fracture risk; with conflicting findings, possibly explained by the use of different classification systems to define occupation (266, 270) (Table 7).

Suen conducted a case-control study among older men and women residing in western Sydney, Australia; self-reported information was used to assign occupational group based on a national classification system that included professionals, tradespersons and clerks (270). For men and women combined, professional persons (based on longest job) compared with labourers had lower age- and gender-adjusted odds of hip fracture. No association between occupation and hip fracture risk was observed for the remaining groups; however, this study may not have been powered to detect a difference owing to the small number of study participants across the eight occupational groups. Farahmand et al used national census data to determine employment status and occupational category among postmenopausal women residing in south-central Sweden (266). Hip fracture odds were 26% lower among women employed in the prior decade compared to unemployed women; however, for employed women, hip fracture risk did not differ according to occupational category based on a Swedish classification system.

Occupational roles are known to differ in men and women (169), and therefore the use of national classification systems that are likely to be based on male-dominated occupations may not adequately capture differences in social stratification among women (168). Furthermore, Suen presented analyses adjusted for gender, which may have masked gender differences in the relationship between occupation and hip fracture risk (‘effect modification’). Whilst Farahmand et al obtained national census data, Suen used self-reported information which may have introduced recall bias if inaccurate reporting of occupational group differed among hip fracture cases and community controls.

Table 7: Summary of findings reported by studies examining the association between *individual-level occupational status* and *hip fracture risk*

Author, year (country)	**Measurement of exposure**	**Ascertainment of outcome**	**Main findings presented for hip fracture**	**Summary**
Farahmand, 2000 (266) (Sweden)	National census databases	Hospital records, radiological reports, national inpatient register	Ref – unemployed in 1990 Employed OR 0.74 (0.56,0.96)	Lower hip fracture risk among employed vs. unemployed women; no association between occupational category and hip fracture risk among employed women
Suen, 1998 (270) (Australia)	Questionnaire and interview	Hospital records (surgical or imaging reports)	Ref – labourers (longest job held) Professionals OR 0.08 (0.01,0.48)	Lower hip fracture risk among professionals vs. labourers, no association observed for other occupational groups

OR – odds ratio; ref – reference category

Type of residence

Three studies examined the relationship between type of residence and hip fracture (264, 266, 275). Whilst it is not possible to draw clear conclusions from these few studies with differing methodologies, there is some suggestion that residing in a smaller compared with larger home is associated with higher hip fracture risk. Type of residence was defined differently across studies; two studies used different categorisations of housing type, whilst the third study was based on number of rooms in a dwelling (Table 8). All three studies took account of confounding by age; however, adjustment for other covariates differed across studies.

Farahmand and colleagues showed, using national census data, that older Swedish women living in an apartment versus a one-family house had higher age-adjusted odds of hip fracture that persisted after further adjustment for marital status (266), which is known to be a protective factor for hip fracture (252). Hokby et al similarly used national census data to determine the number of rooms in a dwelling (275). They did not find evidence of a clear association between number of rooms and hip fracture risk in both Swedish men and women residing in Stockholm County; only men residing in a one-room compared with more than three room dwelling had higher age-adjusted odds of hip fracture (275). Interestingly, Wilson et al found that residing in a mobile home, but not an apartment, compared to a house was associated with greater odds of hip fracture in a cohort of older US men and women (264). These analyses were adjusted for net worth, thus taking account of mobile home residence as a proxy for low income status (264).

Table 8: Summary of findings reported by studies examining the association between *individual-level residential status* and *hip fracture risk*

Author, year (country)	Measurement of exposure	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Farahmand, 2000 (266) (Sweden)	National census databases	Hospital records, radiological reports, national inpatient register	Ref – apartment One-family house adjusted OR 0.85 (0.72, 0.99)	Living in a house vs. apartment associated with lower odds of hip fracture
Hokby, 2003 (275) (Sweden)	National census data	Regional hospital inpatient register	Ref – more than 3 rooms in dwelling Males 1 room OR 1.35 (1.07,1.78)	Greater odds of hip fracture among men residing in a one-room vs. more than three-room dwelling
Wilson, 2006 (264) (USA)	Interview	Interview	Ref – house Mobile home OR 2.5 (1.21,5.17)	Living in a mobile home vs. house associated with higher odds of hip fracture

OR – odds ratio; ref – reference category

3.4.4. Area-based measures of deprivation and hip fracture incidence

Eighteen studies examined the relationship between area-based deprivation and hip fracture risk, although the specific measure used differed across studies. All but one study used a single measure to define deprivation (281). Study exposures measured at the level of geographical areas included income, country-specific indices and other constructs of deprivation. Most studies were conducted in North America and Europe, with the remaining three studies conducted in Oceania and the Middle East.

Area-based income and hip fracture incidence

Of the seven studies that examined the effect of area-based income on hip fracture risk, four were cross-sectional in design (271, 273, 274, 279), two were cohort studies (262, 263) and one was an ecological study (281). For ease of comparability, studies are described according to the geographic region in which they were conducted. Studies presenting gender-stratified analyses are then summarised.

North America

Three US-based studies showed that, among men and women, higher levels of area-based income were associated with lower rates of hip fracture (263, 271, 279) (Table 9). It was not possible to directly compare absolute and relative associations across studies owing to heterogeneity in the methods employed; area-based income was defined using different ranges and categorisations, and analysed at different levels of geography.

Bacon et al used hospital discharge and national census data to examine the association between area-based income and hip fracture risk among a nationally-representative sample of US individuals surveyed between 1989 and 1991 (271). Median annual household income based on zip code area of residence was categorised into six groups that ranged from less than US$20,000 to $40,000+. Zip code areas are based on geographical boundaries determined by the US Postal Service for mail delivery (289). Increasing median household income was associated with lower age- and gender-adjusted hip fracture incidence (271). Similarly, the population-based, cross-sectional study conducted by Zingmond et al measured median per capita income (based on household income) at the level of zip code areas, categorising income into deciles that ranged from US $4,079 to $114,359 (279). Hip fracture incidence was 21% lower among those residing in the highest income versus lowest income areas. These analyses were not age-adjusted and therefore may have underestimated the true association between area-based income and hip fracture incidence. Age is positively associated with hip fracture risk (see Chapter 1.6.2, page 25) and, in general, income increases until retirement age (154). Taylor et al studied a 5% random sample of Medicare beneficiaries aged 65+ years (2000-2005) and used 2000 census data to measure median household income at the level of census block groups (263). Census block groups are geographical areas containing between 600 and 3,000 people (289). Higher income was associated with lower hip fracture incidence; hip fracture risk was 16% lower among individuals residing in the highest income (US$ 75,000+) versus lowest income areas (<US$30,000) adjusted for patient characteristics and time period (263).

Table 9: Summary of findings reported by studies examining the association between *area-based income* and *hip fracture risk* in *North America*

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Bacon, 2000 (271) (USA)	Median annual household income from national census data (zip code areas)	Hospital discharge survey	Annual incidence rates per 10,000 Lowest income group (US$ 0-20,000) 50.9 Highest income group (US$ 40,000+) 30.8	Higher area-based income associated with lower hip fracture incidence
Taylor, 2011 (263) (USA)	Median household income from national census data (census block groups)	Medicare HI claims database	Ref – US$ 0-30,000 US 75,000+ IRR 0.84 (0.81,0.87)	Higher area-based income associated with lower hip fracture incidence
Zingmond, 2006 (279) (USA)	Median household income from national census data (zip code areas)	Regional hospital discharge database	Ref – lowest decile (US$ 4,079-12,529) Highest decile (US$ 40,392-114,359) IRR 0.79 (0.77,0.82)	Higher area-based income associated with lower hip fracture incidence

HI – health insurance; IRR – incidence rate ratio; ref – reference category

Europe

Two European studies were identified that reported inconsistent findings on the relationship between area-based income and hip fracture risk (Table 10). Guilley et al conducted a cross-sectional study among individuals admitted to a single tertiary hospital in Geneva, Switzerland (1991-2000) (274). Median household income data were derived from national census data and used to assign individuals into income tertiles based on their postal code of residence. Although area-based income was inversely associated with age-adjusted odds of hip fracture, this association was explained by rural/urban locality of residence. In comparison, Icks et al conducted an ecological study that included all hip fracture admissions in Germany over the period 1995 to 2004 (281). Analyses were conducted at the level of census tracts, which are large geographical areas with a median population of more than 500,000 people (281). Annual official statistics and representative household surveys were used to measure household income per person (in Euros) and determine the proportion of welfare recipients in census tract areas. Age-specific analyses conducted among individuals aged 70+ years showed that areas with an increasing proportion of welfare recipients had a higher risk of hip fracture but surprisingly, area-based household income was not associated with hip fracture risk.

The differing findings reported by both studies may be explained by the measurement of deprivation for large geographical areas in the study by Icks et al, which may have introduced non-differential misclassification bias. It is unlikely that bias would have been introduced differentially according to the burden of incident hip fractures in a census tract area, and therefore this study may have underestimated the true association between area-based income and hip fracture risk.

Table 10: Summary of findings reported by studies examining the association between *area-based income* and *hip fracture risk* in *Europe*

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Guilley, 2011 (274) (Switzerland)	Median household income from census data (postal code areas)	Hospital discharge database	Ref – 0-53,170 CHF 53,170-58,678 CHF OR 0.91 (0.82,0.99) 58,678+ CHF OR 0.93 (0.84,1.03)	No association between area-based income and odds of hip fracture
Icks, 2009 (281) (Germany)	National statistics on household income and welfare recipient status (census tract areas)	National hospital discharge register	*For each 2% increase in welfare recipient status* RR 1.09 (95% CI not reported)	Higher hip fracture risk in areas with higher proportion of welfare recipients No association between household income and hip fracture risk

CHF – Swiss franc; CI – confidence interval; OR – odds ratio; RR – relative risk; ref – reference category

Gender sub-groups

Two studies were identified that examined the association between area-based income and hip fracture risk in men and women separately (273, 274), and a further study was conducted among women only (262) (Table 11).

Brennan and colleagues conducted two studies among different study populations in the same Canadian region (Manitoba province) (262, 273). A prospective cohort study conducted among women aged 50+ years who underwent routine clinical femoral neck BMD measurement in Manitoba, Canada showed that mean household income (based on dissemination area (DA) of residence) was negatively associated with hip fracture risk (262). DAs are the smallest unit of administrative geography in Canada and have a population size of 400 to 700 individuals (262). Women in the highest income versus lowest income quintile had 30% lower risk of hip fracture after adjustment for BMD and FRAX covariates (see Chapter 1.7.1, page 32 for further discussion of FRAX risk factors). In a second study, also conducted in Manitoba, Canada, Brennan et al reported that the age-adjusted risk of hip fracture was lower among men in the highest income versus lowest income quintile, with no association observed in women (273). Contrary to the findings of other studies that have reported stronger associations between deprivation and fracture risk in men than women (50, 285), Guilley et al showed that, among adults admitted to a single hospital in Geneva, Switzerland, median household income was not associated with hip fracture incidence in men (274). Whilst among women, residing in a medium income versus low income area was associated with 14% lower age-adjusted odds of hip fracture, that persisted after further adjustment for rurality. This study was conducted in a single Swiss hospital and therefore these study findings may not be generalisable to other hip fracture populations.

Table 11: Summary of findings reported by studies examining the association between *area-based income* and *hip fracture risk* stratified by gender

Author, year (country)	**Measurement of exposure (geographical unit)**	**Ascertainment of outcome**	**Main findings presented for hip fracture**	**Summary**
Brennan, 2014 (262) (Canada)	Mean annual household income (dissemination areas)	Hospital discharge records and physician billing claims	Ref – Q5 (highest income group) Q1 HR 1.30 (1.05,1.60)	Higher hip fracture risk among women residing in areas of low versus high income
Brennan, 2015 (273) (Canada)	Mean intra-quintile annual household income (dissemination areas)	Administrative health data repository	Ref – Q5 (Canadian $101,076) *Males (Q1 Canadian $34,355)* RR 1.62 (1.30,2.02) *Females (Q1 Canadian $34,355)* RR 1.15 (0.93,1.41)	Higher hip fracture risk among men residing in areas of low versus high income No association observed in women
Guilley, 2011 (274) (Switzerland)	Median household income from census data (postal code areas)	Hospital discharge database	Ref – 0-53,170 CHF *Males* 53,170-58,678 CHF OR 1.05 (0.86,1.27) 58,678+ CHF OR 0.89 (0.73,1.09) *Females* 53,170-58,678 CHF OR 0.86 (0.76,0.96) 58,678+ CHF OR 0.94 (0.84,1.06)	Lower odds of hip fracture among women residing in areas with medium levels of income No association observed in men, or women residing in high income areas

HR – hazard ratio; RR – relative risk; CHF – Swiss franc; ref – reference category

Index of Multiple Deprivation and hip fracture incidence

Three UK-based studies used the IMD to measure area-based deprivation, all demonstrated that hip fracture incidence was higher among individuals residing in the most deprived versus least deprived areas (21, 50, 277) (Table 12). The IMD is a relative measure of deprivation for small areas that is comprised of seven domains and has been described in detail in Chapter 2.5.3, page 64 (195).

Quah et al prospectively studied a cohort of hip fracture patients admitted to a single hospital in Nottingham, England (277). They reported that hip fracture incidence was 1.3 times higher among those in the most deprived versus least deprived quintile (277). Using English hospital administrative data, Smith et al conducted a large population-based cross-sectional study, demonstrating that hip fracture incidence increased with greater deprivation (21). Following indirect standardisation for age and gender, 15.9% more hip fracture admissions than expected occurred among individuals in the most deprived versus least deprived decile (21). Analysing UK primary care data, Curtis et al found that hip fracture risk was 7% higher among individuals in the most deprived versus least deprived quintile (50). Gender-stratified analyses showed that greater deprivation was associated with higher hip fracture risk in men, with no association observed among women.

Although all three studies showed that greater area-based deprivation was associated with higher hip fracture incidence in older adults, several methodological differences were noted across these limited studies conducted in the UK. Firstly, Quah et al conducted a hospital-based study in a single English region (277), thus limiting generalisability. In comparison, Smith et al analysed hospital administrative data capturing all hip fracture admissions to English NHS hospitals (21), whilst Curtis et al used UK primary care data from a nationally-representative sample of individuals registered with a

GP practice (50). Secondly, Quah et al and Curtis and colleagues did not adjust their analyses for potential confounding by age (50, 277). Hip fracture risk increases markedly with age (see Chapter 1.6.2, page 25), and more deprived individuals tend to be younger than those least deprived. Both studies may therefore have underestimated the true association between deprivation and hip fracture incidence.

Townsend Deprivation Index and hip fracture incidence

West and colleagues conducted an ecological study that assessed the relationship between area-based deprivation and hip fracture admission rates in the Trent region of England (284) (Table 12). The TDI, which has been described in Chapter 2.5.1, was used to measure deprivation (see page 62). In brief, the TDI is a composite measure of material deprivation that is based on four census variables (car ownership, housing tenure, overcrowding and unemployment). Higher TDI scores indicate greater deprivation. West et al did not find an association between deprivation and hip fracture admission; however, their study sample was restricted to patients aged 75+ years, which may explain these findings. Prior studies have shown that socioeconomic inequalities in health are weaker among older compared to younger individuals (193, 202), possibly due to a healthy survivor effect. Furthermore, West et al analysed all hip fracture admissions (i.e. including second hip fractures) and therefore may have overestimated the incidence of hip fractures. It is not known whether greater deprivation is associated with higher rates of second hip fracture; however, if such a relationship exists, hip fracture admission rates may have been overestimated to a greater degree in more deprived individuals.

Table 12: Summary of findings reported by studies examining the association between *area-based indices of deprivation* and *hip fracture risk* in the *UK*

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Curtis, 2016 (50) (UK)	National statistics database (IMD – LSOAs)	Primary care electronic medical records database	Ref – Q1 (least deprived) Overall Q5 RR 1.07 (1.03,1.11) Males Q5 RR 1.30 (1.21,1.41) Females Q5 RR 1.00 (0.96,1.05)	Higher hip fracture risk among the most deprived individuals Greater deprivation associated with higher hip fracture risk in men; similar trend not observed in women
Quah, 2011 (277) (England)	National statistics database (IMD – LSOAs)	Hospital admissions for hip fracture	Annual incidence rate (per 10,000) Q1 (least deprived) 35.3 Q5 45.8 Ref – Q1 Q5 IRR 1.30 (1.02,1.64)	Higher hip fracture incidence among the most deprived individuals
Smith, 2013 (21) (England)	National statistics database (IMD – LSOAs)	National hospital admissions database	Decile 1 (most deprived) Standardised admission ratio 115.9 (15.9% greater than national rate)	Higher hip fracture incidence among more deprived individuals
West, 2004 (284) (England)	National census database (TDI – electoral wards)	Regional hospital admissions database	Ref – Q1 (least deprived) Q5 IRR 1.05 (0.95,1.06)	No association between deprivation and hip fracture admission rates

CPRD – Clinical Practice Research Datalink; HES – Hospital Episode Statistics; IMD – Index of Multiple Deprivation; LSOA – lower super output area; TDI – Townsend Deprivation Index; IRR – incidence rate ratio; RR – relative risk; ref – reference category

Index of Relative Social Disadvantage and hip fracture incidence

Two studies used the Index of Relative Social Disadvantage (IRSD) to measure area-based deprivation in southeast Australia (272, 283), although for differently-sized geographical units (Table 13). The IRSD is a weighted-index of relative disadvantage at the area-level that is based on sixteen indicators across several domains that includes health and disability, employment, income and housing (290).

Brennan et al conducted a cross-sectional study among older individuals residing in Barwon Statistical Division, southeast Australia, demonstrating that greater area-based deprivation was associated with higher age-standardised hip fracture incidence in both men and women (272). Although no clear relationship between deprivation and hip fracture incidence was observed in age-stratified analyses, this study may not have had the power to detect a true difference owing to the small number of hip fractures across strata of age in 10-yearly intervals, gender and deprivation quintiles. In contrast, the ecological study by Turner et al showed that, among older men and women residing in the state of New South Wales, southeast Australia, age- and sex-standardised hip fracture admission ratios were higher in the least deprived compared with more deprived areas (283). These contrasting findings may be explained by the measurement of deprivation for differently-sized geographical units. Whilst Brennan et al assigned IRSD scores based on Census Collection Districts (CCDs) (approximate population size 250 households), Turner et al measured deprivation status for local government areas (283). The measurement of deprivation for large geographical areas may have introduced exposure misclassification bias in the study by Turner et al owing to the classification of smaller areas as more or less deprived than their true deprivation status. Furthermore, the study by Turner et al may be prone to the ecological fallacy (discussed further in section 3.5.3, page 132), and therefore the findings from these studies may not be comparable.

Table 13: Summary of findings reported by studies examining the association between the *Index of Relative Social Disadvantage* and *hip fracture risk* in *Australia*

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Brennan, 2011 (272) (Australia)	National statistics database (CCD)	Hospital medical records and radiological reports	Incidence rate (per 1,000 person-years) Q1 (most deprived) *Males* Q2 2.6 (2.59, 2.60) Q5 1.2 (1.19, 1.20) *Females* Q2 5.0 (4.99, 5.00) Q5 2.4 (2.39, 2.40)	Greater deprivation associated with higher hip fracture incidence in both men and women
Turner, 2009 (283) (Australia)	National statistics database (LGA)	Regional hospital admission database	Ref – Q5 (least disadvantaged) Q4 SAR 0.86 (0.74,0.99) Q3 SAR 0.84 (0.72, 0.97)	Slightly higher rates of hip fracture in least deprived compared with more deprived areas

CCD – census collection district; SAR – standardised admission ratio; LGA – local government area; ref – reference category

Other area-based measures of deprivation and hip fracture incidence

Five studies used area-based measures other than income and country-specific indices to define deprivation (276, 278, 280-282). It was not possible to directly compare the findings of these five studies owing to considerable heterogeneity in the methods used to measure deprivation (Table 14). Four studies were conducted in Europe and one in Iran (276).

Bugeja et al conducted an ecological study in the Maltese Islands, using a composite score of district-level SES derived from national statistics data (280). This aggregate measure was based on seven socioeconomic variables that included income, unemployment, living conditions, illiteracy and health status. A higher score indicated lower SES levels. A negative correlation between area-level SES and hip fracture incidence was observed ($r = –0.60$).

Icks et al conducted an ecological study that examined the relationship between unemployment rate and total living space per person, and hip fracture risk in Germany (281). Interestingly, among men and women aged 70+ years, a 6% increase in census tract-based unemployment was associated with a 11% lower risk of hip fracture, whilst an association was not observed for total living space. Unemployment and overcrowding may not be adequate measures of deprivation in older people, many of whom are likely to be retired or residing in an institutional facility.

Maharlouei and colleagues conducted a retrospective, hospital-based study in the city of Shiraz, southwest Iran (276). Deprivation was defined based on municipality of residence. Age-standardised hip fracture incidence was similar among individuals living in low and high SES areas but higher than those residing in middle SES areas. Maharlouei et al provide no details of the methodological approach used to measure deprivation in their study, that is, whether area-level attributes were used to define deprivation. Rather, the study authors describe the northern and southern parts of the city as being high and low SES areas respectively. The use of such an approach may not have adequately captured socioeconomic differences between the nine municipalities in Shiraz.

Oliveira et al used national census data for municipalities in Portugal to construct an aggregate measure that described the socioeconomic characteristics of individuals, families, households and buildings (282). An association between deprivation and hip fracture risk was not observed in men or women aged 50+ years; however, differing patterns were observed when analyses were further stratified by age (in 5-yearly intervals). Hip fracture risk was higher among both men and women aged 75+ years residing in affluent versus deprived areas, whilst an association was not observed in younger individuals. These findings may be confounded by age given that about 60% of both men and women in this study were from affluent areas and approximately 15% from deprived areas; it is likely that a higher proportion of older individuals, in whom hip fracture risk is higher, resided in affluent areas.

Reimers et al measured parish-level social status and economic deprivation in Stockholm, Sweden, using two composite indices derived from regional registry data (278). Social status was based on variables for education and living conditions, whilst economic deprivation included low income, unemployment and welfare recipient status (278). Parishes are subdivisions of municipalities that are used for administrative data collection in Sweden (291). In both men and women, lower parish social status was associated with lower odds of hip fracture after taking account of individual-level characteristics and economic deprivation. Although economic deprivation was positively associated with hip fracture, this relationship was fully explained by adjustment for individual-level characteristics and parish-level social status.

Table 14: Summary of findings reported by studies examining the association between *other area-based measures of deprivation* and *hip fracture risk*

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Bugeja, 2018 (280) (Maltese Islands)	National statistics obtained for seven socioeconomic variables (districts)	Hospital discharge and radiology database	Incidence rate per 10,000 Lowest SES district 6.7 Highest SES district 12.0 Correlation coefficient r = -0.60	Increasing district-level SES associated with lower hip fracture incidence
Icks, 2009 (281) (Germany)	National statistics on living space and unemployment rate (census tracts)	National hospital discharge register	Age-specific analyses (70+ years) RR 0.89 per 6% increase in unemployment rate (95% CIs not presented, p<0.01)	Hip fracture risk lower in census tract areas with higher unemployment rates
Maharlouei, 2014 (276) (Iran)	Not stated (municipality districts)	Computerised hospital records	Incidence rate per 100,000 High SES regions 157.1 Medium SES regions 38.2 Low SES regions 152.5 Small towns 27.8	Higher hip fracture incidence in high and low SES areas compared to middle SES areas and small towns
Oliveira, 2015 (282) (Portugal)	National census data obtained for socioeconomic variables relating to individuals, families, households and buildings (municipalities)	National hospital discharge register	Ref – deprived areas *Affluent areas* Males RR 0.90 (0.66,1.33) Females RR 0.83 (0.65,1.00)	No association between deprivation and hip fracture risk in men or women

SES – socioeconomic status; RR – relative risk; ref – reference category

Table 14: Summary of findings reported by studies examining the association between *other area-based measures of deprivation* and *hip fracture risk* (contd.)

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for hip fracture	Summary
Reimers, 2007 (278) (Sweden)	Regional registers (parish)	Regional hospital inpatient register	*Social status* Ref – high social status Males Low OR 0.61 (0.48,0.76) Females Low OR 0.67 (0.59,0.77) *Economic deprivation* Ref – low economic deprivation Males High OR 1.10 (0.97,1.26) Females High OR 0.98 (0.91,1.06)	Lower odds of hip fracture among both men and women residing in areas with lower compared with high social status No association between parish-level economic deprivation and hip fracture in men or women

OR – odds ratio; ref – reference category

3.4.5. Individual-level SEP and area-based deprivation and the incidence of major osteoporotic fracture

Six studies assessed the relationship between social disadvantage and MOF incidence (50, 262, 263, 267, 273, 285), of which three were conducted in Canada or the USA (262, 263, 273). There was considerable heterogeneity in the measure used; one study used individual-level income, three studies were based on area-based income and the remaining two studies used country-specific indices of deprivation (Table 15).

A large population-based, age- and sex-matched case-control study conducted by Hansen et al showed that, among men and women in Denmark, individuals in the highest income quintile had lower adjusted odds of humerus and wrist fractures compared to those in the average income group (267).

Two of the three studies using area-based income were conducted in Manitoba province, Canada, although in different fracture populations (262, 273). Both studies measured income at the level of DAs (262). An inverse association between mean household income and MOF risk was observed among women aged 50+ years who underwent routine clinical femoral neck BMD measurement between 1996 and 2011 (262). A further study conducted by Brennan et al (2000-2007) reported that higher mean household income was associated with lower age-adjusted risk of MOF in both men and women (273). When stratified by fracture type, in men, this pattern was observed for vertebral, forearm and humerus fractures. Whilst in women, an association between mean household income and fracture risk was only observed for forearm fractures, and the strength of this association was weaker than for men. Further analyses stratified by age group (in 5-yearly intervals) showed that higher income was associated with lower MOF risk in both men and women below the age of 80 years. Taylor et al showed, among a retrospective sample of male and female US Medicare beneficiaries, that higher median household income (based on census block groups with an average population size of 600 to 3,000 people (289)) was associated with lower adjusted incidence of vertebral, forearm and humerus fractures (263).

Using the IMD score (described in Chapter 2.5.3, page 64), Curtis et al found that, in men and women combined, vertebral and wrist fracture risk was not associated with greater deprivation; however, contrasting findings were observed when analyses were stratified by gender (50). Whilst in men, vertebral fracture risk was higher among those in the most deprived compared with least deprived quintile, the reverse pattern was seen among women, possibly explained by the lack of adjustment for age in this study. Deprivation was not found to be associated with wrist fracture risk in men or women. Brennan and colleagues used the IRSD (described earlier in section 3.4.4, page 104) to examine the association between area-based deprivation and MOF risk in southeast Australia (285). MOF incidence was 2.6 times higher among individuals in the most deprived compared with least deprived quintile after indirect standardisation for age and gender. When analyses were stratified by gender, stronger associations were observed in men than women, although the study authors do not state whether they formally tested for an interaction between gender and deprivation. The standardised fracture ratio was 4.3 times higher for men and 2.5 times for women in the most deprived versus least deprived quintile (285).

Table 15: Summary of findings reported by studies examining the association between *individual-level SEP or area-based deprivation* and *MOF risk*

Author, year (country)	Measurement of exposure (geographical unit)	Ascertainment of outcome	Main findings presented for MOF	Summary
Individual-level measures				
Hansen, 2018 (267) (Denmark)	Individual income on latest annual tax return before fracture (Danish Kroner)	National hospital inpatient and outpatient register	Ref – Q3 (average income) *Humerus fracture* Q5 OR 0.85 (0.80,0.91) *Wrist fracture* Q5 OR 0.95 (0.91,0.99)	Reduced odds of humerus fracture among individuals in highest versus average income group; no association observed for wrist fractures
Area-based measures				
Brennan, 2014 (262) (Canada)	Mean annual household income (dissemination areas)	Hospital discharge records and physician billing claims	Ref – Q5 (highest income group) Q1 HR 1.28 (1.15,1.42)	Higher MOF risk among women residing in low versus high income areas
Brennan, 2015 (273) (Canada)	Mean annual household income (dissemination areas)	Administrative health data repository	Ref – Q5 (Canadian $101,076) *Males (Q1 Canadian $34,355)* Humerus RR 1.65 (1.28,2.13) Spine RR 1.97 (1.59,2.43) Forearm RR 1.41 (1.23,1.62) *Females (Q1 Canadian $34,355)* Forearm RR 1.09 (1.01,1.17)	Lower area-based income associated with higher risk of humerus, spine and forearm fractures in men, and forearm fractures in women
Taylor 2011, (263) (USA)	Median household income obtained from national census data (census block groups)	Medicare HI claims database	Ref – US$ 0-30,000 Highest income group (US 75,000+) Humerus IRR 0.86 (0.81,0.92) Spine IRR 0.89 (0.85,0.93) Wrist IRR 0.92 (0.87,0.97)	Higher area-based income associated with lower incidence of humerus, spine and forearm fractures

Table 15: Summary of findings reported by studies examining the association between *individual-level SEP or area-based deprivation* and *MOF risk* (contd.)

Author, year (country)	**Measurement of exposure (geographical unit)**	**Ascertainment of outcome**	**Main findings presented for MOF**	**Summary**
Country-specific indices				
Curtis, 2016 (50) (UK)	National statistics database (IMD – LSOAs)	Primary care electronic medical records database	Ref – Q1 (least deprived) *Spine (Q5)* Overall RR 0.95 (0.88,1.02) Males RR 1.18 (1.04,1.34) Females RR 0.86 (0.79,0.94) *Wrist (Q5)* Overall RR 0.98 (0.95,1.02) Males RR 1.08 (0.98,1.18) Females RR 0.96 (0.93,1.00)	No overall association between deprivation and vertebral or wrist fracture risk Higher vertebral fracture risk among most deprived men, whilst lower risk in most deprived women No association between deprivation and wrist fracture risk in men or women
Brennan, 2015 (285) (Australia)	National statistics database (IRSD – CCD)	Hospital medical records and radiological reports	Ref – Q5 (least deprived) *Incidence rate (per 1,000 person-years) (Q1)* Overall Q1 22.4; Q5 8.6 Males Q1 22.8; Q5 5.3 Females Q1 29.3; Q5 11.7 *SFR (Q1)* Overall 2.6 (2.4,2.8) Males 4.3 (3.9,4.7) Females 2.5 (2.2,2.8)	Higher MOF incidence among most deprived individuals; stronger associations observed in men than women

CCD – census collection district; IMD – Index of Multiple Deprivation; IRSD – Index of Relative Social Disadvantage; LSOA – lower super output area; MOF – major osteoporotic fracture; RR – relative risk; SFR – standardised fracture ratio; ref – reference category

3.4.6. Methodological quality

As described earlier in section 3.3.5, the methodological quality of ecological studies was not assessed as part of this review given that a widely accepted quality appraisal tool does not exist for this study design. Therefore, the results presented below relate to cohort, case-control and cross-sectional studies included in this review.

Two-thirds of studies were deemed to be of good quality, largely on account of methodologically well-designed cohort and cross-sectional studies. Total and domain-specific quality scores according to study design are summarised in Table 16 below. For all observational study designs, the maximum quality score across the three assessment domains was 9. Total scores for the four cohort studies included in this review ranged from 7 to 9, and for the seven case-control studies, methodological quality was more variable, ranging from 2 to 9. Five case-control studies were judged to be of poor or moderate quality mainly due to limited information provided on the methods used to select cases and controls, and to define study exposures. Most cross-sectional studies were scored 8 or 9. Variability in quality scores for cross-sectional studies, particularly the two moderate quality studies, was largely due to lack of adjustment for important confounders such as age and gender.

Table 16: Summary of methodological quality assessment of observational studies included in this review

Author, year	Selection (max. score 4)	Comparability (max. score 2)	Outcome[a] (max. score 3)	Total score (max. score 9)
Cohort				
Benetou, 2015 (261)	4	2	2	**8**
Brennan, 2014 (262)	4	2	3	**9**
Taylor, 2011 (263)	4	2	3	**9**
Wilson, 2006 (264)	4	2	1	**7**
Case-control				
Cano, 1993 (265)	0	1	1	**2**
Chen, 2018 (259)	3	0	1	**4**
Farahmand, 2000 (266)	3	2	3	**8**
Hansen, 2018 (267)	4	2	3	**9**
Meyer, 1995 (268)	3	2	1	**6**
Peel, 2007 (269)	1	2	1	**4**
Suen, 1998 (270)	1	2	2	**5**
Cross-sectional				
Bacon 2000 (271)	4	1	3	**8**
Brennan, 2011 (272)	4	2	3	**9**
Brennan, 2015 (25)	4	1	3	**8**
Brennan, 2015 (26)	4	1	3	**8**
Curtis, 2016 (50)	4	2	3	**9**
Guilley, 2011 (274)	4	1	3	**8**
Hokby, 2003 (275)	4	1	3	**8**
Maharlouei, 2014	4	0	2	**6**
Quah, 2011 (277)	4	0	3	**7**
Reimers, 2007 (278)	4	2	3	**9**
Smith, 2013 (21)	4	1	3	**8**
Zingmond, 2006 (279)	4	2	3	**9**

[a]Exposure for case-control studies

Table legend

	Total score	Quality assessment
(red)	0-3	Poor
(amber)	4-6	Moderate
(green)	7-9	Good

3.5. Summary

There is a growing evidence base examining the effect of deprivation on fragility fracture risk as demonstrated by the number of studies published on this subject over the last decade. Twenty-eight studies were identified that met the inclusion criteria for this review, of which more than half used an area-based measure to define deprivation. The majority of studies were conducted in high-income countries and therefore the findings of this review are not generalisable to fracture populations in low- and middle-income countries with differing societal structures and healthcare systems. Most studies were conducted among hip fracture populations, with comparatively less known about the relationship between deprivation and incidence of MOFs.

Overall, greater socioeconomic deprivation is associated with higher incidence of hip fractures; however, the magnitude of this association depends on the specific individual-level and/or area-based exposure used to measure deprivation. In general, individual-level education and income, and area-based income and composite indices of deprivation were all shown to be predictors of hip fracture incidence. There is some suggestion that greater deprivation is associated with higher incidence of MOFs, albeit based on a limited number of studies that used different exposures to measure deprivation.

Several themes emerged from this systematic review relating to three key methodological areas: measurement of study exposure, ascertainment of study outcome and the study design employed. Each of these methodological factors are discussed further below.

3.5.1. Study exposure – measurement of deprivation

Studies identified as part of this review defined social disadvantage using a broad range of measures. Commonly used measures of individual-level SEP and area-based deprivation have been discussed in Chapter 2. Whilst Lynch and Kaplan suggest that the choice of indicator should be determined by the hypothesised relationship between SEP and health (147), it is likely that country context, including acceptability of measure, and data availability also influence the indicator selected. Studies conducted in Canada and the USA primarily used area-based income, whilst all UK studies used a national composite index of deprivation (described further in Chapter 2.5, page 61). Unsurprisingly, studies using area-based measures of deprivation were derived from routinely collected national data sources such as census databases, except for one moderate-quality study by Maharlouei et al that provided no description of the methods used to define deprivation (276). There was greater variability in the methods used to measure individual-level SEP that was largely determined by the type of exposure studied and country context. All studies assessed educational status using self-reported information, except for one study by Farahmand et al that also used national census data (266). In general, for the remaining individual-level exposures, information was obtained from national databases in countries with well-established national registries such as Denmark and Sweden, and through self-report from questionnaires or interviews in other countries.

As discussed in Chapter 2.4, different individual-level exposures may be better measures of SEP at different stages of the life course (see page 59). Education is a measure of early life SEP that is usually completed by early adulthood, whilst occupation and income are likely to vary across the life course (154). Whilst education influences occupational status and thus income level (170), the correlation between education and income is not strong enough for them to be considered appropriate proxy measures for each other (178). Rather, Davey Smith et al highlight the importance of measuring SEP at different stages of the life course to fully capture the effect of SEP on health (180). All studies included in this review used individual-level or area-based exposures measured at a single time point, and thus it cannot be determined whether variation in deprivation status across the life course influences fracture risk as populations age.

Whilst some studies used the same measure to define social disadvantage, different categorisations were then used between studies, thus limiting comparability of study findings. Studies examining the effect of education on fracture risk either measured the number of years in education or level of educational attainment. The choice of categorisation is likely to be determined by societal and cultural norms in different countries. Chen et al studied the relationship between education and hip fracture risk among postmenopausal women in Taiwan, defining education according to the following three categories: unschooled, primary school and secondary or higher education (259). The selection of an unschooled category may reflect historical periods during which universal access to education was not available in Taiwan. In contrast, elementary schooling was the lowest level of education for analyses conducted by Farahmand et al among postmenopausal women in Sweden (266).

Studies measured income at either the level of individuals (based on personal or household income) or geographical areas, or using health insurance status as a proxy measure. Whilst many income-based studies were conducted in the USA, it was not possible to compare absolute incomes across studies owing to differences in the income ranges and categorisations used (263, 271). Bacon et al studied a nationally-representative sample of US individuals surveyed between 1989 and 1991 among whom area-based income ranged from less than US$20,000 to $40,000+ (271), whilst Taylor et al conducted a retrospective cohort study among a 5% random sample of Medicare beneficiaries (2000-2005) in which area-based income was categorised into groups that ranged from less than US$30,000 to $75,000+ (263). The different income ranges across this approximately 15-year period may reflect differences in purchasing power over time. Studies conducted in other country contexts measured income based on their local currency that included Canadian dollars, Danish kroner and Swiss francs. The categorisation of income data into tertiles or quintiles allowed assessment of relative differences in hip fracture risk between the highest and lowest income groups for example. Income data can also be standardised to an international equivalent such as US dollars; however, variable exchange rates and country-level differences in living standards need to be considered when interpreting such data.

Similar patterns were observed for area-based measures, with considerable heterogeneity in the measures used to define deprivation that included country-specific indices and other constructs of deprivation. The domains and specific indicators used to construct area-based measures are likely to be context-specific and therefore may not be strictly comparable across studies owing to the assessment of different aspects of socioeconomic deprivation relevant to the local area. Country-specific composite indices were used to measure deprivation in Australian and UK studies included in this review. The IMD is a multidimensional measure of relative deprivation that is based on thirty-eight indicators (see Chapter 2.5.3, page 64). The Australian IRSD is also an aggregate measure of relative disadvantage that it is based on a more limited number of indicators across multiple domains. The IRSD is comprised of sixteen indicators across domains that includes health and disability, employment, income and housing (290).

3.5.2. Study outcome – ascertainment of fragility fractures

All studies included in this review identified cases of fragility fracture from primary care databases, hospital discharge registers or hospital medical records, except for two studies that used self-reported data (261, 264). Administrative databases have been shown to be a valid method for identifying fractures. Hudson et al systematically reviewed studies conducted in Canada, Finland, the UK and USA reporting that hip fractures were ascertained with good sensitivity and specificity using hospital admission data (n=7 studies) (292). Although based on fewer studies than for hip fractures, it was found that vertebral fractures were difficult to identify from hospital admission or outpatient data (n=2 studies) but fractures not requiring hospital admission such as wrist and humerus fractures could be identified from outpatient data in combination with procedures codes (n=2 studies) (292).

The two studies that used self-reported information to identify fracture cases may have introduced misclassification bias if individuals inaccurately reported their fracture status, although this proportion is likely to be small given that fracture occurrence is a definitive outcome. The SOF study, a large prospective cohort study conducted among community-dwelling older women in the USA that has been described in Chapter 1.6.1, page 25, found that the accuracy of self-reported fractures of the hip, wrist and humerus was good when compared with medical records and radiology reports; false-positive rates ranged from 5% for shoulder fractures to 11% for hip fractures (293).

3.5.3. Study design

Of the twenty-eight studies included in this review, thirteen were cross-sectional studies. Although cross-sectional studies are relatively quick and easy to conduct, it is not possible to determine causality because exposure, outcome and confounder variables are all measured at the same time (294). Whilst this is not an issue for certain measures such as educational level that are established in earlier life, this may introduce bias for area-based measures if individuals at high risk of fracture move to a different area prior to the occurrence of fracture, for example, to live with relatives or move into a care home. Seven of the included studies were case-control in design. In case-control studies, study participants are selected based on the presence or absence of fracture, and information on the study exposure is obtained retrospectively, thus introducing the potential for recall bias (294); however, this may not be an issue for measures such as educational level, as described above. Although time-consuming and expensive to conduct, cohort studies provide stronger evidence for causality, particularly prospective cohort studies, because one or more study exposures are measured at baseline (i.e. prior to fracture occurrence), thus allowing the temporal sequence of events to be determined (294). However, they are still prone to confounding and other biases due to selection. Differential loss to follow-up of exposed and unexposed groups can introduce attrition bias in cohort studies (294). Five ecological studies were identified as part of this review. Whilst ecological studies utilising routinely collected data are cheap and easy to conduct (295), they are prone to ecological fallacy such that associations observed at the area-level may not describe associations among individuals (296).

3.6. Conclusion

This systematic review has highlighted that greater social disadvantage, measured using individual-level and area-based exposures, predicts higher incidence of fragility fractures; however, there has been considerable variability across studies in the methods used to define social disadvantage thus limiting comparability of study findings. Whilst the derivation and use of a standardised measure would help address this problem, this is likely to be a challenging task given that meaningful social stratifications differ according to country context and study populations. Of less certainty is whether the association between deprivation and fragility fracture risk is the same in men and women, or differs according to gender as some studies have suggested a stronger effect in men whilst others in women.

It is evident from this review that limited national studies have examined the relationship between social disadvantage and hip fracture incidence among older adults in England, according to gender, and taken account of potential confounding by age. The following chapters of this thesis, analysing routinely collected hospital administrative data, examine the effect of area-based deprivation on hip fracture incidence among older adults in England, and assess whether this relationship differs among men and women. Subsequent chapters build upon these analyses by examining the effect of deprivation on clinical outcomes after hip fracture.

CHAPTER 4. AIMS OF THE HIP FRACTURE INCIDENCE AND OUTCOMES STUDIES

4.1. Summary

Hip fractures are an important public health problem. Approximately 60,000 hip fractures occur annually in England (30). Hip fractures are associated with significant morbidity and mortality (84, 297, 298), and have a considerable financial impact upon healthcare systems (31).

Previous studies have shown that greater deprivation is associated with higher hip fracture incidence in many high-income countries, including the UK (21, 50, 271-273, 277, 279) (see Chapter 3). Over the last two decades, age-standardised hip fracture incidence has plateaued or declined in high-income countries (15, 16, 20-22, 25). Analysis of UK primary care data has shown that considerable regional variation in hip fracture incidence exists in England, with the lowest rates observed in London and highest in the South West (50). It is however not known whether the relationship between deprivation and hip fracture incidence has changed over the last two decades, and whether regional inequalities in hip fracture incidence exist across England.

Hip fractures are associated with reduced survival, greater need for hospital readmission and longer hospital stays, as described in Chapter 1.8, page 33. Whilst it is known that greater deprivation is associated with higher mortality after hip fracture (20, 21, 83, 299-302), few studies have examined the effect of deprivation on hospital readmission and acute hospital LOS. Several risk factors are known to predict poor clinical outcomes after sustaining a hip fracture, including male gender, older age and comorbidity (91, 92, 101, 102); however, it is not known whether the relationship between deprivation and clinical outcomes after hip fracture differs according to patient characteristics.

4.2. Study aims

The overall aim of this research is to describe social and regional inequalities in hip fracture incidence and outcomes among older men and women in England, with the aim of informing national policy initiatives that aim to prevent hip fractures and improve hip fracture care.

The specific aims of the deprivation and hip fracture incidence study are:

1. To examine the effect of area-based social deprivation on hip fracture incidence (Chapter 7)
2. To assess whether secular trends in hip fracture incidence differ by levels of deprivation (Chapter 7)
3. To examine the effect of deprivation on hip fracture incidence between and within geographic regions in England (Chapter 8)

The specific aims of the deprivation and hip fracture outcomes study are:

1. To examine the effect of area-based social deprivation on mortality in the year after hip fracture (Chapter 9)
2. To investigate the impact of deprivation on healthcare utilisation in the year after hip fracture (Chapter 10)
3. To assess whether the relationship between deprivation and clinical outcomes post-hip fracture differs according to patient characteristics (Chapters 9 and 10)

CHAPTER 5. METHODS – THE EFFECT OF DEPRIVATION ON HIP FRACTURE INCIDENCE

This chapter describes the methods used to examine the effect of deprivation on hip fracture incidence, and across geographic regions in England, over a 14-year period. Hospital Episode Statistics (HES) Admitted Patient Care (APC) data extracts were obtained from the Department of Population Health Sciences (PHS), University of Bristol (UoB) that included hospital admissions for hip fracture to English NHS hospitals between 2001 and 2014. These HES APC data, together with Office for National Statistics (ONS) mid-year population estimates (MYPE) for England for years 2001 to 2014, were used to calculate hip fracture incidence rates for men and women aged 50+ years residing in England. The methods used to generate the HES APC and ONS MYPE datasets for analysis are described in detail below.

5.1. Hospital Episode Statistics

5.1.1. Background

HES is an administrative database of routinely collected data on all hospital care delivered by NHS hospitals in England, including attendances to an ED, hospital admissions and outpatient appointments (303). NHS healthcare providers submit patient-level data to NHS Digital for processing, and information relating to payment for activity undertaken is used to pay hospitals for the care they deliver. HES data are validated and cleaned prior to being made available for ‘secondary uses’ not directly related to patient care, including research (304). NHS Digital are the health and social care information and data providers for England (305).

5.1.2. Purpose of HES data collection

Hospital administrative data are primarily used as a mechanism by which hospitals can be reimbursed for the care they provide, known as payment by results (306). NHS hospital providers are paid a standard national tariff for each patient treated, that takes account of patient complexity and is adjusted for differences in the cost of healthcare provision across the country, by applying the market forces factor (306).

Secondary uses of HES data include for healthcare research, planning of local healthcare services, monitoring trends in hospital care provision and assessing secular trends in disease burden (303). HES data are increasingly being used for research purposes; a systematic review identified 2 publications in 1993 that analysed HES APC data (307), whilst a PubMed search demonstrated that this had increased to 88 in 2015 (308). HES data have primarily been used to examine inequalities or trends in treatments and outcomes; other research uses of HES data include studying the epidemiology of disease and the coding quality of HES data (307). Access to HES data for research purposes are made using the Data Access Request Service (309), which is responsible for providing patient-level data to organisations that meet information governance criteria, and are subject to approval from the Health Research Authority’s Confidential Advisory Group and Research Ethics Committee (310, 311).

5.1.3. Data collection by NHS Digital

Hospital trusts collect patient-level administrative and clinical data for the purpose of patient care, which are submitted to a national data repository called the Secondary Uses Service (SUS) (304). Raw HES data are extracted from SUS each month during a financial year and the cumulative HES extracts thus generated reflect data submitted to SUS up to the month of data collection. The ‘Annual Refresh’ is used to generate a Month 13 data extract that allows hospital trusts to review their data submissions for the past financial year and make any necessary amendments. Whilst hospital providers can amend episodes of care already submitted if additional data become available, these changes will not be reflected in the final HES data extract for the financial year, which is finalised after the Annual Refresh.

5.1.4. Data processing by NHS Digital

NHS Digital undertake data quality checks prior to, during and post-submission to SUS (312). Pre-submission checks include using a standard dataset structure to submit hospital activity data to SUS and preferred values for each data field to ensure consistency and quality of data. Validation checks are performed when data are submitted to SUS and the dataset is only accepted if all validation checks are met. Following submission, the HES data extract is validated, cleaned and additional data fields are derived. Post-submission data processing involves ensuring the correct entry of provider codes, removing duplicate records submitted to SUS, and conducting data cleaning and derivation steps. Final consistency checks are undertaken to ensure that the amount of data received from hospital providers is within the expected range and to identify any issues with the completion of data fields.

5.1.5. HES APC data coverage

HES APC data captures information on all NHS hospital admissions in England (313, 314); this includes care provided to NHS patients, privately-financed patients treated in NHS hospitals, patients ordinarily resident outside of England and NHS patients treated in the independent sector (303). Whilst HES does not capture information on hospital activity in the private sector, the majority of hospital care delivered in England is funded by the NHS (315).

HES data extracts cover the financial year period 1st April to 31st March and are generated based on the financial year in which hospital discharge occurred. HES records include information on patient demographics, socioeconomic status, clinical diagnoses and procedures, details relating to the hospital admission, and information on patient-level geography and hospital provider (316). Clinical diagnoses are classified based on the ICD-10 coding system and procedures using the OPCS Classification of Interventions and Procedures version 4 (314).

5.1.6. Structure of HES APC data

Each row in the HES APC database describes a period of care provided under an individual consultant, known as a ‘finished consultant episode’ (FCE). HES data extracts are based on FCEs as opposed to unfinished hospital episodes; the latter represents ongoing hospital care provision on the final date of the financial year and does not include relevant clinical information (314).

A hospital provider spell (or hospital admission) represents the total length of stay in a single NHS trust and includes transfers between several hospitals or sites within a single NHS trust. There may be one or more FCEs during a hospital admission if a patient's care is transferred between hospital consultants (317). A hospital spell ends when a patient is discharged from hospital, transferred to another hospital provider or dies during the hospital admission. Continuous inpatient spells are defined as the overall time spent in continuous NHS care; they are comprised of one or more hospital provider spells and thus include transfers of care between different hospital providers (317).

Figure 4 below describes the care pathway of a hip fracture patient and how this relates to the structure of HES data.

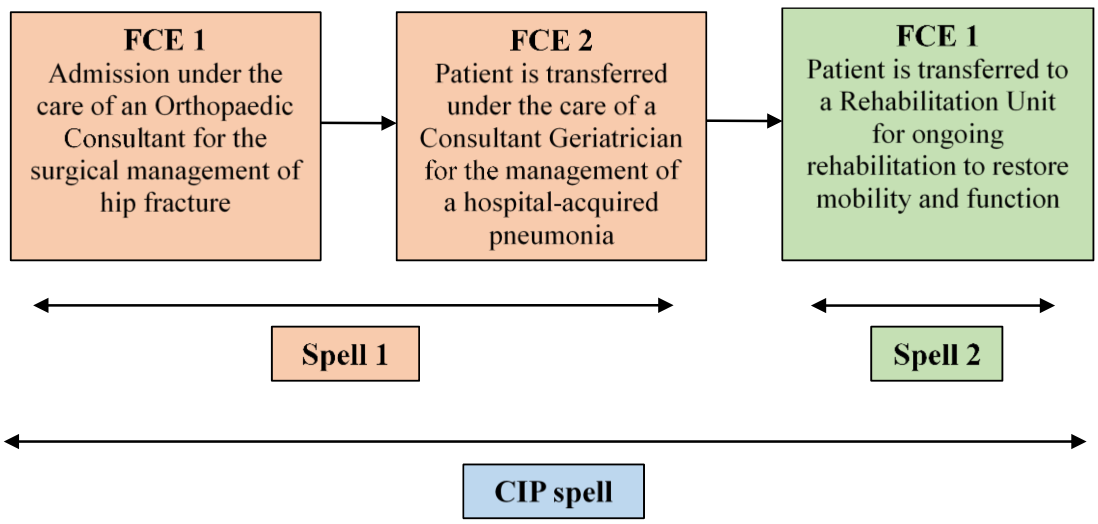

Figure 4: Structure of HES data (FCE – finished consultant episode; spell – hospital provider spell; CIP - continuous inpatient spell)

5.1.7. HESID

A unique alphanumeric patient identifier, referred to as the HES patient ID (HESID), is assigned to each patient in the HES database. The HESID can be used to generate hospital provider spells, identify emergency readmissions, and link HES data across multiple financial years and to other data sources without identifying the patient (318).

5.2. HES data cleaning for hip fracture incidence study

5.2.1. Data extracts

Two anonymised, patient-level extracts of HES APC data were obtained from the Department of PHS, UoB. The first data extract was obtained at the start of my PhD, whilst the second extract captured more recent HES APC data that became available during my PhD. The second data extract included only the most recent ten years of available HES APC data due to changes in NHS Digital data access criteria. The two data extracts were cleaned and appended to generate a single dataset for analysis, as discussed in detail below.

Data were extracted for patients admitted for hip fracture to an English NHS hospital between 1st April 2000 and 31st March 2012 (subsequently referred to as the '2000 APC dataset') and between 1st April 2005 and 31st March 2014 (subsequently referred to as the '2005 APC dataset'). Both datasets included all-cause hospital admissions during the year after the index (first) hip fracture admission; however, only the 2005 APC dataset included all-cause hospital admissions that occurred during the preceding five years and was used to identify comorbidity among this hip fracture population (see section 5.3.6, page 152).

5.2.2. Variables and dates

The 2000 APC dataset included 656,387 hip fracture patients admitted to hospital over the period 2000 to 2011 and the 2005 APC dataset included hospital admissions for 599,926 hip fracture patients for the period 2005 to 2014.

Firstly, the key variables of interest were extracted that included patient demographics, details of the period of care, area-based measures of deprivation and clinical information (Table 17). Secondly, date variables relating to the period of hospital care were converted from string to date format (i.e. date of hospital admission and discharge, and start and end date of hospital episodes). No patients were identified in either the 2000 APC or 2005 APC datasets for whom the date of admission or discharge was recorded as missing or unknown.

Table 17: Variables extracted from HES APC 2000 and 2005 data extracts

Category	HES variables
Patient identifier	HES unique patient identifier (HESID)
Patient demographics	Age on admission, gender
Period of care	Admission date, discharge date, method of discharge, discharge destination Episode status, episode key, episode start date, episode end date
Clinical diagnosis	Primary diagnosis and up to 20 secondary diagnosis fields containing ICD-10 diagnosis codes
Deprivation	IMD overall score, rank and decile IMD scores for each of the 7 domains of deprivation: income, crime, education, employment, health and disability, housing and services, living environment
Geography	Government Office Region of residence, 2001 LSOA, 2011 LSOA

ICD-10 – International Classification of Diseases version 10; IMD – Index of Multiple Deprivation; LSOA – Lower Super Output Area

5.2.3. Validity of HES data for hip fracture case ascertainment

Administrative databases have been widely used for case ascertainment of disease, including hip fractures, and shown to be a valid method for identifying hip fractures. Hudson et al identified twelve studies that examined the validity of administrative databases for hip fracture ascertainment (292). Hip fractures were identified with good sensitivity and specificity from hospital admission data; however, this was improved further with the inclusion of outpatient data and procedural codes.

In the UK, HES has been widely used to conduct population-based studies among individuals with a hip fracture (20-22). Neuburger and Cromwell showed, using HES APC data and local fracture liaison service databases for two NHS trusts, that there was a high level of agreement in hip fracture numbers between both databases suggesting that HES is a valid method for identifying hip fracture cases (319).

5.2.4. Index hospital admissions for hip fracture

In HES, clinical diagnoses are recorded in up to 20 diagnosis fields using the first four alphanumeric characters of ICD-10 codes. Hip fractures were defined using ICD-10 codes for fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1), and subtrochanteric fracture (S72.2). A hip fracture ICD-10 code recorded in the primary diagnosis field usually represents the primary reason for admission, whilst secondary diagnosis codes typically capture a prior occurrence of hip fracture. Index hip fracture admissions were identified using the primary diagnosis field in any episode of the hospital admission in this study, thus allowing in-hospital fractures to be captured. The NHFD reported that 4.1% of all hip fractures that occurred in England, Wales and Northern Ireland in 2016 were among hospital inpatients (30). In HES, it is difficult to differentiate between two separate fracture events occurring at the same anatomical site (i.e. laterality of fracture is not specified) and therefore, to avoid double-counting, analyses were restricted to the index hip fracture admission (i.e. the first occurrence of hip fracture).

Different methodological approaches had been used to identify the cohort of hip fracture patients in the 2000 APC and 2005 APC datasets. The 2000 APC hip fracture cohort had been generated by identifying index hospital admissions with a hip fracture ICD-10 code recorded in the *primary diagnosis field* of a hospital episode, whilst the 2005 APC dataset had been generated by identifying hip fracture ICD-10 codes recorded in *any diagnosis field* of a hospital episode. To ensure consistency across both datasets and identify patients for whom the primary reason for admission was hip fracture, the 2005 APC dataset was similarly restricted to index admissions with a hip fracture ICD-10 code recorded in the primary diagnosis field (22,332 patients were excluded).

Both the 2000 APC and 2005 APC datasets included all-cause hospital admissions that occurred within one year of the index hip fracture admission. One-year follow-up data were not required for these analyses and therefore index hospital admissions for hip fracture that occurred up to and including 31st March 2015 were included as part of these analyses.

5.2.5. Final dataset for analysis

Both the 2000 APC and 2005 APC datasets were restricted to the first hospital episode of the index hip fracture admission i.e. included one row of observation per hip fracture patient. The 2000 APC dataset included 656,387 hip fracture patients admitted over the period 2000 and 2011, whilst the 2005 APC dataset included 577,974 hip fracture patients admitted between 2005 and 2014. Both datasets were appended to generate a final dataset that consisted of 1,234,361 hip fracture patients. The appended dataset was restricted to 832,940 patients with an index hospital admission for hip fracture, that is patients with either a duplicate index hip fracture admission or two different index admissions were excluded (Figure 5).

Duplicate hip fracture admissions refer to the same index admission being identified in both datasets due to an overlap in hospital admission data for the period 1st April 2005 to 31st March 2012. For patients with duplicate hip fracture admissions, the 2005 APC hospital admission was included in the final dataset for analysis so as to capture derived comorbidity data. Two index hip fracture admissions were captured in the appended dataset if a hip fracture patient was first admitted between 1st April 2000 and 31st March 2005 and again between 1st April 2012 and 31st March 2015 (i.e. time periods over which the two datasets did not overlap) in which case the earliest of the two index hip fracture admissions was included in the final dataset for analysis.

The final dataset consisted of male and female English residents aged 50+ years admitted to hospital with a hip fracture or who sustained a hip fracture during a hospital admission between 1st April 2001 and 31st March 2015. ONS MYPE for England were available from 2001 onwards and therefore hip fracture patients admitted between 1st April 2000 and 31st March 2001 were excluded (n=53,566 patients). Hip fracture admissions among non-English residents were excluded (n=5,974 patients), which included patient's resident in Scotland, Wales, Northern Ireland, overseas residents and those with no fixed address. Hip fracture admissions among infants or individuals below the age of 50 years were excluded (n=21,364 patients) because hip fractures occurring among patients under the age of 50 years are primarily due to high-impact trauma (254). The dataset was restricted to hip fracture patients with non-missing data for age, sex, deprivation or Government Office Region (GOR) of residence (n=4,667 patients excluded); patients may have had missing values for one or more criteria. Table 18 demonstrates the level of missing data for each of these four variables.

The flow diagram below summarises the data cleaning steps employed to generate the final cohort of hip fracture patients for these analyses (Figure 5).

Table 18: Level of missing data for key study variables among patients aged 50+ years admitted to hospital with a hip fracture between 1st April 2001 and 31st March 2015

Variable	**N (%)**
Age	1,078 (<0.01%)
Gender	143 (<0.01%)
Deprivation	4,220 (0.56%)
GOR of residence	3,413 (0.45%)
Total	752,036

GOR – Government Office Region

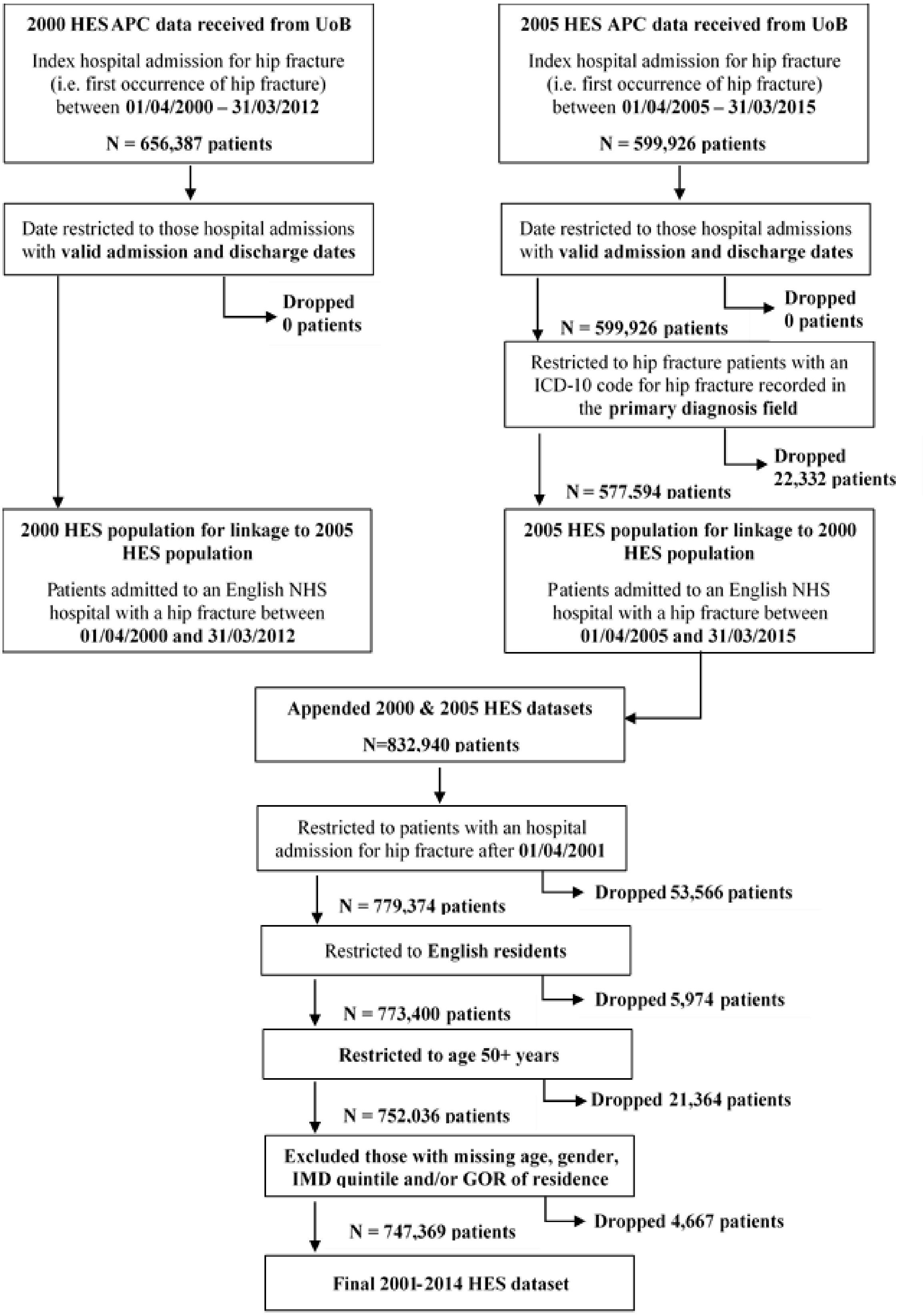

Figure 5: Flow diagram describing the process undertaken to generate the index hip fracture population

5.3. HES study variables

HES variables were derived for the study exposure (deprivation) and other study covariates (age, gender, comorbidity and geographic region of residence).

5.3.1. Missing data

Several methods are available for the handling of missing data; missing observations can be replaced with values imputed from an observed set of data or with the last measured observation carried forward (LOCF) (320, 321). Multiple imputation is a statistical method for the handling of missing data that involves *"creating several different plausible imputed data sets and appropriately combining results obtained from each of them"* (320). The LOCF method, unlike multiple imputation, does not take account of the uncertainty about the imputed missing data and therefore may introduce bias (320). The LOCF method was considered to be a suitable approach for these analyses that aimed to capture patient demographic information as recorded upon admission to hospital.

Hospital episodes with missing data for age, gender, geographic region or deprivation that constituted an index hip fracture admission were identified and non-missing data were extracted from the next hospital episode of the same index hip fracture admission. For example, if patient age was recorded as missing in the first hospital episode of the index hip fracture admission but a valid observation was entered for the second episode then the variable for age group was derived from the second episode. This process was repeated for each of the HES study variables described below.

5.3.2. Deprivation

The HES database includes data fields for the IMD, an area-based measure of deprivation that has been described in detail in Chapter 2.5.3, page 64. The IMD was used to measure an individual's level of socioeconomic deprivation. The HES database includes data fields for the overall IMD score, rank and decile as well as the score and rank for individual domains of deprivation (316).

HES IMD data fields are assigned based on a patients LSOA of residence, which is derived from the postcode recorded in the HES home address field. HES uses different versions of the IMD that have been published at sequential time points to measure deprivation in England. The IMD 2004 version was used for financial years 2001/02 to 2006/07 in HES; the IMD 2007 version was used for financial years 2007/08 to 2009/10; and the IMD 2010 version was used for financial years 2010/11 to 2014/15 (316).

The IMD rank for a patient's LSOA was used to categorise patients into quintiles based upon the national ranking of LSOAs, with quintile 1 being the least deprived group and quintile 5 being the most deprived group (Table 19). An overall IMD rank of 1 represents the most deprived LSOA in England, whereas a rank of 32,482 is assigned to the least deprived LSOA. IMD quintiles were further categorised into a three-level ordinal variable that was used to assess secular changes in hip fracture incidence among the extreme groups of deprivation (Table 19).

Table 19: IMD ranks used to derive variables for IMD quintile

IMD rank	IMD quintile	Re-categorisation of IMD quintile
25987 to 32482	Q1 (least deprived)	Q1 (least deprived)
19490 to 25986 12994 to 19489 6497 to 12993	Q2 Q3 Q4	Q2-Q4
1 to 6496	Q5 (most deprived)	Q5 (most deprived)

5.3.3. Age

The HES variable *startage* denotes the age of a patient at the start of a hospital episode in whole years (316). The distribution of patient age as a continuous variable was assessed using a histogram and found to be approximately normally-distributed (Figure 6).

ONS MYPE data for age was only available in 5-yearly intervals at the LSOA level and therefore, for consistency, HES patient age was also categorised in 5-yearly intervals. Patient age was further binarised for the age-stratified analyses presented in Chapter 7. The median age of the hip fracture population was 83 years (inter-quartile range (IQR) 77-88) and therefore, the study population was divided into those aged 50-84 years and 85+ years.

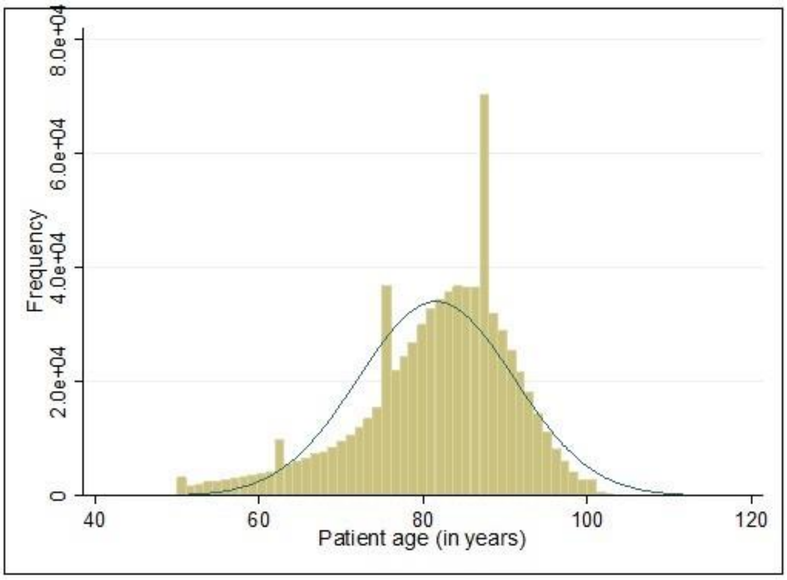

Figure 6: Histogram describing the age distribution of men and women aged 50+ years admitted to hospital with a hip fracture between 1st April 2001 and 31st March 2015

5.3.4. Gender

The HES variable *sex* was recoded as 0 and 1 for males and females respectively; patients for whom sex was unknown were recoded as missing.

5.3.5. Government Office Region of residence

In 1996, the ONS introduced GORs as the main classification system for the reporting of regional statistics in England (322). GORs are defined based on 9-character codes with the prefix 'E' (Table 20). The HES variable *resgor* is defined as the GOR in which a patient resides based on their postcode and uses the ONS classification of GORs (316). A three-level ordinal variable for geographic region was derived from the HES *resgor* variable, and used to describe broad regional patterns in inequalities in hip fracture incidence across England (Table 20); the findings of these analyses are presented in Chapter 8.

Table 20: GOR codes and names used to derive a variable for geographic region

GOR code	GOR name	Geographic region
E12000001	North East	North
E12000002	North West	
E12000003	Yorkshire and the Humber	
E12000004	East Midlands	Midlands
E12000005	West Midlands	
E12000006	East of England	
E12000007	London	South
E12000008	South East	
E12000009	South West	

GOR – Government Office Region

5.3.6. Comorbidity

All-cause hospital admission data prior to the index hip fracture admission were only available in the 2005 APC dataset and therefore it was not possible to quantify the burden of comorbidity among the 2000 APC cohort of hip fracture patients.

Methodological approaches for measuring comorbidity

Different methods exist for the measurement of comorbidity as discussed in Chapter 2.6.4, page 68. Comorbidity can be defined as the presence or absence of specific diseases, a count of the number of comorbid diseases present for an individual and an index that takes account of the number and severity of comorbid diseases, of which the CCI is the most widely used (220). The CCI has been described in Chapter 2.6.4, page 68. In brief, the CCI is a weighted index of nineteen comorbid conditions identified from hospital records of medical patients that predicts one-year mortality (221). The CCI has been adapted for use with hospital administrative databases that record clinical diagnoses using ICD-9 and ICD-10 coding systems; however, these adaptions have been developed and validated using administrative data from Australia, Canada and the USA (222-225). The Royal College of Surgeons of England (RCS) Charlson score was used to define comorbidity as part of these analyses because it was specifically developed to identify comorbidity in adult surgical patients using English hospital administrative data (323). Armitage et al developed a modified version of the CCI that is based on comorbid conditions categorised into fourteen disease groupings. Comorbid conditions were identified from ICD-10 diagnosis codes recorded in the index admission and hospital admissions during the previous year. The RCS comorbidity score is a count of the number of recorded comorbid conditions and therefore does not take account of disease severity; however, Armitage et al showed that assigning weights to disease categories resulted in only a slight improvement to the scores ability to predict mortality (323).

Measurement of comorbidity using the RCS Charlson score

Whilst the RCS Charlson score uses one year of retrospective data to identify comorbidity, it has previously been demonstrated, using hospital administrative data for a six-year period in Western Australia, that 46.8% of comorbidity captured during the preceding five years was recorded in the index hospital admission and, as expected, greater comorbidity was identified when longer lookback periods were used (324). An exploratory analysis was therefore conducted to determine the number of years of prior hospital admission data that were required to adequately capture comorbidity in this hip fracture population, yet still permit a sufficient time period over which to conduct secular trend analyses (the results of which are presented in Chapter 7). Time period variables were generated that captured ICD-10 codes recorded in any diagnosis field of the first five episodes of a hospital admission using data recorded for the index hip fracture admission and hospital admissions in the preceding one to five years (Table 21).

Table 21: Hospital admission data captured by derived time period variables

	Time period variable				
	1-year	**2-years**	**3-years**	**4-years**	**5-years**
Index admission + 1 year prior					
Index admission + 2 years prior					
Index admission + 3 years prior					
Index admission + 4 years prior					
Index admission + 5 years prior					

Table 22 below summarises comorbidity data captured using one to five years of retrospective all-cause hospital admission data; the use of three years of retrospective data identified the majority of comorbidity recorded among this hip fracture population. The use of ICD-10 codes recorded in the index admission and hospital admissions in the preceding three years captured 74.0% of comorbidity; only an additional 0.9% of recorded comorbid conditions were captured when one extra year of retrospective hospital admission data were included. The comorbidity analyses presented in Chapter 7 were therefore restricted to the most recent seven years of HES APC data (2008/09 to 2014/15) to allow for a three-year retrospective period from which to derive comorbidities.

Table 22: RCS Charlson comorbidity data captured using up to five years of retrospective all-cause hospital admission data for patients admitted to hospital with a hip fracture between 1st April 2014 and 31st March 2015

	No. of comorbid conditions							
	0		**1**		**2**		**3**	
No. of years of retrospective data (Time period)	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
1 (2014/15 – 2013/14)	15,759	28.6	18,024	32.7	11,551	21.0	9,758	17.7
2 (2014/15 – 2012/13)	14,886	27.0	17,300	31.4	11,663	21.2	11,243	20.4
3 (2014/15 – 2011/12)	14,299	26.0	16,760	30.4	11,746	21.3	12,287	22.3
4 (2014/15 – 2010/11)	13,819	25.1	16,470	29.9	11,793	21.4	13,010	23.6
5 (2014/15 – 2009/10)	13,458	24.4	16,127	29.3	11,885	21.6	13,622	24.7

5.3.7. Time period

An ordinal variable for time period was generated for which the financial year of hip fracture admission was categorised into two-yearly intervals and used to describe patient characteristics over time, as presented in Chapter 7. The financial year of hip fracture admission was further categorised into three pooled time periods (2001-2005, 2006-2010 and 2011-2014) to allow assessment of regional inequalities in hip fracture incidence over time (the results of these analyses are presented in Chapter 8).

5.4. Office for National Statistics

5.4.1. Background

The ONS is a national statistical agency that is responsible for conducting the decennial census in England and Wales as well as collecting, analysing and publishing official statistics related to the UK's economy, population and society (325). The ONS regularly publishes national statistics for key areas such as the economy, labour market and welfare, health and social care, and population (326). Population estimates and mortality data are two key national population statistics routinely collected for England. ONS MYPE data are described below and mortality data are discussed in Chapter 6.

5.4.2. Mid-year population estimates

Annual MYPE relate to the usually resident population in England on 30th June of each year and are derived from population estimates based on the decennial census (327). Annual MYPE are generated using the cohort component method as part of which the previous year's MYPE are aged by one year. Births, deaths, net internal and international migration, and population changes among specific groups (e.g. students and members of the armed forces) are accounted for between the previous year and current year's MYPE (327).

5.5. ONS data cleaning for hip fracture incidence study

5.5.1. Data extract

Annual MYPE for England were obtained for the years 2001 to 2014 from the ONS. Population estimates were received as single year data extracts that were stratified by age categories (0 to 90+ years in 5-yearly intervals), gender, IMD 2015 quintiles and geography (32,844 LSOAs). The single year data extracts were appended to generate a dataset of MYPE for this 14-year period; the 2001-2014 ONS MYPE dataset was reshaped from wide to long format and then restricted to individuals aged 50+ years.

5.5.2. Data consistency and validation

Several data consistency and validation checks were conducted prior to data analysis. Firstly, for each year of population estimate data, ONS-generated GOR code and GOR name variables were cross-tabulated. For years 2004 and 2005, the GOR code of certain LSOAs had been labelled with the incorrect GOR name and therefore GOR code was used to derive further geographical variables. A publicly-available lookup table was used to confirm that correct GOR codes had been assigned to LSOAs in the MYPE data file received from the ONS (328).

Secondly, the ONS MYPE data file was validated against a ONS MYPE dataset held by a colleague (TJ) within the Department of PHS, UoB for the period 2005 to 2014. Population counts for the total number of men and women resident in England were consistent between both datasets; however, a discrepancy was noted when population counts were further stratified by IMD quintiles (Appendix 13.3, page 423). A publicly-available lookup table of IMD deciles to LSOAs was obtained to confirm that correct IMD quintiles had been assigned to LSOAs (328). IMD deciles were re-categorised into quintiles and cross-tabulated with the ONS-derived IMD quintile variable, which highlighted that differing methods had been used to generate IMD quintiles in both datasets.

Following correspondence with the ONS, it became apparent that the ONS had generated IMD quintiles within GORs; LSOAs within each GOR were ranked based on their IMD score weighted for the population of the LSOA within a GOR. The focus of this PhD was on relative area-based deprivation for England as a whole; the IMD deciles to LSOAs lookup table, which is based on the national IMD ranking of LSOAs, was therefore used to derive deprivation-related variables for the analyses presented in Chapters 7 and 8 of this thesis.

5.6. ONS study variables

Variables for deprivation, age, gender and GOR were derived from the 2001-2014 ONS MYPE dataset using the same criteria employed for deriving HES study variables. There were no missing values for deprivation, age, gender and GOR.

5.6.1. Deprivation

The methodology used to generate an ordinal variable for IMD quintiles has been described in section 5.5.2, page 156. In brief, IMD quintiles were derived from a publicly-available lookup table of IMD deciles to LSOAs. IMD quintiles were further categorised to generate a three-level ordinal variable according to the groupings shown in Table 19.

5.6.2. Age

ONS data for age were obtained in 5-yearly intervals; more refined age groupings by LSOA were not available due to small numbers suppression. Age group was further binarised using a cut-off of 85 years to ensure consistency with the approach used for HES data.

5.6.3. Gender

The variable for gender was recoded such that males and females were coded as 0 and 1 respectively.

5.6.4. Government Office Region of residence

An ordinal variable for GOR was derived from the ONS string variable for GOR code; GORs were further categorised into the North, Midlands and South of England according to the groupings for geographic region presented in Table 20.

5.6.5. Time period

Time period was categorised in two-yearly intervals for the analyses presented in Chapter 7 and according to the following three groupings for those presented in Chapter 8: 2001-2005, 2006-2010 and 2011-2014.

5.7. Statistical methods

5.7.1. Summarising data

Continuous variables

Histograms were constructed to display the distribution of numerical data. Means and SD were used to summarise continuous variables that were normally distributed and, medians and IQRs were presented for variables with a skewed distribution because the mean may not be representative of the average value of skewed distributions (329). Continuous outcomes with a skewed distribution were transformed to satisfy the assumption of normality for linear regression (329).

Categorical variables

Counts and proportions were used to summarise the distribution of categorical data. Cross-tabulations presented in contingency tables were used to display the distribution of one variable relative to the distribution of another variable. Pearson's chi-squared test was used to examine the association between two categorical variables, that is, whether the distribution of observations for one variable differed according to a second variable (329).

5.7.2. Incidence rates

Incidence rates were defined as the "*number of new events that occurred per person per unit time"* and were calculated as the total number of new events divided by the total person-years of observation (329). To compare the rate of disease among two exposure groups, the attributable risk was calculated as the difference between the rate of disease in the exposed and unexposed groups (330).

5.7.3. Selection of potential confounders

Confounding occurs when the association between an exposure and outcome is influenced by another factor, the distribution of which differs according to exposure status and affects the outcome (329). Confounding bias may be introduced if such factors are not controlled for, thus generating inaccurate estimates of the association between an exposure and outcome (329).

A causal diagram describing the hypothesised relationship between deprivation and hip fracture risk is presented in Figure 7 below. It was postulated that greater deprivation would be associated with a higher risk of hip fracture in keeping with the positive association between deprivation and disease incidence reported for CHD, diabetes and cancer for example (249, 251, 331). Some of the relationship between deprivation and hip fracture risk is likely to be explained by age and gender given that more deprived individuals tend to be younger and male (see Chapter 2.6, page 65), and hip fracture risk increases with older age and female sex (see Chapter 1.6, page 24).

More deprived individuals tend to have a higher burden of comorbidity as discussed in Chapter 2.6.4, page 68, and certain comorbid conditions such as diabetes and COPD are known to increase fracture risk (see Chapter 1.6.10, page 30). Comorbidity may therefore mediate the relationship between deprivation and hip fracture risk. However, greater comorbidity may also have a negative impact on employment opportunities and income potential due to poor health status, which may result in worsening deprivation status. In this scenario, the relationship between deprivation and hip fracture risk may be confounded by comorbidity.

There is a social gradient of lifestyle-associated risk factors for fracture; the prevalence of smoking, heavy alcohol intake and obesity all increase with greater levels of deprivation (231-233). Whilst alcohol consumption and tobacco use are both positively associated with hip fracture risk (58, 61), obesity is associated with a decreased risk of hip fracture but an increased risk of other types of fractures as it is thought to reduce bone quality (63, 332). It was not possible to control for the effect of lifestyle risk factors on the relationship between deprivation and hip fracture risk as part of these analyses due to a lack of available data on tobacco use, alcohol consumption and BMI in HES.

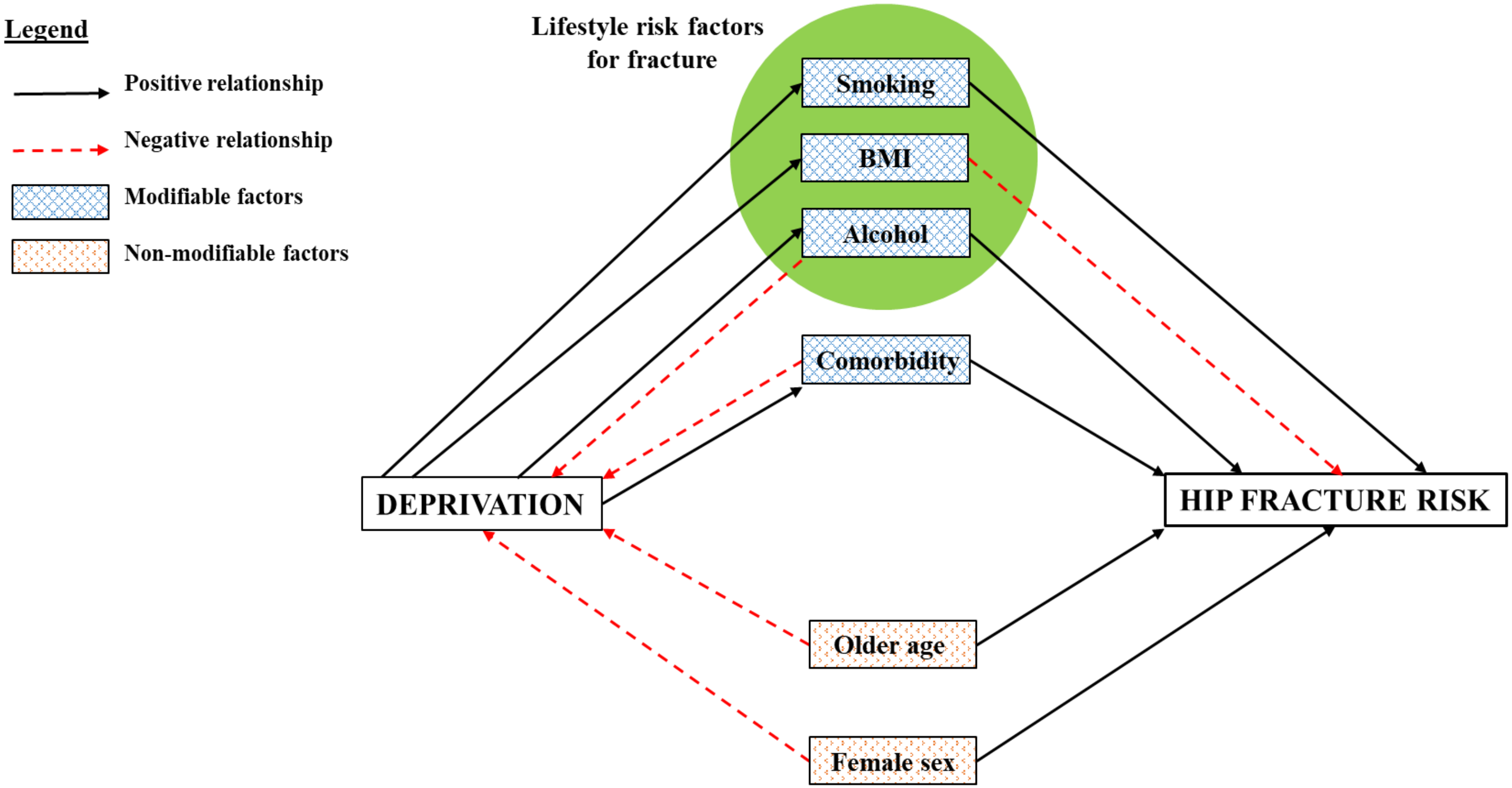

Figure 7: Directed acyclic graph summarising the hypothesised relationship between deprivation and hip fracture risk

5.7.4. Adjustment for potential confounders

The following approaches were used to control for the effect of confounding on the association between an exposure and outcome: standardisation, stratification and multivariable regression.

Standardisation

Annual age-standardised incidence rates and 95% CIs were calculated to determine the number of incident events that would be expected to occur if the age composition of the populations being compared were the same (333), thus accounting for secular changes in the age distribution of the English population over the period 2001 to 2014. Direct standardisation was used to calculate the weighted average of age-specific rates for the study population, using weights derived from a standard population (333). The English population in 2001, the earliest time point for which data were available, was used as the reference population for this study.

Stratification

Stratification was used to control for confounding by comparing the association between an exposure and outcome among individuals within the same strata of a confounding variable such as comorbidity. Separate estimates of the strength of this association were generated for each strata of the confounding variable (329).

Regression modelling

Multivariable Poisson regression modelling was used to examine the association between an exposure and the occurrence of an event, adjusting for the effect of potential confounders. Poisson regression was modelled on a log scale and the outputs were exponentiated to generate rate ratios (329). The number of events per group was modelled as the dependent variable and the exposure as the independent variable, with the population size included as an offset. Incidence rate ratios (IRRs) and 95% CIs were calculated to describe the rate of the outcome in the exposed group compared with the rate in the unexposed group.

5.7.5. Tests for interaction

Interaction, also known as effect modification, occurs when the association between an exposure and outcome differs according to strata of the modifying variable, that is, the variable modifies the effect of the exposure on the outcome (329). Regression modelling was used to test for interaction by including an interaction term between the exposure and potential modifier. The baseline regression model assumes that the effect of the potential modifier is the same in each strata of the exposure, whilst the alternative model includes an interaction term between the exposure and potential modifier.

A likelihood ratio test (LRT) was conducted to examine model fit by comparing log-likelihoods from regression models with and without an interaction term. If the variable was found to be an effect modifier, analyses were presented stratified by levels of the modifier because it is not appropriate to report measures of association adjusted for a variable when effect modification is present (329).

CHAPTER 6. METHODS – THE EFFECT OF DEPRIVATION ON CLINICAL OUTCOMES AFTER HIP FRACTURE

This chapter describes the methods used to examine the effect of deprivation on clinical outcomes after hip fracture among men and women aged 60+ years residing in England. Data were obtained from NHS Digital and Crown Informatics, which were linked together to generate a linked HES-ONS-NHFD dataset that included hospital admissions for hip fracture over the period 2011 to 2014. The methods used to generate the HES-ONS and NHFD datasets for analysis, and their subsequent linkage, are described in detail below.

6.1. Data extracts

6.1.1. HES data

An anonymised, patient-level HES APC data extract was obtained from NHS Digital that included all-cause admissions to English NHS hospitals between 1st April 2004 and 31st March 2016. As described previously, each HES record includes information on patient demographics, clinical diagnoses and procedures, geography and deprivation status; further details about the background and structure of HES data have been provided in Chapter 5.1, page 136. The study period for these analyses was 1st April 2011 to 31st March 2015 to ensure consistency with the time period for which NHFD data were obtained;

however, HES APC all-cause hospital admission data were obtained for the period prior to April 2011 to allow comorbidity burden to be measured.

6.1.2. ONS mortality data

ONS mortality data contains information related to a person's death such as the date and cause of death, and are obtained from death certificates of all registered deaths in England and Wales (334). ONS mortality data therefore captures information on deaths occurring outside of hospital (334). The role of the ONS in generating national statistics for England has been described in Chapter 5.4.1, page 155.

ONS mortality data were obtained for all hip fracture admissions captured by HES that occurred between 1st April 2009 and 31st March 2016. Due to NHS Digital data access restrictions, it was not possible to obtain date of death. Instead, using ONS date of death information, NHS Digital derived a mortality flag that was defined as death status at a series of ten specified time points ranging from 7 days to 365 days' post-hip fracture (see Table 32 for details of the ten time points).

Linkage of HES APC data and ONS mortality data were conducted by NHS Digital using an eight-step algorithm that is based on several patient identifiers, including NHS number, sex, date of birth (DOB) and postcode (335).

6.1.3. NHFD data

An anonymised, patient-level data extract was obtained from the NHFD patient audit database that included hip fracture admissions to NHS hospitals in England, Wales and Northern Ireland over the period 1st April 2011 to 31st December 2015. Each row of observation in NHFD relates to one hip fracture admission, and includes information on patient demographics, type of hip fracture and operation performed. NHFD data have been described in detail in Chapter 1.9.4, page 44.

6.2. HES-ONS data extract

6.2.1. HES-ONS data extract generated by NHS Digital

NHS Digital identified a cohort of hip fracture patients for whom to extract HES APC hospital admission data using the following process. Crown Informatics, the data processor of NHFD data (336), identified hospital admissions for hip fracture that occurred between 1st April 2011 and 31st December 2015 (subsequently referred to as cohort 1). Patient identifiers were extracted for cohort 1, including name, DOB, postcode, NHS number and a unique identifier (study ID). These patient identifiers were transferred to and used by NHS Digital to identify cohort 1 for whom all HES APC records over the period 1st April 2004 to 31st March 2016 were extracted (i.e. all-cause hospital admissions).

NHS Digital extracted all HES records for a second cohort of hip fracture patients over the same time period i.e. April 2004 to March 2016 (subsequently referred to as cohort 2). This cohort of patients was identified using ICD-10 codes for hip fracture recorded in any of the twenty diagnosis fields. Hip fractures were defined using the same ICD-10 codes described in Chapter 5.2.4, page 143: fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1), and subtrochanteric fracture (S72.2). Additionally, for cohort 2, HES records with an ICD-10 code for fracture of shaft of femur (S72.3) and fracture of femur, part unspecified (S72.9) were extracted for planned analyses beyond the scope of this PhD.

HES records for both cohorts of hip fracture patients were merged to generate a single combined cohort of hip fracture patients admitted to hospital over the period 1st April 2004 to 31st March 2016. NHS Digital then appended ONS mortality data to hip fracture admissions that occurred between 1st April 2009 to 31st March 2016. NHS Digital anonymised the HES-ONS data extract after which the data were transferred to the UoB in August 2017.

6.2.2. HES-ONS data validation

On receipt of data at the UoB, it was confirmed that all patients in the NHS Digital-generated HES-ONS data extract had a hip fracture admission between 1st April 2004 and 31st March 2016.

6.2.3. HES-ONS data cleaning

HES-ONS data file

The HES-ONS data extract included 779,588 patients with a hospital admission for any cause between 1st April 2004 and 31st March 2016. For ease of data management, the dataset was restricted to all-cause hospital admissions for the same time period for which NHFD data were obtained i.e. 1st April 2011 and 31st March 2016.

Variables and dates

The HES-ONS dataset was restricted to key variables of interest, including variables relating to patient demographics, details of the period of care, area-based measures of deprivation, clinical information (diagnoses and operations) and geography (Table 23). Thereafter, date variables relating to the period of hospital care were converted from string to date format (i.e. date of hospital admission and discharge, and start and end date of hospital episodes). The dataset was then restricted to patients with valid admission and discharge dates (i.e. 925 patients with missing or unknown dates were excluded).

As described in Chapter 5.1.5, HES data extracts are generated based on the financial year in which hospital discharge occurred. The HES-ONS dataset therefore included hospital admissions with an admission date prior to 1st April 2011 but a discharge date on or after 1st April 2011; 2,413 patients admitted to hospital prior to 1st April 2011 were excluded.

Table 23: Variables extracted from the HES-ONS data extract

Category	**HES variables**
Patient identifier	HES unique patient identifier (HESID)
Patient demographics	Age on admission, gender
Period of care	Admission date, discharge date, method of admission, source of admission, method of discharge, discharge destination Episode status, episode key, episode start date, episode end date
Clinical diagnosis	Primary diagnosis and up to 20 secondary diagnosis fields containing ICD-10 diagnosis codes, operation date
Deprivation	IMD overall score, rank and decile IMD scores for each of the 7 domains of deprivation: income, crime, education, employment, health and disability, housing and services, living environment
Geography	GOR of residence and treatment, 2001 LSOA, 2011 LSOA

ICD-10 – International Classification of Diseases version 10; IMD – Index of Multiple Deprivation; GOR – Government Office Region; LSOA – Lower Super Output Area

Hospital admissions for hip fracture

The HES-ONS dataset included all-cause hospital admissions. For ease of data management, the dataset was restricted to hospital admissions for hip fracture identified using the same hip fracture ICD-10 codes described earlier in section 6.2.1, page 167 (ICD-10 codes S72.0-S72.2). Of the 173,188 patients identified without a HES record for hip fracture, 20,049 patients had a hospital admission for femoral fracture (ICD-10 codes S72.3 or S72.9) and the remainder of patients had a hip fracture admission prior to 1st April 2011.

The flow diagram below summarises the data cleaning steps employed to generate the HES-ONS cohort of hip fracture patients (Figure 8). The final HES population for linkage to NHFD data consisted of 325,861 patients admitted to an English NHS hospital with a hip fracture between 1st April 2011 and 31st March 2016.

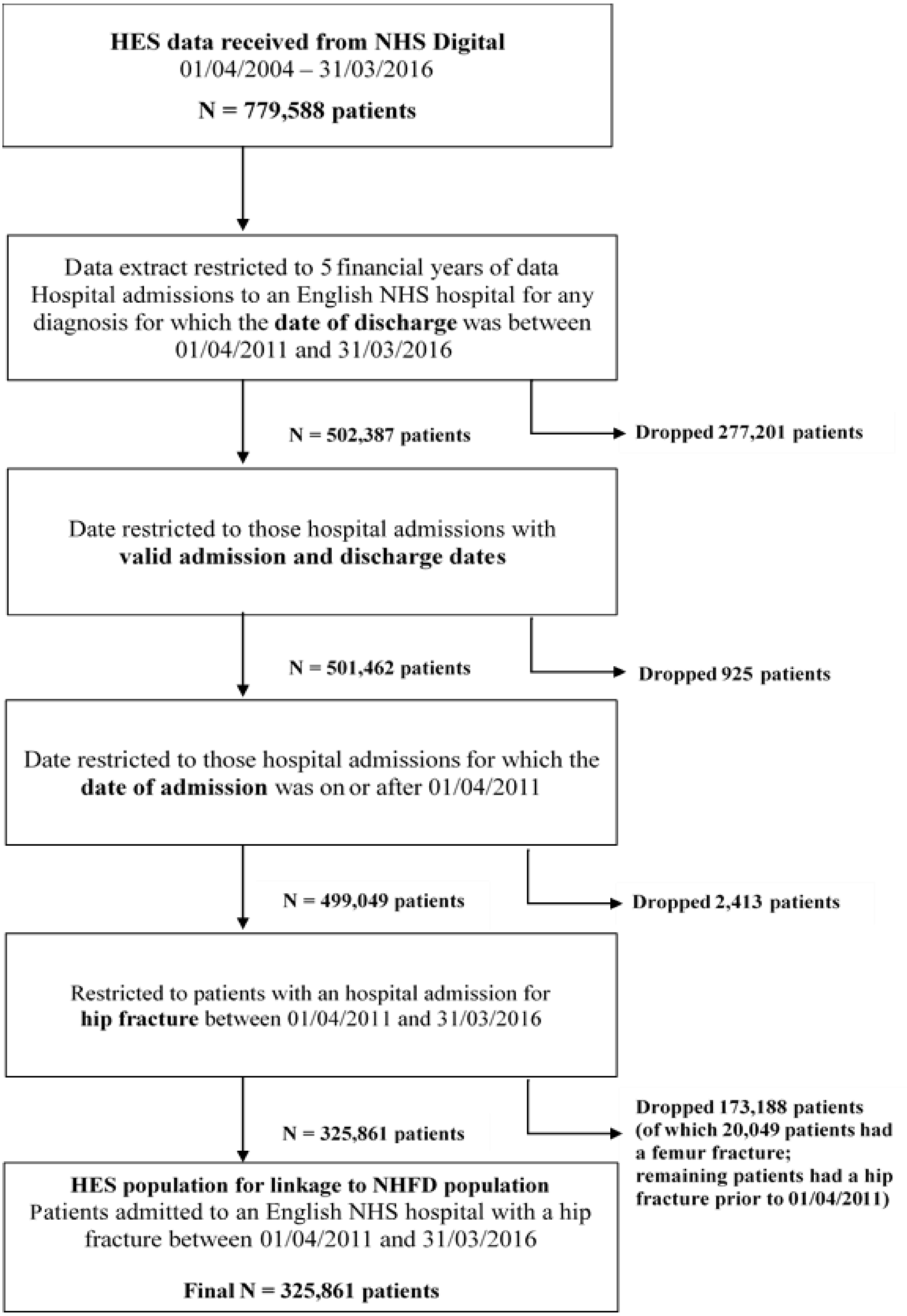

Figure 8: Overview of HES-ONS data cleaning to identify a cohort of patients admitted to hospital for hip fracture between 1st April 2011 and 31st March 2016

6.3. NHFD data extract

6.3.1. NHFD data file

The NHFD data extract included 309,559 hip fracture admissions among men and women aged 60+ years admitted to an English, Welsh or Northern Ireland NHS hospital between 1st April 2011 and 31st December 2015. The NHFD data extract included more than one record for a given patient if a second contralateral hip fracture occurred; however, using NHFD data alone, it is not possible to identify hip fracture admissions for separate fracture events occurring in the same patient because each NHFD entry is assigned a unique study identifier.

6.3.2. Variables

The NHFD dataset was restricted to key variables of interest, including variables relating to patient demographics, hospital admission and discharge dates, hip fracture type and operation, level of mobility and residential status (Table 24).

Table 24: Variables extracted from the NHFD data extract

Category	NHFD variables
Patient identifier	NHFD unique patient identifier (study ID)
Patient demographics	Age at event, gender
Period of care	Admission date, discharge date, source of admission, discharge destination
Clinical diagnosis	Hip fracture type and side, pathological fracture, operation performed, operation date
Deprivation	IMD overall score and rank
Geography	LSOA

IMD – Index of Multiple Deprivation; LSOA – Lower Super Output Area

6.4. Linked HES-ONS-NHFD dataset

6.4.1. Linkage of HES-ONS and NHFD datasets

Cleaned HES-ONS and NHFD datasets were merged using a unique patient identifier (study ID) following which three distinct hip fracture populations were identified: linked HES-ONS-NHFD patients, unlinked HES patients and unlinked NHFD patients.

The linked HES-ONS-NHFD group consisted of 271,134 patients for whom hospital admission records were identified in both HES and NHFD databases, of which 11,256 patients had more than one hip fracture event. The unlinked HES group was comprised of 54,727 patients for whom hospital admission records were identified in the HES APC database only, and the unlinked NHFD group consisted of 27,173 hip fracture events captured by the NHFD database only.

The data cleaning process used to identify index hospital admissions for hip fracture (i.e. first occurrence of hip fracture) among the three groups of patients are described in detail below and summarised in Figure 9. For clarity, these data cleaning steps are described with reference to linked HES-ONS-NHFD patients; however, as shown in Figure 9, similar steps were employed for patients in the unlinked HES and unlinked NHFD groups.

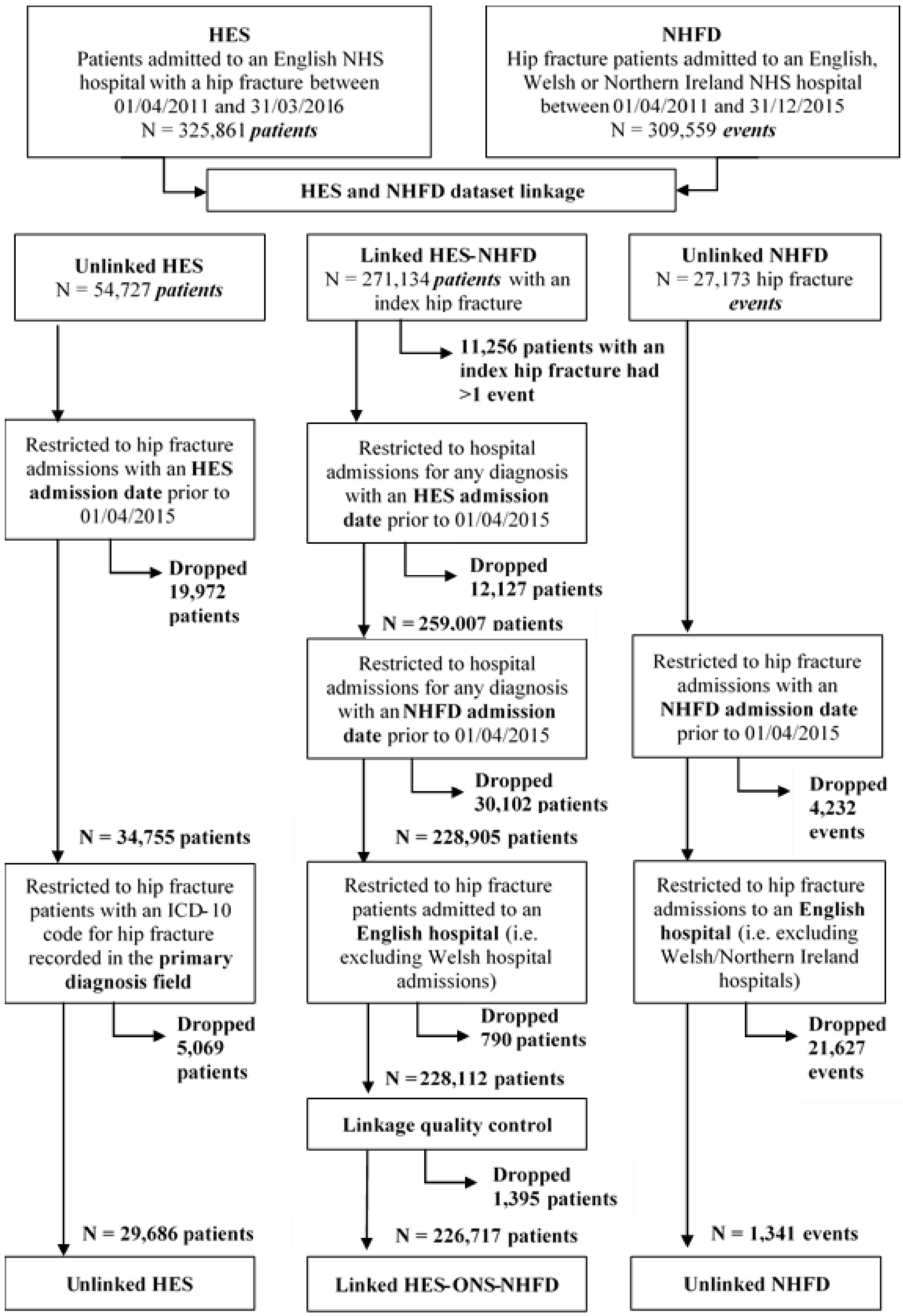

Figure 9: Overview of data cleaning steps applied to HES-ONS and NHFD datasets after linkage to identify patients admitted to hospital for hip fracture between 1st April 2011 and 31st March 2015

6.4.2. Date of hip fracture admission

As described in section 6.2.3, the HES-ONS dataset that was merged with NHFD data included hip fracture patients admitted to an English NHS hospital up to and including 31st March 2016 (page 168). To allow a 365-day follow-up period from which to derive study outcomes, the linked HES-ONS-NHFD cohort was restricted to hip fracture patients admitted to hospital prior to 1st April 2015. The methods used to generate study outcomes are described later in section 6.6, page 183. Hip fracture admissions with a HES admission date (n=12,127 patients) and NHFD admission date (n=30,102 patients) on or after 1st April 2015 were excluded.

6.4.3. Hospital admissions to English NHS hospitals

The HES APC database collects patient-level data for hospital admissions to English NHS hospitals only, whereas the NHFD captures data for NHS hospitals in England, Wales and Northern Ireland. Of interest for these analyses were hip fracture patients admitted to English NHS hospitals only and therefore, 790 patients with linked HES-ONS-NHFD data who were admitted to a Welsh NHS hospital were excluded.

6.4.4. Quality assessment of linked HES-ONS-NHFD hip fracture admissions

Several quality assessment criteria were used to ensure that the same hip fracture admission was correctly linked in both HES-ONS and NHFD datasets. Quality of linkage was assessed based on the following parameters: patient age and gender, hospital admission date, operation date and hospital provider of treatment. These parameters were selected because they were considered to be key patient characteristics and admission-related data that would be collected and entered into both databases with a high level of accuracy. The four quality assessment criteria are described in detail below and summarised in Table 25. Hospital admissions with good linkage were defined as those for which the criteria for admission date plus one or more other parameters were met i.e. age, gender or hospital provider.

Table 25: Summary of quality assessment criteria for identifying linked hip fracture admissions in HES-ONS and NHFD datasets

Quality assessment parameter	Description of criteria
HES and NHFD admission and operation dates	Admission date difference ≤10 days or
	Admission date difference >10 days and operation date difference ≤3 days
Age	Age difference ≤1 year
Gender	Same gender
Hospital code	Same hospital provider code

Admission date

In 2014, mean acute hospital LOS for hip fracture was 19.3 days in England (99). Hip fracture admissions for which HES-ONS and NHFD admission dates differed by ≤10 days were defined as relating to the same fracture event; a cut-off of 10 days (i.e. 50% of mean hospital LOS) was selected because it was considered unlikely for a patient to be discharged home and newly admitted to hospital within 10 days of the index hip fracture admission. To allow for coding and data entry inconsistencies, admission dates that differed by >10 days but for which HES-ONS and NHFD operation dates differed by an arbitrary cut-off of ≤3 days were accepted.

More than 95% of linked hip fracture patients had HES-ONS and NHFD admission dates that differed by ≤10 days, and of the 14,161 patients with admission date differences of >10 days, 77.4% of patients had operation dates that differed by ≤3 days (Appendix 13.4, page 424). Combining both criteria, 99.2% of the 388,778 linked patients satisfied the admission date criteria for this study i.e. admission date difference ≤10 days ***or*** admission date difference >10 days plus operation date difference ≤3 days (Table 26).

Table 26: Tabulation of linked HES-ONS and NHFD hip fracture admissions based on admission and operation dates

Linkage of HES-ONS and NHFD admission and operation dates	N (%)[a]
Linked	385,571 (99.2)
Unlinked	1,783 (0.46)
Missing	1,424 (0.37)
Total	388,778 (100.0)

[a]column percentage does not total to 100% due to rounding error

Patient age and gender

HES-ONS and NHFD hospital admissions with the same patient age and/or gender recorded were defined as relating to the same hip fracture admission. In the case of patient age, a difference of 1 year was accepted to allow for patients hospitalised around the time of their birthday. Of the 388,778 linked hip fracture patients, 99.3% of patients had ≤1 year difference in patient age and 99.2% had the same gender recorded (Appendix 13.4, page 424).

Hospital provider

Hospital admissions with the same hospital provider code recorded in HES-ONS and NHFD datasets were considered to relate to the same hip fracture admission. The HES variable *procodet* was used to determine the hospital provider of treatment. In HES, hospital providers are assigned codes based on the Organisation Data Service (ODS) classification system (3- or 5-character alphanumeric codes) (316). In contrast, the NHFD uses 3-letter hospital codes to determine the NHS hospital provider of hip fracture care. A NHFD-ODS hospital provider code lookup table, obtained from the Falls and Fragility Fracture Audit Programme (C. Boulton, personal communication, 01/12/2017), was used to convert NHFD hospital codes to their respective ODS hospital provider codes. More than 95% of linked hip fracture patients had the same hospital provider code recorded in both HES-ONS and NHFD datasets (Appendix 13.4, page 424).

Quality of linkage

Quality of linkage was assessed by concatenating variables for the four quality control parameters. As stated previously, HES-ONS and NHFD hip fracture admissions with good linkage were defined as those for which the criteria for admission date plus one or more other parameters were met i.e. age, gender or hospital provider. All remaining hospital admissions were categorised as being of poor linkage. Hospital admission data for 99.2% of the 388,778 linked hip fracture patients fulfilled the criteria for good linkage (Table 27); hospital admissions for the remaining hip fracture patients were excluded.

Table 27: Tabulation of quality of linkage of hip fracture admissions identified in HES-ONS and NHFD datasets

Quality of linkage	N (%)[a]
Good linkage	385,570 (99.2)
Poor linkage	3,208 (0.83)
Total	388,778 (100)

[a]column percentage does not total to 100% due to rounding error

6.4.5. Dataset for analysis

The linked HES-ONS-NHFD dataset was restricted to the first hospital episode of the index hip fracture admission i.e. included one row of observation per hip fracture patient. The final dataset consisted of male and female English residents aged 60+ years admitted to hospital with a hip fracture or who sustained a hip fracture during a hospital admission between 1st April 2011 and 31st March 2015. Hip fracture admissions for patients under the age of 60 years were excluded to ensure consistency with the study population for whom the NHFD routinely collect data. Hip fracture patients with missing data for age and/or sex were excluded. Exclusion criteria for patient age and sex were based on HES rather than NHFD data because HES data are primarily collected for administrative purposes and therefore were considered to be the gold standard in this analysis.

The final hip fracture population consisted of 220,567 patients with linked HES-ONS-NHFD data, 20,679 patients with unlinked HES data and 1,214 unlinked NHFD fracture events (Figure 10). Hence, hip fracture admission data were successfully linked across HES-ONS and NHFD datasets for 91% of patients identified from the HES APC database and 99% of hip fracture events captured by the NHFD.

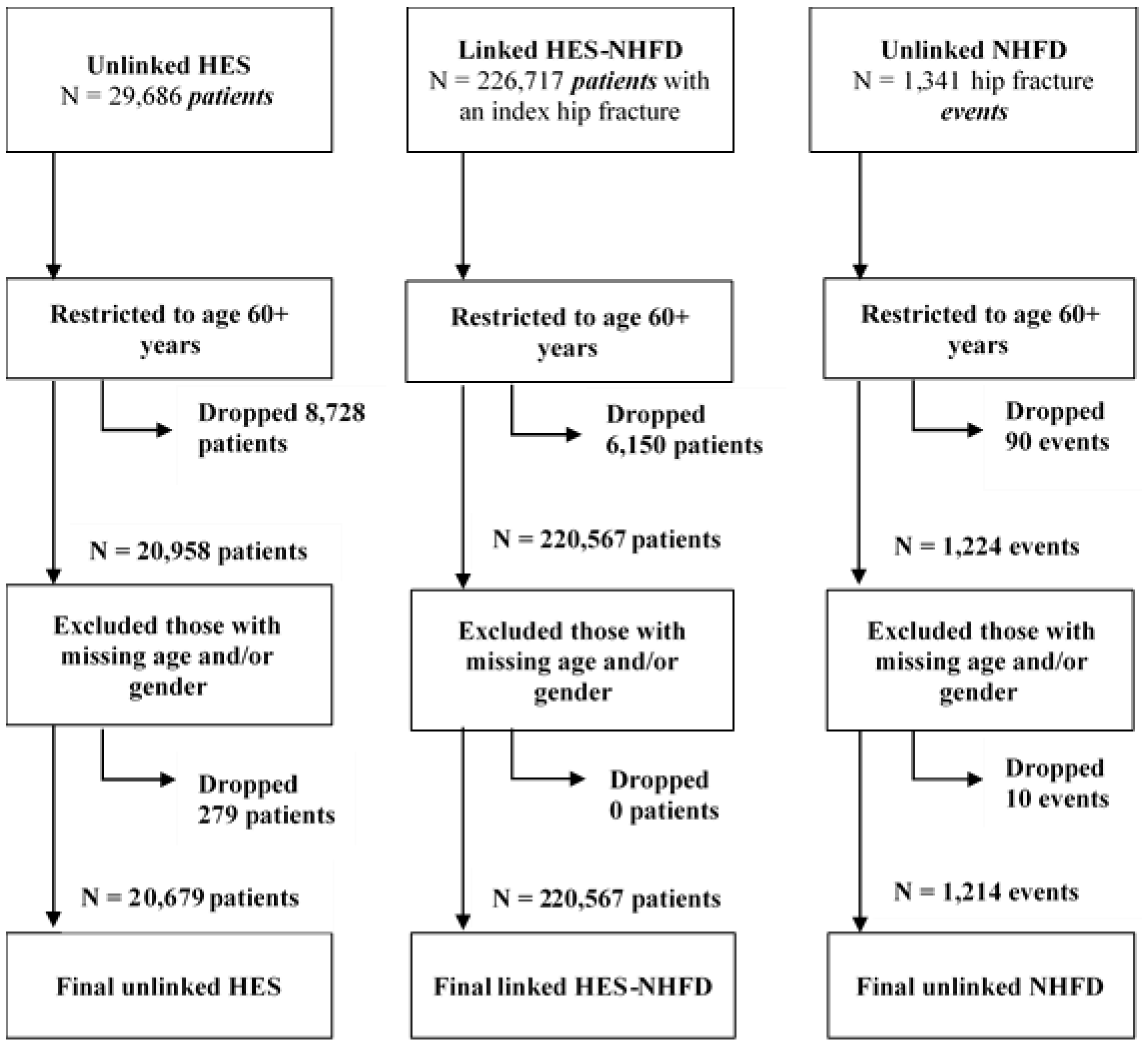

Figure 10: Overview of exclusion criteria applied to HES-ONS and NHFD datasets after linkage to identify men and women aged 60+ years admitted to hospital for hip fracture between 1st April 2011 and 31st March 2015

6.5. Study variables

As described earlier, HES-ONS and NHFD datasets were merged using a unique patient identifier (study ID variable) to identify index hospital admissions for hip fracture (i.e. first occurrence of hip fracture) between 2011 and 2015 (see section 6.4.1, page 173). Several study variables were derived from HES and/or NHFD data that were used to describe patient and fracture characteristics among the linked cohort of hip fracture patients.

Study variables for deprivation (study exposure), and patient and fracture characteristics were derived from HES and/or NHFD records for the index hip fracture admission. HES data were used to derive variables for deprivation and the following patient characteristics at the time of hip fracture admission: age, gender, ethnicity, and GOR of residence. NHFD data were used to derive fracture-related variables (e.g. hip fracture type, pathological fracture and operation performed) and variables for patient characteristics (ASA grade and cognition). NHFD data were further used to determine residential status prior to hip fracture admission.

For the linked cohort of hip fracture patients, HES all-cause hospital admission data in the year after the index hip fracture admission were used to derive the four outcome measures: mortality, emergency 30-day readmission, superspell LOS and total NHS bed days. Comorbidity burden in the linked HES-ONS-NHFD hip fracture population was assessed using HES records for the index hip fracture admission and all-cause hospital admissions in the preceding five years.

Figure 11 below provides an overview of the key variables of interest in this study and the data sources from which they were derived. Derived HES and NHFD study variables are described in detail below.

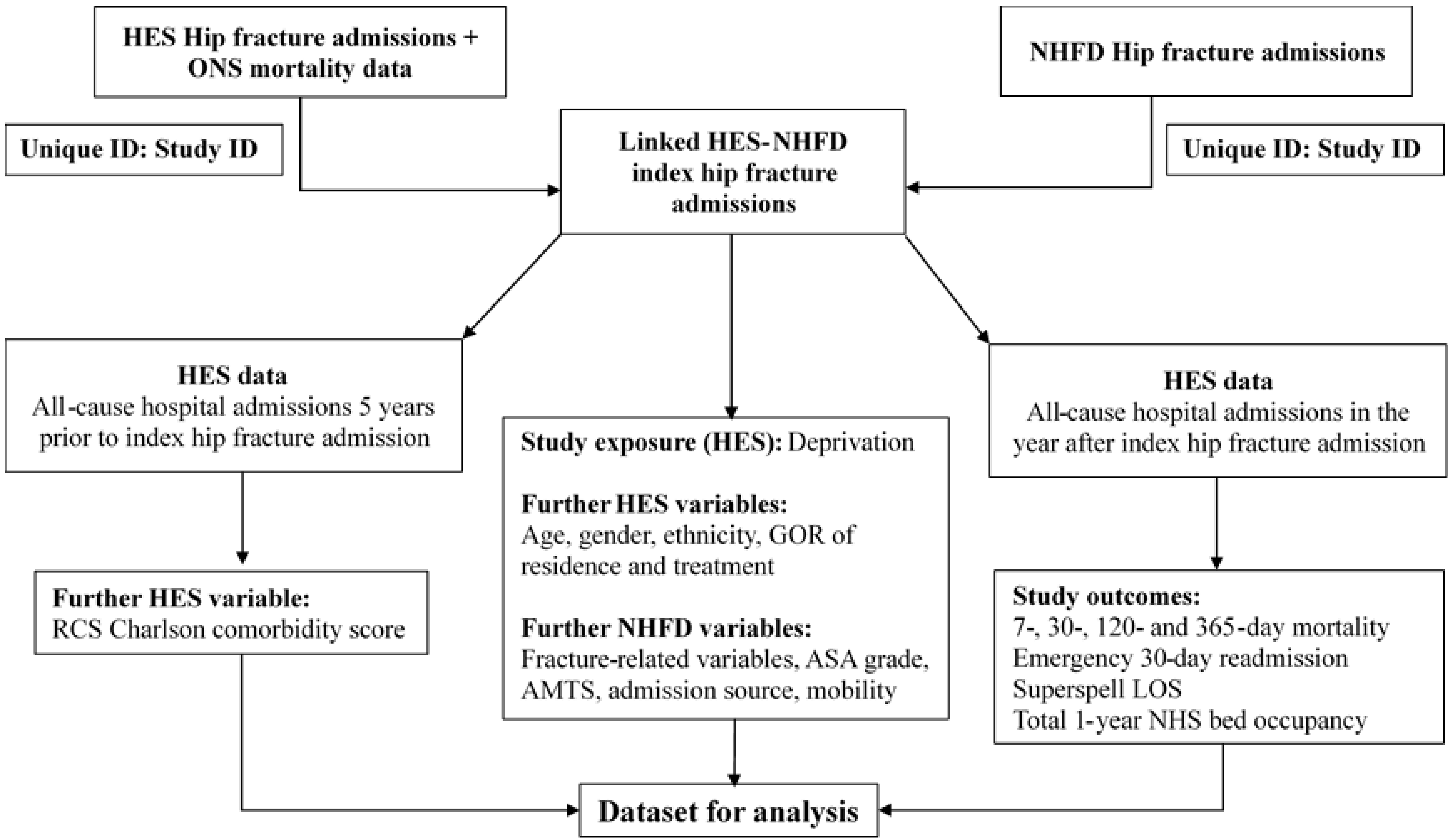

Figure 11: Overview of key study variables and the respective data sources from which they were derived

ASA – American Society of Anaesthiologists; AMTS – Abbreviated mental test score; LOS – Length of stay

6.6. HES study variables

HES variables were derived for the study exposure, four outcome measures and further study variables as described below.

6.6.1. Missing data

As discussed in Chapter 5.3.1, several methods are available for the handling of missing data, including replacing missing observations with the last measured observation (320, 321) (see page 148). The last observation carried forward method was used to capture patient demographic data recorded upon hospital admission; hospital episodes with missing data were replaced with non-missing data extracted from the next hospital episode of the same index hip fracture admission (see Chapter 5.3.1, page 148 for further details). This process was repeated for the following HES study variables: age, gender, geographic region of patient's residence and hospital providing treatment, and deprivation.

6.6.2. Deprivation

The IMD was used to measure an individual's level of socioeconomic deprivation. The HES database includes data fields for the IMD (Chapter 5.3.2, page 149), an area-based measure of deprivation that has been described in detail in Chapter 2.5.3, page 64. Patients LSOAs of residence were categorised into quintiles of deprivation based upon the national IMD ranking of LSOAs, with quintile 1 being the least deprived and quintile 5 being the most deprived group (Table 28).

Table 28: IMD ranks used to derive variable for IMD quintile

IMD rank	IMD Quintile
25987 to 32482	Q1 (least deprived)
19490 to 25986	Q2
12994 to 19489	Q3
6497 to 12993	Q4
1 to 6496	Q5 (most deprived)

6.6.3. Age

The HES variable *startage*, described in Chapter 5.3.3, page 150, was categorised in 5-yearly intervals ranging from 60 to 90+ years, and used to adjust for potential confounding by age in regression analyses. Patient age was further binarised for the age-stratified analyses presented in Chapters 9 and 10. The median age of the hip fracture population was 84 years (IQR 78-89 years) and therefore, the study population was binarised as those aged 60-84 years and 85+ years.

6.6.4. Gender

The HES variable *sex* was recoded as 0 and 1 for males and females respectively; patients for whom sex was unknown were recoded as missing.

6.6.5. Ethnicity

The HES variable *ethnos* describes a patient's self-reported ethnicity and consists of nineteen ethnic groups based on the categorisation of ethnicity in the 2001 census. For these analyses, ethnicity was categorised according to the six broad groups shown in Table 29 below. Patients for whom ethnicity was not known were recoded as missing.

Table 29: HES ethnicity codes and names used to derive a variable for ethnicity

HES ethnicity code	**HES ethnicity name**	**Derived ethnicity variable**
A	British (White)	White
B	Irish (White)	
C	Any other White background	
D	White and Black Caribbean (Mixed)	Mixed
E	White and Black African (Mixed)	
F	White and Asian (Mixed)	
G	Any other Mixed background	
H	Indian (Asian or Asian British)	Asian
J	Pakistani (Asian or Asian British)	
K	Bangladeshi (Asian or Asian British)	
L	Any other Asian background	
M	Caribbean (Black or Black British)	Black
N	African (Black or Black British)	
P	Any other Black background	
R	Chinese (other ethnic group)	Chinese
S	Any other ethnic group	Other
Z	Not stated	Unknown
X or 99	Not known (prior to 2013) Not known (2013 onwards)	

6.6.6. Government Office Region of residence and treatment

The HES variables *resgor* and *gortreat* are defined as the GOR of a patients residence and the hospital providing treatment respectively. Whilst *resgor* is derived from a patients postcode, *gortreat* is derived from the HES hospital provider code variable *procode*. HES variables *resgor* and *gortreat* are categorised according to the ONS coding system of GORs (316). Patients for whom GOR of residence and/or GOR of treatment were not known were recoded as missing. Table 30 below demonstrates the mapping of ONS GOR codes to GOR names for HES variables *resgor* and *gortreat*.

Table 30: Mapping of ONS GOR codes to GOR names

GOR code	GOR name
E12000001	North East
E12000002	North West
E12000003	Yorkshire and the Humber
E12000004	East Midlands
E12000005	West Midlands
E12000006	East of England
E12000007	London
E12000008	South East
E12000009	South West

The HES variables *resgor* and *gortreat* were cross-tabulated to examine consistency between the GOR in which a hip fracture patient resided and was treated. As demonstrated in Table 31, for all GORs except London, more than 90% of hip fracture patients resided and were treated within the same GOR i.e. <10% of hip fracture patients were treated outside their area of residence.

The HES variable *gortreat*, as opposed to *resgor*, was used to define geography for analyses presented in Chapter 9 given that regional differences in hospital-level provision of hip fracture care may contribute to geographic variation in mortality after hip fracture.

Table 31: Consistency between HES variables for GOR of residence and GOR of treatment

GOR	Same GOR of residence/treatment (N (%))	Different GOR of residence/treatment (N (%))	Total (N)
North East	12,663 (94.7)	716 (5.4)	13,379
North West	29,333 (97.5)	766 (2.5)	30,099
Yorkshire & Humber	21,329 (93.8)	1,423 (6.3)	22,752
East Midlands	16,122 (98.3)	273 (1.7)	16,395
West Midlands	23,104 (96.1)	942 (3.9)	24,046
East of England	24,695 (95.4)	1,179 (4.6)	25,874
London	19,540 (88.9)	2,434 (11.1)	21,974
South East	35,804 (96.3)	1,362 (3.7)	37,166
South West	26,042 (95.7)	1,180 (4.3)	27,222

6.6.7. Comorbidity

The RCS Charlson score was used to define comorbidity as part of these analyses (323). The methodology used to generate the RCS Charlson score has been described in detail in Chapter 5.3.6, page 152. In summary, the RCS Charlson score is a modified version of the CCI, which is based on several comorbid conditions that are categorised into fourteen disease groupings. As demonstrated in Chapter 5.3.6, greater comorbidity is identified among hip fracture patients when longer retrospective periods are used (page 152). Therefore, for these current analyses, comorbid conditions were identified using ICD-10 diagnosis codes recorded in the index hip fracture admission and all-cause hospital admissions in the preceding five years. To allow for a five-year retrospective period, HES APC data for financial years 2006 to 2014 were used to identify comorbid conditions among hip fracture patients admitted to hospital between 1st April 2011 and 31st March 2015.

Dementia is a predictor of adverse outcomes after hip fracture, as discussed in Chapter 1.8, page 33. To examine the effect of dementia on the relationship between deprivation and outcomes after hip fracture, the RCS Charlson comorbidity score was categorised into a three-level ordinal variable for these analyses. Patients were categorised as having either no comorbid condition, ≥1 comorbid condition that excluded dementia, or dementia with or without other comorbidities. Internal consistency checks were conducted using NHFD variables to validate the RCS Charlson comorbidity measure used (see section 6.7.1, page 194 and section 6.7.2, page 195).

6.6.8. Cumulative mortality

Cumulative mortality was calculated at 7-days, 30-days, 120-days, and 365-days from the date of index hip fracture admission, using the NHS Digital-derived mortality flag variable described earlier in section 6.1.2, page 166. In brief, patients who died within 365-days post-hip fracture were assigned a mortality flag that indicated the specified time point by which death occurred.

Separate binary variables were generated for the four mortality outcomes. Table 32 below summarises the mortality flags captured by each of the cumulative mortality variables. ONS mortality data were only available for hip fracture admissions captured by HES (see section 6.1.2, page 166), and therefore mortality status was not known for unlinked NHFD hip fracture patients.

Table 32: Mortality flags captured by the four cumulative mortality variables

Time points (days)	Cumulative mortality variable			
	7-days	30-days	120-days	365-days
7				
14				
21				
30				
60				
90				
120				
182				
274				
365				

6.6.9. Superspell LOS

Superspell LOS was defined as the total amount of time spent in NHS care following hip fracture (98). Hip fracture superspells were identified using the approach outlined by Busby et al; hospital LOS was calculated for the admission spell, elective (or rehabilitation spells) and an emergency (or new condition) spell (100). Published HES methodology was used to construct hip fracture superspells based on the following variables: source of admission, method of admission, and date of admission and discharge (317).

A hip fracture superspell was defined as the index hip fracture admission, and if applicable, planned transfers to another NHS hospital for elective care (e.g. ongoing rehabilitation) plus a subsequent unplanned transfer to another NHS hospital for emergency care (e.g. a hip fracture-related complication or a new clinical problem) (Figure 12). All patients within the study cohort had an index hip fracture admission but not all patients had subsequent elective or emergency admissions for further NHS care. Superspell LOS was calculated as the difference between the date of hospital admission for hip fracture and the final date of discharge, from an NHS hospital if the patient was transferred, or following the index hip fracture admission if the patient was not transferred.

Analyses of superspell LOS were restricted to patients discharged alive from hospital following a hip fracture superspell given that in-hospital mortality will influence the amount of time spent in hospital after hip fracture. Other approaches for handling the competing risk of mortality are discussed later (see section 6.9.6, page 210).

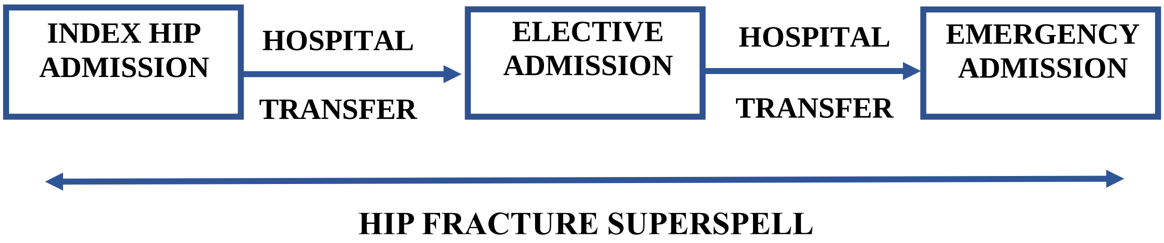

Figure 12: Overview of hospital admission scenarios captured by the definition of superspell LOS used in this study

Index hip fracture admissions and hospital transfers

Index hip fracture admissions were identified as described earlier (see section 6.2, page 167 and section 6.4, page 173). Index hip fracture admissions resulting in a planned hospital transfer for ongoing elective care were identified using the HES discharge destination code for hospital transfer. In addition, the method of admission code for the subsequent hospital admission had to indicate that the hospital transfer was planned.

Elective and emergency hospital admissions

Elective and emergency hospital admissions were those for which the HES source of admission code indicated that the patient had been transferred from another NHS hospital provider, and the method of admission code represented a planned hospital transfer in the case of elective admissions and unplanned transfer for emergency admissions. Importantly, the unplanned transfer for emergency care had to be preceded by an elective hospital admission to satisfy the definition of hip fracture superspell used in this study. This latter condition was stipulated to differentiate between emergency *admissions* occurring as part of a hip fracture superspell and emergency *readmissions* following a previous hospital discharge.

The NHFD definition of hip fracture superspell captures the index hip fracture admission plus hospital transfers for rehabilitation (98). Emergency admissions were additionally captured by the definition of superspell used in this current study because, although accounting for only 1.2% of the time spent in hospital after hip fracture, this equated to 10,000 bed days among hip fracture patients admitted to an English NHS hospital over a nine-month period (100), and thus represents a considerable need for additional healthcare in the period after hip fracture.

Linking hospital admissions to construct hip fracture superspells

To ensure that the different types of hospital admission described above related to one another and formed part of a hip fracture superspell, the following three conditions needed to be satisfied. Firstly, the discharge date of one hospital admission had to precede the admission date of the next admission to ensure a plausible sequence of events. Secondly, a difference of ≤2 days between discharge and admission dates of the two admissions was accepted to allow for minor coding discrepancies. Finally, the same HESID had to be recorded for both hospital admissions to ensure that they related to the same patient.

6.6.10. Emergency 30-day readmissions

Emergency 30-day readmissions were defined as emergency all-cause admissions to any English NHS hospital within 30-days of hospital discharge among patients discharged alive following a hip fracture superspell.

Emergency admissions were identified based on HES method of admission codes for an unplanned admission. Hospital admissions occurring within 30-days of discharge following a hip fracture superspell were calculated as the difference between the discharge date of the hip fracture superspell and admission date of the next hospital admission; same-day emergency readmissions were captured by this definition. Although 30-day readmissions are usually defined as hospital admissions occurring within 30-days of the *last discharge from hospital* (337), of interest for these analyses were readmissions that occurred following a *hip fracture superspell* and therefore were based on the *last hospital discharge that constituted a hip fracture superspell*.

Analyses of 30-day readmission were restricted to patients discharged alive following a hip fracture superspell given that readmission is not possible among patients who died during an inpatient stay. Other approaches can be used to account for the competing risk of mortality as discussed later (see section 6.9.6, page 210). The HES discharge method code for in-hospital death was used to identify deaths that occurred during a hip fracture superspell.

6.6.11. Total NHS bed days

The total number of days spent in hospital during the year after hip fracture was calculated for each patient as the sum of the LOS of all hospital admissions i.e. hip fracture superspell, an emergency 30-day readmission (if this occurred), and elective and emergency all-cause hospital admissions. Figure 13 below provides an overview of the hospital admission scenarios captured by this definition of total NHS bed days. The date of hip fracture admission was used as the reference point for calculating total NHS bed days so that each patient in the study had the same period of observation. Hip fracture superspells were censored at 365-days given that this is the maximum number of days an individual can spend in hospital in the year after hip fracture.

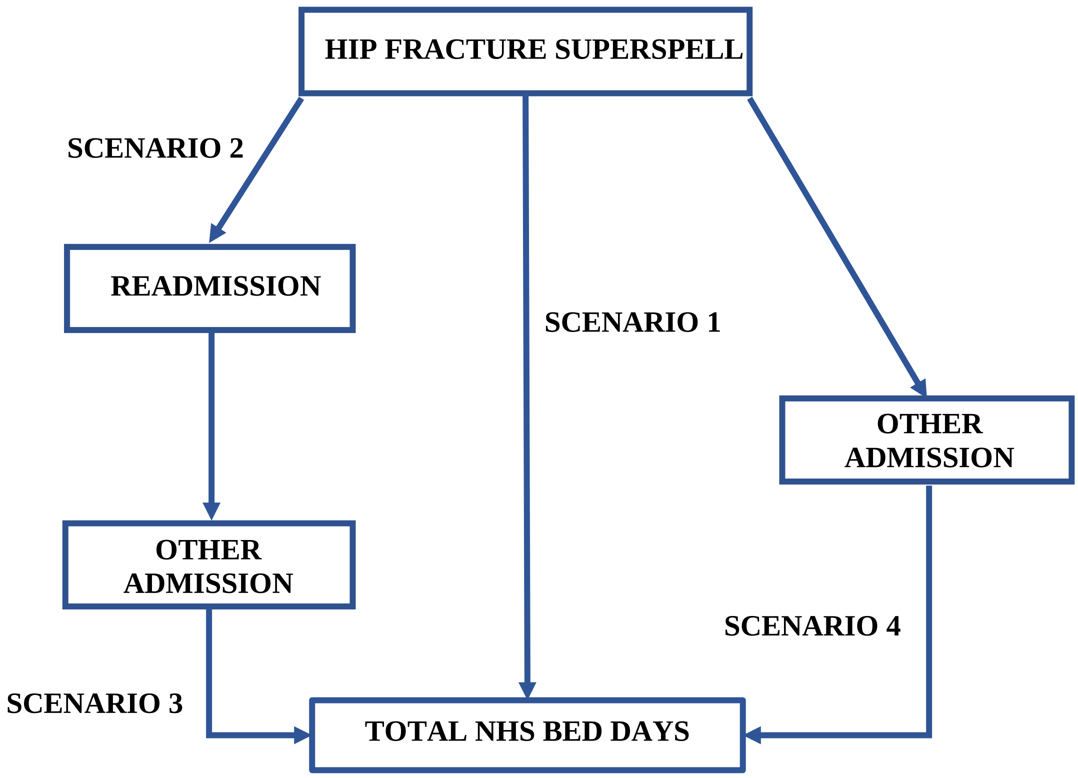

Figure 13: Overview of hospital admission scenarios captured by the definition of total NHS bed days used in this study

6.7. NHFD study variables

NHFD data were used to derive further study variables that described patient and fracture characteristics.

6.7.1. ASA grade

The ASA classification of physical status is an assessment of a patient's preoperative health status and is a predictor of poor outcomes after hip fracture, including increased mortality risk, as discussed in Chapter 1.8.1, page 33. ASA grade is based on the five classes presented in Table 33 below. The NHFD routinely collects information on ASA grade for hip fracture patients who have undergone surgery (120).

Table 33: ASA classification of physical status

ASA grade	Definition
I	A normal healthy patient
II	A patient with mild systemic disease
III	A patient with severe systemic disease
IV	A patient with severe systemic disease that is a constant threat to life
V	A moribund patient who is not expected to survive without the operation

In this current study, comorbidity was assessed using the RCS Charlson comorbidity score, as described earlier in section 6.6.7, page 187. Validity of the HES-derived RCS Charlson score for measuring comorbidity in this hip fracture population was assessed using the NHFD variable *ASA grade*. As expected, the burden of comorbidity was greater among those with higher ASA grade; 8.0% and 74.4% of hip fracture patients classified as ASA grade I and ASA grade V had 2+ comorbid conditions respectively (Table 34).

Table 34: Cross-tabulation of HES comorbidity score and NHFD ASA grade

No. of comorbid conditions	**ASA grade (N (%))**				
	I	**II**	**III**	**IV**	**V**
0	3,583 (77.4)	25,769 (43.0)	18,901 (16.5)	1,526 (6.0)	58 (6.6)
1	675 (14.6)	19,896 (33.2)	35,748 (31.3)	5,465 (21.5)	169 (19.1)
2+	372 (8.0)	14,254 (23.8)	59,701 (52.2)	18,393 (72.5)	659 (74.4)

6.7.2. Abbreviated Mental Test Score

In 1972, Hodkinson introduced the Abbreviated Mental Test Score (AMTS) as a simple and quick screening tool for the assessment of cognitive impairment in older patients (338). The AMTS is comprised of ten questions that focus on several aspects of cognition, including memory, recall, and orientation to time, place and person. An individual can score a maximum of 10 points, with an AMTS score of less than 7 indicating cognitive impairment. NHFD assessment of AMTS on admission constitutes part of the BPT criteria for hip fracture, as discussed in Chapter 1.9.2, page 43 (120).

Whilst it is acknowledged that the AMTS does not distinguish between acute confusional states such as delirium and chronic cognitive impairment (e.g. dementia), the NHFD variable for baseline AMTS was cross-tabulated with the HES-derived comorbidity variable to check for broad consistency. The HES comorbidity variable identifies hip fracture patients with a recorded ICD-10 diagnosis of dementia, as described in section 6.6.7, page 187. Table 35 below demonstrates that the prevalence of dementia increased as baseline AMTS declined, which is consistent with the patterns expected.

Table 35: Cross-tabulation of HES dementia and NHFD baseline AMTS variables

Baseline AMTS score	No recorded ICD-10 code for dementia (N (%))	Recorded ICD-10 code for dementia (N (%))	Total (N)
0	3,332 (13.8)	20,887 (86.2)	24,219
1	958 (18.1)	4,329 (81.9)	5,287
2	1,485 (24.6)	4,563 (75.5)	6,048
3	1,901 (32.4)	3,973 (67.6)	5,874
4	2,502 (39.7)	3,797 (60.3)	6,299
5	3,458 (49.9)	3,467 (50.1)	6,925
6	4,627 (58.7)	3,258 (41.3)	7,885
7	7,616 (73.4)	2,755 (26.6)	10,371
8	14,109 (84.3)	2,634 (15.7)	16,743
9	23,233 (92.4)	1,908 (7.6)	25,141
10	75,550 (96.6)	2,690 (3.4)	78,240

6.7.3. Type of hip fracture

Hip fractures were categorised based on anatomical site of hip fracture in accordance with the definition used by the NHFD: undisplaced and displaced intracapsular fractures, intertrochanteric fractures and subtrochanteric fractures.

6.7.4. Pathological fracture

Hip fractures were categorised as pathological, atypical or non-pathological fractures in accordance with the definition used by the NHFD. Pathological fractures occur as a result of a primary or secondary malignancy affecting the fracture site, and atypical hip fractures are associated with the use of specific drug treatments (e.g. bisphosphonates) (120).

6.7.5. Hip fracture operation type

Operation type is a mandatory NHFD data field for hip fracture patients who have undergone surgery. Whilst the NHFD captures detailed information on type of operation performed such as insertion of a short/long IM nail and use of cement for hip arthroplasties, operation type was categorised using the six groupings shown below for these analyses (Table 36).

Consistency between information recorded in the NHFD on type of hip fracture and operation performed was assessed (Table 36); observed patterns were broadly consistent with recommended surgical management guidelines for hip fracture (discussed in Chapter 1.2, page 19). More than 85% of patients with an undisplaced intracapsular hip fracture underwent internal fixation with screws or hemiarthroplasty, and 90.8% of patients with a displaced intracapsular hip fracture underwent hip arthroplasty (hemiarthroplasty or THA). Approximately three-quarters of hip fracture patients with a subtrochanteric fracture were managed with an IM nail.

Table 36: Cross-tabulation of NHFD variables for hip fracture type and operation

	Hip fracture operation type (N (%))					
Hip fracture type	**Undisplaced intracapsular**	**Displaced intracapsular**	**Intertrochanteric**	**Subtrochanteric**	**Other**	**Total**
No operation performed	1,186 (5.3)	2,025 (1.9)	1,174 (1.6)	261 (2.1)	167 (8.2)	4,813 (2.2)
IF - DHS	4,920 (22.0)	4,713 (4.5)	63,230 (83.8)	2,627 (20.6)	613 (30.2)	76,103 (34.9)
IF - Cannulated screws	6,242 (27.9)	2,365 (2.2)	249 (0.33)	22 (0.17)	225 (11.1)	9,103 (4.2)
Internal fixation - IM nail	86 (0.38)	99 (0.09)	9,897 (13.1)	9,510 (74.6)	325 (16.0)	19,917 (9.1)
Hemiarthroplasty	8,644 (38.7)	84,916 (80.4)	389 (0.52)	55 (0.43)	457 (22.5)	94,461 (43.3)
THA	1,161 (5.2)	11,009 (10.4)	282 (0.37)	48 (0.38)	114 (5.6)	12,614 (5.8)
Other procedure	115 (0.51)	522 (0.49)	275 (0.36)	226 (1.8)	128 (6.3)	1,266 (0.58)
Total	22,354	105,649	75,496	12,749	2,029	218,277

IF – Internal fixation; DHS – Dynamic hip screw; IM – Intramedullary; THA – Total hip arthroplasty

6.7.6. Residential status

NHFD data were used to derive an ordinal variable for residential status prior to admission (Table 37). Information on source of admission can be used to determine an individual's level of dependence prior to the fracture event and identify hip fractures arising following an inpatient fall (120).

The NHFD variable *residential status at 30-days* can be used to identify patients who returned to their pre-fracture place of residence or patients with a new requirement for institutional care. However, owing to the high level of missing data for this variable (54.9%), it was not possible to examine the effect of deprivation on functional outcomes post-hip fracture such as need for institutionalisation. Other studies analysing NHFD data have used multiple imputation methods to handle missing data (339, 340); however, these studies imputed data for variables with less than 5% missing values.

Table 37: Residential status prior to hospital admission for hip fracture

Value	Description
0	Own home/sheltered housing
1	Already in hospital
2	Rehabilitation unit
3	Residential care
4	Nursing care
5	Other

6.7.7. Mobility

NHFD variables for pre-fracture and post-fracture mobility can be used to assess baseline mobility and mobility at 30-days post-hip fracture, and thus determine an individual's return to pre-fracture mobility levels (Table 38). It was not possible to assess the relationship between deprivation and return to baseline mobility in this current study due to the high level of missing data for baseline (7.6%) and 30-day mobility (77.4%); however, as discussed earlier, other studies have used alternative approaches for handling missing NHFD data, including multiple imputation methods (339, 340) (see section 6.7.6, page 199).

Table 38: Mobility status at baseline and 30-days after hip fracture

Value	Description
0	Freely mobile without aids
1	Mobile outdoors with one aid
2	Mobile outdoors with two aids or frame
3	Some indoor mobility but never goes outside without help
4	No functional mobility

6.8. Comparison of descriptive characteristics for patients in all three cohorts

As described earlier, hospital admission records for three cohorts of hip fracture patients were identified after merging HES-ONS and NHFD datasets: linked HES-ONS-NHFD patients, unlinked HES patients and unlinked NHFD patients. Study variables derived from HES and NHFD data were used to assess whether systematic differences existed between hip fracture patients with and without linked data.

Descriptive characteristics of all three cohorts of hip fracture patients were broadly similar (Table 39). There was a slightly higher proportion of women and older individuals in the linked group than in the unlinked HES and NHFD groups. Levels of deprivation were similarly distributed in all three groups except for an under-representation of hip fracture patients in the most deprived quintile, which is likely to be explained by the positive association between deprivation and premature mortality that has been demonstrated among individuals with CVD, respiratory disease and cancer amongst other diseases (248, 341).

Information on ethnicity, GOR of treatment and comorbidity were compared between linked HES-ONS-NHFD and unlinked HES patients. Regional representation of hip fracture patients treated in England was similar in both groups except for London; 10.1% of patients in the linked group were treated in London compared with 15.1% in the unlinked HES group. The proportion of hip fracture patients with a recorded ICD-10 diagnosis of dementia was higher for the linked group compared with the unlinked HES group (28.1% *vs*. 21.9%).

NHFD variables for ASA grade, hip fracture type and operation, and source of admission were compared between linked HES-ONS-NHFD patients and unlinked NHFD events, although numbers were small in the latter group. Hip fracture patients in the linked group were frailer than unlinked NHFD patients as suggested by the higher proportion of linked individuals with ASA grade III and IV status, and who were admitted from a care home. NHFD data for ASA grade and pathological fracture were not analysed further in this current study due to the level of missing data; 6.3% of linked hip fracture patients had missing data for ASA grade and 5.3% for pathological fracture. Although other studies have used statistical methods to address missing NHFD data as discussed earlier (see section 6.7.6, page 199), the use of similar methods for missing ASA grade and pathological fracture data were considered beyond the scope of this current study.

Hip fracture patients in the three groups were broadly similar with respect to demographic and fracture characteristics, and therefore analyses were restricted to linked HES-ONS-NHFD patients with complete data: 1,660 patients with missing data for deprivation and/or GOR of residence were excluded. The final study population consisted of 218,907 male and female English residents aged 60+ years admitted to hospital with an index hip fracture between 1st April 2011 and 31st March 2015.

Table 39: Comparison of descriptive characteristics based on HES study variables of three cohorts of hip fracture patients identified after merging HES-ONS and NHFD datasets

		HES-ONS-NHFD	HES	NHFD
N (%)		220,567	20,679	1,214
Age (years)	Mean (SD)	82.8 (8.4)	81.5 (9.1)	79.8 (9.3)
Age (years), n (%)	60-69	19,001 (8.6)	2,669 (12.9)	203 (16.7)
	70-79	48,092 (21.8)	4,930 (23.8)	348 (28.7)
	80-89	104,461 (47.4)	8,915 (43.1)	468 (38.6)
	90+	49,013 (22.2)	4,165 (20.1)	195 (16.1)
Gender, n (%)	Female	160,142 (72.6)	14,229 (68.8)	871 (71.7)
Ethnicity, n (%)	White	203,388 (97.9)	18,672 (96.2)	
	Missing	12,711	1,272	
IMD, n (%)	Q1 (Least deprived)	43,868 (20.0)	4,022 (20.1)	87 (20.0)
	Q2	47,188 (21.6)	4,336 (21.6)	85 (19.5)
	Q3	47,053 (21.5)	4,361 (21.7)	84 (19.3)
	Q4	42,378 (19.4)	3,900 (19.4)	104 (23.9)
	Q5 (Most deprived)	38,435 (17.6)	3,434 (17.1)	75 (17.2)
	Missing	1,645	626	779
GOR of treatment, n (%)	North East	13,427 (6.1)	822 (4.0)	
	North West	30,579 (13.9)	3,099 (15.0)	
	Yorkshire and Humber	22,789 (10.3)	1,722 (8.3)	
	East Midlands	16,470 (7.5)	1,396 (6.8)	
	West Midlands	24,547 (11.1)	2,576 (12.5)	
	East of England	25,949 (11.8)	2,188 (10.6)	
	London	22,174 (10.1)	3,117 (15.1)	
	South East	37,280 (16.9)	3,477 (16.8)	
	South West	27,352 (12.4)	2,282 (11.0)	
RCS Charlson comorbidity score, n (%)	No comorbidity	53,340 (24.2)	5,652 (27.3)	
	Comorbidity excl. dementia	105,189 (47.7)	10,493 (50.7)	
	Dementia	62,038 (28.1)	4,534 (21.9)	

IMD – Index of Multiple Deprivation; GOR – Government Office Region; RCS – Royal College of Surgeons of England; SD – Standard deviation

Table 40: Comparison of descriptive characteristics based on NHFD study variables of three cohorts of hip fracture patients identified after merging HES-ONS and NHFD datasets

	Variable	HES-ONS-NHFD	HES	NHFD
N (%)		220,567	20,679	1,214
ASA grade, n (%)	I	4,706 (2.3)		69 (6.3)
	II	60,485 (29.3)		429 (39.2)
	III	115,114 (55.7)		512 (46.8)
	IV	25,523 (12.3)		82 (7.5)
	V	889 (0.4)		<2%[a]
	Missing	13,850		119
Hip fracture type, n (%)	Intracapsular - undisplaced	22,598 (10.3)		147 (12.1)
	Intracapsular - displaced	106,508 (48.4)		548 (45.2)
	Intertrochanteric	76,097 (34.6)		422 (34.8)
	Subtrochanteric	12,843 (5.8)		80 (6.6)
	Other	2,051 (0.9)		<2%[a]
	Missing	470		<2%[a]
Pathological fracture, n (%)	No	203,308 (97.7)		1,130 (97.9)
	Yes	3,408 (1.6)		<2%[a]
	Atypical	1,424 (0.7)		<2%[a]
	Missing	12,427		60
Hip fracture operation, n (%)	No operation performed	4,892 (2.2)		40 (3.3)
	IF - DHS	76,754 (34.9)		438 (36.1)
	IF - Cannulated screw	9,179 (4.2)		66 (5.4)
	IF - IM nail	20,050 (9.1)		115 (9.5)
	Hemiarthroplasty	95,082 (43.2)		418 (34.5)
	THA	12,757 (5.8)		120 (9.9)
	Other	1,283 (0.6)		<2%[a]
	Missing	570		<2%[a]
Source of admission, n (%)	Own home/sheltered housing	168,514 (76.5)		901 (74.3)
	Already in hospital	8,448 (3.8)		71 (5.9)
	Rehabilitation unit	1,163 (0.5)		<2%[a]
	Residential care	25,583 (11.6)		127 (10.5)
	Nursing care	15,294 (6.9)		53 (4.4)
	Other	1,366 (0.6)		56 (4.6)
	Missing	199		<2%[a]

[a] Small numbers suppression (N<20)

ASA – American Society of Anaesthiologists; IF – Internal fixation; DHS – Dynamic hip screw; IM – Intramedullary; THA – Total hip arthroplasty

6.9. Statistical methods

6.9.1. Summarising data

The methods used to summarise numerical and categorical data have been described in detail in Chapter 5.7.1, page 159. In summary, histograms were constructed to display the distribution of continuous data; means and SDs were used to summarise normally-distributed data, and medians and IQRs for skewed data. Categorical data were summarised with counts and proportions, and Pearson's chi-squared test was used to examine the association between two categorical variables.

6.9.2. Selection of potential confounders

Controlling for confounding to generate unbiased estimates of the association between an exposure and outcome has been discussed in Chapter 5.7.3, page 160. Most of the published literature on outcomes after hip fracture has focused on mortality, with comparatively less known about other outcomes such as hospital LOS and emergency 30-day readmission. Therefore, for clarity, the causal diagram presented in Figure 14 summarises the hypothesised relationship between deprivation and mortality post-hip fracture, with discussion of the proposed relationships for other outcomes included in the sections below.

Studies conducted among different study populations, including those with CVD and diabetes, have shown that deprivation predicts adverse outcomes such as mortality and hospital readmission (197, 248, 342, 343). It was hypothesised that similar relationships would be observed among hip fracture patients, that is, greater deprivation would be associated with increased mortality, longer hospital stays and higher odds of readmission post-hip fracture. Part of the relationship between deprivation and outcomes after hip fracture is likely to be explained by individual-level characteristics such as age, gender and comorbidity; however, hospital-level factors may also explain some of this association.

Individual-level characteristics

More deprived hip fracture patients tend to be younger and male (see Chapter 2.6, page 65), and male gender and older age are both predictors of adverse outcomes after hip fracture (see Chapter 1.8, page 33). Comorbidity can be a mediator or confounder of the relationship between deprivation and outcomes post-hip fracture, as discussed in Chapter 5.7.3, page 160. The prevalence of comorbidity is higher among more deprived individuals (see Chapter 2.6, page 65), and thus may mediate the relationship between deprivation and hip fracture outcomes. However, comorbidity can also confound the relationship between deprivation and outcomes post-hip fracture through its negative impact on employment and earning potential, thus resulting in greater deprivation.

The prevalence of smoking, heavy alcohol intake and obesity all increase with greater levels of deprivation (231-233). Furthermore, these lifestyle risk factors are associated with higher odds of mortality and readmission; however, the effect on hospital LOS is not known (101, 344, 345). Unfortunately, it was not possible to adjust for these lifestyle risk factors due to a lack of available data on tobacco use, alcohol consumption and BMI in HES and NHFD databases.

Early surgery is associated with reduced mortality and shorter hospital stays after hip fracture (346, 347). Some studies have shown that area-based deprivation is associated with a delay in surgery post-hip fracture (300, 302); however, this relationship has not been consistently demonstrated (299, 301).

Hospital-level factors

Hospital-level factors such as hospital type (based on hospital size and teaching status), hospital case volume and orthogeriatric input may explain some of the relationship between deprivation and outcomes post-hip fracture. Hospital type influences patient survival after hip fracture, with admission to a teaching versus non-teaching hospital being associated with a decreased risk of mortality (348). The effect of hospital case volume on mortality post-hip fracture is not clear; one study showed that higher hospital volume is associated with higher mortality (349), whilst other studies have reported no association between hospital volume and mortality (350, 351). Studies have consistently shown that orthogeriatric models of hip fracture care are associated with decreased mortality risk (352). Few studies have examined the effect of hospital-level factors on readmission risk and/or acute hospital LOS post-hip fracture, thus limiting the ability to draw conclusions. There is some evidence to suggest that hospital LOS after hip fracture is longer in low-volume compared with high-volume hospitals (350), and joint orthopaedic and orthogeriatric care is associated with shorter hospital stays (352).

It is not known whether hospital-level factors, and thus quality of health care provision, differ according to level of area-based deprivation. However, it is known that hospitals serving more deprived populations have a greater demand on their health care services (353), which may result in fewer available resources and poorer quality of health care. This, in turn, may have a negative impact on health and deprivation status.

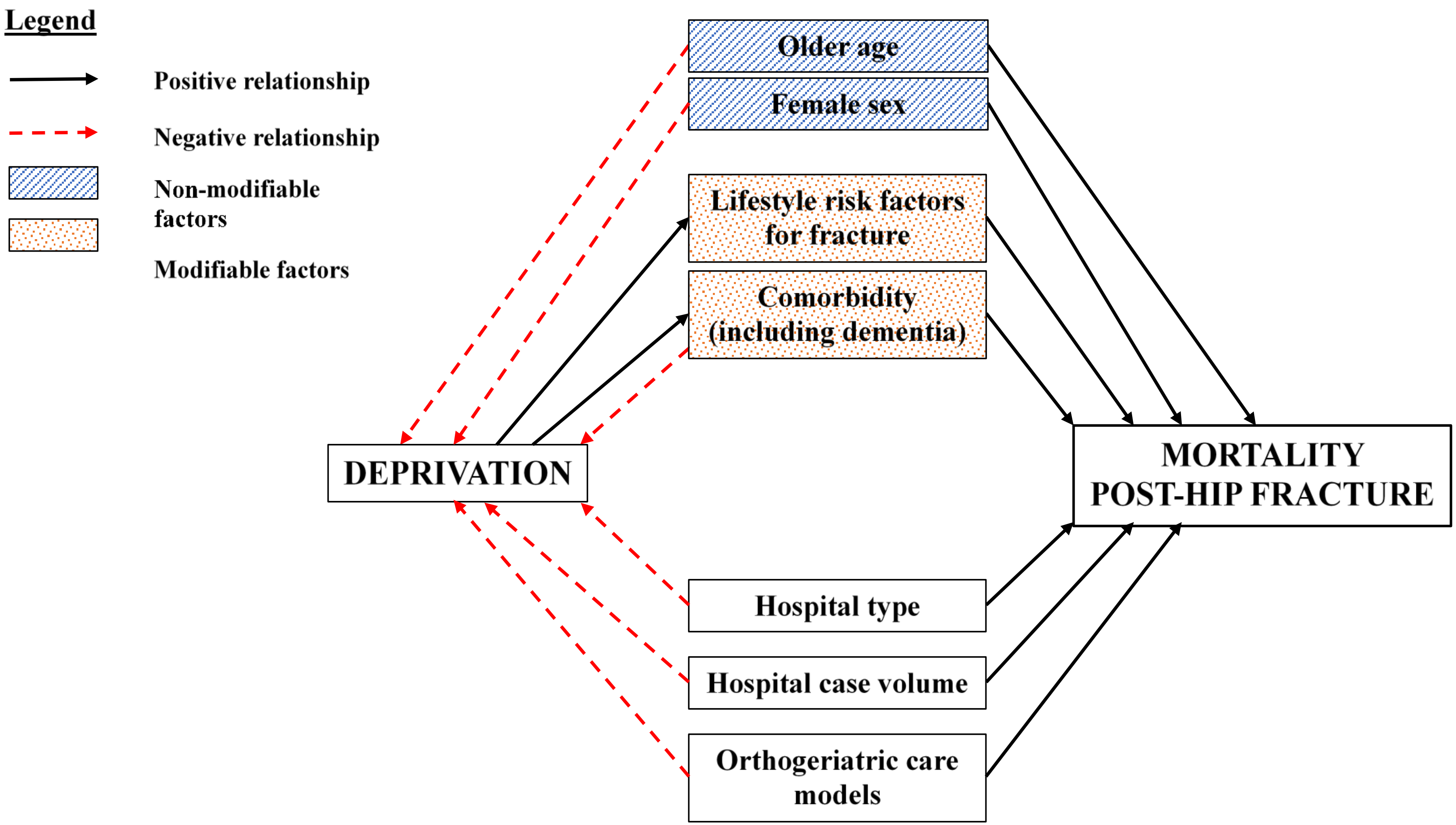

Figure 14: Directed acyclic graph summarising the hypothesised relationship between deprivation and mortality after hip fracture

6.9.3. Adjusting for potential confounders

The following approaches were used to control for the effect of confounding on the association between an exposure and outcome: stratification and multivariable regression.

Stratification

Stratification as a method for controlling for confounding has been described in Chapter 5.7.4, page 163. In brief, the association between an exposure and outcome was examined for each stratum of a potential confounder, and separate estimates of the strength of this association were generated.

Regression modelling

Multivariable regression modelling was used to examine the association between an exposure and outcome, adjusting for the effect of potential confounders.

Linear regression was used to describe the association between an exposure and continuous outcome such as hospital LOS. Regression coefficients and 95% CIs were calculated to describe the slope and intercept of the regression line. The regression coefficient represents the change in mean value of the dependent variable (e.g. hospital LOS) for a unit change in the independent variable (e.g. deprivation quintiles), and the intercept represents the value at which the regression line crosses the y-axis e.g. hospital LOS for the least deprived quintile (reference category) (329).

Logistic regression was used to examine the association between an exposure and binary outcome variable such as mortality or hospital readmission. Odds ratios (ORs) and 95% CIs were calculated on the ratio scale and were derived by exponentiating logistic regression coefficients and CIs on the log scale (329). ORs can be interpreted as the odds of the outcome in the exposed group compared to the unexposed group e.g. the probability of death among hip fracture patients in the most deprived compared with the least deprived quintile.

6.9.4. Tests for interaction

The methods used to test for interaction have been described in detail in Chapter 5.7.5, page 164. In brief, regression modelling was used to test for interaction by including an interaction term between the exposure and potential confounder. LRTs were used to examine model fit by comparing log-likelihoods from regression models with and without an interaction term. Analyses were presented stratified by levels of the confounder if the relationship between an exposure and outcome was modified by a confounder i.e. evidence of an interaction between the exposure and confounder.

6.9.5. Tests for trend

Tests for trend were conducted to determine if there was a constant change in the dependent variable for a unit increase in the independent variable, with the independent variable modelled as a linear term (329). Linear regression modelling was used for continuous outcomes and logistic regression modelling for binary outcomes.

6.9.6. Competing risks

A competing risk is defined as *"an event whose occurrence either precludes the occurrence of another event under examination or fundamentally alters the probability of* *occurrence of this other event"* (354). For analyses of superspell LOS and 30-day readmission, it is important to take account of competing events such as in-hospital mortality that will prevent the occurrence of the study outcome. In-hospital death will influence the amount of time an individual spends in hospital after hip fracture and readmission is not possible among patients who died during an inpatient stay.

Different methods can be used to account for the competing risk of mortality. Analyses can be restricted to those patients discharged alive from hospital. However, there are certain limitations to this approach. The study sample size is decreased and, importantly, survivor bias may be introduced given that those individuals who survived are healthier than the overall study population (355). Statistical methods also exist for the handling of competing risks. Traditionally, the Kaplan-Meier (KM) method has been used to conduct time-to-event analyses. However, in the presence of competing risks, the KM method overestimates the probability of outcome occurrence because competing events are treated as right censored observations and thus assumed to remain at risk of the outcome (354, 356). The cumulative incidence function is an alternative statistical approach that generates unbiased estimates by estimating the probability of an outcome occurring by a given time, while taking into account the occurrence of other events (354, 356) i.e. the probability of being discharged from or readmitted to hospital after hip fracture given that the individual is still alive.

The former method was used to handle the competing risk of mortality for analyses of superspell LOS and 30-day readmission conducted as part of this study, that is, the study sample was restricted to patients discharged alive from hospital. This approach was chosen because, as previously discussed, it was not possible to obtain date of death from the ONS (see section 6.1.2, page 166). Instead, information on mortality status at specified time points in the year after hip fracture was obtained from which it was not possible to conduct statistical analyses of competing risks.

CHAPTER 7. THE EFFECT OF SOCIAL DEPRIVATION ON HIP FRACTURE INCIDENCE OVER 14 YEARS IN ENGLAND

7.1. Introduction

Hip fractures are common with a substantial public health impact, as described in Chapter 1. There were approximately 65,000 hip fractures in England, Wales and Northern Ireland in 2015 (99); this number is projected to increase as our population ages. Hip fractures are associated with significant morbidity and mortality, including a reduction in mobility and an increased risk of mortality (84, 297, 298). Furthermore, hip fractures have a considerable financial impact upon healthcare systems; annual hospital costs associated with incident hip fractures have been estimated at £1.1 billion for the UK (31).

Greater deprivation is associated with increased hip fracture incidence in many countries including Australia (272), Canada (273), Portugal (282), Sweden (266) and the USA (271, 279) (see Chapter 3 for further discussion). In contrast, a reverse relationship has been reported in France where hip fracture risk was higher in the least deprived compared to most deprived areas (357). A similar inverse relationship between deprivation and hip fracture risk has been observed in Spain; however, this association was fully attenuated after adjustment for BMI suggesting that a higher prevalence of obesity in more deprived areas may have accounted for the observed findings (358). In the UK, a number of studies have identified an association between worsening deprivation and higher hip fracture incidence (21, 50, 277); but this has not been consistently demonstrated albeit by studies of varying durations (284, 359). In addition, recent evidence suggests that the relationship between deprivation and hip fracture risk may be stronger in men than women (50), potentially explained by differing predispositions in men and women towards lifestyle habits that increase fracture risk, such as tobacco and heavy alcohol consumption (360, 361).

Over the last two decades efforts have been made to prevent hip fractures, through development of fracture liaison services that prioritise secondary fracture prevention (362). Over this period, hip fracture incidence has plateaued or declined in high-income countries; age-standardised hip fracture incidence declined in Australia (25), Canada (16) and the USA (15), and rates have plateaued in England (20-22) (see Chapter 1.4, page 20). However, a recent US analysis of Medicare claims data for women aged 65+ years showed that whilst age-adjusted hip fracture incidence had declined over the period 2002 to 2012, incidence rates had stabilised at higher than projected levels between 2013 and 2015 (17).

Contrasting gender-specific trends in England have been reported, with hip fracture incidence rising amongst men aged 85+ years, but declining amongst women aged 75+ years (between 2003 and 2013) (23). In support of this, analysis of the CPRD showed that hip fracture incidence had remained unchanged in women between 1990-1994 and 2008-2012, and had increased in men over the same period (24). Furthermore, differing age-specific trends in hip fracture incidence have been demonstrated, with hip fracture incidence reported to have increased in men aged 85+ years and women aged 90+ years (24).

7.2. Aims of this Chapter

It is not known whether the relationship between deprivation and hip fracture incidence has changed over the last two decades in men and women. It was hypothesised that secular changes in hip fracture incidence in men and women, and younger and older adults, have not been the same across all levels of deprivation. It was postulated that greater declines in hip fracture incidence would be observed amongst women living in less deprived areas, given a greater awareness of osteoporosis risk amongst women, and that individuals living in less deprived areas are more likely to engage with preventative healthcare services (363). HES data and ONS MYPE for the period 2001 to 2014 were used to identify if secular trends in hip fracture incidence differed by levels of deprivation among men and women in England over this 14-year period.

7.3. Methods

7.3.1. Data sources

Anonymised patient-level data from the routinely collected HES APC database that included admissions to all English hospitals within the NHS (*i.e.* excluding privately-financed healthcare) were analysed for the period 1st April 2001 to 31st March 2015. Each entry, or episode, in HES relates to a period of care under a single hospital consultant; there are one or more hospital episodes during a hospital admission. Each HES episode includes information on patient demographics and up to 20 clinical diagnoses using ICD-10 disease codes (316). Further background to HES data has been provided in Chapter 5.1, page 136.

ONS MYPE were obtained for England for each year from 2001 to 2014, as described in Chapter 5.5, page 156. Population denominator data were received stratified by age categories (0 to 90+ years in 5-yearly intervals), gender, IMD 2015 quintiles and geography (32,844 LSOAs).

7.3.2. Study population

The study population consisted of index cases of hip fracture, that is the first occurrence of hip fracture, among male and female English residents aged 50+ years who were admitted to hospital with a hip fracture or who sustained a hip fracture during a hospital admission. Second hip fractures were excluded in order to avoid double-counting because ICD-10 coding does not allow differentiation of laterality, and therefore it was not possible to distinguish reliably between two separate hip fracture events in HES. Patients under the age of 50 years were excluded as hip fractures in this age group are primarily due to high-impact trauma (254). Patients with missing data for age, gender, IMD and geographic region of residence (n= 4,667) were also excluded. The methods used to define this study population have been described in Chapter 5.2, page 141.

7.3.3. Study variables

Deprivation

The IMD was used to measure socioeconomic deprivation (195). As described in Chapter 5.3.2, the IMD rank for a patient's LSOA was used to categorise patients into quintiles based upon the national ranking of local areas, with quintile 1 being the least deprived group and quintile 5 being the most deprived group (see page 149).

Occurrence of hip fracture

Hip fracture admissions were identified using ICD-10 disease codes for fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1), and subtrochanteric fracture (S72.2) in the first diagnosis field of any episode that comprised an index hospital admission, thus capturing in-hospital hip fractures (see Chapter 5.2.4, page 143). The first diagnosis field in HES includes information on the primary diagnosis, whereas ICD-10 codes in the other diagnosis fields are for secondary diagnoses, such as a prior history of hip fracture (316).

Further study variables

Further variables were derived to describe patient characteristics, including 5-yearly age groupings from 50 to 90+ years, gender and comorbidity (see Chapter 5.3, page 148). The RCS Charlson score was used to measure comorbidity (323). This is based upon several chronic conditions identified using ICD-10 diagnosis codes for the index hip fracture admission and admissions in the preceding three years. Comorbidity data were only available for the most recent ten financial years (2005/06 to 2014/15) in the HES APC data extract analysed and therefore comorbidity-specific analyses were restricted to the most recent seven years (2008/09 to 2014/15) to allow a three-year retrospective period in which to identify comorbidities. The comorbidity score was categorised into a four-level ordinal variable (0, 1, 2 or 3+ comorbid conditions).

7.3.4. Research approvals

NHS Research Ethics Committee approval was obtained for this study (REC reference: 15/LO/1056).

7.3.5. Statistical analyses

All statistical analyses were conducted using Stata, version 14 IC (StataCorp, College Station, TX, USA).

Descriptive analyses

Demographic characteristics of the hip fracture population were described (see Chapter 5.7.1, page 159 for further details). Counts and percentages were used to summarise categorical variables according to quintiles of deprivation and time period (in two-yearly intervals). χ^2 test examined the association between two categorical variables to determine whether the distribution of age group, gender and comorbidity differed by deprivation quintiles and time period.

The distribution of continuous variables was assessed using histograms. Mean and SD was used to describe age (in single years), which was normally distributed; IMD score was positively skewed and summarised by the median and IQR. The most appropriate transformation of IMD score was assessed to satisfy the assumption of normality for linear regression. Linear regression was used to assess linear trends in age and log-transformed IMD score by deprivation quintiles and time period respectively.

Age-standardised hip fracture incidence

Annual incidence rates of hip fracture per 100,000 population were calculated as the number of index hip fractures divided by the population count for each year group, gender and IMD quintile. To assess time trends, direct standardisation was used to calculate age-standardised rates using the population of England in 2001 as the reference year and grouping age into nine bands (see Chapter 5.7.2, page 159).

Association between deprivation and hip fracture incidence

Poisson regression modelling was used to determine the association between deprivation and hip fracture incidence by modelling the number of hip fractures as the dependent variable and IMD quintile and age group as independent variables, accounting for population size as an offset. IRRs with 95% CIs were calculated to compare the rate of hip fracture among individuals in each strata of deprivation (i.e. Q2 – Q5) with individuals in quintile 1, the least deprived quintile, which was used as the reference category (see Chapter 5.7.4, page 163). IRRs were presented unadjusted and adjusted for age group (in 5-yearly intervals).

Formal tests for interaction

Tests for interaction were conducted to examine whether time trends in hip fracture incidence differed by gender (time by gender interaction) and then, separately for men and women, by deprivation quintiles (time by deprivation interaction). An interaction term between gender and year or deprivation and year was included, adjusting for age, with year modelled as a linear term. The LRT was used to examine an improvement in model fit by comparing estimates from models with and without the interaction term. Further details of the statistical methods used to test for interaction have been provided in Chapter 5.7.5, page 164.

Differences in the effect of deprivation on hip fracture incidence among men and women were also assessed (deprivation by gender interaction) given possible gender differences. As the effect of deprivation on hip fracture incidence was shown to differ by gender, subsequent analyses were conducted separately for men and women.

Similarly, tests for interaction were conducted to determine whether the effect of deprivation on hip fracture incidence differed among individuals aged 50-84 years and 85+ years (deprivation by age group interaction) and whether time trends in hip fracture incidence differed by deprivation quintiles among men and women aged 50-84 years and 85+ years (i.e. time by deprivation interaction for each gender and strata of age group as a binary variable).

Secular trends in comorbidity by levels of deprivation among hip fracture patients

As a secondary analysis, time trends among hip fracture patients with comorbidities were investigated and differences by levels of deprivation were examined. It was not possible to determine differences in hip fracture incidence by comorbidity because comorbidity data for the English population as a whole were unavailable. Instead, direct standardisation was used to calculate the age-standardised proportion of hip fracture admissions with low (≤1 comorbid condition) and high (≥2 comorbid conditions) comorbidity by gender and IMD quintiles. The hip fracture population in 2008 was used as the reference year given that this was the earliest time point for which comorbidity data were available.

7.4. Results

7.4.1. Description of study population

There were 752,036 hospital admissions with an index hip fracture among English residents aged 50+ years from 2001 to 2014, of which 4,667 (0.6%) patients were excluded due to their missing data for age, sex, IMD and/or geographic region of residence. Of the remaining 747,369 cases of hip fracture, 74.2% occurred in women and 37.7% had 2 or more coded comorbid conditions (Table 41). 19.2% of hip fracture admissions occurred among individuals in the least deprived quintile and 18.8% among those in the most deprived quintile. The mean [SD] age of this study population was 81.6 [9.5] years; 79.3 [10.2] in men and 82.4 [9.1] in women. Hip fracture patients in the most deprived quintile were more likely to be younger, male and have a higher burden of comorbidity when compared to patients in the least deprived quintile (Table 41). Over time, the proportion of men increased, and the burden of comorbidity increased within this hip fracture population; the proportion of individuals aged 85+ years increased from 41.5% to 44.7% (Table 42).

Table 41: Characteristics of patients admitted to hospital and sustaining a hip fracture according to quintiles of deprivation, 2001-2014

		Total population	**IMD Q1 (Least deprived)**	**IMD Q2**	**IMD Q3**	**IMD Q4**	**IMD Q5 (Most deprived)**	**p value**
N (%)		747,369 (100)	143,183 (19.2)	157,054 (21.0)	158,969 (21.3)	147,933 (19.8)	140,230 (18.8)	
Age (years)	Mean (SD)	81.6 (9.5)	82.2 (9.2)	82.1 (9.3)	82.0 (9.3)	81.4 (9.5)	80.2 (10.0)	p<0.001
Age (years), n (%)	50-64	48,230 (6.5)	7,816 (5.5)	8,834 (5.6)	9,276 (5.8)	9,997 (6.8)	12,307 (8.8)	p<0.001
	65-74	97,331 (13.0)	17,061 (11.9)	19,196 (12.2)	19,795 (12.5)	19,401 (13.1)	21,878 (15.6)	
	75-84	280,303 (37.5)	53,209 (37.2)	58,230 (37.1)	59,211 (37.3)	56,009 (37.9)	53,644 (38.3)	
	≥85	321,505 (43.0)	65,097 (45.5)	70,794 (45.1)	70,687 (44.5)	62,526 (42.3)	52,401 (37.4)	
Gender, n (%)	Female	554,573 (74.2)	106,604 (74.5)	117,637 (74.9)	119,091 (74.9)	109,700 (74.2)	101,541 (72.4)	p<0.001
RCS comorbidity score[a], n (%)	0	116,739 (30.4)	26,217 (34.5)	26,448 (32.4)	24,891 (30.5)	21,288 (28.4)	17,895 (25.8)	p<0.001
	1	122,165 (31.8)	23,935 (31.5)	26,347 (32.2)	26,229 (32.2)	23,840 (31.8)	21,814 (31.5)	
	2	76,775 (20.0)	14,292 (18.8)	15,654 (19.1)	16,214 (19.9)	15,566 (20.7)	15,049 (21.7)	
	≥3	67,958 (17.7)	11,492 (15.1)	13,317 (16.3)	14,214 (17.4)	14,350 (19.1)	14,585 (21.0)	

[a] Restricted to financial years 2008-2014 and calculated using comorbidity data derived from the index hip fracture admission and hospital admissions in the previous 3 years

Pearson's chi-squared test was used to assess the association between deprivation quintiles and categorical outcome variables; linear regression was used to assess trends in log-transformed age by deprivation quintiles

IMD – Index of Multiple Deprivation; RCS – Royal College of Surgeons of England; SD – Standard deviation

Table 42: Characteristics of patients admitted to hospital and sustaining a hip fracture over time from 2001 to 2014

		2001&2002	2003&2004	2005&2006	2007&2008	2009&2010	2011&2012	2013&2014	p value
N (%)		102,784 (13.8)	103,095 (13.8)	103,828 (13.9)	106,214 (14.2)	108,894 (14.6)	110,510 (14.8)	112,044 (15.0)	
Age (years)	Mean (SD)	81.5 (9.2)	81.5 (9.3)	81.6 (9.4)	81.6 (9.5)	81.6 (9.6)	81.7 (9.6)	81.7 (9.7)	p<0.001
Age (years), n (%)	50-64	5,748 (5.6)	6,086 (5.9)	6,710 (6.5)	7,277 (6.9)	7,585 (7.0)	7,421 (6.7)	7,403 (6.6)	p<0.001
	65-74	13,829 (13.5)	13,596 (13.2)	13,020 (12.5)	13,291 (12.5)	14,058 (12.9)	14,429 (13.1)	15,108 (13.5)	
	75-84	40,534 (39.4)	41,800 (40.6)	40,288 (38.8)	39,615 (37.3)	39,385 (36.2)	39,196 (35.5)	39,485 (35.2)	
	≥85	42,673 (41.5)	41,613 (40.4)	43,810 (42.2)	46,031 (43.3)	47,866 (44.0)	49,464 (44.8)	50,048 (44.7)	
Gender, n (%)	Female	80,085 (77.9)	79,498 (77.1)	78,283 (75.4)	78,663 (74.1)	78,848 (72.4)	79,909 (72.3)	79,287 (70.8)	p<0.001
IMD Score	Median (IQR)	17.3 (10.1-29.9)	17.1 (10.1-29.6)	17.0 (10.0-29.4)	16.7 (9.7-29.1)	16.7 (9.8-28.9)	16.6 (9.8-28.5)	16.4 (9.7-28.2)	p<0.001
RCS Charlson score[a,b], n (%)	0				39,314 (37.1)	35,873 (33.1)	31,855 (28.9)	29,354 (26.2)	p<0.001
	1				34,742 (32.8)	35,311 (32.6)	35,079 (31.8)	34,404 (30.7)	
	2				18,746 (17.7)	20,661 (19.1)	22,876 (20.8)	23,865 (21.3)	
	≥3				13,106 (12.4)	16,543 (15.3)	20,441 (18.5)	24,421 (21.8)	

[a] Restricted to financial years 2008-2014; calculated using comorbidity data derived from the index hip fracture admission and hospital admissions over the previous 3 years

[b] The numerator for year 2008 has been doubled to derive the number of hip fractures stratified by comorbidity for the equivalent of 2007 and 2008

IQR – Interquartile range; IMD – Index of Multiple Deprivation; RCS – Royal College of Surgeons of England; SD – Standard deviation

7.4.2. Hip fracture incidence

Whilst the number of hip fracture admissions increased over the 14 years examined, from 50,640 in 2001 to 55,092 in 2014, overall crude hip fracture incidence rates decreased from 308 to 285 hip fractures per 100,000 population between 2001 and 2014. However, after standardising for age, further declines in hip fracture incidence were observed over time; age-standardised hip fracture incidence went from 308 in 2001 to 271 per 100,000 population in 2014 (Figure 15).

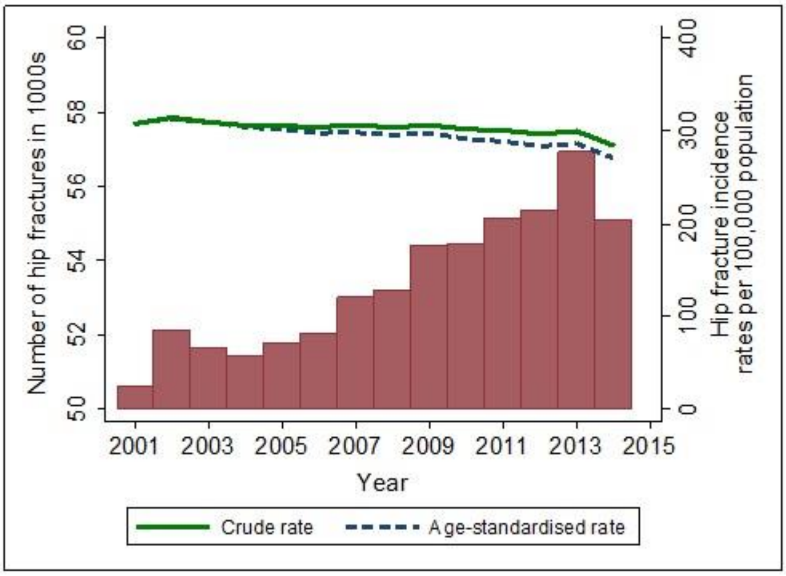

Figure 15: Secular trends in the absolute number of hip fractures, and crude and age-standardised annual hip incidence rates per 100,000 population in men and women aged 50+ years, 2001-2014

7.4.3. Crude hip fracture incidence by age and gender

As expected, considerably higher incidence rates of hip fracture were observed among older individuals (85+ *vs.* <85 years: IRR 11.45 [95% CI 11.40,11.51], p<0.001). Crude hip fracture incidence increased exponentially with advancing age amongst both men and women; rates were similar for men and women between the ages of 50-54 years and 65-69 years, with more marked increases in hip fracture incidence observed among women aged 70-74 years and older compared to men of the same age (Figure 16).

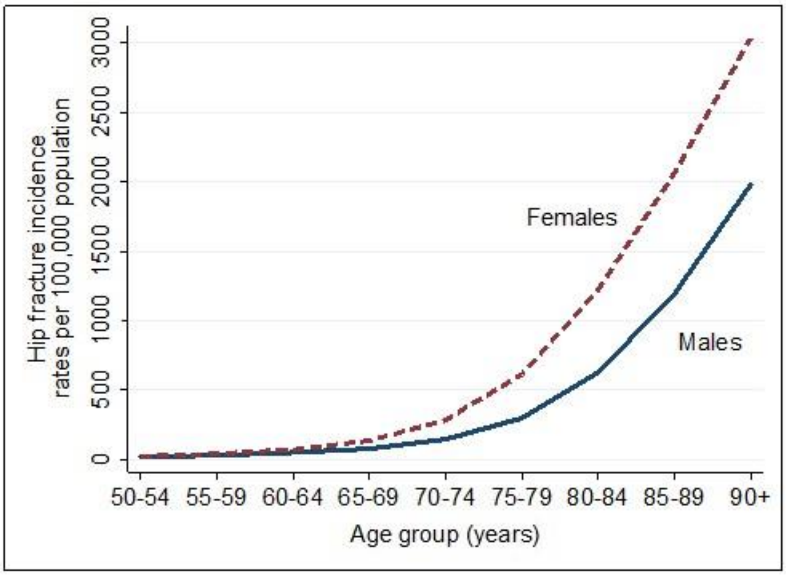

Figure 16: Hip fracture incidence rates per 100,000 population by age group (5-year intervals) in men and women aged 50+ years, 2001-2014

Between 2001 and 2014, crude hip fracture incidence remained stable among men under the age of 85 years and women up to the age of 75 years, whilst incidence rates increased among men aged 85+ years and declined in women aged 75+ years (Figure 17).

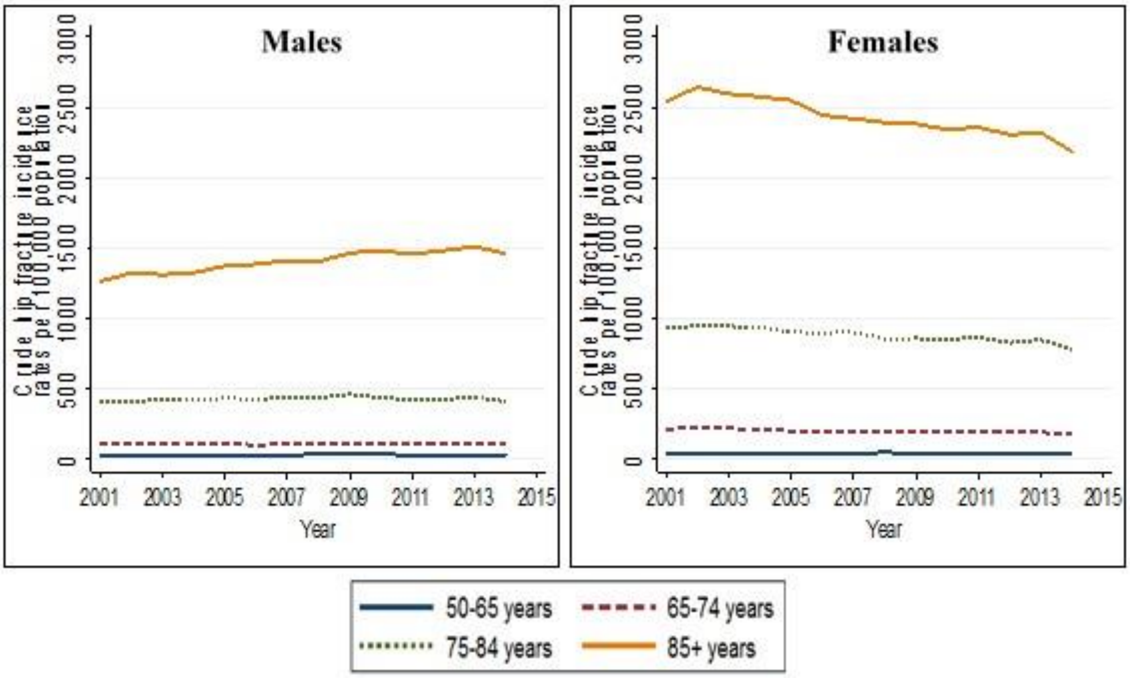

Figure 17: Crude annual hip fracture incidence rates per 100,000 population by age group in men and women aged 50+ years, 2001-2014

7.4.4. Age-standardised hip fracture incidence

Trends in age-standardised incidence differed markedly by gender with a decline observed for women at an average rate of 1.1% per year, whilst rates increased for men at an average rate of 0.6% per year (gender by time interaction p <0.001) (Figure 18). Age-adjusted hip fracture incidence was approximately 80% higher among women than men (age-adjusted IRR 1.78 [1.77,1.79], p<0.001).

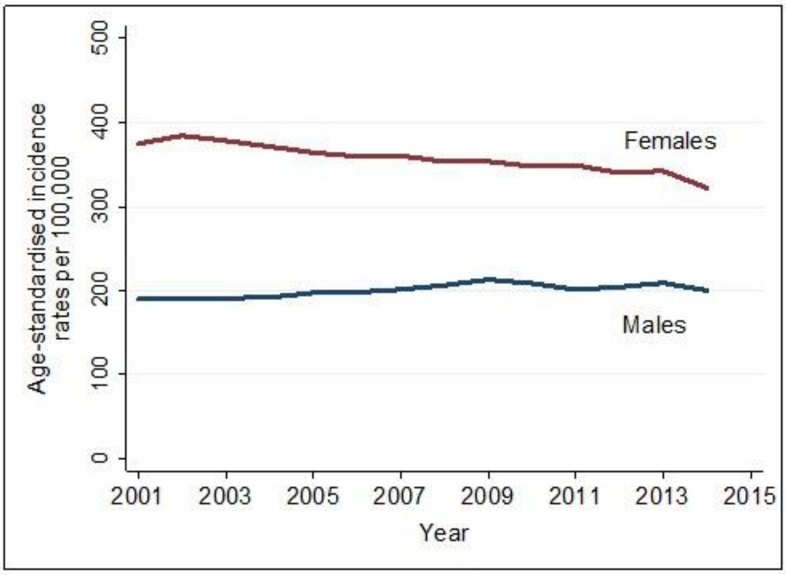

Figure 18: Annual age-standardised hip fracture incidence rates per 100,000 population in men and women aged 50+ years, 2001-2014

7.4.5. Hip fracture incidence by levels of deprivation

Hip fracture incidence was highest in the most deprived versus the least deprived quintile (IRR 1.32 [1.31,1.33], p<0.001); adjustment for age modestly attenuated this relationship (IRR 1.27 [1.26,1.28], p<0.001).

From 2001 to 2014, age-standardised hip fracture incidence was higher in the most deprived compared to the least deprived quintile (Figure 19 & Appendix 13.5, page 426); however, trends in hip fracture incidence over this 14-year period differed by levels of deprivation (age-adjusted deprivation by time interaction p<0.001) (Appendix 13.6, page 427). Age-standardised incidence declined among individuals in all deprivation quintiles; however, the rate of decline was more marked among individuals in the least deprived quintile compared with the most deprived quintile, equating to an average decline of 1.6% and 0.35% per year respectively.

The effect of deprivation on hip fracture incidence was greater in men than women (age-adjusted deprivation by gender interaction p<0.001), and among individuals under the age of 85 years compared to those aged 85+ years (deprivation by age interaction p<0.001) (Appendix 13.6, page 427).

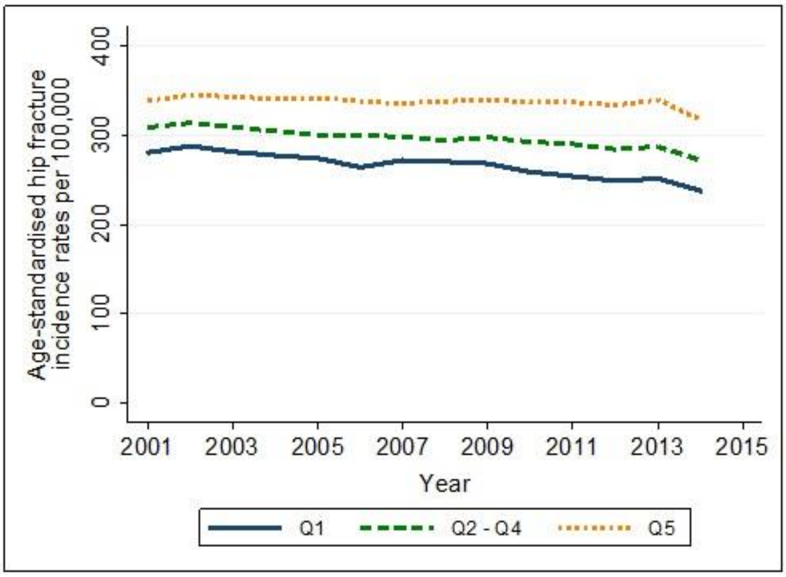

Figure 19: Annual age-standardised hip fracture incidence rates per 100,000 population by quintile of deprivation in men and women aged 50+ years, 2001-2014 (Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

Hip fracture incidence by levels of deprivation in men

Hip fracture incidence was substantially higher for men in the most deprived compared with the least deprived quintile (unadjusted IRR 1.45 [1.43,1.47], p<0.001); the relationship between deprivation and hip fracture incidence was augmented after adjustment for age (IRR 1.50 [1.48,1.52], p<0.001) with a dose-response pattern (Figure 20).

From 2001 to 2014, age-standardised hip fracture incidence rates increased similarly for men across all strata of deprivation and this rate of increase did not differ by levels of deprivation (age-adjusted deprivation by time interaction, p=0.11) (Figure 21) (Appendix 13.6, page 427).

Hip fracture incidence by levels of deprivation in women

In women, there was a less marked association between levels of deprivation and hip fracture incidence, but still with a dose-response pattern (Figure 20). Hip fracture incidence was 27% higher in the most deprived versus the least deprived quintile (unadjusted IRR 1.27 [1.26,1.28], p<0.001); this effect persisted after adjustment for age (IRR 1.17 [1.16,1.18], p<0.001).

Whereas age-standardised incidence declined in women across all strata of deprivation from 2001 to 2014, more marked declines in hip fracture incidence were observed among women in the least deprived quintile as compared to the most deprived quintile (age-adjusted deprivation by time interaction, p<0.001) (Appendix 13.6, page 427). For example, amongst the least deprived quintile, hip fracture incidence decreased by 60 hip fractures per 100,000 women between 2001 and 2014 equating to an average decline of 1.41% per year, whilst amongst the most deprived quintile a more modest decline of 31 hip fractures per 100,000 women was seen, equating to an average decline of 0.59% per year (Figure 21).

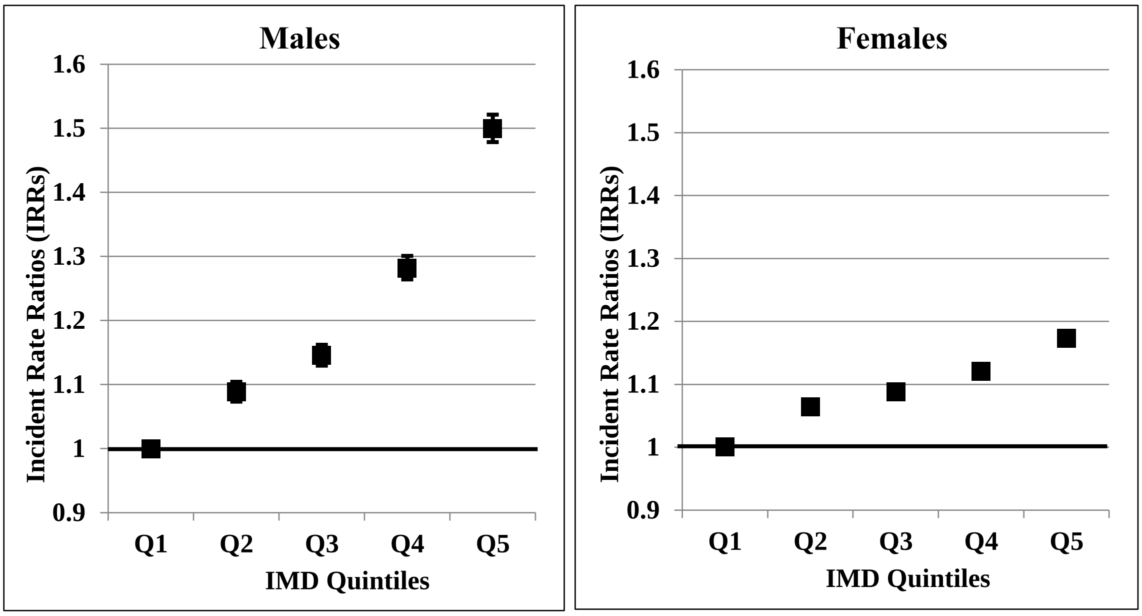

Figure 20: Association between quintiles of deprivation and age-adjusted hip fracture incidence rates in men and women aged 50+ years, 2001-2014
(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile) (IRRs and 95% confidence intervals presented)

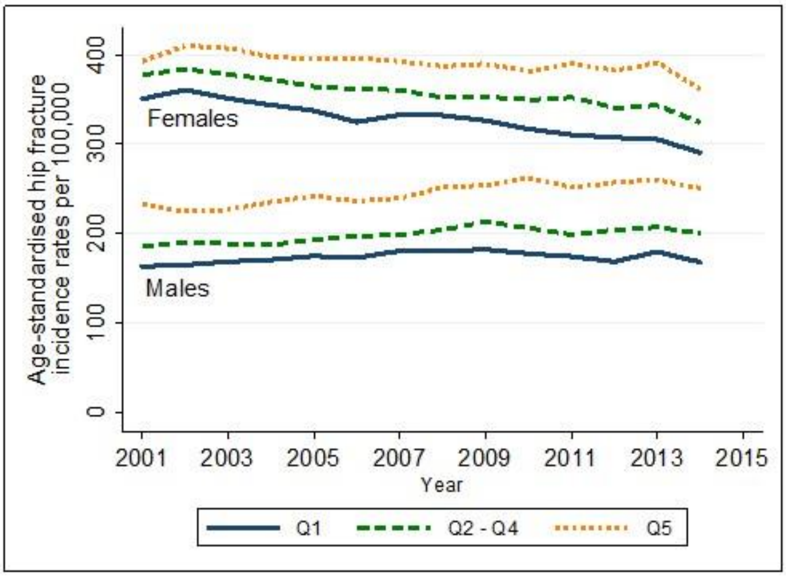

Figure 21: Annual age-standardised hip fracture incidence rates per 100,000 population by quintile of deprivation in men and women aged 50+ years, 2001-2014
(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

Hip fracture incidence by levels of deprivation and age group in men and women

There was a clear association between deprivation and hip fracture incidence in both men and women aged 50–84 years with a dose response pattern; a less marked association between deprivation and hip fracture incidence was observed among men and women aged 85+ years (

Figure ***22***). Among individuals aged 50-84 years, hip fracture incidence was 76% and 42% higher in the most deprived compared to the least deprived quintile for men (IRR 1.76 [1.73,1.79], $p<0.001$) and women (IRR 1.42 [1.41,1.44], $p<0.001$). In contrast, among men aged 85+ years, hip fracture incidence was only slightly higher in the most deprived versus the least deprived quintile (IRR 1.04 [1.02,1.07], $p<0.001$), with no association between deprivation and hip fracture incidence observed in women aged 85+ years (IRR 1.01 [0.99,1.02], $p=0.32$).

For both age groups, hip fracture incidence increased in men and decreased in women across all strata of deprivation between 2001 and 2014; however, the rate of change differed by quintiles of deprivation (Figure 23). Among men aged 50-84 years, hip fracture incidence increased at an average rate of 0.13% and 0.99% per year in the most and least deprived quintiles respectively (deprivation by time interaction, $p<0.001$), whereas in men aged 85+ years, the rate of increase was more marked in the most deprived compared to the least deprived quintile (1.68% *vs.* 0.68%) (deprivation by time interaction, $p=0.02$) (Appendix 13.6, page 427). In women aged 50-84 years, hip fracture incidence decreased at a greater rate in the most deprived compared to the least deprived quintile (1.97% *vs.* 0.95%) (deprivation by time interaction, $p<0.001$). The converse was observed among women aged 85+ years; hip fracture incidence decreased at an average rate of 0.52% and

1.66% per year in the most and least deprived quintiles respectively (deprivation by time interaction, $p<0.001$) (Appendix 13.6, page 427).

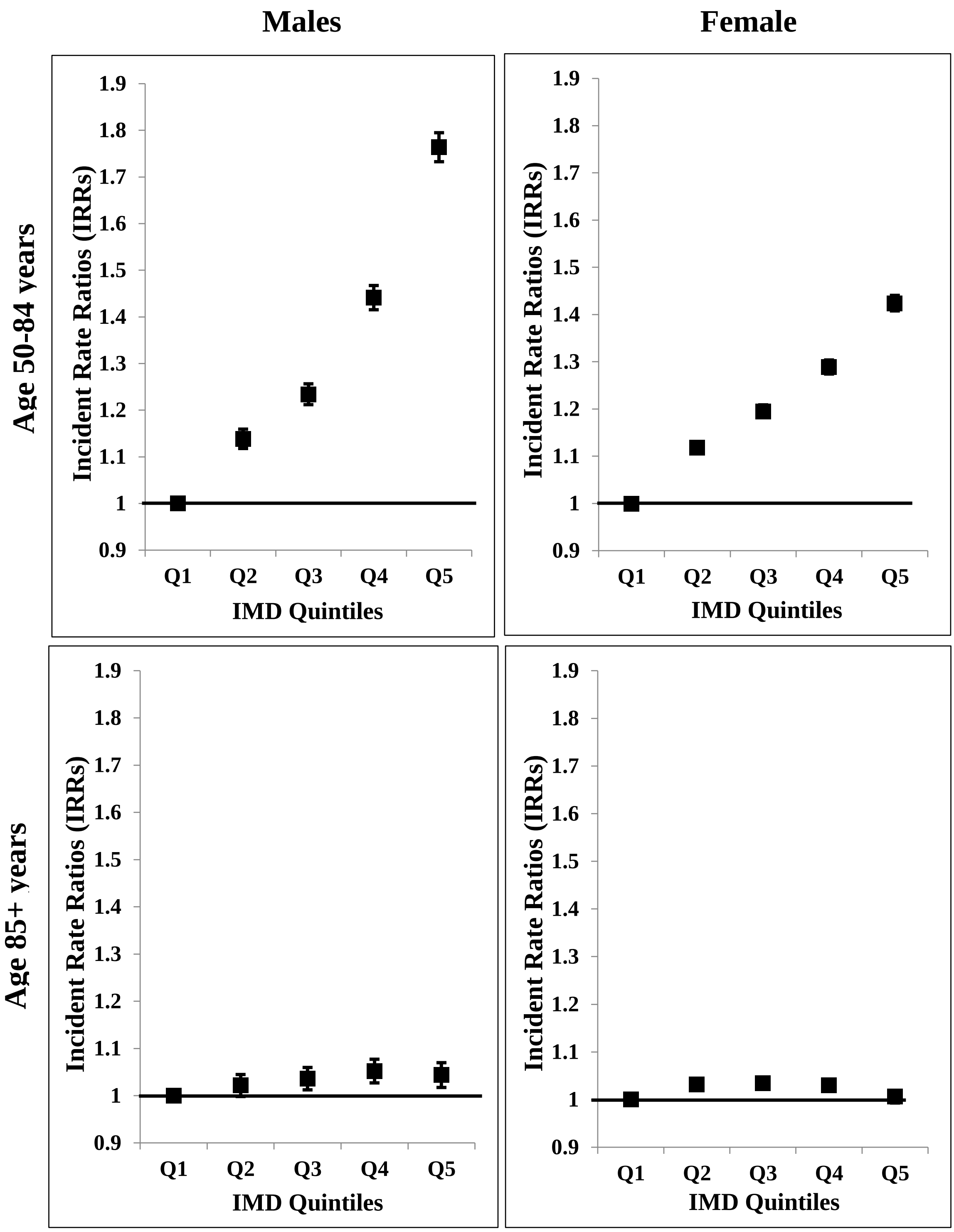

Figure 22: Association between quintiles of deprivation and hip fracture incidence rates in men and women aged 50-84 years and 85+ years, 2001-2014

(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile) (IRRs and 95% confidence intervals presented)

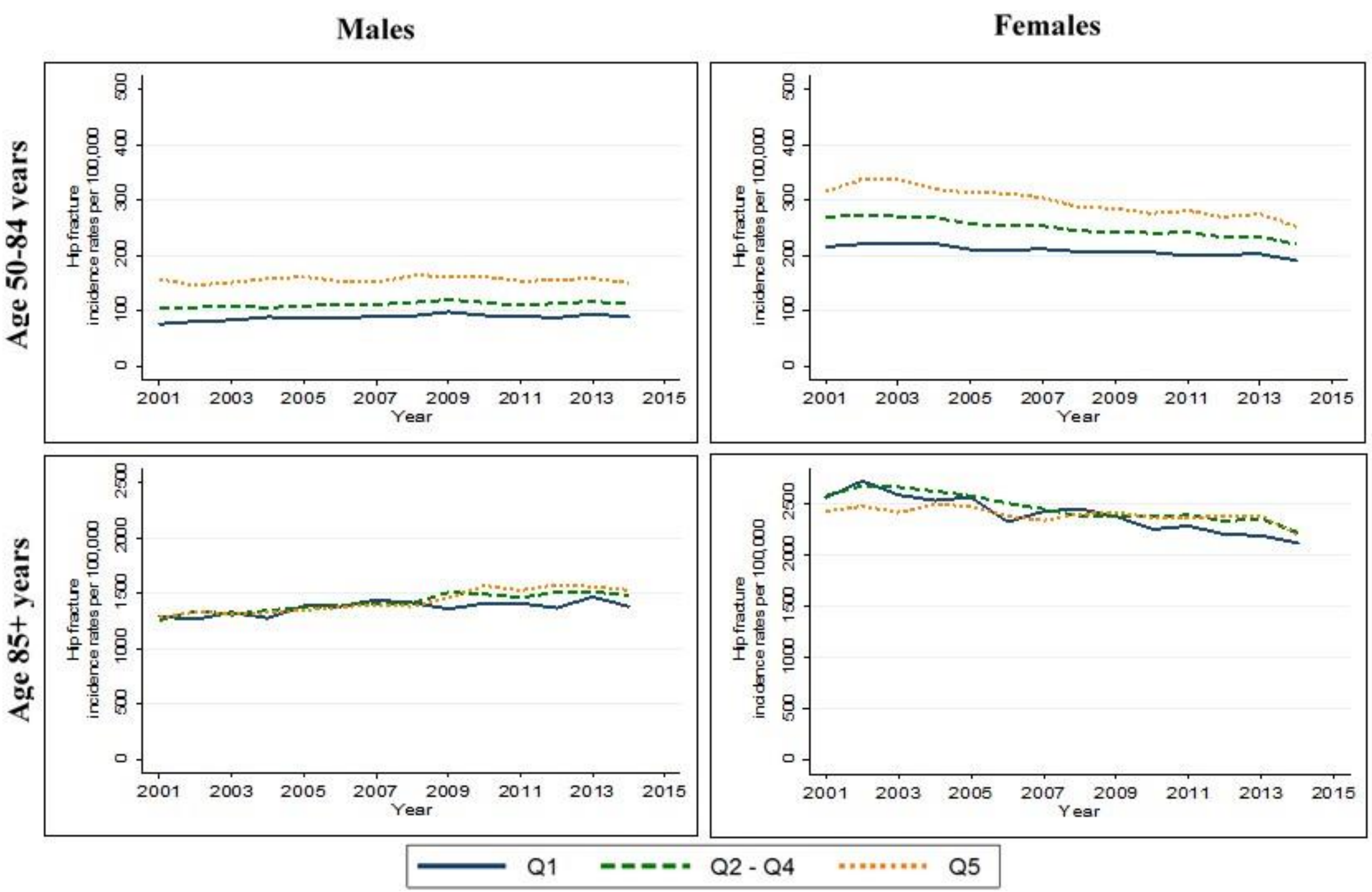

Figure 23: Annual hip fracture incidence rates per 100,000 population, by quintile of deprivation in men and women aged 50-84 years and 85+ years, 2001-2014
(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

7.4.6. Hip fracture admissions amongst those with high levels of comorbidity

Over the period 2008 to 2014, 46.2% of men and 34.5% of women with a hip fracture admission had high levels of comorbidity (≥2 comorbid conditions). After standardising for age, the proportion of hip fracture admissions rose from 39.3% to 53.5% among men, and 26.9% to 39.6% among women between 2008 and 2014. The age-standardised proportion of hip fracture admissions amongst those with high levels of comorbidity was higher in the most deprived compared with the least deprived quintile in both men and women, and this proportion increased similarly across all strata of deprivation (Figure 24).

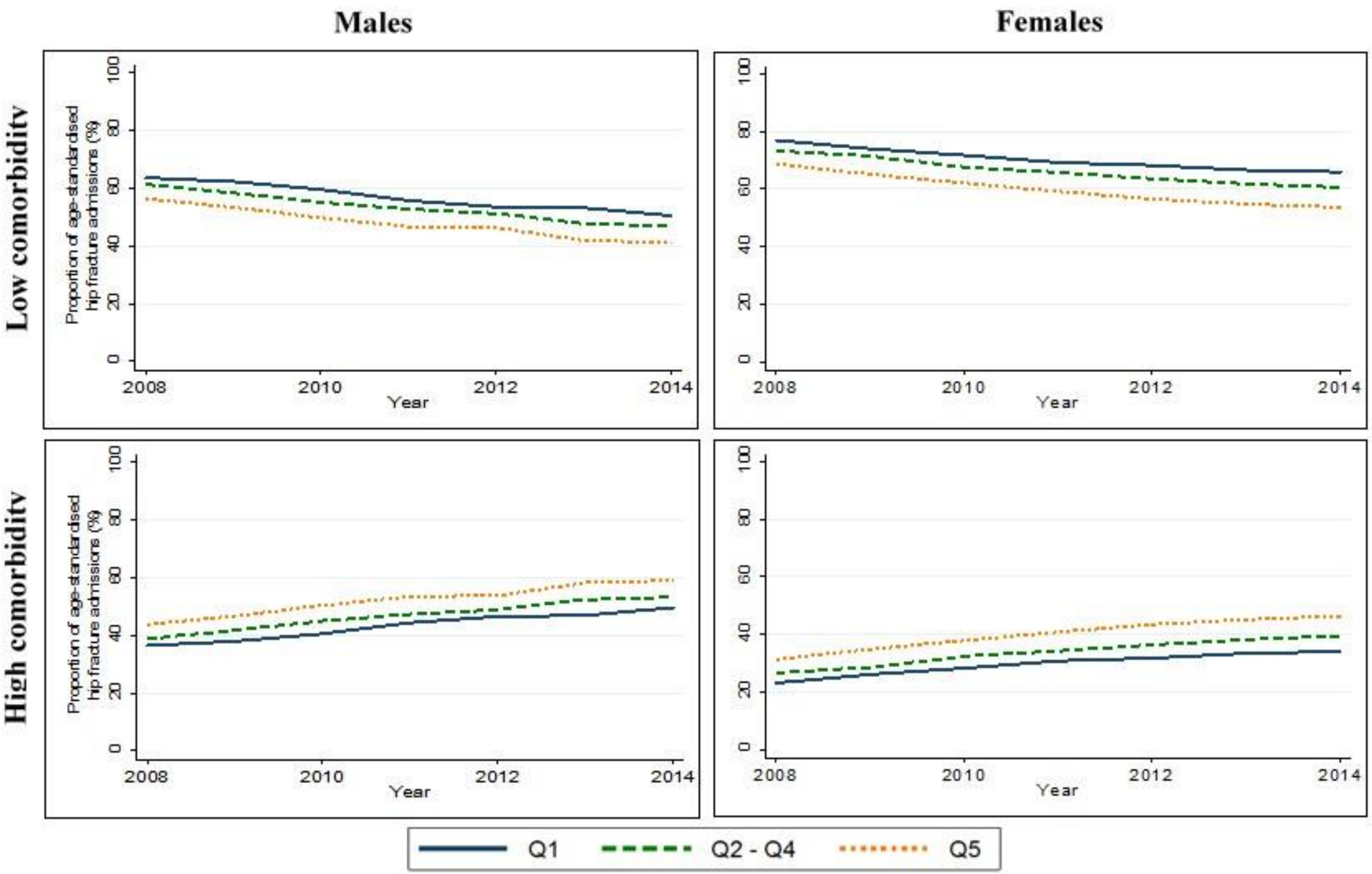

Figure 24: Proportion of age-standardised hip fracture admissions with low or high comorbidity, by quintile of deprivation in men and women aged 50+ years, 2008-2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

7.5. Summary

This study examined the relationship between area-based deprivation and hip fracture incidence in men and women aged 50+ years in England over a 14-year period, confirming that whilst age-standardised hip fracture incidence is declining in women, there has been an increase amongst men. Among men, social deprivation is associated with substantially higher hip fracture rates, and these inequalities have not improved over more than a decade, so that men who are most deprived are 50% more likely to fracture their hip than those who are least deprived. Across England, when averaged over 14 years, this equates to approximately 8,546 excess hip fractures per year occurring among men with greater deprivation (quintiles 2 to 5 *vs*. 1). Amongst women, the effect of deprivation on hip fracture incidence is weaker: however, owing to the higher incidence of hip fractures in women, the absolute burden of deprivation on hip fractures is greater in women than men. Differences in hip fracture incidence have become more overt over time, with women who are most deprived benefiting the least from improved secular trends in hip fracture incidence. Comorbidity levels have increased within the hip fracture population over time, and these increases have occurred in men and women across all deprivation strata.

This chapter has demonstrated that greater deprivation predicts higher hip fracture incidence in both men and women, and that absolute inequalities in hip fracture incidence have persisted over the 14 years studied. Whilst regional variation in hip fracture incidence has been observed in the UK (50), it is not known whether regional inequalities in hip fracture incidence exist and whether this relationship has changed over time. The next chapter examines the effect of deprivation on hip fracture incidence, according to geographic regions in England, over a 14-year period.

CHAPTER 8. REGIONAL ANALYSIS OF THE EFFECTS OF SOCIAL DEPRIVATION ON HIP FRACTURE INCIDENCE ACROSS ENGLAND

8.1. Introduction

As described in Chapter 1, hip fractures are an important public health problem and are associated with significant morbidity and mortality. Approximately 60,000 hip fractures occur annually in England (30), and incidence is predicted to rise as our population ages. Hip fractures are costly with annual hospital costs estimated at £1.1 billion for the UK (31).

Worldwide geographic variation in hip fracture incidence is well-documented, with the highest rates reported in Northern Europe and the USA and the lowest in Latin America and Africa (9). Regional variation in hip fracture incidence rates has been demonstrated within New Zealand and across the USA (364, 365). Importantly, considerable regional variation in hip fracture incidence has been observed in the UK based on analysis of primary care data, with the lowest rates in London and the highest rates in the South West of England, Northern Ireland and Scotland (50).

Greater deprivation has been associated with higher hip fracture rates in many high-income countries, including the UK. In Chapter 7, analysing English HES data, it was shown that despite public health efforts to prevent hip fractures, amongst both men and women, greater deprivation predicts higher hip fracture incidence, and that, over the last 14 years, this health inequality gap has remained unchanged amongst men, and has marginally widened in women. It is unknown whether inequalities in hip fracture incidence rates differ between geographic regions in England and to what extent this has changed over time.

8.2. Aims of this Chapter

It was hypothesised that inequalities in hip fracture incidence are not uniformly distributed across the geographic regions of England, that is the absolute burden of incident hip fractures would be greater among more deprived individuals residing in poorer regions of England such as the North, in part potentially owing to variation in lifestyle risk factors for fracture. Hence, this current study examined the effect of area-level social deprivation on hip fracture incidence in England, across nine geographic regions, over a 14-year period.

8.3. Methods

8.3.1. Study population

As described in Chapter 5, HES data from all English NHS hospitals for the period 1st April 2001 to 31st March 2015 were used to identify patients aged 50+ years with an index case of hip fracture on or during hospital admission. Patients aged under 50 years in whom hip fractures are primarily due to high-impact trauma (254), and those with missing data (n=4,667) for age, gender, IMD or region of residence were excluded. ONS annual MYPE for England from 2001 to 2014 were used as population denominators, stratified by age, gender, IMD quintiles and nine GORs.

8.3.2. Study variables

Deprivation

The IMD was used to measure socioeconomic deprivation (195). Patients were categorised into deprivation quintiles based upon the national ranking of their local residential area, with quintile 1 being the least deprived group and quintile 5 being the most deprived group (see Chapter 5.3.2, page 149).

Occurrence of hip fracture

As described in Chapter 5.2.4, ICD-10 disease codes for fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1), and subtrochanteric fracture (S72.2) recorded in the first diagnosis field of any hospital episode were used to identify hip fracture admissions (see page 143).

Further study variables

Further variables were derived to describe patient characteristics, including 5-yearly age groupings from 50 years to 90+ years, gender and comorbidity (see Chapter 5.3, page 148). The RCS Charlson score was used to measure comorbidity and was categorised into a four-level ordinal variable (0, 1, 2 or 3 or more comorbid conditions) (323). The nine GORs in England were categorised into three geographic regions: North of England (North East, North West and Yorkshire & the Humber), the Midlands (East Midlands, West Midlands and East of England) and South of England (South East, South West and London). Time period was defined as a three-level ordinal variable of four- to five-yearly intervals: 2001-2005, 2006-2010 and 2011-2014.

8.3.3. Research approvals

NHS Research Ethics Committee approval was obtained for this study (REC reference: 15/LO/1056).

8.3.4. Statistical analyses

All statistical analyses were conducted using Stata, version 14 IC (StataCorp, College Station, TX, USA).

Descriptive analyses

Demographic characteristics of the hip fracture population were summarised (see Chapter 5.7.1, page 159). Counts and percentages were used to summarise categorical variables according to quintiles of deprivation and, mean and SD was used to describe continuous variables. χ^2 test examined the association between two categorical variables and linear regression was used to assess linear trends in continuous variables.

Age-standardised hip fracture incidence

Direct standardisation was used to calculate age-standardised hip fracture incidence rates per 100,000 population for men and women, stratified by geographic region and IMD quintiles, using the 2001 English population as the reference population structure (see Chapter 5.7.2, page 159). Age-standardised hip fracture incidence rates, further stratified by time-period, were calculated to assess secular trends. Age-standardised rates for individual GORs were also calculated using the same approach.

Geographic variation in age-standardised hip fracture incidence

Separately for men and women, a map of age-standardised hip fracture incidence stratified by GORs in England was constructed using ArcGIS software (ArcMap 10.4.1), with incidence rates per 100,000 population expressed as an average over the 14-year period.

Association between deprivation and hip fracture incidence

To describe the association between local area deprivation and hip fracture incidence stratified by geographic regions, Poisson regression models were fitted with the number of hip fractures per group as the dependent variable and IMD quintile and age as independent variables, including the population size as the offset (see Chapter 5.7.4, page 163). Further analyses were conducted to examine the association between time period and hip fracture incidence, stratified by deprivation quintile and geographic region, adjusted for age. Associations are presented as IRRs with 95% CIs.

Formal tests for interaction

Tests for interaction were conducted to assess for differences in the effect of deprivation on hip fracture incidence among men and women (deprivation by gender interaction). The effect of deprivation on hip fracture incidence was shown to differ by gender, and therefore analyses were conducted separately for men and women. The statistical methods used to test for interaction have been described further in Chapter 5.7.5, page 164.

8.4. Results

8.4.1. Description of study population

As described in Chapter 7.4.1, 747,369 people were admitted to hospital with a hip fracture over 14 years. Three-quarters (74.2%) were women and the mean [SD] age of this study population was 81.6 [9.5] years. 19.2% occurred among individuals in the least deprived quintile and 18.8% among those in the most deprived quintile. Age-standardised hip fracture incidence was higher in women than in men, and higher among people living in the most deprived compared to the least deprived local areas.

8.4.2. Regional variation in hip fracture incidence

Over the period 2001 to 2014, the greatest number of hip fracture admissions occurred in the East Midlands and the lowest in the North East, whereas both crude and age-standardised hip fracture incidence were highest in the North East and lowest in London (Table 43). Following age-standardisation, hip fracture incidence increased from 332 to 343 hip fractures per 100,000 population in the North East corresponding to an increase of

3.3%, and from 271 to 279 per 100,000 in London equating to an increase of 3.0%. In contrast, after standardising for age, hip fracture incidence decreased in the East of England, South East and South West.

In men, age-standardised hip fracture incidence was highest in the North East (230 per 100,000) and lowest in the East of England (192 per 100,000), whilst among women, incidence was also highest in the North East (414 per 100,000), but lowest in London (330 per 100,000) (Figure 25).

Table 43: Crude and age-standardised hip fracture incidence rates per 100,000 population in men and women aged 50+ years according to the 9 GORs in England, 2001-2014

Region	No. of cases	Crude rate per 100,000	Age-standardised rate per 100,000
North East	43,254	332	343
North West	103,808	307	311
Yorkshire and Humber	75,716	302	301
East Midlands	64,411	294	295
West Midlands	81,329	307	304
East of England	84,934	298	285
London	76,483	271	279
South East	128,669	311	289
South West	88,765	317	284

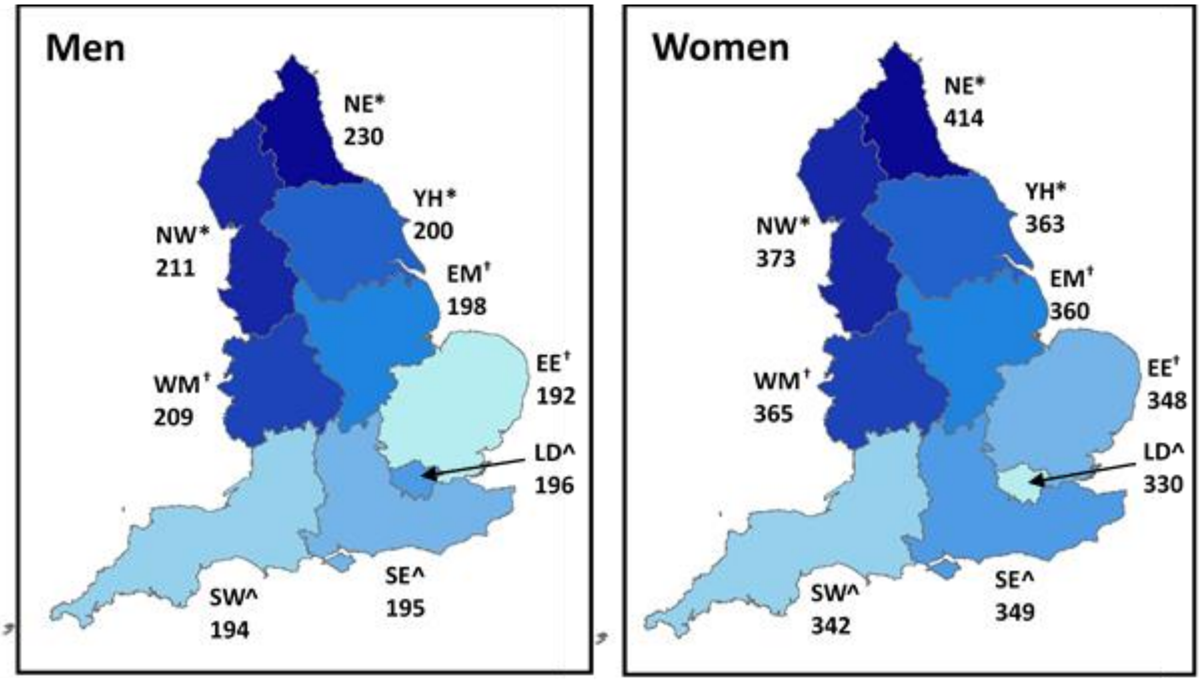

Figure 25: Regional variation in age-standardised hip fracture incidence among men and women aged 50+ years residing in England averaged over a 14-year period

(Colour grading from light blue to dark blue indicates higher incidence rates of hip fracture)

***North of England: North East (NE), North West (NW) and Yorkshire and the Humber (YH)**
†Midlands: East Midlands (EM), West Midlands (WM) and East of England (EE)
^South of England: South East (SE), South West (SW) and London (LD)

8.4.3. Regional variation in hip fracture incidence by deprivation

The association between greater deprivation and higher age-adjusted hip fracture incidence was strongest in the North of England, with a dose-response pattern observed in both men and women (Figure 26). A less marked relationship between greater deprivation and higher hip fracture incidence was observed among men in the Midlands and the South, with no clear pattern seen among women residing in these regions (Figure 26). Age-standardised hip fracture incidence was highest in the North compared to the Midlands and the South for both women and men, and particularly in the most deprived local areas (Table 44).

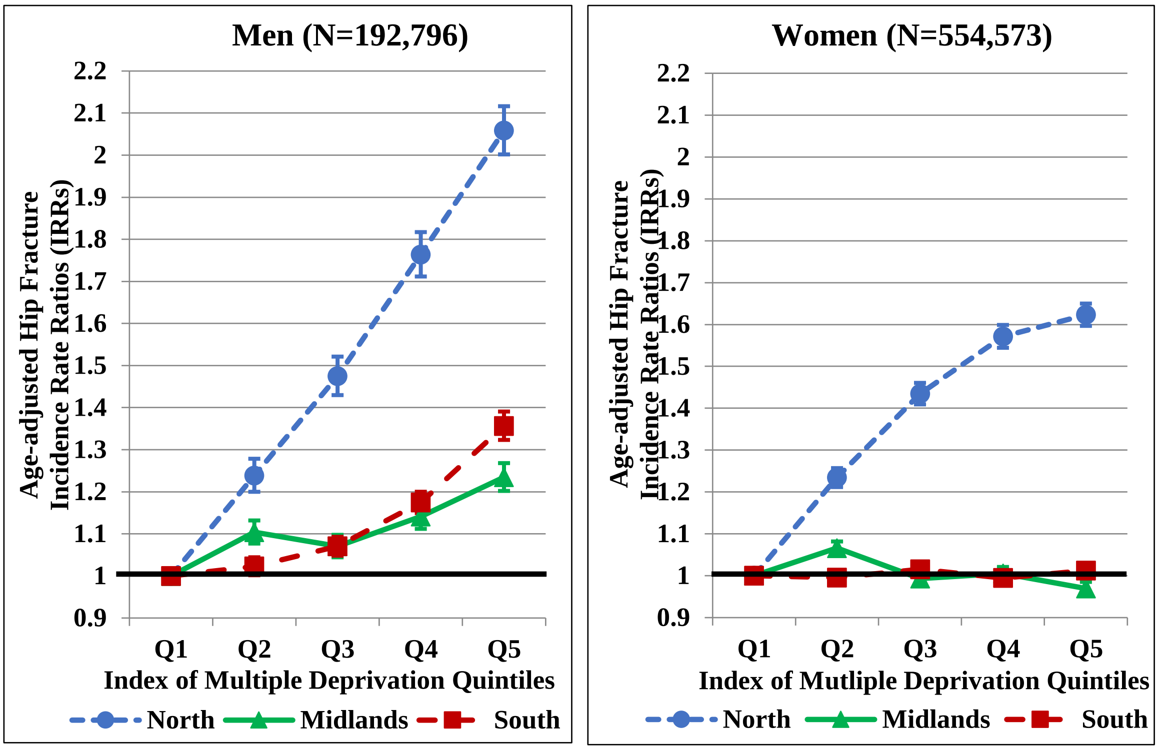

Figure 26: Geographical variation in the association between quintiles of deprivation and age-adjusted hip fracture incidence rate ratios in men and women aged 50+ years residing in England between 2001-2014

(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile)

(North (North East, North West, and Yorkshire and the Humber); Midlands (East Midlands, West Midlands and East of England); South (South East, South West and London))

Table 44: Age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation, overall and in men and women aged 50+ years residing in the North, Midlands and South of England, 2001-2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

IMD Quintiles	Overall		Men		Women	
	No. of cases	Rate/100,000 population	No. of cases	Rate/100,000 population	No. of cases	Rate/100,000 population
North						
Q1	26,341	217	6,679	142	19,662	267
Q2	36,328	268	8,937	174	27,391	331
Q3	40,696	315	9,892	204	30,804	384
Q4	48,288	354	12,040	240	36,248	423
Q5	71,125	379	19,220	271	51,905	442
Midlands						
Q1	44,328	283	11,463	185	32,865	352
Q2	53,433	306	13,570	202	39,863	375
Q3	52,453	289	13,398	194	39,055	352
Q4	43,893	298	11,275	205	32,618	357
Q5	36,567	299	10,063	216	26,504	349
South						
Q1	72,514	275	18,437	182	54,077	339
Q2	67,293	277	16,910	185	50,383	338
Q3	65,820	286	16,588	193	49,232	346
Q4	55,752	291	14,918	208	40,834	341
Q5	32,538	308	9,406	234	23,132	350

When analysed within the nine individual GORs, greater levels of deprivation were associated with higher hip fracture incidence in the North East, North West, Yorkshire & the Humber, East Midlands, West Midlands and London, for both men and women. Amongst men, patterns in the South East and South West were similar. In contrast, an inverse association between deprivation and hip fracture incidence was observed amongst women living in the East and South East of England, and amongst men in the East of England, where hip fracture incidence was lower among people living in more deprived local areas (Appendix 13.7, page 429).

8.4.4. Secular trends in hip fracture incidence by deprivation and region

In men, age-standardised hip fracture incidence increased across all strata of deprivation and all geographic regions between 2001 and 2014, except for more deprived men in the North and the least deprived men in the South among whom hip fracture incidence remained relatively stable (Figure 27a). The greatest increase in age-standardised hip fracture incidence was observed among the least deprived men in the North and the most deprived men in the South; however, the magnitude of this increase in hip fracture incidence waned over the study period. For example, among the most deprived men in the South, hip fracture incidence increased by 30 hip fractures per 100,000 men between 2001-2005 and 2006-2010, and by 8 hip fractures per 100,000 men between 2006-2010 and 2011-2014 (Appendix 13.8, page 430).

From 2001 to 2014, age-standardised hip fracture incidence decreased in women of all strata of deprivation and all geographical regions, except for the most deprived women in the Midlands and South in whom hip fracture incidence remained stable over time, and in the least deprived women in the North who showed a paradoxical increase in age-standardised hip fracture incidence over time (Figure 27b). The greatest absolute decline in age-standardised hip fracture incidence was observed among the least deprived women in the South, decreasing from 387 to 296 hip fractures per 100,000 women between 2001-2005 and 2011-2014 (Appendix 13.8, page 430).

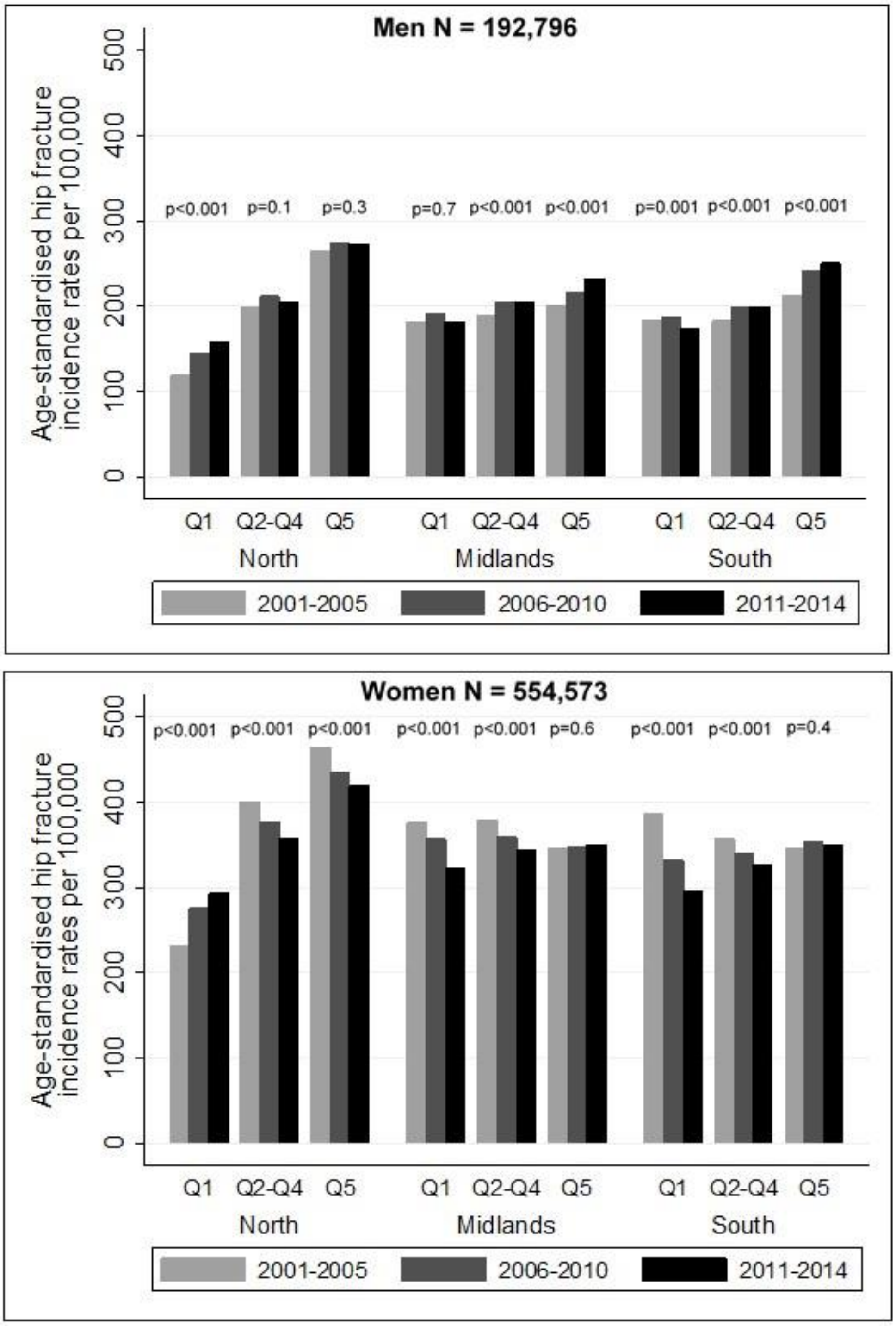

Figure 27: Secular trends in age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation, in (a) men and (b) women aged 50+ years residing in England, 2001-2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

Poisson regression was used to assess trends in hip fracture incidence, adjusted for age group

8.5. Summary

This is the first population-based study of inequalities in hip fracture incidence between and within geographic regions of England, using hospital administrative data collected over more than a decade. It has demonstrated that, among men and women aged 50+ years, marked regional variation in age-standardised hip fracture incidence exists across England. The absolute burden of age-standardised hip fracture incidence was greatest in the North East for both men and women, and lowest in the East of England and London for men and women respectively. If age-standardised hip fracture incidence across all GORs was reduced to the level seen in the East of England in men and London in women, then each year across England 3,248 fewer (738 male and 2,510 female) hip fractures would be recorded. Furthermore, absolute and relative inequalities in hip fracture incidence linked to local area deprivation were greatest in the North of England for both men and women. There were an additional 129 fractures per 100,000 men and 175 per 100,000 women in the most versus least deprived quintile in the North; this contrasts with an equivalent additional 52 per 100,000 male and 11 per 100,000 female hip fractures in the South.

8.5.1. Comparison of hip fracture incidence rates derived from HES and CPRD databases

The clear North-South gradient in hip fracture incidence observed in England contrasts with a recent UK study by Curtis et al analysing CPRD records from 1988 to 2012, which reported English hip fracture incidence to be highest in the South West and lowest in London for both men and women (50). However, importantly, the CPRD analysis was not age-standardised (50). Whilst crude hip fracture incidence was also found to be high in the

South West in this HES study, second only to the North East, this pattern was no longer evident after standardising for age (Table 45 & Table 46).

Table 45: Comparison of crude and age-standardised hip fracture incidence rates per 100,000 population derived from HES and CRPD data in men aged 50+ years

	HES			CPRD	
Region	**No. of hip fractures**	**Crude rate/ 100,000**	**ASIR/ 100,000**	**No. of hip fractures**	**Crude rate/ 100,000**
North East	11,011	182	230	316	129
North West	26,690	169	211	1,742	108
Yorkshire and the Humber	19,067	163	200	610	112
East Midlands	16,657	161	198	613	109
West Midlands	21,277	171	209	1,233	107
East of England	21,835	164	192	1,272	102
London	20,682	159	196	1,052	91
South East	32,662	169	195	1,350	108
South Central[a]				1,713	129
South West	22,915	176	194	1,547	142

[a] CPRD uses Strategic Health Authority (SHA) boundaries that is comprised of 10 regions. The additional South Central SHA region is captured within the South East region of the ONS classification

ASIR – age-standardised incidence rate

Table 46: Comparison of crude and age-standardised hip fracture incidence rates per 100,000 population derived from HES and CRPD data in women aged 50+ years

	HES			CPRD	
Region	**No. of hip fractures**	**Crude rate/ 100,000**	**ASIR/ 100,000**	**No. of hip fractures**	**Crude rate/ 100,000**
North East	32,243	463	414	988	350
North West	77,118	428	373	5,367	291
Yorkshire and the Humber	56,649	424	363	2,178	347
East Midlands	47,754	413	360	2,012	323
West Midlands	60,052	427	365	3,902	302
East of England	63,099	417	348	4,315	309
London	55,801	368	330	3,420	258
South East	96,007	434	349	4,402	304
South Central[a]				5,439	369
South West	65,850	439	342	4,954	398

[a] CPRD uses SHA boundaries that is comprised of 10 regions. The additional South Central SHA region is captured within the South East region of the ONS classification

ASIR – age-standardised incidence rate

Differing methodological approaches

Methodological differences when defining the hip fracture populations may explain the differing findings from both studies. This current HES-based study examined hip fracture incidence over a 14-year period from 2001, whilst Curtis et al studied a 24-year period from 1988 over which time marked changes in hip fracture incidence rates have been reported by other studies. It has been shown, using English HES data, that age-standardised hip fracture incidence increased among older men and women between 1989 and 1997 (22), and has remained stable over the period 2002 to 2011 (21).

Furthermore, such earlier data periods used ICD-9 codes to classify hip fractures whilst these current analyses used ICD-10 codes. Similarities exist in the types of hip fracture captured by specific ICD-9 and ICD-10 codes used to define hip fractures, namely the detection of ‘fractures of the neck of femur’ and ‘pertrochanteric fractures’ (366); however, Curtis et al also included ‘fractures of other and unspecified parts of the femur’. The inclusion of patients with other types of femoral fractures in the analyses conducted by Curtis et al suggests that this current HES study and that of Curtis et al may have assessed incidence of different fracture types.

Also, this current study analysed individual-level data derived from secondary rather than primary care sources. As described in Chapter 5.1, HES is an administrative database that collects data on all healthcare provided by NHS hospitals in England, thus allowing hospitals to be reimbursed for the services delivered (303). A key advantage of the HES database is that it captures data on all NHS hospital admissions for hip fracture in England, except for hip fractures managed within privately-financed healthcare facilities; however, this proportion is likely to be small. In contrast, CPRD is a longitudinal database of patient-level clinical data that covers 4.4 million individuals (registered with a GP) from 674 GP practices representing 6.9% of the UK population and is broadly representative of the age and sex distribution within the UK (based on the 2011 census) (367). The English CPRD population, whilst generally representative of the 2013 English population in terms of geography, has a higher proportion of individuals from the South East and a lower proportion from Yorkshire & Humber and the East Midlands. Furthermore, the North West and London regions contribute the largest number of English GP practices participating in CPRD, whilst the North East contributes the least (367).

Validation studies have shown that, using CPRD data alone, it may not be possible to identify all cases of diseases that require hospitalisation. A study conducted among patients with COPD, using linked data from HES and CPRD databases, reported that hospital admissions for acute exacerbations of COPD were identified with high sensitivity in HES but, when CPRD was analysed alone, the sensitivity was low (368). Another study showed that whilst most cancers were identified using CPRD data, a considerable proportion of cancers, typically those that require management in secondary care, were not identified using CPRD alone and required linkage to other data sources such as HES or national cancer databases for their identification (369).

8.6. Conclusion

Whilst Chapters 7 and 8 have shown that, among both men and women, greater deprivation predicts higher hip fracture incidence and regional inequalities in hip fracture incidence exist across England, the effect of deprivation on clinical outcomes after hip fracture is not known. Chapters 9 and 10 examine the effect of deprivation on mortality and healthcare utilisation in the year after hip fracture, over a 4-year period.

CHAPTER 9. SOCIAL DEPRIVATION PREDICTS MORTALITY AFTER HOSPITAL ADMISSION WITH HIP FRACTURE IN ENGLAND

9.1. Introduction

Social deprivation predicts a range of adverse health outcomes, including increased morbidity and mortality (143, 150). Incidence of and mortality from CVD, T2DM and cancer are all higher among deprived individuals (198, 248-251). In Chapter 7, it was shown that greater deprivation predicts higher hip fracture incidence amongst both men and women in England, and that deprivation is a stronger relative predictor of hip fracture incidence in men than women.

Hip fracture has been associated with poor clinical outcomes. Approximately one-tenth of patients die during the first 30-days after hip fracture, with cumulative mortality increasing to about one-third at 365-days (29). Mortality risk is higher among hip fracture patients compared with control populations; the highest risk of all-cause mortality is during the first year after hip fracture, particularly in the first 3 to 6 months (87).

Several risk factors predict reduced survival after sustaining a hip fracture, including male gender, older age and comorbidity. All-cause mortality is eightfold higher in men and fivefold in women during the first 3 months after hip fracture (87), with the risk of death at 365-days after hip fracture increasing with older age in both men and women (91). Number of comorbidities and presence of comorbid conditions such as CVD, COPD and stroke are associated with increased mortality after hip fracture, with the strongest associations observed among those with renal disease and dementia (89).

Whilst most studies examining the effect of deprivation on mortality after hip fracture have reported a positive association (20, 21, 83, 299-302), this has not been consistently demonstrated (277). A positive relationship between deprivation and 30-day mortality post-hip fracture has been demonstrated in Denmark and Italy (301, 302). In England, several population-based studies have shown that greater deprivation is associated with increased mortality up to 365-days after hip fracture (20, 21, 83, 299, 300). However, a prospective cohort study did not find evidence in support of a relationship between deprivation and 30-day mortality (277), which may be explained by the assessment of mortality among patients with a hip fracture from a single urban population in Nottingham, England. Furthermore, little is known about the effect of individual-level risk factors on the relationship between deprivation and mortality post-hip fracture. Analysis of English HES data over the period 2004 to 2011 showed that younger age, female gender and admission from own home were associated with higher 30-day mortality in more deprived patients with a hip fracture, and 365-day mortality risk was higher among the most deprived hip fracture patients without dementia (299).

9.2. Aims of this Chapter

Whilst it is known that greater deprivation is associated with reduced survival at 30-days, 90-days and 365-days after hip fracture (21, 83, 299-302), the relationship between deprivation and mortality during the immediate (7-days) and intermediate (120-days) post-fracture period is not known, and whether these may be modified by other factors such as dementia. It was hypothesised that higher rates of mortality would be observed among more deprived hip fracture patients owing to the higher prevalence of lifestyle risk factors and greater burden of comorbidity in more deprived individuals (226, 231, 232, 370).

This study firstly examined the effect of area-based social deprivation on mortality at 7, 30, 120, and 365 days among patients admitted to hospital with a hip fracture in England and secondly, examined whether the relationship between deprivation and mortality after hip fracture differs according to patient characteristics such as age, gender, comorbidity and dementia.

9.3. Methods

9.3.1. Data sources

Anonymised patient-level data from the routinely collected HES APC database that included admissions to all English hospitals within the NHS were analysed for the period 1st April 2011 to 31st March 2015. This HES data extract was linked by NHS Digital, the national health and social care data provider, to ONS mortality data for the same 4-year period. The resulting HES-ONS data extract was linked to an extract of NHFD data. The data sources and methods used to generate the linked HES-ONS-NHFD dataset for analysis have been described in detail in Chapter 6.

Each episode in HES relates to a period of care under a single hospital consultant; there are one or more hospital episodes during a hospital admission. Each HES episode includes information on patient demographics, clinical diagnoses and procedures performed (316) (see Chapter 5.1, page 136). ONS mortality data includes information related to a person's death such as the date and cause of death and are obtained from death certificates of all registered deaths in England and Wales (334), thus capturing deaths that occurred outside of hospital (see Chapter 6.1.2, page 166). The NHFD is a national clinical audit of hip fracture care. Each entry in NHFD relates to patient-level data on hip fracture admissions to NHS hospitals in England, Wales and Northern Ireland; there may be more than one NHFD record for a given patient if a second hip fracture occurred. Each NHFD record includes information on patient demographics, type of hip fracture and surgical operation performed. NHFD data have been described in detail in Chapter 1.9.4, page 44.

9.3.2. Study population

The study population consisted of index cases of hip fracture, that is the first occurrence of hip fracture, among male and female English residents aged 60+ years who were admitted to hospital with a hip fracture. Whilst the NOGG uses an age threshold of 50+ years to define a population group in whom the incidence of hip fracture is more common (66), an age cut-off of 60+ years was selected for these analyses to ensure consistency with the study population for whom the NHFD routinely collect clinical data.

9.3.3. Study variables

Deprivation

The IMD was used to measure socioeconomic deprivation (195). The IMD is a relative measure of deprivation for small areas that is comprised of seven domains of deprivation (see Chapter 2.5.3, page 64). Patients were categorised into quintiles based upon the national ranking of local areas, with quintile 1 being the least deprived group and quintile 5 being the most deprived group (see Chapter 6.6.2, page 183).

Outcomes

Cumulative mortality was determined at 7, 30, 120, and 365 days after hospital admission for hip fracture. The methods used to define cumulative mortality post-hip fracture have been described in Chapter 6.6.8, page 188. In brief, it was not possible to obtain information on the precise date of death from the ONS mortality database due to NHS Digital data access restrictions and therefore, using information on death status at specified time points, binary variables were generated by NHS Digital which defined patients as alive or dead at 7, 30, 120, and 365 days from the day of hospital admission.

Further variables

Further variables were derived to describe patient and fracture characteristics, including 10-yearly age groupings from 60 years to 90+ years, gender, comorbidity, fracture type and operation performed. The methods used to derive study variables have been described in Chapter 6.6, page 183 and Chapter 6.7, page 194.

Patient age and gender were derived from HES data fields. The RCS Charlson score was used to measure comorbidity (323). This was based upon several chronic conditions identified using ICD-10 diagnosis codes recorded in HES for the index hip fracture admission and admissions in the preceding five years. The comorbidity score was categorised into a three-level ordinal variable (no comorbid condition, ≥1 comorbid condition that excluded dementia, and dementia with or without other comorbidities referred to henceforth as dementia). Internal consistency checks were conducted to validate the method used to measure comorbidity in this study (see Chapter 6.7.1, page 194 and Chapter 6.7.2, page 195).

Using NHFD data, hip fractures were defined according to their anatomical location and separately, were defined as pathological, atypical or non-pathological fractures. Different types of operations are performed for the surgical management of hip fractures; however, for simplicity, hip fracture operations were categorised using the following groupings for these analyses: no operation performed, internal fixation with screws, internal fixation using an IM nail, hemiarthroplasty, THA, and other procedure.

9.3.4. Research approvals

The following research approvals were obtained for this study: NHS Research Ethics Committee (REC reference: 15/LO/1056), Falls and Fragility Fracture Audit Programme from the Healthcare Quality Improvement Partnership, NHS Digital Data Sharing Agreement, and NHS Information Governance Toolkit version 13.

9.3.5. Statistical analyses

All statistical analyses were conducted using Stata, version 14 IC (StataCorp, College Station, TX, USA).

Descriptive analyses

Demographic characteristics of the hip fracture population were described (see Chapter 6.9.1, page 205 for further details). Counts and percentages were used to summarise categorical variables according to quintiles of deprivation. χ^2 test examined the association between two categorical variables to determine whether the distribution of patient characteristics, including age, gender and comorbidity, differed by deprivation quintiles. Mean and SD was used to describe age (in single years), which was normally-distributed.

The proportion of hip fracture patients who had died at 7, 30, 120 and 365 days after hip fracture was calculated for each quintile of deprivation stratified by age, gender and comorbidity. χ^2 test was used to examine the association between deprivation quintiles and cumulative mortality to determine whether mortality rates differed according to deprivation quintiles.

Association between deprivation and mortality after hip fracture

Logistic regression was used to determine the association between deprivation and mortality, adjusted for age group (in 5-yearly intervals), gender and comorbidity. ORs were calculated with a 95% CI to determine the odds of death among individuals in each quintile of deprivation (i.e. Q2 – Q5) with the odds of death among individuals in quintile 1, the least deprived quintile, which was used as the reference category. Logistic regression was used to assess trends in the log odds of death by deprivation quintiles, including deprivation as a linear term.

Formal tests for interaction

Formal tests for interaction were conducted to determine whether the relationship between deprivation and mortality differed between men and women (gender by deprivation interaction). An interaction term between gender and deprivation was included, adjusting for age and comorbidity, with deprivation modelled as a linear term. The LRT was used to examine model fit by comparing estimates from models with and without the interaction term.

Interactions tests were conducted in a similar manner to determine whether the association between deprivation and mortality differed among individuals aged 60-84 years and 85+ years, adjusted for gender and comorbidity (age by deprivation interaction), and among individuals with different levels of comorbidity, adjusted for age and gender (deprivation by comorbidity interaction). The median age of this hip fracture population was 84 years (IQR 78-89 years) and therefore, a cut-off of 85 years was used to generate the binary variable for age so that approximately 50% of the population was in each age group. The statistical methods used to test for interaction have been described further in Chapter 6.9.4, page 210.

Regional variation in 30-day mortality after hip fracture

As a secondary analysis, cumulative mortality at 30-days post-hip fracture was calculated for each quintile of deprivation stratified by English GORs. Separately for each GOR, χ^2 test was used to describe the distribution of 30-day mortality rates according to deprivation quintiles, and logistic regression was used to examine the association between deprivation and 30-day mortality, using the least deprived quintile (quintile 1) as the reference category. Associations are presented as ORs with 95% CIs, adjusted for age, gender and comorbidity.

9.4. Results

9.4.1. Description of the study population

There were 220,567 hospital admissions with an index hip fracture among English residents aged 60+ years between 2011 and 2014, of which 1,660 (0.8%) patients were excluded with missing data for IMD and/or geographic region of residence. Of the remaining 218,907 cases of hip fracture, 72.6% occurred in women, 75.9% had one or more coded comorbid conditions and 97.9% were among patients of White ethnic origin (Table 47). The mean [SD] age of this study population was 82.8 [8.4] years; 81.5 (8.6) in men and 83.3 (8.3) in women. 20.0% of hip fracture admissions occurred among individuals in the least deprived quintile and 17.6% among those in the most deprived quintile.

Hip fracture patients in the most deprived quintile were more likely to be younger, male, and have a higher burden of comorbidity and higher ASA grade when compared to patients in the least deprived quintile. Fewer THAs were performed among more deprived patients (Table 47).

Table 47: Characteristics of patients admitted to hospital with a hip fracture according to quintiles of deprivation, 2011-2014

		Total popn	IMD Q1	IMD Q2	IMD Q3	IMD Q4	IMD Q5	p value
N (%)		218,907	43,866	47,185	47,047	42,375	38,434	
Age (years)	Mean (SD)	82.8 (8.4)	83.4 (8.1)	83.2 (8.3)	83.1 (8.3)	82.7 (8.5)	81.7 (8.7)	<0.001
Age (years), n (%)	60-69	18,790 (8.6)	3,185 (7.3)	3,695 (7.8)	3,803 (8.1)	3,844 (9.1)	4,263 (11.1)	<0.001
	70-79	47,683 (21.8)	8,873 (20.2)	9,937 (21.1)	10,103 (21.5)	9,293 (21.9)	9,477 (24.7)	
	80-89	103,742 (47.4)	21,409 (48.8)	22,614 (47.9)	22,314 (47.4)	20,032 (47.3)	17,373 (45.2)	
	90+	48,692 (22.2)	10,399 (23.7)	10,939 (23.2)	10,827 (23.0)	9,206 (21.7)	7,321 (19.0)	
Gender, n (%)		158,925 (72.6)	31,913 (72.8)	34,516 (73.2)	34,330 (73.0)	30,809 (72.7)	27,357 (71.2)	<0.001
Ethnicity, n (%)	White	201,931 (97.9)	40,422 (98.7)	43,596 (98.6)	43,538 (98.1)	39,020 (97.2)	35,355 (96.4)	<0.001
RCS Charlson comorbidity score[a], n (%)	No comorbidity	52,825 (24.1)	12,279 (28.0)	12,299 (26.1)	11,332 (24.1)	9,308 (22.0)	7,607 (19.8)	<0.001
	Comorbidity excl. dementia	104,458 (47.7)	19,890 (45.3)	21,725 (46.0)	22,460 (47.7)	20,669 (48.8)	19,714 (51.3)	
	Dementia	61,624 (28.2)	11,697 (26.7)	13,161 (27.9)	13,255 (28.2)	12,398 (29.3)	11,113 (28.9)	
ASA grade, n (%)	1	4,630 (2.3)	1,185 (2.9)	1,162 (2.6)	1,005 (2.3)	752 (1.9)	526 (1.5)	<0.001
	2	59,919 (29.2)	13,774 (33.5)	13,799 (31.2)	13,096 (29.7)	10,622 (26.7)	8,628 (24.1)	
	3	114,350 (55.7)	21,702 (52.8)	24,096 (54.4)	24,589 (55.7)	22,970 (57.8)	20,993 (58.6)	
	4	25,384 (12.4)	4,314 (10.5)	5,043 (11.4)	5,272 (11.9)	5,257 (13.2)	5,498 (15.3)	
	5	886 (0.4)	156 (0.4)	189 (0.4)	205 (0.5)	156 (0.4)	180 (0.5)	
Hip fracture type, n (%)	IC - displaced	105,749 (48.4)	22,065 (50.4)	23,208 (49.3)	22,742 (48.4)	20,055 (47.4)	17,679 (46.1)	<0.001
	IC - undisplaced	22,385 (10.2)	4,397 (10.0)	4,766 (10.1)	4,838 (10.3)	4,243 (10.0)	4,141 (10.8)	
	Intertrochanteric	75,524 (34.6)	14,394 (32.9)	16,010 (34.0)	16,158 (34.4)	15,045 (35.6)	13,917 (36.3)	
	Subtrochanteric	12,756 (5.8)	2,538 (5.8)	2,662 (5.7)	2,788 (5.9)	2,521 (6.0)	2,247 (5.9)	
	Other	2,032 (0.9)	389 (0.9)	416 (0.9)	441 (0.9)	425 (1.0)	361 (0.9)	
Hip fracture operation, n (%)	No operation	4,824 (2.2)	898 (2.1)	960 (2.0)	1,054 (2.2)	1,001 (2.4)	911 (2.4)	<0.001
	IF - DHS	76,120 (34.9)	14,367 (32.8)	16,129 (34.3)	16,474 (35.1)	15,191 (35.9)	13,959 (36.4)	
	IF - Cannulated screw	9,105 (4.2)	1,934 (4.4)	2,064 (4.4)	1,960 (4.2)	1,648 (3.9)	1,499 (3.9)	
	IF - IM nail	19,918 (9.1)	3,983 (9.1)	4,163 (8.8)	4,120 (8.8)	3,949 (9.3)	3,703 (9.7)	
	Hemiarthroplasty	94,492 (43.3)	19,279 (44.0)	20,522 (43.6)	20,355 (43.4)	18,150 (42.9)	16,186 (42.2)	
	THA	12,620 (5.8)	3,089 (7.1)	2,952 (6.3)	2,703 (5.8)	2,093 (5.0)	1,783 (4.7)	
	Other	1,267 (0.6)	218 (0.5)	256 (0.5)	282 (0.6)	237 (0.6)	274 (0.7)	

ASA – American Society of Anaesthiologists; excl. – excluding; IC – intracapsular; IF – Internal fixation; DHS – Dynamic hip screw; IM – Intramedullary; IMD – Index of Multiple Deprivation; RCS – Royal College of Surgeons of England; SD – Standard deviation; THA – Total hip arthroplasty

9.4.2. Cumulative mortality

Cumulative mortality rates at 7-days, 30-days, 120-days and 365-days were 2.9%, 7.8%, 18.1% and 28.1%, respectively. Mortality rates were higher in men than women, among individuals aged 85+ years, and patients with dementia at all time points up to 365-days post-hip fracture.

Mortality rates at 7-days after hip fracture were 3.9% and 2.5% in men and women, increasing to 35.8% and 25.3% at 365-days post-hip fracture (Figure 28). When stratified by age, 7-day mortality was 1.8% and 4.1% in patients aged 60-84 years and 85+ years, with a marked increase in mortality observed at 365-days after hip fracture; 365-day mortality was 20.0% and 37.3% in patients aged 60-84 years and 85+ years (Figure 29). Cumulative mortality at 7-days after hip fracture was lowest in patients with no recorded comorbidity (1.0%); 7-day mortality rates were similar in patients with comorbidity, regardless of a diagnosis of dementia. Marked differences in mortality rates according to comorbidity category were apparent at 120-days and 365-days after hip fracture; 365-day mortality was 11.0%, 27.8% and 43.4% in individuals with no comorbidity, comorbidity that excluded dementia, and dementia respectively (Figure 30).

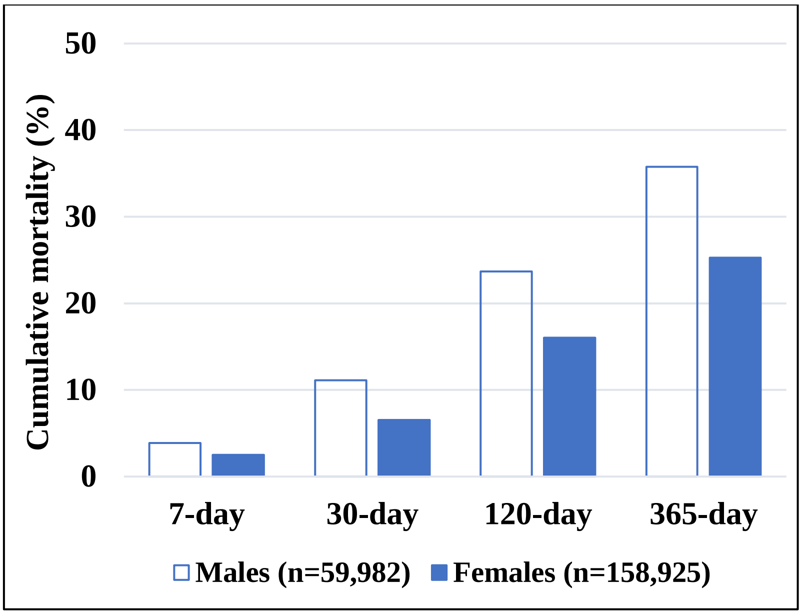

Figure 28: Cumulative mortality rates up to 365-days after hip fracture in men and women

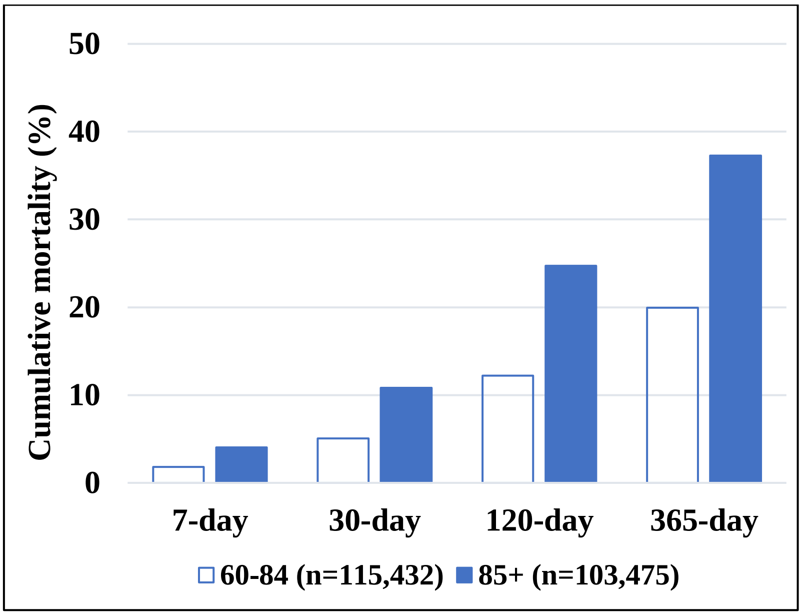

Figure 29: Cumulative mortality rates up to 365-days after hip fracture in patients aged 60-84 years and 85+ years

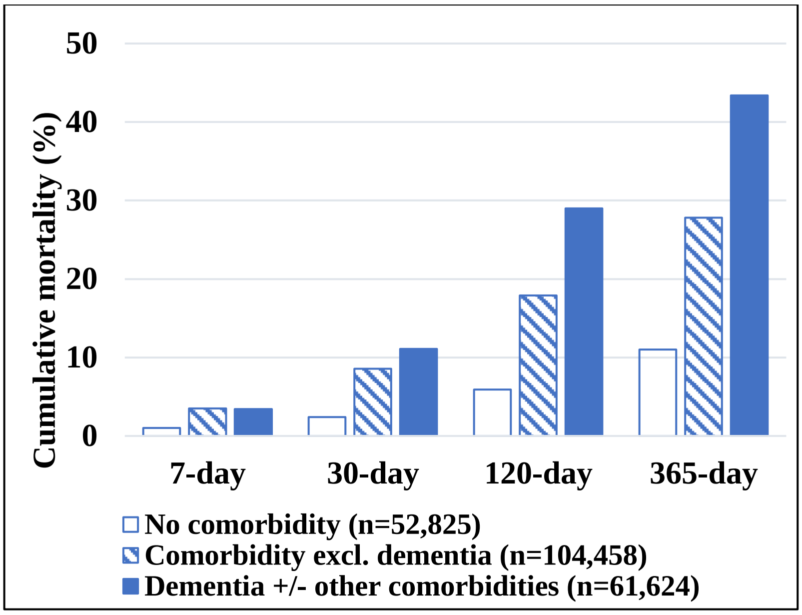

Figure 30: Cumulative mortality rates up to 365-days after hip fracture according to comorbidity category

9.4.3. Cumulative mortality by age group in men and women

Mortality rates were highest in men aged 85+ years at all time points up to 365-days after hip fracture. Among men, mortality at 7-days after hip fracture was 2.6% and 5.7% in patients aged 60-84 years and 85+ years, increasing to 27.2% and 47.9% at 365-days after hip fracture. In comparison, 7-day mortality was 1.5% and 3.5% in women aged 60-84 years and 85+ years, and 16.8% and 33.9% at 365-days post-hip fracture (Figure 31).

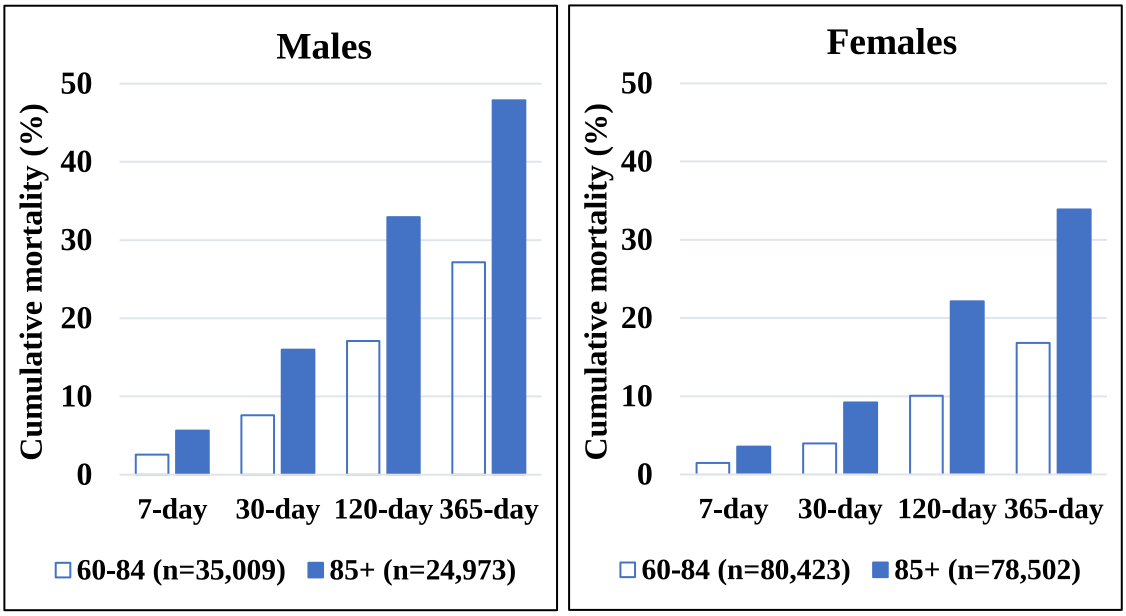

Figure 31: Cumulative mortality rates up to 365-days after hip fracture by age group in men and women

9.4.4. Cumulative mortality by levels of deprivation

Cumulative mortality rates increased with greater deprivation at all time points up to 365-days after hip fracture; however, the magnitude of this increase was more marked at 365-days post-hip fracture. Mortality at 7-days after hip fracture was 2.6% and 3.1% among patients in the least deprived and most deprived quintiles, increasing to 26.3% and 29.8% at 365-days after hip fracture (Figure 32).

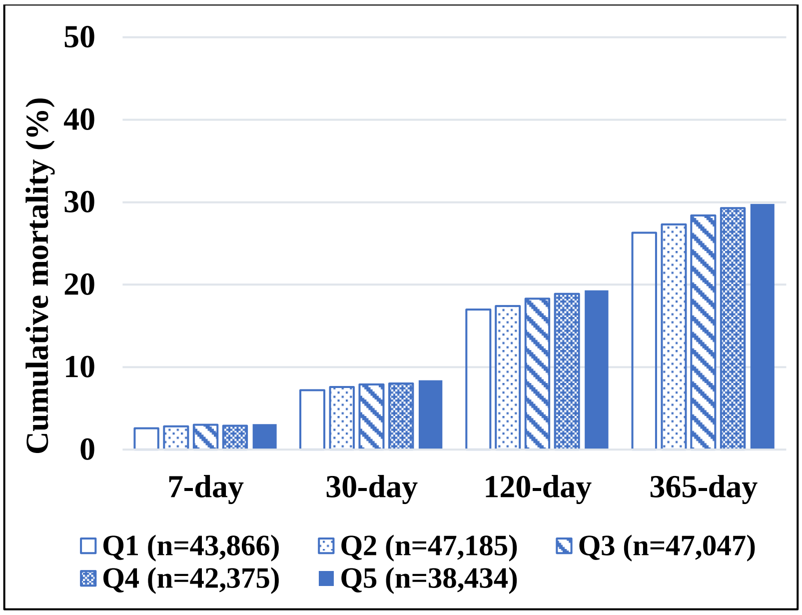

Figure 32: Cumulative mortality rates up to 365-days after hip fracture by quintiles of deprivation in men and women aged 60+ years, 2011–2014
(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

9.4.5. Association between deprivation and mortality

Overall, greater deprivation was associated with higher mortality at all time points up to 365-days post-hip fracture (Table 48). The odds of death at 30-days after hip fracture were 19% higher among patients in the most deprived compared with the least deprived quintile (unadjusted OR 1.19 [1.13,1.25], p<0.001). The relationship between deprivation and 30-day mortality was augmented following adjustment for age and gender (adjusted OR 1.32 [1.25,1.39], p<0.001); however, additional adjustment for comorbidity partially attenuated this relationship (adjusted OR 1.23 [1.17,1.30], p<0.001). The strength of the association between deprivation and mortality was similar at all four time points post-hip fracture. For example, the odds of death at 365-days post-hip fracture were 24% higher among patients in the most deprived versus the least deprived quintile following adjustment for age, gender and comorbidity (adjusted OR 1.24 [1.20,1.28], p<0.001).

Table 48: Association between quintiles of deprivation and mortality up to 365-days after hip fracture in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile)

	7-day mortality				**30-day mortality**			
	N (%)	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)**	**Age, gender & comorbidity-adjusted OR[a] (95% CI)**	**N (%)**	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)**	**Age, gender & comorbidity-adjusted OR[a] (95% CI)**
Q1	1,149 (2.6)	Reference category			3,143 (7.2)	Reference category		
Q2	1,328 (2.8)	1.08 (0.99,1.17)	1.10 (1.01,1.19)	1.08 (1.00,1.17)	3,593 (7.6)	1.07 (1.02,1.12)	1.09 (1.04,1.15)	1.07 (1.02,1.13)
Q3	1,396 (3.0)	1.14 (1.05,1.23)	1.16 (1.08,1.26)	1.14 (1.05,1.23)	3,704 (7.9)	1.11 (1.05,1.16)	1.14 (1.08,1.19)	1.10 (1.05,1.16)
Q4	1,240 (2.9)	1.12 (1.03,1.22)	1.18 (1.08,1.28)	1.13 (1.04,1.23)	3,403 (8.0)	1.13 (1.08,1.19)	1.19 (1.13,1.25)	1.13 (1.08,1.19)
Q5	1,173 (3.1)	1.17 (1.08,1.27)	1.29 (1.19,1.41)	1.23 (1.13,1.34)	3,229 (8.4)	1.19 (1.13,1.25)	1.32 (1.25,1.39)	1.23 (1.17,1.30)
p value[b]	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

	120-day mortality				**365-day mortality**			
	N (%)	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)**	**Age, gender & comorbidity-adjusted OR[a] (95% CI)**	**N (%)**	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)**	**Age, gender & comorbidity-adjusted OR[a] (95% CI)**
Q1	7,462 (17.0)	Reference category			11,513 (26.3)	Reference category		
Q2	8,198 (17.4)	1.03 (0.99,1.06)	1.05 (1.01,1.08)	1.02 (0.99,1.06)	12,875 (27.3)	1.05 (1.02,1.09)	1.08 (1.05,1.11)	1.06 (1.02,1.09)
Q3	8,609 (18.3)	1.09 (1.06,1.13)	1.12 (1.09,1.16)	1.08 (1.05,1.12)	13,350 (28.4)	1.11 (1.08,1.15)	1.15 (1.12,1.19)	1.11 (1.07,1.14)
Q4	7,988 (18.9)	1.13 (1.09,1.17)	1.20 (1.16,1.24)	1.13 (1.09,1.17)	12,433 (29.3)	1.17 (1.13,1.20)	1.24 (1.20,1.28)	1.17 (1.13,1.21)
Q5	7,426 (19.3)	1.17 (1.13,1.21)	1.31 (1.26,1.36)	1.21 (1.17,1.26)	11,433 (29.8)	1.19 (1.15,1.23)	1.34 (1.30,1.39)	1.24 (1.20,1.28)
p value[b]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia, and dementia

[b] Pearson's chi-squared test was used to assess the association between deprivation quintiles and mortality variables; logistic regression was used to assess trends in mortality variables by deprivation quintiles

9.4.6. Tests for interaction by age, gender and comorbidity

The effect of deprivation on mortality at all time points up to 365-days after hip fracture was similar in men and women, and among patients aged 60-84 years and 85+ years (Appendix 13.9, page 431). Regardless, cumulative mortality rates up to 365-days post-hip fracture were calculated for each quintile of deprivation stratified by age, gender and comorbidity as a prognostic tool for use in clinical settings (Table 49 & Table 50).

The relationship between deprivation and mortality at 30-days, 120-days and 365-days post-hip fracture was found to differ according to strata of comorbidity (p-value for interaction <0.001), and therefore further analyses were conducted stratified by comorbidity, adjusted for age and gender. The effect of deprivation on mortality after hip fracture was similar in patients with no comorbidity and with comorbidity that excluded dementia, and weaker among patients with dementia compared to those with no comorbidity (Appendix 13.9, page 431).

9.4.7. Cumulative mortality by levels of deprivation and comorbidity

Consistent with the trends described earlier, mortality rates were higher in men than women, among older individuals and those with dementia at all time points after hip fracture (section 9.4.2, page 265). Mortality rates at 7-days after hip fracture were aggregated for IMD quintiles 1 and 2, and IMD quintiles 4 and 5, for suppression of small numbers less than 20.

Among men, mortality rates increased with greater deprivation in patients aged 60-84 years and 85+ years with comorbidity that excluded dementia at 30-days, 120-days and 365-days after hip fracture; mortality rates were similar across deprivation quintiles at 7-

days after hip fracture. Mortality rates were similar according to levels of deprivation for men with no comorbidity and with dementia at all time points up to 365-days post-hip fracture (Table 49).

In women, mortality rates increased with greater deprivation in patients aged 60-84 years and 85+ years with no comorbidity and with comorbidity that excluded dementia at 30-days, 120-days and 365-days after hip fracture, except for women aged 85+ years with comorbidity that excluded dementia in whom mortality rates were similar across deprivation quintiles at 30-days after hip fracture (Table 50). Mortality rates at 7-days after hip fracture were similar according to levels of deprivation for women in all strata of comorbidity, except for women aged 60-84 years with comorbidity that excluded dementia in whom 7-day mortality rates increased with greater deprivation.

Table 49: Cumulative mortality rates up to 365-days after hip fracture by levels of deprivation and comorbidity in men aged 60-84 and 85+ years

	7-day mortality[a] (N (%))		30-day mortality (N (%))		120-day mortality (N (%))		365-day mortality (N (%))	
	60-84 years	**85+ years**	**60-84 years**	**85+ years**	**60-84 years**	**85+ years**	**60-84 years**	**85+ years**
No comorbidity								
Total	52 (0.7)	102 (2.7)	147 (2.1)	263 (7.0)	321 (4.5)	578 (15.5)	646 (9.1)	975 (26.1)
Q1	19 (0.61)	47 (2.6)	25 (1.7)	64 (6.6)	72 (4.8)	152 (15.7)	125 (8.3)	244 (25.2)
Q2			33 (2.1)	54 (6.2)	60 (3.7)	112 (12.8)	134 (8.3)	209 (23.9)
Q3	<1%	25 (3.1)	26 (1.8)	57 (7.2)	62 (4.2)	124 (15.6)	130 (8.9)	216 (27.2)
Q4	22 (0.88)	30 (2.7)	29 (2.3)	49 (7.7)	63 (4.9)	107 (16.7)	121 (9.5)	176 (27.5)
Q5			34 (2.8)	39 (8.5)	64 (5.2)	83 (18.0)	136 (11.0)	130 (28.2)
p value[b]	0.50	0.69	0.29	0.54	0.33	0.10	0.09	0.30
Comorbidity that excluded dementia								
Total	614 (3.0)	802 (6.1)	1,643 (8.0)	2,072 (15.7)	3,387 (16.5)	4,039 (30.5)	5,406 (26.4)	5,977 (45.2)
Q1	209 (2.8)	345 (5.8)	257 (7.2)	426 (14.2)	569 (16.0)	847 (28.2)	887 (24.9)	1,289 (43.0)
Q2			302 (7.6)	457 (15.4)	606 (15.3)	895 (30.3)	980 (24.7)	1,324 (44.8)
Q3	133 (3.1)	180 (6.2)	326 (7.6)	450 (15.4)	704 (16.5)	896 (30.7)	1,144 (26.8)	1,327 (45.4)
Q4	272 (3.1)	277 (6.4)	359 (8.6)	390 (16.2)	738 (17.7)	749 (31.1)	1,156 (27.8)	1,093 (45.4)
Q5			399 (8.8)	349 (18.1)	770 (17.0)	652 (33.7)	1,239 (27.4)	944 (48.8)
p value[b]	0.36	0.45	0.03	0.007	0.03	0.002	0.002	0.002
Dementia								
Total	240 (3.2)	509 (6.4)	878 (11.8)	1,655 (20.7)	2,282 (30.6)	3,607 (45.0)	3,452 (46.3)	5,003 (62.5)
Q1	95 (3.4)	197 (5.8)	153 (12.1)	330 (20.0)	405 (32.1)	726 (43.9)	585 (46.4)	1,013 (61.2)
Q2			176 (11.7)	369 (21.1)	450 (29.8)	758 (43.3)	690 (45.8)	1,088 (62.1)
Q3	50 (3.4)	130 (7.3)	192 (12.9)	397 (22.2)	472 (31.6)	839 (47.0)	711 (47.7)	1,128 (63.1)
Q4	95 (3.0)	182 (6.5)	180 (11.5)	285 (18.8)	487 (31.0)	679 (44.9)	739 (47.1)	949 (62.7)
Q5			177 (10.9)	274 (21.0)	468 (28.8)	605 (46.4)	727 (44.7)	825 (63.2)
p value[b]	0.58	0.11	0.52	0.17	0.28	0.16	0.51	0.78

[a] 7-day mortality data were aggregated for Q1/Q2 and Q4/Q5 for suppression of small numbers (N<20)

[b] Pearson's chi-squared test was used to assess the association between deprivation quintiles and mortality variables

Table 50: Cumulative mortality rates up to 365-days after hip fracture by levels of deprivation and comorbidity in women aged 60-84 and 85+ years

	7-day mortality[a] (N (%))		30-day mortality (N (%))		120-day mortality (N (%))		365-day mortality (N (%))	
	60-84 years	85+ years	60-84 years	85+ years	60-84 years	85+ years	60-84 years	85+ years
No comorbidity								
Total	82 (0.3)	306 (1.7)	192 (0.8)	667 (3.7)	498 (2.1)	1,724 (9.6)	1,060 (4.4)	3,141 (17.4)
Q1	37 (0.33)	121 (1.5)	35 (0.6)	128 (3.1)	100 (1.8)	349 (8.4)	213 (3.8)	638 (15.4)
Q2			45 (0.8)	142 (3.4)	115 (2.0)	377 (9.1)	245 (4.3)	720 (17.3)
Q3	<1%	75 (1.9)	31 (0.6)	164 (4.2)	78 (1.5)	389 (9.9)	193 (3.7)	728 (18.6)
Q4	33 (0.44)	110 (1.9)	40 (1.0)	126 (3.8)	99 (2.4)	319 (9.7)	208 (5.1)	576 (17.6)
Q5			41 (1.2)	107 (4.2)	106 (3.1)	290 (11.4)	201 (6.0)	479 (18.9)
p value[b]	0.13	0.07	0.008	0.04	<0.001	0.001	<0.001	0.001
Comorbidity that excluded dementia								
Total	812 (2.0)	1,413 (4.6)	2,019 (5.1)	3,224 (10.4)	4,503 (11.3)	6,777 (21.8)	7,333 (18.5)	10,333 (33.3)
Q1	286 (1.9)	574 (4.4)	320 (4.5)	604 (9.6)	712 (10.1)	1,276 (20.3)	1,133 (16.1)	1,929 (30.8)
Q2			375 (4.7)	701 (10.3)	843 (10.5)	1,465 (21.5)	1,369 (17.1)	2,241 (33.0)
Q3	156 (1.9)	332 (4.8)	417 (5.0)	722 (10.5)	917 (10.9)	1,538 (22.4)	1,502 (17.8)	2,350 (34.3)
Q4	370 (2.3)	507 (4.6)	425 (5.3)	629 (10.5)	961 (11.9)	1,313 (21.8)	1,581 (19.6)	2,043 (34.0)
Q5			482 (5.9)	568 (11.2)	1070 (13.1)	1,185 (23.3)	1,748 (21.4)	1,770 (34.8)
p value[b]	0.02	0.35	0.001	0.12	<0.001	0.003	<0.001	<0.001
Dementia								
Total	296 (1.8)	1,058 (3.6)	984 (5.9)	3,328 (11.3)	3,096 (18.5)	8,871 (30.1)	5,144 (30.8)	13,134 (44.6)
Q1	127 (2.0)	420 (3.4)	162 (5.4)	639 (11.0)	539 (18.0)	1,715 (29.6)	896 (30.0)	2,561 (44.2)
Q2			204 (5.9)	735 (11.4)	621 (18.0)	1,896 (29.4)	1,042 (30.2)	2,833 (43.9)
Q3	56 (1.6)	236 (3.6)	202 (5.8)	720 (11.0)	643 (18.6)	1,947 (29.9)	1,052 (30.4)	2,869 (44.0)
Q4	113 (1.7)	402 (3.8)	214 (6.1)	677 (11.6)	677 (19.3)	1,796 (30.9)	1,128 (32.2)	2,663 (45.8)
Q5			202 (6.1)	557 (11.5)	616 (18.5)	1,517 (31.2)	1,026 (30.9)	2,208 (45.5)
p value[b]	0.29	0.39	0.79	0.79	0.63	0.13	0.29	0.12

[a] 7-day mortality data were aggregated for Q1/Q2 and Q4/Q5 for suppression of small numbers (N<20)

[b] Pearson's chi-squared test was used to assess the association between deprivation quintiles and mortality variables

9.4.8. Association between deprivation and mortality by levels of comorbidity

Crude analyses

For men and women combined, a positive association between deprivation and mortality was observed at all time points up to 365-days after hip fracture among patients with no recorded comorbidity and comorbidity that excluded dementia, with the exception of patients with comorbidity that excluded dementia in whom the odds of death were similar according to deprivation quintiles at 7-days after hip fracture (Table 51 & Table 52).

Adjusted analyses

Following adjustment for age and gender, a relationship between greater deprivation and increased mortality was observed at all four time points up to 365-days after hip fracture among patients with no recorded comorbidity and comorbidity that excluded dementia. The strength of the association between deprivation and mortality at 30-days, 120-days and 365-days post-hip fracture was augmented after adjustment for age and gender, particularly among patients with comorbidity that excluded dementia. Among patients with dementia, an association between greater deprivation and increased odds of death was observed at 120-days and 365-days post-hip fracture after taking account of age and gender.

The magnitude of the association between deprivation and mortality was strongest in patients with no recorded comorbidity. Following adjustment for age and gender, the odds of death at 365-days after hip fracture among patients with no comorbidity and comorbidity that excluded dementia were 40% (adjusted OR 1.40 [1.27,1.54], $p<0.001$) and 32% (adjusted OR 1.32 [1.26,1.38], $p<0.001$) higher in the most deprived compared with the least deprived quintile, respectively. This is in contrast to an OR of 1.06 ([1.01,1.13], p=0.001) for the most deprived versus the least deprived patients with dementia (Table 51 & Table 52).

Table 51: Association between quintiles of deprivation and mortality at 7-days and 30-days after hip fracture by levels of comorbidity in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile)

	7-day mortality			30-day mortality		
	N (%)	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)[a]**	**N (%)**	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)[a]**
No comorbidity						
Q1	110 (0.90)	Reference category		252 (2.1)	Reference category	
Q2	114 (0.93)	1.04 (0.80,1.35)	1.06 (0.81,1.38)	274 (2.2)	1.09 (0.91,1.29)	1.12 (0.94,1.33)
Q3	123 (1.1)	1.21 (0.94,1.57)	1.23 (0.95,1.59)	278 (2.5)	1.20 (1.01,1.43)	1.22 (1.02,1.45)
Q4	110 (1.2)	1.32 (1.01,1.73)	1.34 (1.03,1.75)	244 (2.6)	1.28 (1.08,1.54)	1.31 (1.09,1.57)
Q5	85 (1.1)	1.25 (0.94,1.66)	1.33 (1.00,1.78)	221 (2.9)	1.43 (1.19,1.71)	1.54 (1.28,1.85)
p value[b]	0.17	0.02	0.008	0.001	<0.001	<0.001
Comorbidity that excluded dementia						
Q1	659 (3.3)	Reference category		1,607 (8.1)	Reference category	
Q2	755 (3.5)	1.05 (0.94,1.17)	1.07 (0.96,1.19)	1,835 (8.5)	1.05 (0.98,1.13)	1.07 (1.00,1.15)
Q3	801 (3.6)	1.08 (0.97,1.20)	1.13 (1.01,1.25)	1,915 (8.5)	1.06 (0.99,1.14)	1.11 (1.03,1.19)
Q4	689 (3.3)	1.01 (0.90,1.12)	1.09 (0.97,1.21)	1,803 (8.7)	1.09 (1.01,1.17)	1.17 (1.09,1.26)
Q5	737 (3.7)	1.13 (1.02,1.26)	1.31 (1.17,1.46)	1,798 (9.1)	1.14 (1.06,1.23)	1.31 (1.22,1.40)
p value[b]	0.12	0.09	<0.001	0.005	<0.001	<0.001
Dementia						
Q1	380 (3.3)	Reference category		1,284 (11.0)	Reference category	
Q2	459 (3.5)	1.08 (0.94,1.24)	1.10 (0.96,1.26)	1,484 (11.3)	1.03 (0.95,1.12)	1.05 (0.97,1.14)
Q3	472 (3.6)	1.10 (0.96,1.26)	1.12 (0.98,1.29)	1,511 (11.4)	1.04 (0.96,1.13)	1.06 (0.98,1.15)
Q4	441 (3.6)	1.10 (0.96,1.26)	1.15 (1.00,1.32)	1,356 (10.9)	1.00 (0.92,1.08)	1.04 (0.96,1.13)
Q5	351 (3.2)	0.97 (0.84,1.13)	1.05 (0.90,1.21)	1,210 (10.9)	0.99 (0.92,1.08)	1.07 (0.98,1.16)
p value[b]	0.29	0.87	0.38	0.62	0.57	0.24

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years

[b] Pearson's chi-squared test was used to assess the association between deprivation quintiles and mortality variables; logistic regression was used to assess trends in mortality variables by deprivation quintiles

Table 52: Association between quintiles of deprivation and mortality at 120-days and 365-days after hip fracture by levels of comorbidity in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile)

	120-day mortality			**365-day mortality**		
	N (%)	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)[a]**	**N (%)**	**Crude OR (95% CI)**	**Age-gender adjusted OR[a] (95% CI)[a]**
No comorbidity						
Q1	673 (5.5)	Reference category		1,220 (9.9)	Reference category	
Q2	664 (5.4)	0.98 (0.88,1.10)	1.01 (0.90,1.13)	1,308 (10.6)	1.08 (0.99,1.17)	1.11 (1.02,1.21)
Q3	653 (5.8)	1.05 (0.94,1.18)	1.07 (0.95,1.20)	1,267 (11.2)	1.14 (1.05,1.24)	1.16 (1.07,1.27)
Q4	588 (6.3)	1.16 (1.04,1.30)	1.19 (1.06,1.33)	1,081 (11.6)	1.19 (1.09,1.30)	1.22 (1.12,1.34)
Q5	543 (7.1)	1.33 (1.18,1.49)	1.44 (1.28,1.62)	946 (12.4)	1.29 (1.18,1.41)	1.40 (1.27,1.54)
p value[b]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Comorbidity that excluded dementia						
Q1	3,404 (17.1)	Reference category		5,238 (26.3)	Reference category	
Q2	3,809 (17.5)	1.03 (0.98,1.08)	1.05 (1.00,1.11)	5,914 (27.2)	1.05 (1.00,1.09)	1.07 (1.03,1.12)
Q3	4,055 (18.1)	1.07 1.01,1.12)	1.12 (1.06,1.17)	6,323 (28.2)	1.10 (1.05,1.14)	1.15 (1.10,1.20)
Q4	3,761 (18.2)	1.08 (1.02,1.13)	1.17 (1.11,1.23)	5,873 (28.4)	1.11 (1.06,1.16)	1.21 (1.16,1.26)
Q5	3,677 (18.7)	1.11 (1.05,1.17)	1.28 (1.22,1.35)	5,701 (28.9)	1.14 (1.09,1.19)	1.32 (1.26,1.38)
p value[b]	0.001	<0.001	<0.001	p<0.001	<0.001	<0.001
Dementia						
Q1	3,385 (28.9)	Reference category		5,055 (43.2)	Reference category	
Q2	3,725 (28.3)	0.97 (0.92,1.02)	0.99 (0.93,1.04)	5,653 (43.0)	0.99 (0.94,1.04)	1.01 (0.96,1.06)
Q3	3,901 (29.4)	1.02 (0.97,1,08)	1.04 (0.99,1.10)	5,760 (43.5)	1.01 (0.96,1.06)	1.03 (0.98,1.08)
Q4	3,639 (29.3)	1.02 (0.97,1.08)	1.06 (1.01,1.13)	5,479 (44.2)	1.04 (0.99,1.09)	1.09 (1.03,1.15)
Q5	3,206 (28.9)	1.00 (0.94,1.05)	1.07 (1.01,1.13)	4,786 (43.1)	0.99 (0.94,1.05)	1.06 (1.01,1.13)
p value[b]	0.27	0.46	0.001	0.30	0.46	0.001

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity,

[b] Pearson's chi-squared test was used to assess the association between deprivation quintiles and mortality variables; logistic regression was used to assess trends in mortality variables by deprivation quintiles

9.4.9. Regional variation in 30-day mortality by levels of deprivation

Overall, the highest rates of mortality at 30-days post-hip fracture were observed in the North of England; 30-day mortality was highest in Yorkshire and the Humber (8.5%) and lowest in London and the West Midlands (7.4%) (Table 53). Cumulative 30-day mortality after hip fracture increased with greater deprivation among patients residing in the North East, North West and West Midlands; 30-day mortality rates were similar across deprivation quintiles among patients residing in the other English GORs. Absolute inequalities in 30-day mortality were most marked in the North East; mortality at 30-days post-hip fracture was 6.0% and 9.0% among patients in the least deprived and most deprived quintiles respectively.

Greater deprivation was associated with higher mortality at 30-days after hip fracture among patients residing in the North East, North West and West Midlands (Table 53). The most marked association between deprivation and 30-day mortality post-hip fracture was observed in the North East; the odds of death at 30-days post-hip fracture were 55% higher among patients in the most deprived compared with the least deprived quintile (unadjusted OR 1.55 [1.23,1.95], $p<0.001$). This relationship persisted following adjustment for age, gender and comorbidity (adjusted OR 1.58 [1.25,1.99], $p<0.001$).

Table 53: Association between quintiles of deprivation and mortality at 30-days after hip fracture according to geographic region in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile (reference category), quintile 5 (Q5) – most deprived quintile)

	N (%)	Crude OR (95% CI)	Age, gender & comorbidity-adjusted OR[a] (95% CI)	N (%)	Crude OR (95% CI)	Age, gender & comorbidity-adjusted OR[a] (95% CI)	N (%)	Crude OR (95% CI)	Age, gender & comorbidity-adjusted OR[a] (95% CI)
	North East			**North West**			**Yorkshire & Humber**		
Q1	99 (6.0)	Reference category		314 (6.8)	Reference category		225 (7.1)	Reference category	
Q2	173 (7.9)	1.34 (1.04,1.73)	1.39 (1.07,1.80)	399 (7.5)	1.12 (0.96,1.31)	1.14 (0.97,1.33)	382 (8.6)	1.24 (1.04,1.47)	1.19 (1.00,1.42)
Q3	153 (7.3)	1.24 (0.95,1.61)	1.26 (0.97,1.65)	419 (8.0)	1.19 (1.02,1.39)	1.19 (1.02,1.39)	401 (8.9)	1.28 (1.08,1.52)	1.23 (1.03,1.46)
Q4	268 (8.3)	1.42 (1.12,1.80)	1.45 (1.14,1.85)	532 (9.0)	1.36 (1.18,1.58)	1.37 (1.18,1.59)	398 (8.5)	1.22 (1.03,1.45)	1.14 (0.96,1.36)
Q5	382 (9.0)	1.55 (1.23,1.95)	1.58 (1.25,1.99)	797 (8.8)	1.32 (1.16,1.52)	1.40 (1.22,1.61)	517 (8.7)	1.26 (1.07,1.48)	1.22 (1.03,1.44)
p value[b]	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.05	0.05	0.11
	East Midlands			**West Midlands**			**East of England**		
Q1	241 (7.3)	Reference category		208 (6.2)	Reference category		451 (7.0)	Reference category	
Q2	264 (7.4)	1.01 (0.84,1.21)	1.02 (0.85,1.23)	356 (7.0)	1.14 (0.96,1.36)	1.09 (0.91,1.30)	518 (7.5)	1.08 (0.94,1.23)	1.06 (0.93,1.21)
Q3	250 (7.4)	1.02 (0.85,1.22)	0.99 (0.82,1.19)	407 (7.4)	1.21 (1.02,1.44)	1.16 (0.97,1.38)	513 (8.1)	1.16 (1.02,1.32)	1.13 (0.99,1.30)
Q4	257 (7.4)	1.01 (0.84,1.21)	1.00 (0.83,1.20)	371 (8.2)	1.35 (1.13,1.61)	1.32 (1.10,1.58)	353 (7.9)	1.14 (0.98,1.31)	1.10 (0.95,1.27)
Q5	230 (8.6)	1.19 (0.99,1.44)	1.19 (0.98,1.44)	433 (7.8)	1.27 (1.07,1.51)	1.30 (1.09,1.54)	137 (7.5)	1.07 (0.88,1.31)	1.09 (0.89,1.34)
p value[b]	0.32	0.123	0.17	0.01	0.001	<0.001	0.22	0.09	0.14
	London			**South East**			**South West**		
Q1	252 (7.2)	Reference category		939 (7.6)	Reference category		414 (7.5)	Reference category	
Q2	303 (7.3)	1.03 (0.86,1.22)	1.04 (0.87,1.24)	686 (7.8)	1.02 (0.92,1.13)	1.05 (0.94,1.16)	512 (7.5)	1.00 (0.88,1.15)	0.99 (0.86,1.14)
Q3	332 (7.3)	1.03 (0.87,1.22)	1.04 (0.88,1.24)	632 (7.8)	1.03 (0.93,1.15)	1.05 (0.94,1.17)	597 (8.1)	1.08 (0.95,1.23)	1.06 (0.93,1.21)
Q4	395 (7.2)	1.01 (0.86,1.19)	1.05 (0.89,1.24)	403 (7.5)	0.98 (0.87,1.11)	1.01 (0.89,1.14)	426 (8.1)	1.08 (0.94,1.25)	1.06 (0.92,1.23)
Q5	341 (7.9)	1.11 (0.93,1.31)	1.17 (0.98,1.39)	209 (8.1)	1.07 (0.92,1.26)	1.10 (0.93,1.29)	183 (8.2)	1.10 (0.92,1.32)	1.14 (0.95,1.38)
p value[b]	0.75	0.33	0.09	0.84	0.66	0.39	0.54	0.11	0.10

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia, and dementia

[b] Pearson's chi-squared test was used to assess the association between deprivation quintiles and 30-day mortality; logistic regression was used to assess trends in 30-day mortality by deprivation quintiles

9.5. Summary

This study examined the relationship between area-based deprivation and mortality up to 365-days after hip fracture in men and women aged 60+ years in England over a 4-year period. Cumulative mortality rates increased with greater deprivation at all time points after hip fracture. Similar patterns were observed at 30-days, 120-days and 365-days after hip fracture among both men and women with no recorded comorbidity and with comorbidity that excluded dementia.

Furthermore, greater deprivation was associated with reduced survival in the year after hip fracture; the odds of death at 365-days post-hip fracture were 24% higher among the most deprived compared with the least deprived patients after adjustment for age, gender and comorbidity. Relative inequalities in mortality after hip fracture were greatest among men and women with no recorded comorbidity, and among those residing in the North of England.

This study has shown that social and regional inequalities in mortality after hip fracture exist in England; however, the effect of deprivation on healthcare utilisation post-hip fracture is not known. The next chapter examines the relationship between deprivation and superspell LOS, emergency 30-day readmission and total NHS bed occupancy in the year after hip fracture, over a 4-year period.

CHAPTER 10. SOCIAL DEPRIVATION PREDICTS HEALTHCARE UTILISATION AFTER HOSPITAL ADMISSION WITH HIP FRACTURE IN ENGLAND

10.1. Introduction

The previous chapter has shown that social deprivation predicts reduced survival in the year after hip fracture, and that relative inequalities in mortality post-hip fracture are greatest among individuals with no recorded comorbidity. This current chapter investigates the effect of deprivation on healthcare utilisation in the year after hip fracture.

In England, 11.9% of hip fracture patients are readmitted within 28-days of discharge (104), with one-year mortality reported to be higher among US hip fracture patients readmitted to hospital (106). Superspell LOS is defined as the overall amount of time spent in NHS care following hip fracture (discussed further in Chapter 1.8.2, page 37). In 2014, mean superspell LOS was 22.7 days for hip fracture patients in England (99), with a cross-sectional study conducted in South West England demonstrating that higher rates of transfer from acute NHS hospitals to community rehabilitation hospitals were associated with longer superspell LOS (371).

Male gender, older age and comorbidity are predictors of hospital readmission and prolonged hospital stay after hip fracture, as discussed in Chapter 1.8, page 33. Studies conducted among hip fracture patients in England, Denmark and the USA have all reported higher hospital readmission rates in men than women (101, 109-111), and the odds of 30-day readmission is higher among US individuals aged 85+ years compared with 60-85 years (106). Analysis of English HES data has similarly demonstrated that acute hospital LOS is longer in men and increases with advancing age (102), possibly explained in part by destination upon discharge which has been shown to influence hospital LOS (103). Specific comorbidities such as COPD, cardiac and renal disease, and diabetes are associated with both higher odds of hospital readmission and longer hospital stays after hip fracture (102, 109). The relationship between dementia and readmission post-hip fracture is unclear, with inconsistent findings reported by two US studies. Kates et al found that dementia was associated with higher odds of 30-day readmission (106), whilst Radcliff et al did not find an association (113); both studies adjusted their analyses for different covariates, which may partly account for the inconsistent findings.

Few studies have examined the effect of deprivation on hospital readmission and acute hospital LOS post-hip fracture, with no known studies focusing specifically on superspell LOS or total healthcare utilisation. It has been demonstrated, using English HES data, that 28-day readmission rates are higher and hospital LOS is longer among hip fracture patients residing in more deprived compared with less deprived areas (measured using the IMD) (21, 102, 103). Kristensen et al also showed, using Danish hip fracture registry data, that 30-day readmission risk was higher among the most deprived compared with the least deprived individuals (based on a combined measure of individual-level education and income); however, hospital LOS was similar according to deprivation categories, the explanation for which is unclear (301). Quah et al similarly reported no difference in acute hospital LOS according to IMD quintiles, although they studied hip fracture patients admitted to a single urban hospital in Nottingham, England (277).

10.2. Aims of this Chapter

The prevalence of smoking, heavy alcohol intake and obesity all increase with greater deprivation (370), and the burden of comorbidity is higher among more deprived individuals (226, 231, 232). It was therefore hypothesised that higher emergency 30-day readmission rates and longer hospital stays after hip fracture would be observed among more deprived patients owing to their more complex healthcare needs. Furthermore, it is not known whether the relationship between deprivation and healthcare utilisation post-hip fracture differs according to individual-level risk factors ('effect modification').

This study firstly examined the effect of area-level social deprivation on emergency 30-day readmission, superspell LOS and total NHS bed days among patients admitted to hospital with a hip fracture in England and secondly, examined whether the relationship between deprivation and study outcomes differs according to patient characteristics such as age, gender, comorbidity and dementia.

10.3. Methods

10.3.1. Study population

An anonymised patient-level data extract of routinely collected HES APC data linked to NHFD and ONS mortality data was used to identify patients aged 60+ years with an index case of hip fracture on or during admission to an English NHS hospital over the period 1st April 2011 to 31st March 2015. The data sources and methods used to generate the linked HES-ONS-NHFD dataset for analysis have been described in Chapter 6. The study population was restricted to patients aged 60+ years for consistency with the hip fracture population for whom the NHFD routinely collect clinical audit data.

10.3.2. Study variables

Deprivation

The IMD was used to measure socioeconomic deprivation (195). The IMD is a relative measure of deprivation for small areas that has been discussed in detail in Chapter 2.5.3, page 64. Patients were categorised into deprivation quintiles based upon the national ranking of local areas, with quintile 1 being the least deprived group and quintile 5 being the most deprived group (see Chapter 6.6.2, page 183).

Outcomes

Superspell LOS

A hip fracture superspell was defined as the index hip fracture admission (i.e. first occurrence of hip fracture), and if applicable, planned hospital transfers for elective care plus a subsequent unplanned hospital transfer for emergency care. The methodological approach used to construct hip fracture superspells has been described in detail in Chapter 6.6.9, page 189. All patients within the study population had an index hip fracture admission; however, not all patients had subsequent hospital transfers for elective or emergency care. Superspell LOS was calculated as the difference between the date of the index hip fracture admission and the final date of discharge from an NHS hospital if the patient was transferred, or following the index hip fracture admission if the patient was not transferred.

Analyses of superspell LOS were restricted to those patients who were discharged alive from hospital following a hip fracture superspell given that in-hospital mortality will influence the amount of time spent in hospital after hip fracture. Other approaches for handling the competing risk of mortality have been discussed in Chapter 6.9.6, page 210.

Emergency 30-day readmission

An emergency 30-day readmission was defined as an emergency all-cause admission to any English NHS hospital that occurred within 30-days of hospital discharge following a hip fracture superspell. Analyses of 30-day readmission were restricted to those patients who were discharged alive following a hip fracture superspell given that readmission is not possible among patients who died during an inpatient stay. The methods used to identify readmissions have been described in Chapter 6.6.10, page 192 and approaches for handling competing risks have been discussed in Chapter 6.9.6, page 210.

Total NHS bed days in the year after hip fracture

Total NHS bed days was defined as the total number of days spent in hospital in the year after hip fracture and calculated as the sum of the LOS of all hospital admissions (i.e. the hip fracture superspell, an emergency 30-day readmission if this occurred, and other all-cause elective and emergency hospital admissions). Hip fracture superspells were censored at 365-days from the date of hip fracture admission for these analyses so that each patient in the study had the same period of observation. Total NHS bed days was calculated for patients regardless of vital status to capture the total burden of healthcare utilisation in the year after hip fracture. Further details of the methods used to calculate total NHS bed days have been provided in Chapter 6.6.11, page 192.

Further variables

Further study variables were derived to describe patient and fracture characteristics, including 10-yearly age groupings from 60 years to 90+ years, gender, comorbidity, fracture type and operation performed. The methods used to derive key study variables have been described in Chapter 6.6, page 183 and Chapter 6.7, page 194. In brief, comorbidity was measured using the RCS Charlson score and categorised as a three-level ordinal variable (no comorbid condition, ≥1 comorbid condition that excluded dementia, and dementia with or without other comorbidities referred to henceforth as dementia). Hip fractures were defined based on their anatomical location and the nature of the fracture (i.e. pathological, atypical or non-pathological fracture). For these analyses, type of hip fracture operation was categorised as no operation performed, internal fixation with screws, internal fixation using an IM nail, hemiarthroplasty, THA and other procedure.

10.3.3. Research approvals

The following research approvals were obtained for this study: NHS Research Ethics Committee (REC reference: 15/LO/1056), Falls and Fragility Fracture Audit Programme from the Healthcare Quality Improvement Partnership, NHS Digital Data Sharing Agreement, and NHS Information Governance Toolkit version 13.

10.3.4. Statistical analyses

All statistical analyses were conducted using Stata, version 14 IC (StataCorp, College Station, TX, USA).

Descriptive analyses

Demographic characteristics of the hip fracture population were described. Counts and percentages were used to summarise categorical variables, and means and SDs were used to describe continuous variables (see Chapter 6.9.1, page 205 for further details).

The proportion of hip fracture patients readmitted within 30-days of discharge following a hip fracture superspell was calculated for each quintile of deprivation stratified by age, gender and comorbidity. χ^2 test was used to examine the association between deprivation and emergency 30-day readmission to determine whether readmission rates differed according to deprivation quintiles.

Mean and median superspell LOS and total NHS bed days, with SD and IQR, were calculated in days and according to deprivation quintiles. The distributions of superspell LOS and total NHS bed days were positively-skewed, as presented in Appendix 13.10, page 434. Skewed data are conventionally summarised by medians and IQRs, and log-transformed to satisfy the assumption of normality for linear regression. Superspell LOS and total NHS bed days were summarised using arithmetic means, as opposed to geometric means, for these analyses to capture the effect of outliers. Linear regression models provide efficient estimates of the mean for skewed data when the sample size is large (372, 373), as was the case for these analyses.

Association between deprivation and emergency 30-day readmission

Logistic regression was used to determine the association between deprivation and emergency 30-day readmission, adjusted for age group (in 5-yearly intervals), gender and comorbidity. ORs with 95% CIs were calculated to determine the odds of readmission among individuals in each quintile of deprivation (i.e. Q2 – Q5) with the odds of readmission among individuals in quintile 1, the least deprived quintile, which was used as the reference category (see Chapter 6.9.3, page 209). Logistic regression was used to assess trends in log odds of readmission by deprivation quintiles, including deprivation as a linear term.

Association between deprivation and hospital LOS

Linear regression was used to determine the association between deprivation and hospital LOS (see Chapter 6.9.3, page 209). To be clinically helpful, mean hospital LOS in days with 95% CIs were predicted for a 'typical' hip fracture patient. The mean age of this hip fracture population was 83 years and therefore, mean hospital LOS was generated for an 85-year old male and female patient separately stratified by deprivation quintiles and comorbidity categories. Linear regression was used to assess trends in mean hospital LOS by deprivation quintiles, including deprivation as a linear term.

Formal tests for interaction

Formal tests for interaction were conducted separately to determine whether the relationship between deprivation and study outcomes (i.e. superspell LOS, emergency 30-

day readmission and total NHS bed days) differed according to age, gender and comorbidity. Deprivation was modelled as a linear term for these analyses. Analyses were adjusted for age, gender and/or comorbidity. The methods used to test for interaction have been described further in Chapter 6.9.4, page 210 and Chapter 9.3.5, page 260.

Outcomes after hip fracture according to levels of comorbidity and residential status

As a descriptive analysis, emergency 30-day readmission rates, superspell LOS and total NHS bed days were calculated for each comorbidity category according to residential status prior to index hip fracture admission. It was decided not to take account of destination upon discharge following a hip fracture admission and thus identify individuals with a change in their residential status due to the high level of missing data for the NHFD variable *residential status at 30-days* (54.9%).

Separately for hip fracture patients admitted from their own home and from an institution (residential or nursing home), χ^2 test was used to determine whether emergency 30-day readmission rates differed according to comorbidity category. Linear regression was used to examine the association between levels of comorbidity and superspell LOS and total NHS bed days, using the no comorbidity group as the reference category.

10.4. Results

10.4.1. Description of the study population

As described in Chapter 9.4.1, there were 218,907 index hospital admissions for hip fracture among English residents aged 60+ years between 2011 and 2014; 72.6% occurred in women and 75.9% had one or more coded comorbid conditions. The mean age of this study population was 82.8 [8.4] years. One-fifth (20.0%) of hip fracture admissions were among individuals in the least deprived quintile and 17.6% were among those in the most deprived quintile. Hip fracture patients in the most deprived quintile were more likely to be younger, male and have a higher burden of comorbidity when compared to patients in the least deprived quintile.

10.4.2. Emergency 30-day readmission

Among the 91.2% patients discharged alive from hospital following their hip fracture superspell, 15.6% were readmitted as an emergency within 30-days of discharge. Emergency 30-day readmission rates were higher in men than women, among individuals aged 85+ years, and patients with dementia.

Emergency 30-day readmission by age, gender and comorbidity

Emergency 30-day readmission rates were 18.5% in men and 14.5% in women ($p<0.001$), and 14.0% and 17.4% in individuals aged 60-84 years and 85+ years respectively ($p<0.001$). The highest rates of emergency 30-day readmission were among older men; 16.9% and 20.9% of men aged 60-84 years and 85+ years were readmitted within 30-days of hospital discharge (p<0.001) compared with 12.8% and 16.4% of women aged 60-84 years and 85+ years (p<0.001). When stratified by comorbidity, 30-day readmission rates were 10.4%, 16.8% and 18.4% in patients with no recorded comorbidity, comorbidity that excluded dementia and with dementia respectively (p<0.001).

Emergency 30-day readmission according to levels of comorbidity and residential status

Of the 77.3% of hip fracture patients admitted from their own home (154,133/199,398), 53.7% had comorbidity that excluded dementia and 15.3% had a recorded diagnosis of dementia. In contrast, 18.2% of patients were admitted from an institution, more than three-quarters of whom had a recorded diagnosis of dementia (76.2%) and 16.9% had comorbidity that excluded dementia.

Emergency 30-day readmission rates were higher among patients with comorbidity compared to those with no recorded comorbidity, regardless of whether they were admitted to hospital for hip fracture from their own home or an institution. Of those patients residing in their own home prior to hip fracture admission, 16.3% with comorbidity that excluded dementia and 19.4% with dementia were readmitted within 30-days of discharge compared with 10.1% with no comorbidity (p<0.001). Among individuals admitted from a residential or nursing home, 30-day readmission rates were 14.9%, 18.7% and 17.3% for those with no comorbidity, comorbidity that excluded dementia and with dementia respectively (p<0.001).

10.4.3. Emergency 30-day readmission by levels of deprivation

Emergency 30-day readmission rates increased with greater deprivation; 14.2% and 17.5% of patients in the least deprived and most deprived quintile were readmitted within 30-days of discharge (p<0.001) (Figure 33).

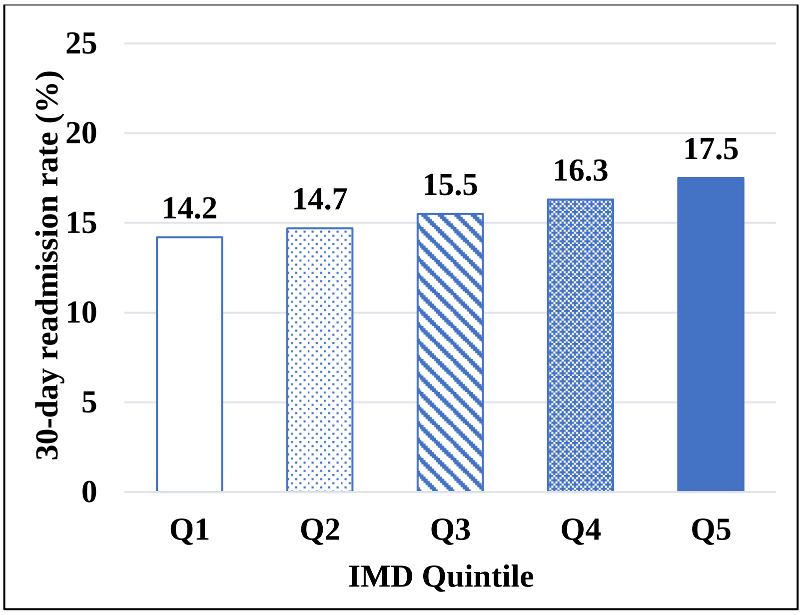

Figure 33: Emergency 30-day readmission rates following hospital admission for hip fracture by quintiles of deprivation
(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

Association between deprivation and emergency 30-day readmission

Overall, greater deprivation was associated with higher emergency 30-day readmission (Table 54). The odds of 30-day readmission were 28% higher among individuals in the most deprived compared with the least deprived quintile (unadjusted OR 1.28 [1.23,1.33], p<0.001). The association between deprivation and 30-day readmission was marginally stronger following adjustment for age and gender (adjusted OR 1.32 [1.27,1.38], p<0.001);

however, additional adjustment for comorbidity then attenuated this relationship (OR 1.27 [1.22,1.32], p<0.001).

Table 54: Association between quintiles of deprivation and emergency 30-day readmission following hospital admission for hip fracture in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) (least deprived quintile) – reference category, quintile 5 (Q5) – most deprived quintile)

IMD quintile	N (%)	Crude OR	Age & gender adjusted OR[a]	Age, gender & comorbidity adjusted OR[a]
Q1	5,744 (14.2)	Reference category		
Q2	6,358 (14.7)	1.04 (1.00,1.08)	1.05 (1.01,1.09)	1.04 (1.00,1.08)
Q3	6,658 (15.5)	1.11 (1.07,1.15)	1.12 (1.08,1.16)	1.10 (1.06,1.14)
Q4	6,250 (16.3)	1.17 (1.13,1.22)	1.19 (1.15,1.24)	1.16 (1.11,1.21)
Q5	6,062 (17.5)	1.28 (1.23,1.33)	1.32 (1.27,1.38)	1.27 (1.22,1.32)
p value[b]	<0.001	<0.001	<0.001	<0.001

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia and dementia +/- other comorbidities

[b] Logistic regression was used to assess trends in emergency 30-day readmission by deprivation quintiles

10.4.4. Tests for interaction by age, gender and comorbidity

The effect of deprivation on emergency 30-day readmission post-hip fracture was similar in men and women, and individuals aged 60-84 years and 85+ years (Appendix 13.9, page 431). Regardless, emergency 30-day readmission rates were calculated for each quintile of deprivation stratified by age, gender and comorbidity as a prognostic tool for use in clinical settings (Table 55 & Table 56).

The relationship between deprivation and emergency 30-day readmission was found to differ according to strata of comorbidity (p-value for interaction 0.009), and therefore further analyses were conducted stratified by comorbidity, adjusted for age and gender. The effect of deprivation on 30-day readmission was similar in patients with no comorbidity and with comorbidity that excluded dementia, and stronger among patients with dementia compared to those with no comorbidity.

10.4.5. Emergency 30-day readmission by levels of deprivation and comorbidity

Consistent with the patterns described earlier, emergency 30-day readmission rates post-hip fracture were higher in men than women, among older individuals and those with dementia.

Emergency 30-day readmission rates increased with greater deprivation in men aged 60-84 years for all strata of comorbidity and men aged 85+ years with dementia. Readmission rates were similar according to deprivation quintiles in men aged 85+ years with no comorbidity and comorbidity that excluded dementia (Table 55). Readmission rates were highest among the most deprived older men with dementia, 25.8% of whom were readmitted within 30-days of hospital discharge.

In women, readmission rates increased with greater deprivation in patients with comorbidity (with or without dementia), regardless of age (Table 56). 30-day readmission rates were highest among the most deprived older women with comorbidity, with one-fifth being readmitted within 30-days of discharge.

Table 55: Emergency 30-day readmission rates following hospital admission for hip fracture by levels of deprivation and comorbidity in men aged 60-84 years and 85+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

IMD quintile	No comorbidity (N (%))		Comorbidity excluding dementia (N (%))		Dementia (N (%))	
	60-84 years	**85+ years**	**60-84 years**	**85+ years**	**60-84 years**	**85+ years**
Total	726 (10.5)	551 (16.1)	3,234 (17.5)	2,323 (21.7)	1,445 (22.1)	1,393 (22.3)
Q1	135 (9.1)	146 (16.5)	521 (16.0)	495 (19.9)	217 (19.7)	267 (20.4)
Q2	139 (8.8)	108 (13.3)	601 (16.7)	511 (21.1)	265 (20.1)	297 (21.8)
Q3	170 (11.9)	114 (15.5)	660 (17.1)	532 (22.5)	311 (23.7)	302 (21.8)
Q4	156 (12.6)	103 (17.8)	674 (18.1)	430 (22.5)	317 (23.1)	268 (22.4)
Q5	126 (10.5)	80 (19.1)	778 (19.3)	355 (23.5)	335 (23.5)	259 (25.8)
p value[a]	0.003	0.06	0.002	0.05	0.03	0.03

[a] Pearson's chi-squared test was used to assess the association between deprivation quintiles and emergency 30-day readmission

Table 56: Emergency 30-day readmission rates following hospital admission for hip fracture by levels of deprivation and comorbidity in women aged 60-84 years and 85+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

IMD quintile	No comorbidity (N (%))		Comorbidity excluding dementia (N (%))		Dementia (N (%))	
	60-84 years	**85+ years**	**60-84 years**	**85+ years**	**60-84 years**	**85+ years**
Total	1,834 (7.7)	2,240 (13.0)	5,280 (14.2)	4,841 (17.8)	2,715 (17.3)	4,490 (17.2)
Q1	397 (7.0)	501 (12.6)	904 (13.5)	943 (16.9)	410 (14.5)	808 (15.6)
Q2	432 (7.7)	524 (13.1)	997 (13.2)	1,025 (17.2)	531 (16.5)	928 (16.2)
Q3	416 (8.1)	466 (12.4)	1,088 (13.7)	1,059 (17.7)	563 (17.4)	977 (16.8)
Q4	308 (7.6)	424 (13.5)	1,102 (14.6)	929 (17.7)	621 (18.9)	918 (17.9)
Q5	281 (8.4)	325 (13.4)	1,189 (15.7)	885 (20.2)	590 (19.0)	859 (20.0)
p value[a]	0.12	0.59	<0.001	<0.001	<0.001	<0.001

[a] Pearson's chi-squared test was used to assess the association between deprivation quintiles and emergency 30-day readmission

Association between deprivation and emergency 30-day readmission by levels of comorbidity

Crude analyses

For all strata of comorbidity, greater deprivation was associated with higher odds of emergency 30-day readmission post-hip fracture; however, the magnitude of this association was strongest among hip fracture patients with dementia in whom the odds of 30-day readmission were 34% higher among the most deprived versus the least deprived individuals (Table 57). In contrast, the probability of being readmitted within 30-days of discharge was 14% and 18% higher for the most deprived compared to the least deprived patients with no recorded comorbidity (OR 1.14 [1.03,1.25], p=0.001) and comorbidity that excluded dementia (OR 1.18 [1.12,1.25], p<0.001).

Adjusted analyses

The observed positive association between deprivation and emergency 30-day readmission persisted for all strata of comorbidity after adjustment for age and gender, although the strength of this association was marginally stronger among patients with no comorbidity and comorbidity that excluded dementia (Table 57). Age and gender adjustment did not explain the association between deprivation and emergency 30-day readmission in patients with dementia.

Table 57: Association between quintiles of deprivation and emergency 30-day readmission following hospital admission for hip fracture by levels of comorbidity in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) (least deprived quintile) – reference category, quintile 5 (Q5) – most deprived quintile)

IMD quintile	N (%)	Crude ORs	Age & gender adjusted ORs[a]
No comorbidity			
Q1	1,179 (9.8)	Reference category	
Q2	1,203 (10.0)	1.02 (0.94,1.11)	1.03 (0.94,1.12)
Q3	1,166 (10.6)	1.08 (0.99,1.18)	1.09 (1.00,1.19)
Q4	991 (11.0)	1.13 (1.03,1.24)	1.14 (1.04,1.24)
Q5	812 (11.0)	1.14 (1.03,1.25)	1.17 (1.06,1.28)
p value[b]	0.01	0.001	<0.001
Comorbidity excluding dementia			
Q1	2,863 (15.9)	Reference category	
Q2	3,134 (16.1)	1.01 (0.96,1.07)	1.02 (0.97,1.08)
Q3	3,339 (16.6)	1.05 (0.99,1.11)	1.07 (1.01,1.13)
Q4	3,135 (17.0)	1.08 (1.03,1.15)	1.12 (1.06,1.18)
Q5	3,207 (18.3)	1.18 (1.12,1.25)	1.25 (1.18,1.32)
p value[b]	<0.001	<0.001	<0.001
Dementia			
Q1	1,702 (16.4)	Reference category	
Q2	2,021 (17.4)	1.07 (1.00,1.15)	1.08 (1.00,1.16)
Q3	2,153 (18.3)	1.15 (1.07,1.23)	1.15 (1.07,1.23)
Q4	2,124 (19.4)	1.23 (1.14,1.32)	1.23 (1.15,1.32)
Q5	2,043 (20.8)	1.34 (1.25,1.44)	1.34 (1.25,1.44)
p value[b]	<0.001	<0.001	<0.001

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years

[b] Logistic regression modelling was used to assess trends in ORs by deprivation quintiles, treating deprivation as a linear term

10.4.6. Superspell LOS

Among the 91.2% patients discharged alive from hospital following their hip fracture superspell, the overall mean and median superspell LOS were 23.6 [21.5] days and 17 [10-30] days respectively. Mean superspell LOS, as compared to the median value, was longer, which is in keeping with the positively-skewed histogram of superspell LOS presented in Appendix 13.10, page 434.

Superspell LOS by age, gender and comorbidity

Both mean and median superspell LOS were longer in men than women, among older individuals and patients with dementia (Table 58). Mean superspell LOS was 21.3 [21.0] days in patients aged 60-84 years, and on average 5.1 days longer in those aged 85+ years ($p<0.001$), whilst in women, mean superspell LOS was 23.0 [20.9] days, and on average 2.5 days longer in men ($p<0.001$). When analyses were stratified by comorbidity, mean superspell LOS was 18.9 days in patients with no recorded comorbidity, and 24.7 days and 26.2 days in patients with comorbidity that excluded dementia and with dementia respectively ($p<0.001$).

Table 58: Mean and median superspell LOS in days by age, gender and comorbidity

	Mean (SD)	Median (IQR)	p value[a]
Age group			
60-84 years	21.3 (21.0)	14 (9-26)	<0.001
85+ years	26.4 (21.9)	20 (12-34)	
Gender			
Males	25.5 (23.3)	18 (10-33)	<0.001
Females	23.0 (20.9)	16 (10-29)	
Comorbidity			
No comorbidity	18.9 (18.2)	13 (8-23)	<0.001
Comorbidity excl. dementia	24.7 (21.8)	18 (11-31)	
Dementia	26.2 (23.4)	19 (10-35)	

[a] Linear regression was used to assess trends in superspell LOS by age, gender and comorbidity, with log-transformation of median superspell LOS; p-values presented are for both mean and median values
SD – standard deviation; IQR – inter-quartile range

Superspell LOS according to levels of comorbidity and residential status

Among hip fracture patients admitted from home, mean superspell LOS was longest for patients with dementia (33.2 [24.7] days), whilst individuals with no comorbidity and comorbidity that excluded dementia spent 18.6 [17.7] days and 24.3 [21.2] days in hospital after hip fracture ($p<0.001$).

As expected, hospital stays after hip fracture were shorter among individuals with comorbidity admitted from an institution compared to their own home. Mean superspell LOS was 18.9 [16.4] days for individuals with no comorbidity, and 20.8 [17.7] days and 18.1 [16.3] days for those with comorbidity that excluded dementia and with dementia respectively ($p<0.001$).

10.4.7. Superspell LOS by levels of deprivation

Superspell LOS increased marginally with greater deprivation (Figure 34 and Appendix 13.11, page 435). Mean superspell LOS was 23.3 [22.1] days among the least deprived patients, and on average 1.1 days longer among those in the most deprived quintile ($p<0.001$). Similarly, the difference between median superspell LOS for patients in the least deprived and most deprived quintile was 1 day, increasing from 16 to 17 days.

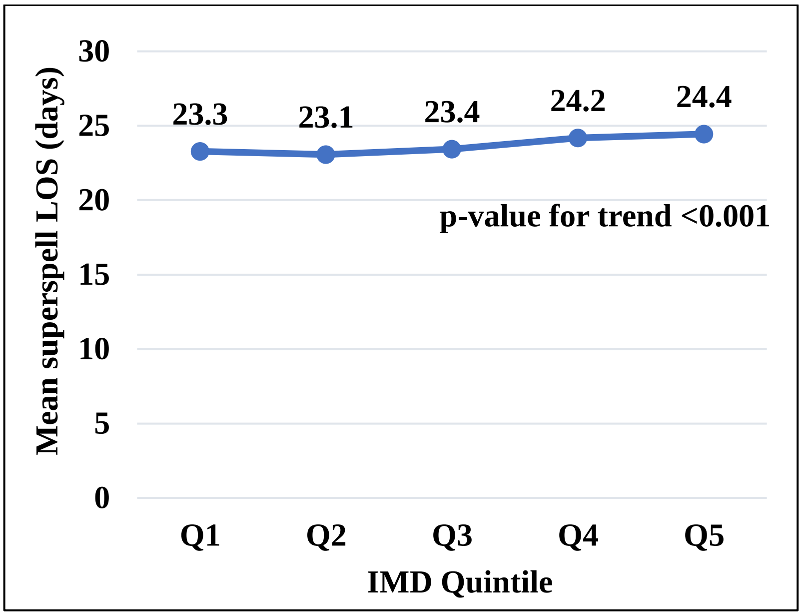

Figure 34: Mean superspell LOS in days by quintiles of deprivation in men and women aged 60+years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)
(95% confidence intervals shown but very narrow)

10.4.8. Tests for interaction by age, gender and comorbidity

The effect of deprivation on superspell LOS was similar in men and women but differed among individuals aged 60-84 years and 85+ years (p-value for interaction 0.004), and according to levels of comorbidity (p-value for interaction <0.001) (Appendix 13.9, page 431).

The relationship between deprivation and superspell LOS was similar in patients with no recorded comorbidity and those with comorbidity that excluded dementia, and stronger in patients with dementia compared to those with no comorbidity. The relative effect of deprivation on superspell LOS was small for age-stratified analyses, and therefore estimates of superspell LOS were generated for a 'typical' male and female hip fracture patient according to deprivation quintiles and comorbidity categories, with methods described earlier in section 10.3.4, page 288.

10.4.9. Superspell LOS by levels of deprivation and comorbidity

Mean superspell LOS increased with greater deprivation for all strata of comorbidity, and hospital stays were longer in men than women (Figure 35). Mean superspell LOS was approximately 1.5 days longer among both men and women in the most deprived compared with the least deprived quintile, regardless of comorbidity status. For both men and women, mean superspell LOS was similar among those with comorbidity that excluded dementia and with dementia. Individuals with comorbidity spent on average an extra 6 days in hospital after hip fracture compared to those with no recorded comorbidity.

In 85-year old men with no recorded comorbidity, mean superspell LOS was 22.3 days and 23.6 days for those in the least deprived and most deprived quintile (Figure 35a).

Mean superspell LOS was 27.8 days for the least deprived men with comorbidity, and on average 1.4 days longer for those in the most deprived quintile.

Similar patterns were observed among older women, although hospital stays after hip fracture were shorter than observed in men. The least deprived and most deprived women with no recorded comorbidity spent 19.5 days and 20.8 days in hospital post-hip fracture (Figure 35b). Whilst, in women with comorbidity, mean superspell LOS was 25.0 days and 26.4 days for those in the least deprived and most deprived quintile.

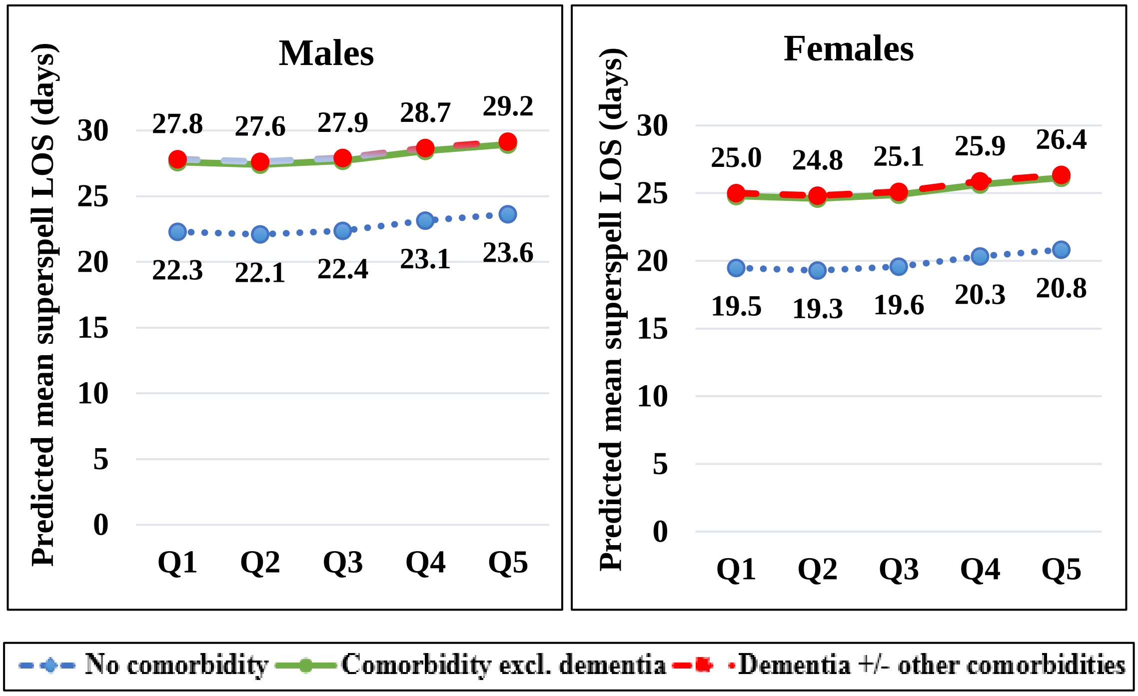

Figure 35: Predicted mean superspell LOS in days by quintiles of deprivation in (a) men and (b) women aged 85 years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)
(95% confidence intervals shown but very narrow)

10.4.10. Total NHS bed days in the year after hip fracture

Overall, mean and median total NHS bed days in the year after hip fracture were 33.4 [32.7] days and 22 [11-44] days respectively. Mean total NHS bed occupancy was longer than the median value in keeping with the positively-skewed distribution of data (Appendix 13.10, page 434).

Total NHS bed days was calculated as the sum of the LOS of all hospital admissions in the year after hip fracture, as described earlier in section 10.3.2, page 285. Mean superspell LOS was previously reported to be 23.6 days among 199,564 patients discharged alive following a hip fracture admission (see section 10.4.6, page 299). Among the 15.6% (31,072/199,564) hip fracture patients readmitted within 30-days of discharge, mean and median LOS for the hospital readmission were 14.6 [19.3] days and 8 [2-20] days respectively. Mean LOS was 23.9 [29.8] days and median LOS was 13 [5-32] days among the 35.9% (71,641/199,564) patients with an emergency and/or elective all-cause hospital admission (i.e. excluding their hip fracture superspell and emergency 30-day readmission if applicable).

Total NHS bed days by age, gender and comorbidity

Both mean and median total NHS bed occupancy were higher in men than women and among older individuals. Individuals aged 60-84 years and 85+ years spent on average 31.1 days and 35.9 days in hospital in the year after hip fracture respectively ($p<0.001$) (Table 59). Hospital bed occupancy was on average 32.2 [31.7] days for women, and 4.2 days longer for men ($p<0.001$). When stratified by comorbidity, patients with comorbidity that excluded dementia spent the greatest amount of time in hospital in the year after hip fracture. Mean total NHS bed occupancy was 26.4 days among patients with no recorded comorbidity, and was 9.7 days and 8.2 days longer among patients with comorbidity that excluded dementia and with dementia respectively (p<0.001).

Table 59: Mean and median total NHS bed days in the year after hip fracture by age, gender and comorbidity

Patient characteristic	Mean (SD)	Median (IQR)	p value[a]
Age group			
60-84 years	31.1 (33.4)	19 (10-40)	<0.001
85+ years	35.9 (31.8)	26 (14-48)	
Gender			
Males	36.4 (35.1)	25 (12-49)	<0.001
Females	32.2 (31.7)	21 (11-42)	
Comorbidity			
No comorbidity	26.4 (28.6)	16 (9-33)	<0.001
Comorbidity excl. dementia	36.1 (34.6)	25 (13-48)	
Dementia +/- other comorbidities	34.6 (32.0)	25 (12-46)	

[a] Linear regression was used to assess trends in total NHS bed days by age, gender and comorbidity, with log-transformation of median values; p-values presented are for both mean and median values
SD – standard deviation; IQR – inter-quartile range

Total NHS bed days according to levels of comorbidity and residential status

Among patients admitted from their own home, mean total NHS bed days was highest for individuals with dementia who spent 44.1 [34.7] days in hospital in the year after hip fracture. Mean total NHS bed occupancy was 26.0 [28.3] days) and 35.8 [34.3] days for individuals with no comorbidity and comorbidity that excluded dementia (p<0.001). These findings are consistent with the higher rates of emergency 30-day readmission and longer hospital stays after hip fracture observed among individuals with comorbidity, particularly those with dementia (see section 10.4.2, page 291 and section 10.4.6, page 299).

As expected, hip fracture patients admitted from an institution spent less time in hospital in the year after hip fracture than those patients admitted from their own home. Mean total NHS bed days was highest for individuals with comorbidity that excluded dementia (28.6 [27.4] days), whilst individuals with no comorbidity spent 25.6 [25.0] days and those with dementia spent 23.7 [22.8] days in hospital in the year after hip fracture ($p<0.001$).

10.4.11. Total NHS bed days by levels of deprivation

Hip fracture patients in the most deprived quintile spent the greatest amount of time in hospital in the year following hip fracture (Figure 36 and Appendix 13.11, page 435). Mean total NHS bed occupancy was 32.3 days among patients in the least deprived quintile, and on average 2.6 days longer among those in the most deprived quintile ($p<0.001$). Similarly, the difference between median total NHS bed days for patients in the least deprived and most deprived quintile was 3 days, increasing from 21 to 24 days.

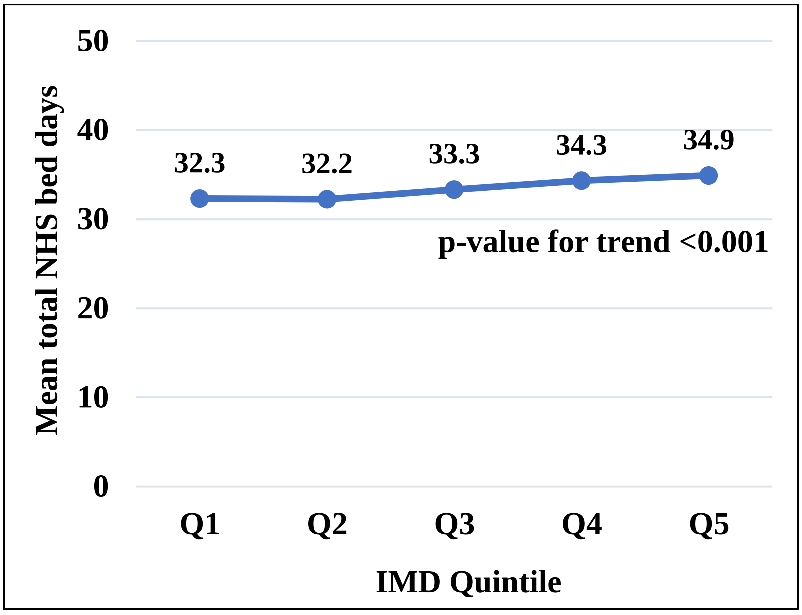

Figure 36: Mean total NHS bed days in the year after hip fracture by quintiles of deprivation in men and women aged 60+ years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)
(95% confidence intervals shown but very narrow)

10.4.12. Tests for interaction by age, gender and comorbidity

The effect of deprivation on total NHS bed days in the year after hip fracture was similar in men and women, and according to levels of comorbidity (Appendix 13.9, page 431). The relationship between deprivation and total NHS bed occupancy was modified by age, although the relative effect was small, and therefore estimates of total NHS bed days were generated for a 'typical' male and female hip fracture patient according to deprivation quintiles and comorbidity categories, with methods described earlier in section 10.3.4, page 288.

10.4.13. Total NHS bed days by levels of deprivation and comorbidity

Total NHS bed occupancy in the year after hip fracture increased with greater deprivation for all strata of comorbidity, with men spending consistently more time in hospital than women (Figure 37). Mean hospital bed occupancy was approximately 2.5 days longer among both men and women in the most deprived compared with the least deprived quintile, regardless of comorbidity status. Hospital stays in the year after hip fracture were longest among both men and women with comorbidity that excluded dementia who spent on average 9 more days in hospital compared to those with no recorded comorbidity, whilst those with dementia spent an extra 6 days.

In 85-year old men with no comorbidity, mean total NHS bed occupancy was 30.2 days and 32.7 days for those in the least deprived and most deprived quintile (Figure 37a). The most deprived men with comorbidity spent the greatest amount of time in hospital in the year after hip fracture; 41.6 days for men with comorbidity that excluded dementia and 38.9 days for those with dementia.

Similar patterns were seen in older women, although total NHS bed days was lower than observed in men (Figure 37b). The least deprived and most deprived women with no comorbidity spent on average 26.2 days and 28.7 days in hospital in the year after hip fracture. As seen in men, mean total NHS bed days was highest among the most deprived women with comorbidity.

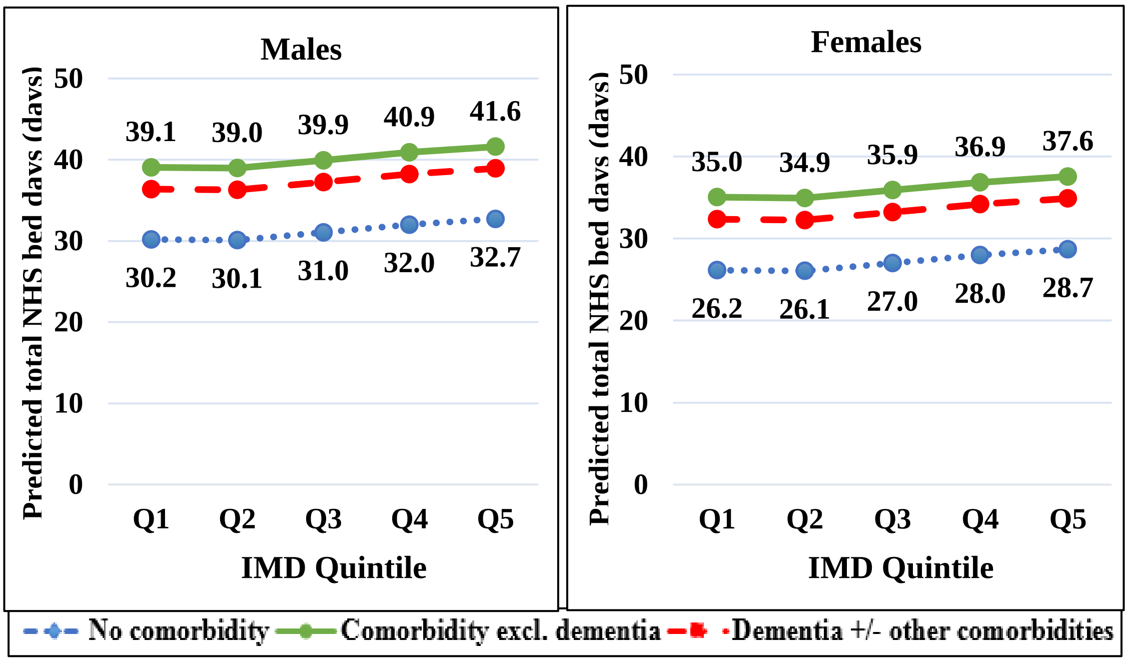

Figure 37: Predicted mean total NHS bed days in the year after hip fracture by quintiles of deprivation in (a) men and (b) women aged 85 years, 2011–2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)
(95% confidence intervals shown but very narrow)

10.5. Summary

This study examined the relationship between area-based deprivation and healthcare utilisation in the year after hip fracture among men and women aged 60+ years in England, using a linked dataset of hospital administrative data and hip fracture audit data collected over a 4-year period. It has been shown that, among patients discharged alive following a hip fracture superspell, emergency 30-day readmission rates increased with greater deprivation, with the highest rates observed among the most deprived older men with dementia (25.8%). Furthermore, after accounting for age, gender and comorbidity, greater deprivation was associated with an increased probability of being readmitted within 30-days of discharge following a hip fracture superspell. The association between deprivation and emergency 30-day readmission was strongest in hip fracture patients with dementia; the odds of readmission were 34% higher among the most deprived compared with the least deprived patients after adjustment for age and gender.

This study has further shown that, among those hip fracture patients who survived to discharge, greater deprivation was associated with longer hospital stays that included time spent in acute plus rehabilitation hospitals. Similar patterns were observed when analyses were stratified by comorbidity, although hospital stays were longest among the most deprived individuals with comorbidity. Increasing levels of deprivation were also associated with greater NHS bed occupancy, with the most deprived individuals with comorbidity that excluded dementia spending the greatest amount of time in hospital in the year after hip fracture.

The last four chapters have demonstrated that, among older men and women in England, greater deprivation predicts higher hip fracture incidence and reduced survival post-hip fracture. It has further been shown that, among those hip fracture patients who survive to discharge, greater deprivation is associated with longer hospital stays and a greater need to be readmitted to hospital. Finally, greater utilisation of healthcare services in the year after hip fracture was observed among more deprived individuals. The next chapter discusses the relevance of these research findings in the context of existing literature, and the implications for clinicians and policy makers.

CHAPTER 11. DISCUSSION

11.1. Overview of study aims

The overall aim of this research was to describe social and regional inequalities in hip fracture incidence and outcomes among older men and women in England, as outlined in Chapter 4.2, page 135.

The incidence studies (Chapters 7 and 8) firstly examined the effect of area-based social deprivation on hip fracture incidence among men and women aged 50+ years in England, and across its nine geographic regions, and secondly assessed whether social inequalities in hip fracture incidence differed by levels of deprivation over a 14-year period.

The outcomes studies (Chapters 9 and 10) firstly examined the effect of area-based social deprivation on clinical outcomes in the year after hip fracture (mortality, emergency 30-day readmission, superspell LOS and total NHS bed occupancy) among men and women aged 60+ years in England over a 4-year period, and secondly assessed whether the relationship between deprivation and clinical outcomes post-hip fracture differed according to patient characteristics.

11.2. Main findings

The analyses presented in this thesis of English HES data for the period 2001 to 2014 have shown that, among both men and women aged 50+ years, area-based deprivation predicts increased age-standardised hip fracture incidence, with a stronger relative effect observed in men. Marked regional variation in hip fracture incidence exists across England, with absolute and relative inequalities in hip fracture incidence being greatest in the North of England for both men and women.

Results have shown, using a linked HES-ONS-NHFD dataset for men and women aged 60+ years in England (2011-2014), that greater deprivation is associated with reduced survival and, among patients discharged alive, increased healthcare utilisation in the year after hip fracture. After accounting for age and gender, relative inequalities in mortality after hip fracture are greatest among hip fracture patients with no recorded comorbidity, and for emergency 30-day readmission in those with dementia. Among both older men and women, hospital stays in the year after hip fracture are longest among the most deprived individuals with comorbidity.

11.3. Comparison with existing literature on hip fracture incidence

In this section, findings of the incidence (Chapter 7) and regional incidence (Chapter 8) studies are discussed in relation to published literature on secular trends in hip fracture incidence, and thereafter studies examining the effect of deprivation on hip fracture incidence are reviewed.

11.3.1. Secular trends in hip fracture incidence

The incidence study (Chapter 7) demonstrated that the absolute number of hip fracture admissions increased between 2001 and 2014 owing to a growing older population who are at high risk of fracture; however, crude hip fracture incidence declined over this period.

Overall age-standardised hip fracture incidence declined further after adjusting for changes in the age distribution of the English population over time.

The secular changes in hip fracture incidence, observed in several high-income countries including the UK, over the last few decades, may be explained by birth cohort and/or period effects. Secular trends in hip fracture incidence have been described in detail in Chapter 1.4, page 20. Birth cohort effects are explained by exposures that affect groups of individuals based on their year of birth and may result from changes in the level of an exposure over time e.g. increase in birth weight by birth cohort, whilst period effects are population-level environmental exposures that occur at a specific time point and usually impact all age groups or cohorts at a given time e.g. improvements in medical care and introduction of the NHFD (29, 374). A study conducted using English hospital admission data (1968-1986), among men and women born between 1860 and 1919, reported that age-standardised hip fracture incidence had increased in both men and women, albeit with a more marked increase in women, and that hip fracture risk increased with later birth cohorts (19). Based on national hospital discharge data for the period 1987-2002, age-standardised hip fracture incidence has declined in Sweden since 1996, and combined period and birth cohort effects have been more marked in women than men with a major reduction in hip fracture incidence observed in later birth cohorts and time periods (375). Rosengren et al hypothesised that the implementation of healthcare initiatives and social reforms in Sweden over the first part of the 20th century may partly account for their observed trends through improvements in childhood nutrition and growth, which would generate a birth cohort effect (375). The contrasting observations reported by both studies may be explained by the study of incident hip fractures over an earlier time period in England, thus not capturing the stabilisation in hip fracture incidence trends since the 1980s that have been reported by other studies (20-22, 376).

The declines in hip fracture incidence seen in several high-income countries over the last few decades may reflect an improvement in early-life exposure to lifestyle factors that predispose to fracture such as improved nutrition and physical activity behaviours. This may be of importance given that the early life environment has an important effect on later fracture risk; a low rate of growth in childhood (aged 7-15 years) has been associated with an increased risk of hip fracture in later life (377).

11.3.2. Secular trends in hip fracture incidence by age and gender

The declines in hip fracture incidence observed among women in the incidence study (Chapter 7) are consistent with previous studies conducted in Australia (25), Canada (16) and the USA (15). However, these also reported, albeit to a lesser degree, declining rates in men. The contrasting observation of increasing hip fracture incidence among men in the incidence study, is consistent with an analysis of UK primary care (CPRD) records, which showed that hip fracture incidence had increased from 108 to 134 hip fractures per 100,000 person-years between 1990-1994 and 2008-2012 (24); although hip fracture incidence was reported as stable in women in the CPRD analysis, their analyses were not age adjusted. By not taking account of age, the apparently stable trend in hip fracture incidence observed among women likely masks an underlying decline in hip fracture incidence given that hip fracture risk increases with advancing age (378), and the older English population has increased in number over this 22-year study period (379). Early HES analyses reported stable age-standardised hospital admission rates for hip fracture among men and women in England over the period 1989 to 1998 (22). Gender-specific trends similar to those reported by the incidence study, were seen in older English adults between 2003 and 2013; hip fracture incidence increased in men aged 85+ years, decreased in women aged 75+ years, and remained stable in men aged 60-84 years and women aged 60-74 years (23). Similarly, the incidence study has demonstrated that the most marked variation in hip fracture incidence trends occurred among older men and women in England, which is consistent with the findings of studies conducted in Canada and the USA, where hip fracture incidence was shown to have decreased in men and women of all age groups, with the greatest declines observed among men and women aged 85+ years (15, 16).

Gender differences in secular trends in hip fracture incidence may partly be explained by the historical use of HRT in post-menopausal women (380), which is known to protect against osteoporosis (381). An under-appreciation of osteoporosis as a disease that affects men may have contributed to the rising rates of hip fracture observed in the incidence study. Despite a third of all hip fractures worldwide occurring in men (7), and men having higher associated mortality (382), men are less likely than women to receive osteoporosis treatment to decrease fracture risk (15, 132, 383). Analysis of UK primary care data for the period 2000 to 2010 found that women were 50% more likely than men to be initiated on an anti-osteoporosis drug within the year following an incident hip fracture (132). Furthermore, the use of androgen deprivation therapy to treat prostate cancer has risen in England since the 1980s from 33,000 prescriptions in 1987 to 470,000 prescriptions in 2004, and is a well-established risk factor for fracture (384, 385).

11.3.3. Secular trends in hip fracture incidence by levels of deprivation

The incidence study (Chapter 7) is only the second study in the UK to examine the association between deprivation and hip fracture incidence over time. The previous analysis (1998-2008) did not identify the clear relationships observed in this current study (20); however, their analyses were not gender stratified and were based upon the Carstairs deprivation index, an area-based measure of relative material deprivation calculated at the ward level using four census indicators (male unemployment, overcrowding, car ownership and low social class), which was specifically developed for use in Scotland (194) (see Chapter 2.5.2, page 63). This incidence study used the IMD which, in contrast, is based on a broader range of deprivation measures across seven domains of deprivation, and therefore can be considered to provide a more comprehensive assessment of deprivation at the small-area level (see Chapter 2.5.3, page 64).

11.3.4. Secular trends in hip fracture admissions by levels of deprivation and comorbidity

The incidence study (Chapter 7) has shown that the proportion of age-standardised hip fracture admissions in both men and women who have comorbidity has risen steadily from 2008 to 2014, which highlights the importance of hip fracture prevention in those with comorbid conditions. A similar trend has been observed in the USA using Medicare claims data from 1985 to 2005 (15). Brauer et al reported that, among male and female hip fracture patients aged 65+ years, the age-adjusted prevalence of most comorbid conditions increased between 1986-1988 and 2003-2005, with comorbidity defined using a modified version of the Charlson score (15). Nationally, the burden of comorbidity is growing; the number of people with multiple comorbidities was predicted to rise from 1.9 million in 2008 to 2.9 million in 2018 in the UK (386). Furthermore, the incidence study has shown that deprivation is associated with higher rates of comorbidity, which is consistent with the findings of other studies conducted in England and Germany (226, 387) (see Chapter 2.6.4, page 68). The increasing burden of comorbid disease amidst a growing older population is likely to have a significant impact on future hip fracture incidence and outcomes.

11.3.5. Deprivation and hip fracture incidence by age, gender, geographic region and lifestyle factors

Age

The findings of the incidence study (Chapter 7) suggest that an association between greater deprivation and increased hip fracture risk exists in younger men and women, which is consistent with the wider body of literature describing more marked socioeconomic inequalities in health outcomes among younger individuals (see Chapter 2.6.1, page 65). The findings of the incidence study are consistent with observations from a regional study conducted among men and women aged 50+ years in Canada (2000-2007), where the risk of MOF (including fractures of the hip) was highest in the lowest income quintile compared to the highest income quintile among men and women aged 50-59, 60-69 and 70-79 years (273). The stronger relationship between deprivation and hip fracture incidence, observed among younger adults, may be explained by the differential age distribution of lifestyle risk factors for fracture. A clear gradient between greater deprivation and higher smoking rates has been demonstrated among both men and women; for all deprivation quintiles, the highest rates of smoking were in middle-aged individuals and declined with advancing age such that the lowest rates of smoking were in older adults residing in the least deprived areas (370).

Gender

Few studies have examined the relationship between deprivation and hip fracture incidence by gender. The findings of the incidence study (Chapter 7) suggest that a stronger association between deprivation and hip fracture incidence exists in men than in women, likely explained in part by gender differences in the prevalence of lifestyle risk factors (360, 361), as discussed further in section 11.3.5, page 318. These findings are consistent with those of a recent UK study conducted in men and women aged 18+ years using general practitioner (CPRD) records from 1988 to 2012 (50); the findings of the incidence study confirm a clear association between deprivation and hip fracture risk in men, and determine a previously unidentified association between deprivation and hip fracture risk in women. The analysis of CPRD data showed that men who are most deprived are 30% more likely to fracture their hip than those who are least deprived; in comparison, the incidence study has shown, using HES data, that the most deprived men have a 50% increased risk of hip fracture compared with the least deprived men. The effect of deprivation on hip fracture incidence may have increased with time, possibly explaining the stronger association between deprivation and hip fracture risk reported by the incidence study; the incidence study analysed HES data for a more recent time period (2001-2014), whilst the CPRD analysis was conducted over a 24-year period (1988-2012).

Geographic region

The regional patterns in hip fracture incidence observed in the regional incidence study (Chapter 8) are in keeping with the wider body of literature documenting a ‘North-South divide’ in England, in which the health experiences in northern regions are generally worse than the average for England, with the reverse being true for southern regions, and where the Midlands is comparable to the ‘average for England’ (234) (see Chapter 2.6.6, page 70).

Several possible explanations may account for the regional differences in hip fracture incidence reported in Chapter 8. Firstly, regional variation in the prevalence of vitamin D deficiency may partly explain the higher rates of hip fracture observed in the

North of England and the lowest in the South. It has been shown, using Health Survey for England data, that 46% of people living in the North and the Midlands and 35% of people in the South (excluding London) have low serum vitamin D concentrations (388), which may be of importance given that low vitamin D levels are associated with an increased risk of falls and hip fracture (389, 390). Secondly, regional differences in the prevalence of lifestyle risk factors such as smoking and high-risk alcohol consumption may contribute to the regional variation in hip fracture incidence observed across England, as discussed further in section 11.3.5, page 318. Finally, latitude from the equator has been associated with hip fracture risk (391), with a large population-based study conducted in Sweden demonstrating that hip fracture incidence rose as latitude increased (392). Latitude coordinates for the northernmost and southernmost points in England range from 49 degrees to 55 degrees (393). It is not known whether such differences are large enough to explain, in part, the regional patterns in hip fracture risk observed in the regional incidence study.

Regional inequalities in hip fracture incidence rates are likely to reflect geographic differences in access to, and engagement with, fracture prevention services through service delivery models such as FLSs. The RCP FLS-DB facilities audit systematically appraises the organisation of FLSs in England and Wales with the aim of improving the quality of fragility fracture care (128) (see Chapter 1.9.5, page 46). Fewer than 50% of eligible sites in England participated in the first facilities audit in 2016, of which 65% (48/74) reported having a dedicated FLS, of which two-thirds (31/48) of these were in the South of England (128). CPRD records (1990-2012) have shown that prescription rates of oral anti-osteoporosis drugs (AODs), which aim to reduce fracture risk, vary across England with the highest prescription rates in the South West in both men and women, and the lowest amongst men in Yorkshire & the Humber and amongst women in the East Midlands (394).

However, AOD prescription does not necessarily translate to medication adherence and whether adherence varies by region is unknown.

A further explanation could be that area-based deprivation is more closely associated with individual deprivation in the North of England compared to the South or Midlands. This could also explain the unexpected relationship between lower levels of deprivation and higher hip fracture incidence in certain Eastern GORs. Internal migration patterns among older people post-retirement could lead to a difference in the socioeconomic status of individuals over the greater part of their lives, relative to the deprivation of the area they currently live in. The greatest movement among older people is away from London and towards the South East, South West and East of England (395). Of all English regions, London has the highest percentage of older people living in the most deprived local areas, as defined by the supplementary IMD income sub-domain for older people (Income Deprivation Affecting Older People Index (IDAOPI)), that is the proportion of adults aged 60+ years living in Pension Credit households (396). It can be hypothesised that people living in relatively deprived areas within London can afford to migrate later in life to more affluent regions in the South and East of England; however, they convey an increased hip fracture risk due to earlier life exposures to lifestyle risk factors for fracture.

Lifestyle risk factors

The greater association between deprivation and increased hip fracture incidence observed in both men and women may partly be explained by the social gradient of lifestyle-associated risk factors for fracture. The prevalence of tobacco and heavy alcohol consumption is higher amongst more deprived populations (232, 233), with men rather than women having a greater propensity towards these lifestyle habits (360, 361) (see

Chapter 2.6.5, page 69). Alcohol consumption and tobacco use are both associated with an increased risk of hip fracture in men (397). Similarly, the prevalence of obesity, physical inactivity and poor nutrition increases with greater levels of deprivation (231). Physical activity has been associated with decreased hip fracture risk in older men and women (398, 399), possibly explained by its positive effect on bone- and falls-related factors that includes higher BMD, increased muscle strength and mass, and improved balance (400-402). However, an increased risk of falls has also been reported among the most active individuals, likely explained by the greater opportunity for falls (403). The less marked relationship between deprivation and hip fracture incidence observed in women may, in part, be explained by the stronger relationship between deprivation and obesity in women (404), as adiposity over the greater trochanter is thought to protect against hip fracture (64). Bann et al analysed longitudinal data from three British birth cohorts demonstrating that socioeconomic inequalities in adult BMI were more marked in women than men, with adult SEP based on the Registrar General's classification of social class (discussed in Chapter 2.3.3, page 58) (404). Interestingly, a regional study conducted among an urban population in Spain (2009-2012) demonstrated that age- and gender-adjusted hip fracture risk was 10% lower among individuals living in the most deprived compared with least deprived areas (358). This association was however fully attenuated after adjustment for BMI suggesting that a higher prevalence of obesity in more deprived areas may have accounted for the inverse relationship observed. It was not possible to adjust for obesity as part of the analyses presented in Chapters 7 and 8 due to a lack of BMI data in HES; similarly, tobacco use and alcohol consumption data were not available for analysis. It has been reported, using nationally-representative survey data for England, that obesity prevalence is 20% and 38% among women residing in the least deprived and most deprived areas (405). It can be hypothesised that, if BMI data were available for adjustment as part of these analyses, a stronger relationship between deprivation and hip fracture risk may have been observed in women, owing to the higher prevalence of obesity in more deprived women.

Regional inequalities in hip fracture incidence across England may partly be explained by regional variation in lifestyle factors. Analysis of household population survey data (2014-2016) has demonstrated a North-South divide in smoking prevalence, with rates being highest in the North East and lowest in the South East (406). A similar geographic pattern has been observed for high-risk alcohol consumption, with prevalence highest in the North and lowest in London and the Midlands.

11.4. Comparison with existing literature on clinical outcomes after hip fracture

In this section, findings of the mortality (Chapter 9) and healthcare utilisation (Chapter 10) studies are discussed, and published studies examining the effect of deprivation on hip fracture outcomes are reviewed.

11.4.1. Mortality after hip fracture

The mortality study (Chapter 9) has demonstrated that, over a four-year period, mortality at 30-days and 365-days post-hip fracture was 7.8% and 28.1% respectively; other English studies have reported comparable mortality rates (92, 299). Analysis of English HES data for the period 2004 to 2011 showed that 30-day and 365-day mortality was 9.3% and 29.0% among hip fracture patients aged 18+ years (299). Similarly, a regional study conducted among hip fracture patients in Nottingham, England (1999-2003) found that mortality at 30-days was 9.6% and at 365-days was 33.0% (92). Both studies were conducted over an earlier time period than the mortality study (Chapter 9), which may explain the slightly higher mortality rates reported; 30-day mortality after hip fracture has decreased over time from 10.9% in 2007 to 8.5% in 2011 (29).

11.4.2. Deprivation and mortality after hip fracture

Studies examining the relationship between deprivation and mortality post-hip fracture, using individual-level and area-based measures are discussed separately below.

Individual-level measures

A regional study conducted in South England analysed hospital statistics for the period 1968 to 1988, reporting higher age- and gender-adjusted 30-day mortality among patients of lower than higher SEP (based on last main employment); this relationship persisted at 90-days and 365-days post-hip fracture (83). In Denmark, the association between individual-level SEP and 30-day mortality was assessed using hip fracture registry data for the period 2010 to 2013; the odds of 30-day mortality were 29% lower among individuals of 'high class' versus 'low class' status (combined measure of education and income) after adjustment for patient- and hospital-level confounders (301).

Area-based measures

The positive association between area-based deprivation and mortality observed in the mortality study (Chapter 9) is consistent with the findings of other studies conducted in England and Italy (299, 302). Barone et al conducted a retrospective cohort study in Rome over the period 2006 to 2007 demonstrating that individuals residing in the most deprived versus least deprived areas (defined using a city-specific deprivation index) had a 51% increased risk of 30-day mortality after adjustment for age, gender and comorbidity (302). Several possible explanations may account for this large effect size compared to the mortality study. Firstly, although both studies used aggregate measures to define area-based deprivation, the specific domains used to construct both indices differed, suggesting that different aspects of deprivation were measured. Secondly, Barone et al identified comorbid conditions using ICD-9 codes recorded in the index hip fracture admission, or hospital admissions or A&E attendances in the preceding two years, whilst the mortality study used ICD-10 codes recorded in the index hip fracture admission and hospital admissions during the preceding five years. Greater comorbidity is captured when longer lookback periods of hospital administrative data are used (324). Hence, residual confounding by comorbidity may account for the larger effect sizes reported by Barone et al. Finally, Barone et al defined deprivation status based on residential area on hospital discharge, whilst the mortality study used area of residence at the time of hospital admission. Hip fracture is associated with functional decline and a greater need for institutional care (243, 407). In 2016, the NHFD reported that one-third of hip fracture patients did not return to their original place of residence at 120-days post-hip fracture (30). Residential area on hospital discharge may therefore not accurately capture an individual's deprivation status.

All but one English study has reported a positive association between area-based deprivation and mortality, using either the IMD or Carstairs deprivation index (20, 21, 299, 300). Bottle and Aylin showed, using HES data from the period 2001 to 2004, that greater deprivation (defined using the IMD 2004 version) was associated with higher in-hospital mortality post-hip fracture; the most deprived versus least deprived patients had 18% higher odds of in-hospital death (300). Wu et al also used HES data (2008) to demonstrate that in-hospital mortality was higher among more deprived patients (based on the Carstairs deprivation index); in-hospital mortality was 117.7 and 93.5 per 1000 hip fracture admissions for the most deprived and least deprived individuals (20). Smith et al analysed English HES data for a ten-year period (2001-2010); patients in the three most deprived deciles (defined using the IMD 2010 version) had a greater number of deaths than expected within 30-days of hip fracture admission (21). Analysing HES data for hip fracture patients aged 18+ years (2004-2011), Thorne et al reported that area-based deprivation (based on the IMD 2007 version) was associated with increased odds of mortality at 30-days, 90-days and 365-days, after controlling for age, gender and comorbidity (299). Thorne et al reported similar effect sizes to those observed in the mortality study (Chapter 9); the adjusted odds of 30-day and 365-day mortality were 19% and 15% higher among the most deprived versus least deprived individuals (299).

Quah et al, however, found no evidence of a relationship between area-based deprivation and 30-day mortality among hip fracture patients aged 65+ years admitted to a single NHS hospital in Nottingham, England (1999-2009) (277). Whilst authors measured deprivation using the IMD, they did not adjust analyses for potential cofounding by age, which may explain their negative study, as younger patients are likely to be more deprived but will have a lower mortality risk.

The hypothesised causal diagram presented in Chapter 6.9.2 proposes the relationship between deprivation, age and mortality risk (see page 205). Age is a negative confounder of the relationship between deprivation and mortality post-hip fracture, as confirmed by data presented in Chapter 9.4.5, page 269; the most deprived compared with least deprived hip fracture patients had 19% higher odds of 365-day mortality, increasing to 34% after adjustment for age. The observed association between an exposure and outcome is underestimated, that is the point estimate is biased towards the null, when negative confounding occurs (408).

11.4.3. Deprivation and mortality after hip fracture by age, gender and comorbidity

Age and gender

The study by Thorne et al, described earlier in section 11.4.2, reported that the effect of deprivation on mortality at 30-days, but not at 365-days, after hip fracture was greater in women than men, and weaker in older individuals compared to other age groups at both 30-days and 365-days post-hip fracture (299). These findings contrast with observations of the mortality study (Chapter 9), which showed that the effect of deprivation on mortality in the year after hip fracture was similar in men and women. A significant deprivation by age interaction was only observed at 365-days post-hip fracture in the mortality study (i.e. the strength of the association between deprivation and 365-day mortality was greater in younger compared to older individuals). Although the direction of this effect is consistent with the published literature (see Chapter 2.6.1, page 65), this observation may be the result of a type I error given that the relationship between deprivation and mortality did not differ according to age at the other mortality time points studied. Sampling error may occur because of chance, that is different samples give different results, and result in type I error which is defined as rejecting the null hypothesis of no association between an exposure and outcome when it is true (409).

The conflicting findings reported by both studies may be explained by differing characteristics of the populations under study. The mortality study was restricted to hip fracture patients aged 60+ years, whilst Thorne et al studied hip fracture patients aged 18+

years. The effect of deprivation on mortality is greater among younger individuals (203, 204), possibly explained by frailty and access to social welfare programmes in older age which may minimise the effects of deprivation on health (206). Furthermore, individuals who survive to older age are healthier than those who die at a younger age known as 'health survivor bias'. Law et al analysed ONS all-cause mortality data for England (1992) according to area-based deprivation (204). The Jarman Index, constructed to measure GP workload rather than deprivation per se, was used to measure district-level deprivation. All-cause mortality risk was 1.54 times higher for the most deprived compared with least deprived individuals aged under 65 years, and 1.07 times higher for individuals aged 65+ years after adjusting for age, gender, urbanisation and ethnicity (204).

Comorbidity

The mortality study (Chapter 9) is the first study to examine the effect of deprivation on mortality after hip fracture according to levels of comorbidity. Greater deprivation was associated with increased mortality at all four time points in the year after hip fracture in patients with no recorded comorbidity and with comorbidity that excluded dementia. A much weaker, but consistent, positive association between deprivation and mortality at 120-days and 365-days after hip fracture was observed in those with dementia.

The prevalence of comorbidity, higher among more deprived individuals, can challenge survival (218, 226). It was therefore surprising to find that greater deprivation was more strongly associated with mortality risk in hip fracture patients with no recorded comorbidity compared with recorded comorbidity that excluded dementia, after taking account of age and gender. The RCS Charlson score that was used to identify comorbidity in the mortality study may not have captured all comorbid conditions prevalent among hip fracture patients and all patient comorbidities may not have been recorded in the HES database, thus misclassifying individuals as having no comorbidity instead of their true comorbidity score (see section 11.7.3, page 353). Misclassification of comorbidity status may have differentially affected individuals residing in more deprived areas, in whom the burden of comorbidity is higher, such that more deprived individuals may have been more likely to have a lower recorded comorbidity score than their true comorbidity status. The mortality study may therefore have overestimated the strength of the association between deprivation and mortality in hip fracture patients with no ‘apparent’ comorbidity. Another explanation is that, once comorbid disease is established, the predominant effects of disease pathology and prognosis outweigh the beneficial impacts of lower levels of deprivation on patient outcomes.

Whilst an association between deprivation and mortality was observed among hip fracture patients with comorbidity that excluded dementia in this study, only a weak association was observed for 120-day and 365-mortality in those with dementia. The English study by Thorne et al did not observe an association between deprivation and 365-day mortality in hip fracture patients with dementia but reported a positive association among those without dementia; analyses were not conducted at 30-days post-hip fracture due to small numbers (299). Pre-fracture residential status may explain, in part, the lack of association between deprivation and mortality in hip fracture patients with dementia. Cross-sectional analysis of English HES data (2011-2012) has shown that, among patients aged 75+ years, those admitted from a care home postcode are more likely to have dementia compared to patients admitted from a non-care home postcode (39.3% *vs*. 5.5%) (410). Furthermore, analysis of 2011 census data has shown that coastal areas in the South and East of England, and areas in Yorkshire and the Humber, have among the highest proportion of the usually resident population living in a care home (411). It can be extrapolated, using a map of geographic variation in deprivation across England (IMD

2015 version) (200), that in general areas with the highest proportion of care homes correspond to areas with lower deprivation levels. Deprivation status, assigned based on current residential postcode, may therefore not accurately capture earlier life exposures that predispose to morbidity and mortality in later life in patients with dementia, many of whom reside in an institution. The mortality study did not take account of pre-fracture residential status and therefore, owing to differential misclassification of exposure status, may not have estimated the true association between deprivation and mortality risk in hip fracture patients with dementia. As described earlier, another explanation is that social deprivation has less of an influence on clinical outcomes after hip fracture in those with established dementia owing to the predominant effects of disease pathology on prognosis.

11.4.4. Regional inequalities in 30-day mortality after hip fracture

The regional patterns in 30-day mortality described in Chapter 9.4.9 (page 279) are consistent with the findings of a recently published population-based study conducted among English patients aged 50+ years with a fragility fracture, using CPRD data linked to ONS mortality data for the period 2001 to 2011 (412). Klop et al reported that the relative risk of one-year all-cause mortality was higher for men residing in the North West and Yorkshire and the Humber compared to London, although for women, mortality risk was higher for all English regions relative to London except for the North East, South East Coast and South West (412).

The mortality study (Chapter 9) has further shown that, among both English men and women, regional inequalities in mortality after hip fracture exist. Deprivation was positively associated with 30-day mortality in the North of England, particularly in the North East, North West and West Midlands. These regional patterns are consistent with those observed for hip fracture incidence as presented in Chapter 8. Regional inequalities in mortality post-hip fracture may partly be explained by regional variation in lifestyle factors such as tobacco use and heavy alcohol consumption that are associated with increased mortality risk (344, 413) (see section 11.3.5, page 318 for further discussion). The prevalence of smoking and high-risk alcohol consumption is highest in the North of England (406). Whilst it is not known whether hip fracture care differs across English regions, linkage of NHFD patient-level clinical audit data to NHFD facilities audit hospital-level data provides an opportunity to investigate whether regional inequalities in mortality are explained by regional variation in hospital care for hip fracture.

11.4.5. Healthcare utilisation after hip fracture

The healthcare utilisation study (Chapter 10) has demonstrated that, among patients discharged alive following a hip fracture superspell, 15.6% were readmitted within 30-days of hospital discharge. Khan et al retrospectively studied a cohort of hip fracture patients admitted to a single NHS hospital in the North East of England (2009-2010) reporting that 11.8% of patients were readmitted within 28-days of discharge (112). Whilst their lower readmission rate may partly be explained by the outcome measure selected (i.e. 28-day readmission), a more likely explanation is that the population under study was not representative of the English hip fracture population given their single-site study design. Smith et al similarly found that 28-day readmission rates were lower than observed in the healthcare utilisation study. Analysing English HES data for an earlier time period (2001-2010), they reported that 9.7% of hip fracture patients were readmitted within 28-days of discharge (21). This figure, however, may mask the rising trend in readmission rates that has been observed in more recent years; age- and sex-standardised 28-day readmission rates increased by 41.3% between 2001 and 2010 (21).

The healthcare utilisation study has reported that hip fracture patients spend, on average, 23.6 days in hospital after hip fracture (acute plus rehabilitation hospital admissions). This figure is comparable to NHFD superspell LOS estimates for a similar time period; mean English hospital superspell LOS was 22.7 days in 2014, based on HES analysis (99). Using HES data (2011-2012) and an organisational survey conducted among hospital orthogeriatricians, Neuburger et al reported that median, rather than mean, superspell LOS ranged from 17 to 27.5 days across eight groups categorised based on their combination of acute hospital and primary care trust in South West England (371). Castelli et al analysed English HES data (2009-2010), albeit for acute hospital LOS, as opposed to superspell LOS, reporting that patients aged 18+ years spent, on average, 20.9 days in hospital after hip fracture (102). Castelli et al did not capture time spent in rehabilitation care and therefore, it is unsurprising that their estimate is lower than that reported by the healthcare utilisation study.

11.4.6. Deprivation and healthcare utilisation after hip fracture

Few studies have examined the relationship between deprivation and hospital readmission and acute hospital LOS post-hip fracture; none have focused specifically on superspell LOS or total NHS bed days in the year after hip fracture. Studies describing the relationship between deprivation and hospital readmission and hospital LOS after hip fracture, using individual-level or area-based deprivation measures, are discussed separately below.

Hospital readmission

The positive association between area-based deprivation and hospital readmission demonstrated by the healthcare utilisation study (Chapter 10) is consistent with findings from studies conducted in England and Denmark (21, 301). Using English HES data (2001-2011), Smith et al showed that more 28-day readmissions were observed than expected among deprived hip fracture patients (based on the IMD) after indirect standardisation for age and gender (21). Kristensen et al analysed Danish hip fracture registry data for the period 2010 to 2013 demonstrating that hip fracture patients with ‘high class’ status (high education and high income) versus ‘low class’ status had 6% lower odds of 30-day readmission, after adjustment for patient-level characteristics and hospital-level factors (301).

Hospital LOS

The healthcare utilisation study has shown that, among patients discharged alive following a hip fracture superspell, greater deprivation is associated with longer hospital stays that includes time spent in acute plus rehabilitation hospitals, and higher NHS bed occupancy in the year after hip fracture.

Whilst other studies have similarly reported longer hospital stays among more deprived hip fracture patients (102, 103), this has not been consistently demonstrated (277, 301). Using English HES data (2009-2010), Castelli et al found that patients residing in more deprived compared with the least deprived areas (based on the IMD income domain) stayed an extra 4 days in hospital after hip fracture (102). Gaughan et al further showed, using English HES data (2008-2009), that superspell LOS was 8% longer among the most deprived compared with less deprived hip fracture patients discharged home (based on the IMD IDAOPI domain, discussed in section 11.3.5, page 318) (103).

In contrast, other studies conducted in England and Denmark did not observe an association between deprivation and hospital LOS (277). Quah et al reported that acute hospital LOS was similar according to IMD quintiles in a prospective cohort of hip fracture patients admitted to a single NHS hospital in Nottingham, England (277). Similarly, Kristensen et al found that individual-level class (combined measure of education and income) was not associated with hospital LOS in a large, population-based cohort study of hip fracture patients in Denmark (301). Several possible explanations may account for the differing observations reported by both studies. Firstly, Quah et al studied hip fracture patients admitted to a single NHS hospital in Nottingham, England (277), and therefore their study population may not be representative of the entire English hip fracture population with respect to patient characteristics such as age, gender and deprivation status. Furthermore, Quah et al did not adjust their analyses for potential confounding by age and comorbidity, both of which are known to predict longer hospital stays after hip fracture (102). Social inequalities in health are more marked among younger individuals (202), and the burden of comorbidity is higher among more deprived individuals (226). Secondly, Kristensen et al adjusted their analyses for both patient characteristics and hospital-level factors (301). As described in section 11.5.2 (page 340), different hospital-level factors are associated with hospital LOS, possibly explaining the lack of association between deprivation and hospital LOS in the study by Kristensen and colleagues.

11.4.7. Deprivation and healthcare utilisation after hip fracture by levels of comorbidity

The healthcare utilisation study (Chapter 10) is the first study to examine the relationship between deprivation and healthcare utilisation after hip fracture according to levels of comorbidity. Greater deprivation was associated with higher 30-day readmission for all strata of comorbidity, with the strongest association observed among hip fracture patients with dementia (see Chapter 10.4.5, page 295). These observations are in keeping with the findings of a US retrospective cohort study, which reported that readmission risk was 60% higher among hip fracture patients with dementia (108). Pre-fracture residential status may partly account for the positive relationship between dementia and readmission risk. Individuals with dementia are more likely to be admitted from an institution (410, 414), a finding that has been confirmed by the healthcare utilisation study (see Chapter 10.4.2, page 291), and readmission risk is higher among hip fracture patients discharged to an institution than to home (101).

The healthcare utilisation study further showed that, greater deprivation was associated with longer hospital stays after hip fracture for all strata of comorbidity; however, hospital stays were longest among the most deprived individuals with comorbidity (regardless of a diagnosis of dementia). Similar patterns were seen for total NHS bed occupancy, with the longest hospital stays observed among the most deprived individuals with comorbidity that excluded dementia. These findings are in keeping with those reported by Castelli et al analysing English HES data; the presence of comorbid conditions such as COPD, CVD and renal disease all increased hospital stays after hip fracture (102). The longest hospital stays were observed among those with paralysis, peptic ulcer disease and diabetes with complications ranging from an extra 4 to 7 days. Similarities in clinical management pathways for hip fracture patients with comorbid disease (with or without dementia) may account for the similar superspell LOS' observed in those with comorbidity that excluded dementia and with dementia (see Chapter 10.4.9, page 302). Furthermore, the BPT for fragility hip fractures recognises the importance of joint orthopaedic and geriatric care on patient outcomes after hip fracture (114). The healthcare utilisation study analysed hip fracture admission data from April 2011 onwards, a time period over which the BPT was introduced, since which there has been increasing orthogeriatric involvement in the medical management of hip fracture patients.

The healthcare utilisation study demonstrated that total NHS bed occupancy in the year after hip fracture was lower among deprived hip fracture patients with dementia compared with comorbidity that excluded dementia, possibly explained in part by pre-fracture residential status. Analysing Australian hospital administrative data (2008-2009), Ireland et al reported that acute and rehabilitation hospital LOS' were longer, and hospital transfer rates for rehabilitation were higher, among those admitted from the community compared to an institution (415). Individuals with dementia are more likely to be admitted from an institution (410, 414), and thus already have social service funding in place and a long-term residential placement secured, resulting in prompt discharges from hospital and shorter hospital stays in the year after hip fracture.

11.5. Possible explanations for the findings of hip fracture outcomes studies

Whilst the outcomes studies presented in Chapters 9 and 10 took account of the effect of patient characteristics such as age, gender and comorbidity, other patient characteristics and hospital-level factors may explain the observed association between deprivation and clinical outcomes after hip fracture as discussed below.

11.5.1. Deprivation and clinical outcomes after hip fracture according to patient characteristics

Lifestyle risk factors

Neither HES nor NHFD databases collect data on smoking consumption, alcohol intake and BMI, and therefore it was not possible to adjust for these lifestyle risk factors that are known to increase mortality risk (344, 413), and most likely healthcare use (101, 102). The prevalence of smoking, heavy alcohol intake and obesity increases with greater levels of deprivation (231, 232, 370) and therefore, after adjustment for these lifestyle risk factors, the true association between deprivation and outcomes after hip fracture may be weaker than suggested by the mortality and healthcare utilisation studies (Chapters 9 and 10). The causal diagram presented in Chapter 6.9.2, page 205 describes the hypothesised relationship between deprivation, lifestyle risk factors and hip fracture outcomes.

Whilst smoking-related diseases such as COPD are captured by a binary variable in the RCS Charlson score, this measure of comorbidity does not take account of the level of exposure to smoking that has been shown to determine mortality risk. Jacobs et al demonstrated, using longitudinal data from sixteen male cohorts in Europe, Japan and the USA, that all-cause mortality risk increases with level of cigarette consumption in a dose-response manner (344). In addition, combined exposure to obesity and current smoking compared with normal BMI and never smoking has been shown to be associated with increased all-cause mortality risk in a nationally representative sample of US older adults (416). Similar patterns have been observed for alcohol consumption. Analysis of individual- and population-level data on daily alcohol consumption has shown that, among men and women aged 15 to 95+ years in 195 countries, all-cause mortality risk increases with rising levels of alcohol intake (413).

The effect of lifestyle risk factors on healthcare utilisation after hip fracture is unclear. There is some suggestion, albeit based on a limited number of studies, that severe obesity may predict hospital readmission after hip fracture (101), and heavy alcohol consumption may be associated with longer hospital stays (102). Basques et al reported, using national surgical quality improvement data (2011-2012), that severe obesity (BMI

$\geq$35 kg/m^2) was associated with 73% increased adjusted odds of 30-day readmission among US hip fracture patients aged 70+ years, whilst an association was not observed for postoperative hospital LOS (101). A retrospective analysis of hospital registry data for hip fracture patients admitted to a single trauma centre in the USA (2005-2010) did not find evidence in support of a relationship between tobacco use or alcoholism and 30-day readmission (106). Whereas, using English HES data, Castelli et al demonstrated that hospital stays were 3 days longer in hip fracture patients with a diagnosis of alcohol and drug abuse (102).

Time to surgery

In the UK, national clinical guidelines recommend that patients undergo surgery on the day of, or the day after, hospital admission for hip fracture (6). Early hip fracture surgery is associated with improved outcomes. A systematic review and meta-analysis summarised existing literature on the relationship between early surgery and all-cause mortality among hip fracture patients aged 60+ years (346). Sixteen prospective observational studies were included in the review, of which only five studies adjusted their analyses for potential confounders (e.g. age, sex and ASA grade). All-cause mortality risk was 19% lower for hip fracture patients undergoing early surgery compared with delayed surgery; three studies used a cut-off of 24 hours and the remaining two studies each used a cut-off of 48 and 72 hours. All-cause mortality was assessed at different time points in the year after hip fracture (30-days, 6-months and 1-year).

The relationship between time to surgery and healthcare utilisation after hip fracture is not clear. Bottle et al showed, using English HES data for the period 2001 to 2004, that delays in surgery of 24-48 hours did not predict 28-day readmission risk (300). A prospective cohort study conducted among hip fracture patients admitted to four hospitals in New York, USA found that delays in surgery of greater than 24 hours prolonged hospital stays by about 2 days (347). Postoperative complications have been associated with longer hospital stays after hip fracture (415), and early surgery (<24 hours) reduces the odds of major postoperative complications in hip fracture patients medically stable on admission (347), possibly explaining the relationship between delays in surgery and prolonged hospital stays.

Studies conducted in England and Italy have reported that area-based deprivation is associated with delays in surgery for hip fracture (300, 302); however, this relationship has not been consistently demonstrated (299, 301). Barone et al studied the effect of area-based deprivation (using a city-specific deprivation index) and time to surgery in Rome (2006-2007) (302). Greater deprivation was associated with surgical delay; the risk of early surgery (<48 hours) was 68% lower among individuals residing in the most deprived versus least deprived areas, after adjustment for age, gender and comorbidity (302). The English study by Bottle and Aylin, described above, further showed that area-based deprivation (IMD 2004 version) predicted surgical delay (300). Poor pre-fracture health status with greater need for preoperative medical optimisation may explain delays in surgery among more deprived individuals (417).

Using national hip fracture registry data (2010-2013), Kristensen et al found no difference in time to surgery according to individual-level education and income (301). The implementation of national policy initiatives, including the Danish Multidisciplinary Hip Fracture Registry, established in 2003 (418), aims to standardise hip fracture care practices in accordance with national guidelines, and may account for the lack of association between deprivation and time to surgery.

11.5.2. Deprivation and clinical outcomes after hip fracture according to hospital-level factors

Different hospital characteristics are associated with improved outcomes after hip fracture, possibly explaining some of the relationship between deprivation and hip fracture outcomes reported in Chapters 9 and 10. Whilst most hip fracture studies have focused on mortality, comparatively less is known about the role of hospital-level factors on healthcare utilisation after hip fracture.

Hospital-level data on hospital type, hip fracture case volume and orthogeriatric input are collected as part of the NHFD facilities audit, described in Chapter 1.9.4, page 44. Whilst beyond the scope of the outcomes studies (Chapters 9 and 10), NHFD facilities audit data could be linked to NHFD patient-level clinical audit data to investigate the effect of hospital-level characteristics on the relationship between deprivation and clinical outcomes after hip fracture.

Hospital type

Studies conducted in hip fracture populations have shown that hospital type influences patient outcomes, with admission to a large hospital being associated with improved survival but higher risk of readmission.

Taylor et al analysed Medicare claims data and national survey data for 802 US hip fracture patients aged 65+ years demonstrating that admission to a major teaching hospital versus for-profit hospital was associated with 46% lower risk of 365-day mortality after adjustment for patient characteristics such as age, gender and comorbidity (348). A larger regional study conducted in Ontario, Canada similarly showed, using hospital admission data for 57,315 hip fracture patients aged 50+ years (1993-1999), that admission to a teaching hospital versus urban community hospital was associated with lower odds of death within 3-months, 6-months and 1-year of hip fracture after adjustment for age, gender, comorbidity and surgical delay. Similar findings were reported by a national study using Canadian hospital admission data (2004-2012) for 154,019 surgically managed hip fracture patients aged 65+ years; adjusted odds of in-hospital mortality were 13% and 18% higher in medium-sized and small community hospitals compared with teaching hospitals (419). Such lower mortality rates in teaching versus non-teaching hospitals may be explained by differences in quality of hospital care. Although limited to US-based studies, a literature review conducted by Ayanian and Weissman demonstrated that quality of care was better in major teaching versus non-teaching hospitals (420).

Limited evidence exists on the relationship between deprivation and mortality after hip fracture according to hospital type. Analysing English HES data for 455,862 hip fracture patients aged 18+ years (2004-2011), Thorne et al showed that the relationship between deprivation and 30-day and 365-day mortality differed according to hospital size (299); associations were strongest among patients admitted to large hospitals (600+ beds) and weakest for medium-sized hospitals (400-599 beds). Odds of death at 30-days post-hip fracture were 27% and 14% higher for the most deprived versus least deprived patients admitted to a large- and medium-sized hospital respectively. Tertiary hospitals are located in large urban centres, that are comprised of smaller geographical areas with high levels of deprivation (based on IMD 2015 version) (200), possibly explaining the stronger association between deprivation and mortality in hip fracture patients admitted to large hospitals.

One study examined the relationship between hospital type and healthcare utilisation post-hip fracture (421). Elkassabany et al conducted a large, retrospective cohort study analysing US Medicare claims data from 2007 to 2009 (421). Admission to a major teaching versus non-teaching hospital was associated with 20% increased adjusted odds of 30-day readmission post-hip fracture. It was further shown that the odds of surgical delay (>48 hours) was higher for those admitted to a teaching versus non-teaching hospital (421). This may explain, in part, the higher readmission risk in those admitted to a teaching hospital given that delays in surgery are associated with poor clinical outcomes (see section 11.5.1, page 336).

Hospital case volume

Studies conducted in Denmark and the USA have examined the effect of hospital case volume on outcomes after hip fracture, with inconsistent findings reported in the literature. One Danish study has shown that higher hospital volume is associated with higher mortality post-hip fracture (349), whilst other US studies have reported no association between hospital volume and mortality (350, 351, 422). Whilst evidence suggests that hospital volume is not associated with 30-day readmission risk (350, 351, 421), admission to a low-volume hospital may predict longer hospital stays (350, 422).

A number of US-based studies have reported that hospital case volume does not predict mortality after hip fracture, albeit using different categorisations of hospital case volume. Browne et al showed, using national hospital discharge data for the period 1988 to 2002, that in-hospital mortality rates did not differ by hospital case volume (422). More recently a large, population-based study conducted in California (2007-2011) found hospital case volume did not predict in-hospital mortality (350). Furthermore, Okike et al reported similar findings for mortality outcomes assessed at 30-days, 90-days and 365-days after hip fracture surgery among patients managed within the Kaiser Permanente health care system (351).

In contrast, Kristensen et al reported that hospital case volume was positively associated with 30-day mortality, using Danish hip fracture registry data (2010-2011) (349). The odds of mortality at 30-days post-hip fracture were 29% higher in high volume hospitals (351-530 cases per year) compared with low-volume hospitals (≤151 cases per year). The strength of this association was augmented after taking account of patient characteristics, fracture-related variables, time to surgery and type of hip fracture unit; however, further adjustment for quality of hospital care explained the observed relationship between hospital volume and 30-day mortality. Using data from the Danish hip fracture registry, quality of hospital care was assessed based on seven process performance measures that included pain and mobility assessment, postoperative mobilisation and falls prevention.

Two large, population-based studies of US hip fracture populations, analysing Medicare Claims data (2007-2009) and hip fracture registry data from an integrated healthcare system (2010-2013), both found no relationship between hospital volume and 30-day readmission (351, 421). The study by Metcalfe et al described earlier further demonstrated that, among hip fracture patients in California, hospital LOS was 0.70 days longer among those admitted to a low-volume versus high-volume hospital after adjusting for patient and hospital-level characteristics but no association was observed for emergency 30-day readmission (350). Browne et al similarly found, using national hospital discharge data, that low hospital case volume was associated with longer hospital stays (422). In contrast, the Danish study by Kristensen et al found that patients admitted to a high-volume hip fracture unit had 25% longer hospital stays compared to those admitted to a low-volume unit (349). Although quality of hip fracture care was not adjusted for as part of these analyses, findings reported by the same study (described earlier) highlight that quality of in-hospital care explained their positive association between hospital volume and 30-day mortality (349).

Unsurprisingly, better quality in-hospital care predicts improved patient outcomes after hip fracture. Kristensen et al showed, in another analysis of Danish hip fracture registry data (2010-2013), that fulfilling 75-100% compared with 0-50% of quality indicators was associated with lower odds of 30-day mortality and 30-day readmission as well as shorter hospital stays, after adjustment for patient and hospital-level characteristics (423).

Hip fracture care models

In the UK, the BPT for fragility hip fractures recognises the benefit of joint orthopaedic and geriatric care on patient outcomes after hip fracture (114). Whilst orthogeriatric care improves patient outcomes (352, 424, 425), it is not known whether hospital provision of orthogeriatric care differs according to deprivation status of the local area.

Grigoryan et al identified three models of orthogeriatric care as part of a systematic review and meta-analysis that included eighteen studies published between 1992 and 2012 (352). Most studies examined the effect of orthopaedic care with geriatric involvement (model 1) on outcomes after hip fracture (n=10 studies). Meta-analyses of all included studies demonstrated that orthogeriatric care was associated with 40% lower risk of in-hospital mortality (n=9 studies) and 17% lower risk of long-term mortality (6-12 months) after hip fracture (n=11 studies). Stratified analyses demonstrated that orthopaedic care with geriatric involvement (model 1) was associated with decreased in-hospital and long-term mortality risk. Joint orthopaedic and geriatric care (model 3) was not associated with in-hospital mortality, albeit based on a meta-analysis of three studies. The effect of model 2 (geriatric care with orthopaedic involvement) on in-hospital and long-term mortality, and model 3 on long-term mortality was not assessed due to the limited number of studies identified.

Two recently published UK-based studies have similarly highlighted the beneficial impact of orthogeriatric care on patient outcomes after hip fracture (424, 425). Hawley et al analysed linked HES-ONS mortality data (2003-2013) and qualitative data on changes in hip fracture service provision for eleven acute hospitals in a single English region (424). Mortality risks at 30-days and 365-days after hip fracture were 27% and 19% lower in the period after, compared with prior, to the introduction of an orthogeriatrician. Neuburger et al demonstrated, using linked HES-ONS data for all English NHS hospitals (2010-2013) and NHFD Facilities Audit data, that an increase of 2.5 orthogeriatrician hours per patient was associated with 3.4% relative reduction in 30-day mortality, adjusted for age, gender, comorbidity and secular trends in mortality (425). Greater orthogeriatric input was associated with higher rates of early surgery; however, this did not explain the observed relationship between orthogeriatric involvement and 30-day mortality post-hip fracture.

Grigoryan et al further examined the effect of three different orthogeriatric models of care on hospital LOS; however, it was not possible to draw conclusions from the identified studies owing to considerable study heterogeneity (352). Whilst joint orthopaedic and geriatric care (model 3) predicted shorter hospital stays (n=5 studies), no association was observed for orthopaedic care with geriatric involvement (model 1). Only three studies examined the effect of geriatric care with orthopaedic involvement (model 2), thus limiting the ability to perform a meta-analysis (352). Suhm et al similarly showed that hospital admission under a joint orthogeriatric care programme compared with usual care (orthopaedic care with geriatric involvement) was associated with shorter hospital stays; however, these findings are not likely to be generalisable to other study populations owing to the inclusion of hip fractures patients admitted to a single hospital in Switzerland (426).

Post-discharge destination

The positive relationship between deprivation and healthcare utilisation after hip fracture reported in Chapter 10 may partly be explained by discharge destination. There is some suggestion, albeit based on a limited number of studies, that discharge to an institution is associated with higher readmission rates and longer hospital stays after hip fracture. Social service funding needs to be secured for those newly discharged to an institution, likely explaining the longer hospital stays after hip fracture. The effect of deprivation status on discharge destination is not known; however, it can be hypothesised that more deprived individuals are less likely to be discharged to an institution owing to a lack of personal financial resources and possibly due to decreased availability of care home beds in more deprived areas.

Analysing national surgical quality improvement data (2011-2012), Basques et al reported that discharge to an institutional facility compared with home was associated with 42% increased adjusted odds of 30-day readmission (101). Another US-based study reported a similar relationship between discharge destination and readmission risk. Pollock et al studied hip fracture patients admitted to a single trauma centre in the US reporting that the odds of 30-day readmission were 50% higher among patients discharged to a skilled versus non-skilled nursing facility (427).

Similar observations have been reported for hospital LOS. Castelli et al showed, using English HES data (2009-2010), that hospital LOS was 8 days longer among hip fracture patients discharged to an institution compared to their usual place of residence (102). Analysing HES data (2008-2009), Gaughan et al reported that superspell LOS was 33 days among hip fracture patients newly discharged to an institution, whilst those who returned home spent 20 days in hospital after hip fracture (including hospital transfers) (103).

11.6. Study strengths

11.6.1. HES data

This large population-based study analysed routinely collected administrative data capturing all NHS hospital admissions for hip fracture in England (see Chapter 5.1, page 136 for further background on HES data), and therefore the findings presented in Chapters 7 to 10 are generalisable to the entire English population. The HES APC database does not capture hip fractures managed within privately-financed healthcare facilities, which may introduce selection bias as discussed later (see section 11.7.1, page 349). The availability of HES data from 1989 onwards allows trends in disease incidence and outcomes to be examined over long time periods, as was the case for analyses presented in Chapter 7 as part of which hip fracture incidence was studied over a 14-year period.

The primary purpose of HES data is for the reimbursement of hospital services provided (303); however, the routine data collection of a broad range of variables, including clinical diagnoses and procedures based on standardised coding practices, allows national comparisons to be made. Owing to the administrative nature of HES data, certain variables of interest may not be routinely available such as individual-level measures of deprivation. NHS Digital, the healthcare data providers for England (305), ensures the accuracy and quality of HES data by undertaking a number of data quality and consistency checks prior to data release (312). There is a good level of accuracy in the recording of diagnoses (median: 80.3%) and procedures (median: 84.2%) in routinely collected hospital administrative datasets for Great Britain (including HES) (428). Furthermore, coding accuracy of primary diagnoses has improved since the introduction of PbR in 2002; median coding accuracy was 73.8% pre-PbR (1990-2002) and 96.0% post-PbR (2002-2010) (428).

Validation studies have demonstrated, albeit among other disease populations, that hospital admissions for diseases that require management in secondary care can be identified with high sensitivity in HES (368, 369). Neuburger and Cromwell have further shown that HES is a valid method for identifying hip fracture cases, reporting a high level of agreement in hip fracture numbers identified from the HES APC database and local FLS databases for two NHS trusts (319) (see Chapter 5.2.3, page 143).

11.6.2. ONS data

Whilst it is possible to identify in-hospital deaths from HES data alone, linkage of HES data with ONS mortality data allows assessment of post-discharge mortality in hip fracture patients over a more longer term period. Furthermore, national mortality statistics are obtained from the death certificates of all registered deaths in England and Wales (334), and given that death registration is a legal requirement (429), it is likely that most deaths occurring outside of hospital are captured by ONS mortality data. Further background on ONS mortality data has been provided in Chapter 6.1.2, page 166.

11.6.3. NHFD data

A novel aspect of the outcomes studies (Chapters 9 and 10) is the linkage of nationally-representative clinical and administrative databases, thus allowing assessment of patient outcomes in all individuals admitted to an English NHS hospital with a hip fracture. The NHFD, described in Chapter 1.9.4 (page 44), is a national clinical audit of hip fracture care that provides a mechanism by which hospitals can monitor compliance with national quality standards (118). All eligible NHS hospitals in England regularly upload NHFD data

(82), thus ensuring the representativeness of these data. Data quality and consistency checks are undertaken to ensure data accuracy (120).

11.7. Study limitations

11.7.1. Selection bias

Although HES does not capture hip fractures admitted directly to privately-financed healthcare facilities, any selection bias is likely minimal given that the vast majority of hip fractures are expected to be managed in an NHS hospital. If selection bias was introduced, this is likely to have led to an underestimation of hip fracture incidence amongst those least deprived who can afford private healthcare.

Only a very small proportion of hip fracture patients with missing data for age, sex, IMD and/or geographic region of residence had to be excluded (<1%). It is therefore likely that findings are generalisable to the whole English population, except for certain population groups such as institutional care residents and international migrants in whom current area of residence may not reflect earlier life exposure to deprivation.

11.7.2. Information bias

Information bias occurs because of error in the measurement of study exposure or outcome thus introducing misclassification bias or ecological fallacy (430); each of these types of information bias are discussed further below.

Misclassification bias

Misclassification bias refers to error in the measurement of study exposure and/or outcome (430). Differential misclassification occurs when misclassification of study variables is different across strata and tends to bias the point estimate either towards or away from the null, whilst non-differential misclassification occurs when misclassification is the same across strata and tends to bias the point estimate towards the null (430, 431). The introduction of misclassification bias in this current study as a result of error in the measurement of study exposure and outcome variables are discussed separately below.

Study exposure

This current study used the English IMD to measure deprivation, which is based on a broad range of indicators across seven domains of deprivation, and therefore provides a comprehensive assessment of deprivation (see Chapter 2.5.3, page 64). The English IMD is constructed using national administrative data available at the small-area level, thus allowing assessment of the extent of deprivation across England (195). LSOAs are small, homogenous areas which should have reduced exposure misclassification. Although not all individuals residing in an area will be deprived (191), a higher proportion of disadvantaged individuals reside in deprived areas (432). If measurement error was introduced by incorrectly assigning individuals as more or less deprived than their true individual deprivation status, the type and degree of misclassification is likely to have been the same among individuals who experienced a hip fracture and among those who did not. Analyses presented in Chapters 7 to 10 may therefore have underestimated the true association between deprivation and hip fracture incidence and outcomes among men and women in England owing to the introduction of non-differential misclassification bias.

The importance of measuring deprivation at different stages of the life course to fully capture the effect of deprivation on health has been discussed in Chapter 2.4, page 59 (180). The incidence and outcomes studies (Chapters 7 to 10) measured deprivation status at a single time point based on an individual's area of residence at the time of hospital admission for hip fracture. Although it was not possible to assess lifetime deprivation exposure due to a lack of available data on previous areas of residence, evidence suggests that individuals with poorer self-reported health status move to areas with poorer health and social attributes (health selective migration) (433). Deprivation based on current residential area may therefore provide a reasonable assessment of an individual's deprivation status. Furthermore, owing to a lack of available data, it was not possible to assess whether the level and duration of deprivation exposure across the life course influences hip fracture risk and outcomes in older adults.

Study outcome

The quality of clinical coding in HES has changed over time in response to changes in healthcare tariff systems (428), which is likely to have influenced the recording of hip fractures and comorbidities. Hence, the proportion of hip fracture admissions, and those with comorbidity, may have been underestimated during earlier years of analyses presented in Chapter 7. This may have contributed to the apparent increasing burden of hip fractures and comorbidities observed over the time period studied.

Hip fracture incidence rates were calculated based on individuals for analyses presented in Chapters 7 and 8, and therefore were limited to the first occurrence of hip fracture for each patient. These analyses may have slightly underestimated hip fracture incidence given that 8.7% of hip fractures are thought to be second hip fractures (434).

The differential recording of hip fractures in HES according to gender and deprivation quintile are unlikely to explain the regional inequalities in hip fracture incidence described in Chapter 8. If non-differential misclassification bias was introduced by incorrectly assigning deprivation status according to geographic region of residence, regional inequalities in hip fracture incidence are likely to have been underestimated.

Clinical outcomes after hip fracture were determined using independent data sources and objective data measures; hospital LOS was calculated using HES variables for admission and discharge date for example, whilst deaths were ascertained from national mortality statistics. The differential recording of patient outcomes according to deprivation status is therefore unlikely to account for the social inequalities in hip fracture outcomes reported in Chapters 9 and 10.

As described in Chapter 6.1.2, linkage of HES APC data and ONS mortality data were conducted by NHS Digital using an eight-step algorithm that is based on patient identifiers such as NHS number, sex, DOB and postcode (page 166) (335). NHS Digital assessed the quality of HES-ONS data linkage based on the accuracy with which patient identifiers matched in both datasets, with the majority of HES-ONS records (98.8%) corresponding to an exact match of three or more patient identifiers that included NHS number. Whilst the mortality analyses presented in Chapter 9 were not stratified by quality of HES-ONS data linkage, this is unlikely to have introduced bias through misclassification of mortality status given that the majority of HES-ONS records were deemed to be of good linkage.

Hip fracture superspells were constructed based on published HES methodology, using the approach described in Chapter 6.6.9, page 189. Whilst systematic checks were undertaken to ensure the correct identification of hip fracture superspells in HES, superspell LOS may have been underestimated if HES codes for source of admission and discharge destination were not recorded correctly, thus not capturing all hospital transfers for further NHS care. Furthermore, superspell LOS may have been overestimated if hospital admissions not related to an index hip fracture admission were inaccurately captured as part of a hip fracture superspell, which may be more likely as the number of hospital transfers for further NHS care increases. Although it is not possible to determine the level of inaccuracy in HES coding for admission and discharge variables in the linked HES-ONS-NHFD dataset analysed, the proportion is likely to be small given the administrative purpose for which HES data are collected.

Ecological fallacy

When individual-level SEP data are not available, area-based measures are often used to describe an individual's level of socioeconomic deprivation based on area of residence (see Chapter 2.5, page 61). The associations observed at the area-level may not describe associations among individuals, defined as 'ecological fallacy' (296); however, studies have demonstrated that area-based measures provide valid estimates of an individual's level of socioeconomic deprivation (184).

11.7.3. Residual confounding

The potential effect of residual confounding by key patient and hospital-level characteristics on the findings reported in this thesis is discussed below.

Age

Increasing age is associated with higher risk of hip fracture (see Chapter 1.6.2, page 25), and as expected, mortality risk increases with advancing age. Analyses were all adjusted for age; however, age was categorised in 5-yearly intervals, which may have allowed residual confounding by age had finer age bands been used. This, however, is likely to be minimal, owing to small changes in hip fracture incidence over limited age ranges such as 5-year groupings (50).

Ethnicity

Ethnic variation in hip fracture risk has been described in Chapter 1.6.4 (page 27), with the highest risk being in White compared with Black individuals. Furthermore, socioeconomic disparities in health differ according to ethnicity, as discussed in Chapter 2.6.3, page 67. Patient-level ethnicity data are routinely available in HES and whilst the quality of ethnicity coding has improved over time, poor consistency in ethnicity codes recorded across multiple hospital admissions limits its research use. Mathur et al reported that 79.4% of index patients had a usable ethnicity code recorded in the HES APC database over the period 1997 to 2011 (increasing from 41% in 1997 to 86% in 2011); however, only 44% of patients had multiple HES APC records with identical ethnicity codes (435). Although the incidence and outcomes studies (Chapters 7 to 10) did not adjust for ethnicity, this is unlikely to have biased these study findings given that the majority of hip fracture patients identified in HES were of White ethnicity.

Comorbidity

The outcomes studies (Chapters 9 and 10) demonstrated that an association between greater deprivation and higher age- and gender-adjusted mortality and emergency readmission persisted after further adjustment for comorbidity (see Chapter 9.4.5, page 269 and Chapter

10.4.3, page 293). These observed relationships may, in part, be explained by unmeasured or residual confounding by comorbidity.

As described in Chapter 9.4.1, 75.9% of patients in whom outcomes post-hip fracture were assessed had one or more comorbid conditions (see page 263). Another English study that analysed HES data for the period 2010 to 2013 similarly reported that approximately 70% of hip fracture patients had one or more comorbid conditions (425), whilst a US analysis of administrative hospital claims data (2008) reported that 92.4% of individuals with osteoporosis had one or more comorbid conditions (436).

The RCS Charlson score was used to measure the burden of comorbidity for these analyses, and is a modified version of the CCI that was developed to identify comorbidity in adult surgical patients using English HES data (323) (see Chapter 5.3.6, page 152). The CCI was constructed using data obtained from 559 medical patients admitted to a single hospital in New York, USA and is based on ICD-10 codes for nineteen disease categories (see Chapter 2.6.4, page 68 for further details). The CCI may not capture all comorbid diseases that predict hip fracture incidence and outcomes, and all comorbidities may not be recorded in patient medical notes and coded into the HES administrative database. It is therefore possible that this current study may have underestimated the burden of comorbidity among hip fracture patients, particularly those who are more deprived in whom the burden of comorbidity is greater, and thus overestimated the strength of the association between deprivation and clinical outcomes after hip fracture.

The RCS Charlson score does not take account of disease severity or duration of illness. The CCI was developed as a weighted index to take account of disease severity, whereas the RCS Charlson score is a count of the number of comorbid conditions; however, Armitage et al showed that assigning weights to disease categories resulted in only a slight improvement in the RCS Charlson scores ability to predict mortality (323).

Analysis of primary care records for one-third of the Scottish population has demonstrated that multimorbidity occurs 10-15 years earlier among individuals residing in the most deprived compared with the least deprived areas (226). It can be hypothesised that more deprived individuals who spend a greater period of their lifetime in poor health are likely to experience greater disease severity and worse health outcomes.

As discussed earlier, lifestyle factors are known to influence the risk of incident hip fractures (see section 11.3.5, page 318) and outcomes post-hip fracture (see section 11.5.1, page 336). Although it was not possible to adjust for lifestyle risk factors as part of these analyses owing to a lack of available data in HES and NHFD databases, the RCS Charlson score does capture some consequences of lifestyle behaviours such as smoking-related COPD.

Whilst many studies use a measure of comorbidity to assess the burden of concurrent disease in an individual, as was the case in this current study, such measures do not capture patient complexity. Frailty represents an alternative construct that can be used to identify individuals at-risk of poor health outcomes. Fried et al define frailty as *"a physiologic state of increased vulnerability to stressors that results from decreased physiologic reserves, and even dysregulation, of multiple physiologic systems"* (437). Frailty reflects an individual's ability to regain functional abilities following a physiological stressor such as illness (438), and is a predictor of adverse health outcomes, including mortality, disability and falls (437). The development of a frailty risk score based on ICD-10 codes recorded in the English HES database allows routine assessment of frailty in hospitalised patients; recently Neuburger et al demonstrated that a high HES frailty risk score compared with a low score was associated with higher 30-day mortality and 30-day readmission, and longer hospital stays (439).

Hospital-level factors

Different hospital-level factors are associated with improved patient survival post-hip fracture with some suggestion that hospital-level characteristics are also associated with decreased healthcare utilisation after hip fracture, although the evidence base is more limited (see section 11.5.2, page 340 for further discussion). Residual confounding by hospital-level factors may explain some of the relationship between deprivation and hip fracture outcomes reported in Chapters 9 and 10. Although hospital-level data are collected as part of the NHFD facilities audit survey (described in Chapter 1.9.4, page 44), linkage of NHFD facilities audit survey data to patient-level clinical audit data was considered beyond the scope of the outcomes studies (Chapters 9 and 10).

11.8. Implications of research findings

11.8.1. Clinicians

Hip fracture patients represent a group of individuals with complex medical and social needs. As discussed in Chapter 1, hip fractures are associated with significant morbidity and mortality, including functional decline and a greater need for institutional care (243, 407). Furthermore, social deprivation is associated with poor health outcomes such as higher disease incidence and mortality risk, and higher prevalence of unhealthy lifestyle behaviours (see Chapter 2).

The incidence and outcomes studies presented in Chapters 7 to 10 demonstrated a high burden of comorbidity among hip fracture patients, particularly those residing in areas with higher levels of deprivation. This, compounded with the knowledge that those most in need of healthcare are less likely to access such services (‘inverse care law’) (440), suggests that clinicians working in more deprived areas manage more complex hip fracture patients, likely owing in part to insufficient active management of more advanced comorbid disease.

11.8.2. Policy makers

Despite efforts made over the last decade by the UK Government to reduce health inequalities in England and the implementation of large-scale policy initiatives nationally to improve the quality of hip fracture care (see Chapter 1.9, page 42 and Chapter 2.7, page 70), it is concerning that findings of the incidence study (Chapter 7) suggest that disparities in fracture prevention persist and in some groups, have worsened. The 'Choosing Health: making healthy choices easier' (2004) and 'Healthy Lives, Healthy People' (2010) white papers highlighted the Government's strategy for addressing public health challenges (441, 442), and the 'Marmot Review' (2010) provided evidence-based policy recommendations for addressing health inequalities in England (143). These efforts coincided with a growing emphasis on the improved management of individuals at risk of fragility fractures; in 2012, NICE issued guidance on targeted assessment of fracture risk among 'at risk' populations (such as those with comorbidities) using validated tools, namely FRAX and QFracture (76), as well as treatment recommendations to protect bone (443). Hip fractures commonly follow another index fragility fracture; hence the importance of FLSs to promptly identify such fractures and instigate management to reduce future fracture risk (362). Despite this, a significant gap in care for secondary fracture prevention has been reported in several countries (444) as well as in the UK (132). Several large-scale initiatives aiming to narrow this care gap have been implemented nationally including the RCP FFFAP and the ROS's Clinical Standards for Fracture Liaison Services (76, 117, 362), and internationally such as the International Osteoporosis Foundation's 'Capture the Fracture' campaign (134). Encouragingly, over the last two decades, considerable gains have been made in reducing hip fracture incidence among women in England as demonstrated by the incidence study (Chapter 7); however, findings of the regional incidence study (Chapter 8) suggest that men and more deprived women in the Midlands and South may not be realising equal benefit from such services. The regional incidence study also demonstrated that for both men and women in the North of England, a progressive increase in age-standardised hip fracture incidence has been observed among those who are least deprived; the explanation for which remains unclear.

Studies have demonstrated better patient outcomes post-hip fracture following the implementation of the NHFD in 2007 and associated BPT in 2010. A large ‘before and after’ time-series study (2003-2011) evaluated the impact of the NHFD on 30-day mortality after hip fracture (29). Neuburger et al demonstrated, using English HES data for 471,590 older hip fracture patients, that more marked declines in 30-day mortality were observed after the NHFD was implemented (2007-2011) compared with before its launch (2003-2007). 30-day mortality decreased from 10.9% to 8.5% between 2007 and 2011 corresponding to an adjusted relative reduction of 7.6% per year, in comparison to a decline of 11.5% to 10.9% over the period 2003-2007 equating to a relative decrease of 1.8% per year. Similarly, achieving BPT criteria for hip fracture has been associated with improved patient survival. A longitudinal ‘before and after’ study conducted in Nottingham, England examined the impact of achievement of BPT criteria on 30-day mortality using hospital hip fracture registry data linked to ONS mortality data (445). The study identified 2,541 patients aged 60+ years admitted for hip fracture over the period 2008 to 2010 (pre-BPT) and 2012 to 2014 (post-BPT). Among the 1,177 hip fracture patients admitted after the introduction of the BPT, 30-day mortality and 365-day mortality were both lower among patients for whom BPT criteria were achieved compared with those for whom it was not fulfilled. Mortality at 30-days post-hip fracture was 6.0% and 21.0% among patients for whom BPT criteria were and were not achieved respectively, and 28.6% and 42.0% at 365-days after hip fracture. Both studies highlight considerable improvements in mortality after hip fracture in England over the last decade; however, findings of the mortality study (Chapter 9) suggest that greater emphasis needs to be placed on reducing inequalities in mortality post-hip fracture, particularly among the most deprived individuals in the North of England. Better understanding of the role of deprivation as a predictor of poor clinical outcomes after hip fracture, in conjunction with further research on hospital-level variation in hip fracture care as discussed below in section 11.9.3, can be used to inform national policy guidance on hip fracture management among more deprived individuals.

11.9. Future research

11.9.1. Fracture risk prediction models

Risk assessment tools are available for the estimation of fracture probability in individuals considered to be at high risk of fracture, as discussed in Chapter 1.7, page 31. Commonly used risk prediction models in the UK include the FRAX and QFracture risk calculators that estimate ten-year absolute probability or risk of hip fracture and MOF based on many of the CRFs discussed in Chapter 1.6 (page 24), including BMD, age, gender, previous and family history of fracture, lifestyle behaviours and comorbidity (77, 79). Analyses presented in Chapter 7 highlight that deprivation predicts hip fracture risk in both men and women, with a stronger relative effect observed in men. Further research is required to determine whether the inclusion of deprivation as a risk factor for fracture improves the performance of existing risk prediction models and their estimation of absolute fracture risk; such models are likely to only be of use in high-income countries with routine data collection on standardised measures of deprivation.

11.9.2. Linkage to other data sources

As described earlier in section 11.3.5, it was not possible to adjust for lifestyle risk factors as part of these analyses owing to a lack of available data in HES and NHFD databases (see page 318). However, linkage to other national databases that routinely collect information on lifestyle behaviours may allow assessment of their effect on the relationship between deprivation and hip fracture incidence and outcomes. The Health Survey for England (HSE) is a nationally-representative, annual cross-sectional survey that collects data on a range of health and lifestyle factors among the adult general population in England (446). The CPRD database, based on primary care records, also collects information on lifestyle risk factors (367). Validation studies have shown that CPRD prevalence estimates of current smoking and non-smoking status are comparable to those derived from HSE data (447), with similar findings observed when obesity rates calculated using recent CPRD BMI records (≤3 years) were compared with estimates based on HSE BMI data (448).

Whilst this thesis examined the effect of deprivation on clinical outcomes after hip fracture, namely mortality and healthcare utilisation post-hip fracture (Chapters 9 and 10), hip fractures have also been associated with poor functional outcomes, including a decline in mobility and greater need for institutionalisation (30, 243). It was not possible to assess the relationship between deprivation and functional outcomes post-hip fracture as part of this thesis owing to the high level of missing NHFD data for 30-day residential and mobility status (see Chapter 6.7.6, page 199 and Chapter 6.7.7, page 199). However, the lack of available data in the NHFD can be addressed through linkage to existing national epidemiological studies on hip fracture outcomes such as the World Hip Trauma Evaluation (WHiTE). The WHiTE study is a multicentre cohort study that prospectively collects data on patient-reported outcome measures and functional status after hip fracture among individuals who meet the NHFD inclusion criteria, thus allowing information on a broader set of outcome measures to be captured among the NHFD hip fracture population (449).

11.9.3. Hospital-level variation in models of hip fracture care

Whilst the relationship between area-based deprivation and clinical outcomes after hip fracture may partly be explained by patient characteristics such as age, gender and comorbidity, hospital-level variation in the provision of hip fracture care may also account for some of the relationship reported in Chapters 9 and 10.

Different hospital-level factors influence clinical outcomes after hip fracture, as discussed earlier in section 11.5.2, page 340, albeit based on a limited number of studies with considerable heterogeneity across studies. Furthermore, considerable variation exists in the organisation and delivery of hip fracture services across the UK (82). A systematic analysis of existing hip fracture services is required to identify key hospital-level factors at different points in the hip fracture care pathway that account for variations in patient outcomes, with particular emphasis on identifying social and regional differences in models of hip fracture care.

11.10. Conclusion

This large population-based study presents an up to date picture of social inequalities in hip fracture care among older men and women in England, using hospital administrative data and a valid measure of area-based deprivation specific to the English context. The availability of patient-level data for all hip fracture admissions to English NHS hospitals allowed detailed assessment of secular trends in hip fracture incidence and examination of clinical outcomes after hip fracture according to deprivation quintiles, gender and geographic region.

Despite UK Government and public health initiatives to address health inequalities and improve hip fracture care, it is concerning that the findings of this study suggest that social and regional inequalities in hip fracture incidence and outcomes continue to exist in England. These findings stress the need for reassessment of current national public health strategies to prevent hip fractures and improve hip fracture care, with particular emphasis placed on the development of health policies that address persisting social and regional inequalities. Established policy initiatives such as the RCP NHFD and FLS-DB provide a mechanism by which socioeconomic differences and regional variation in hip fracture care can be audited.

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CHAPTER 13. APPENDICES

13.1. Journal publications

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ORIGINAL ARTICLE

The effect of social deprivation on hip fracture incidence in England has not changed over 14 years: an analysis of the English Hospital Episodes Statistics (2001–2015)

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Abstract
Summary Deprivation predicts increased hip fracture risk. Over 14 years, hip fracture incidence increased among men with persisting inequalities. Among women, inequalities in incidence were less pronounced; whilst incidence decreased overall, this improvement was seen marginally less in women from the most deprived areas. Hip fracture prevention programmes have not reduced inequalities.
Purpose Deprivation is associated with increased hip fracture risk. We examined the effect of area-level deprivation on hip fracture incidence in England over 14 years to determine whether inequalities have changed over time.
Methods We used English Hospital Episodes Statistics (2001/2002–2014/2015) to identify hip fractures in adults aged 50+ years and mid-year population estimates (2001–2014) from the Office for National Statistics. The Index of Multiple Deprivation measured local area deprivation. We calculated age-adjusted incidence rate ratios (IRR) for hip fracture, stratified by gender and deprivation quintiles.
Results Over 14 years, we identified 747,369 hospital admissions with an index hip fracture; the number increased from 50,640 in 2001 to 55,092 in 2014; the proportion of men increased from 22.2% to 29.6%. Whereas incidence rates decreased in women (annual reduction 1.1%), they increased in men (annual increase 0.6%) (interaction $p < 0.001$). Incidence was higher in more deprived areas, particularly among men: IRR most vs. least deprived quintile 1.50 [95% CI 1.48, 1.52] in men, 1.17 [1.16, 1.18] in women. Age-standardised incidence increased for men across all deprivation quintiles from 2001 to 2014. Among women, incidence fell more among those least compared to most deprived (year by deprivation interaction $p < 0.001$).
Conclusions Deprivation is a stronger relative predictor of hip fracture incidence in men than in women. However, given their higher hip fracture incidence, the absolute burden of deprivation on hip fractures is greater in women. Despite public health efforts to prevent hip fractures, the health inequality gap for hip fracture incidence has not narrowed for men, and marginally widened among women.

Keywords Epidemiology · Health inequality · IMD · Index of multiple deprivation · Neck of femur · Secular trend

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Introduction

Hip fractures are common with a substantial public health impact. There were approximately 65,000 hip fractures in England, Wales and Northern Ireland in 2015 [1]; this number is projected to increase as our population ages. Hip fractures are associated with significant morbidity and mortality [2–4], and have a considerable financial impact upon healthcare systems. Annual hospital costs associated with incident hip fractures have been estimated at £1.1 billion for the UK [5].

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Greater deprivation is associated with an increased hip fracture incidence in many countries including Australia [6], Canada [7], Portugal [8], Sweden [9] and the USA [10, 11]. In contrast, the reverse relationship has been reported in Spain where hip fracture risk was higher in the least deprived compared to most deprived areas, possibly explained by the protective effects of obesity for the hip [12]. In the UK, a number of studies have identified an association between worsening deprivation and higher hip fracture incidence [13–16], but this has not been consistently demonstrated albeit by studies of varying lengths [17, 18]. In addition, recent evidence suggests that the relationship between deprivation and hip fracture risk may be stronger in men than in women [16], potentially explained by differing predispositions in men and women towards lifestyle habits that increase fracture risk, such as tobacco and heavy alcohol consumption [19, 20].

Over the last two decades, efforts have been made to prevent hip fractures, through development of fracture liaison services that prioritise secondary fracture prevention [21]. Over this period, hip fracture incidence has plateaued or declined in high-income countries; age-standardised hip fracture incidence declined in Australia [22], Canada [23] and the USA [24], and rates have plateaued in England [13, 15, 25]. However, contrasting gender-specific trends in England have been reported, with hip fracture incidence rising among older men, but declining among the larger older female population (between 2003 and 2013) [26]. In support of this, analysis of the Clinical Practice Research Datalink (CPRD) showed that hip fracture incidence had remained unchanged in women between 1990–1994 and 2008–2012, but had increased in men over the same period [27].

What is not known is how the relationship between deprivation and hip fracture incidence has changed over recent years in men and women. We hypothesised that secular changes in hip fracture incidence in men and women have not been the same across all levels of deprivation; we hypothesised that greater declines in hip fracture incidence would be observed among women living in less deprived areas, given a greater awareness of osteoporosis risk among women, and that individuals living in less deprived areas are more likely to engage with preventative healthcare services [28]. We used English Hospital Episodes Statistics (HES) and Office for National Statistics (ONS) mid-year population estimates for the period 2001 to 2015, to identify if secular trends differed by levels of deprivation among men and women in England over this 14-year period.

Methods

Data sources

We used anonymised patient-level data from the routinely collected HES Admitted Patient Care database that included admissions to all English hospitals within the National Health Service (NHS) (i.e. excluding privately financed healthcare) for the period 1st April 2001 to 31st March 2015. Each entry, or episode, in HES relates to a period of care under a single hospital consultant; there are one or more hospital episodes during a hospital admission. Each HES episode includes information on patient demographics and up to 20 clinical diagnoses using International Classification of Diseases, Tenth Revision (ICD-10) disease codes [29].

We obtained mid-year population estimates for England for each year from 2001 to 2014 from the ONS. We received population denominator data stratified by age categories (birth to 90+ years in 5-yearly intervals), gender and Index of Multiple Deprivation (IMD) 2015 quintiles.

Study population

We identified hip fracture admissions using ICD-10 disease codes for fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1) and subtrochanteric fracture (S72.2). Our study population consisted of index cases of hip fracture, that is, the first occurrence of hip fracture, among male and female English residents aged 50 years and older who were admitted to the hospital with a hip fracture or who sustained a hip fracture during a hospital admission. We excluded second hip fractures in order to avoid double-counting, since we were not able to distinguish reliably between two separate hip fracture events in HES. We excluded patients under the age of 50 years as hip fractures in this age group are primarily due to high-impact trauma. We also excluded patients with missing data for age, gender, IMD and geographic region of residence ($n = 4667$).

Study variables

We used the IMD to measure socio-economic deprivation. The IMD is a relative measure of deprivation for small areas, termed lower super output areas (LSOAs), which are defined as geographical areas of a similar population size with an average of 1500 residents [30]. The IMD is composed of seven measures of deprivation: income deprivation; employment deprivation; education, skills and training deprivation; health deprivation and disability; crime; barriers to housing and services; and living environment deprivation. There are 32,482 LSOAs in England, and each LSOA is assigned a score and a rank for the individual domains of deprivation. A weighted sum of the ranks for each domain is used to calculate an overall IMD score based upon which LSOAs are then ranked nationally. The IMD 2004 version was used for financial years 2001/2002 to 2006/2007 in HES; the IMD 2007 version was used for financial years 2007/2008 to 2009/2010; and the IMD 2010 version was used for financial years 2010/2011 to 2014/2015 [29]. We used the IMD rank for a patient's LSOA and categorised patients into quintiles based upon the national ranking of local areas, with quintile 1 being the least deprived group and quintile 5 being the most deprived group.

We derived further variables to describe patient characteristics, including 5-yearly age groupings from 50 years to 90+ years, gender and comorbidity. We used the Royal College of Surgeons Charlson Score to measure comorbidity [31]. This is based upon several chronic conditions identified using ICD-10 diagnosis codes for the index hip fracture admission and admissions in the preceding 3 years. In our HES extract, comorbidity data were only available for the most recent 10 financial years (2005/2006 to 2014/2015) so we restricted our comorbidity analyses to the most recent 7 years (2008/2009 to 2014/2015) to allow a 3-year retrospective period. We categorised the comorbidity score into a four-level ordinal variable (0, 1, 2 or 3 or more comorbid conditions).

Research approvals

We obtained NHS Research Ethics Committee approval for this study (REC reference: 15/LO/1056).

Statistical analyses

We summarised key demographic statistics, and used the chi-squared (χ^2) test to assess the association between categorical variables and linear regression to assess trends in log-transformed age and IMD score. We calculated annual incidence rates of hip fracture per 100,000 population as the number of index hip fractures divided by the population count for each year, gender and IMD quintile. To assess time trends, we used direct standardisation to calculate age-standardised rates using the population of England in 2001 as our reference year and grouping age into nine bands.

Separately for women and men, we used Poisson regression modelling to determine the association between IMD and hip fracture incidence and calculated incidence rate ratios (IRRs), using quintile 1, the least deprived quintile, as the reference category and adjusting for age. We then included year as a linear term to test for time trends, and tested for differences in time trends by deprivation by including interaction terms. All statistical analyses were conducted using Stata, version 14 MP.

As a secondary analysis, we explored time trends among hip fracture patients with comorbidities and examined differences by levels of deprivation. We were unable to determine differences in hip fracture incidence by comorbidity because we lacked comorbidity data for the English population as a whole. Instead, we used direct standardisation to calculate the age-standardised proportion of hip fracture admissions with low ($\leq$1 comorbid condition) and high ($\geq$2 comorbid conditions) comorbidity by gender and IMD quintiles using the hip fracture population in 2008 as the reference year.

Results

We identified 752,036 hospital admissions with an index hip fracture among English residents aged 50 years and older from 2001 to 2014. We excluded 4667 (0.6%) patients with missing data for age, sex, IMD and/or geographic region of residence. Of the remaining 747,369 cases of hip fracture, 74.2% occurred in women and 37.7% had two or more coded comorbid conditions (Table 1). The median (inter-quartile range) age of our study population was 83 years (77–88): 81 (74–87) in men and 84 (78–89) in women. Hip fracture patients in the most deprived quintile were more likely to be younger, male and have a higher burden of comorbidity when compared to patients in the least deprived quintile (Table 1). Over time, the proportion of women decreased and the burden of comorbidity increased within our hip fracture population (Table 2).

Hip fracture incidence

Whilst the number of hip fracture admissions increased over the 14 years examined, from 50,640 in 2001 to 55,092 in 2014, overall age-standardised hip fracture incidence rates decreased from 308 to 271 per 100,000 population between 2001 and 2014.

Trends in age-standardised incidence differed markedly by gender with a decline observed for women at an average rate of 1.1% per year, whilst rates increased for men at an average rate of 0.6% per year (gender by time interaction $p < 0.001$). As expected, considerably higher rates of hip fracture were observed among older people (80+ vs. <80 years: IRR 12.64 [95% CI 12.58, 12.70], $p < 0.001$), but the rate among women was approximately 80% higher than that for men even after adjusting for age (IRR 1.78 [95% CI 1.77, 1.79], $p < 0.001$).

Hip fracture incidence by levels of deprivation in men

Age-adjusted incidence was substantially higher for men in the most deprived compared with the least deprived quintile (IRR 1.50 [95% CI 1.48, 1.52], $p < 0.001$) with a dose-response pattern (Fig. 1).

From 2001 to 2014, age-standardised hip fracture incidence rates increased similarly for men across all strata of deprivation and this rate of increase did not differ by levels of deprivation (deprivation by time interaction, $p = 0.11$) (Fig. 2).

Table 1 Characteristics of patients admitted to hospital and sustaining a hip fracture according to quintiles of deprivation, 2001–2014

		Total population	IMD Q1 least deprived	IMD Q2	IMD Q3	IMD Q4	IMD Q5 most deprived	*p* value
N (%)		747,369 (100)	143,183 (19.2)	157,054 (21.0)	158,969 (21.3)	147,933 (19.8)	140,230 (18.8)	
Age (years)	Median (IQR)	83 (77–88)	84 (78–89)	84 (77–89)	83 (77–88)	83 (77–88)	82 (75-87)	$p < 0.001$
Age (years), n (%)	50–64	48,230 (6.5)	7816 (5.5)	8834 (5.6)	9276 (5.8)	9997 (6.8)	12,307 (8.8)	$p < 0.001$
	65–74	97,331 (13.0)	17,061 (11.9)	19,196 (12.2)	19,795 (12.5)	19,401 (13.1)	21,878 (15.6)	
	75–84	280,303 (37.5)	53,209 (37.2)	58,230 (37.1)	59,211 (37.3)	56,009 (37.9)	53,644 (38.3)	
	≥85	321,505 (43.0)	65,097 (45.5)	70,794 (45.1)	70,687 (44.5)	62,526 (42.3)	52,401 (37.4)	
Gender, *n* (%)	Female	554,573 (74.2)	106,604 (74.5)	117,637 (74.9)	119,091 (74.9)	109,700 (74.2)	101,541 (72.4)	$p < 0.001$
Charlson comorbidity score[a]	0	116,739 (30.4)	26,217 (34.5)	26,448 (32.4)	24,891 (30.5)	21,288 (28.4)	17,895 (25.8)	$p < 0.001$
	1	122,165 (31.8)	23,935 (31.5)	26,347 (32.2)	26,229 (32.2)	23,840 (31.8)	21,814 (31.5)	
	2	76,775 (20.0)	14,292 (18.8)	15,654 (19.1)	16,214 (19.9)	15,566 (20.7)	15,049 (21.7)	
	≥3	67,958 (17.7)	11,492 (15.1)	13,317 (16.3)	14,214 (17.4)	14,350 (19.1)	14,585 (21.0)	

Pearson's chi-squared test was used to assess the association between deprivation quintiles and categorical outcome variables; linear regression was used to assess trends in log-transformed age by deprivation quintiles

IQR interquartile range, *IMD* Index of Multiple Deprivation

[a] Restricted to financial years 2008–2014 and is calculated using comorbidity data derived from the index hip fracture admission and hospital admissions in the previous 3 years

Hip fracture incidence by levels of deprivation in women

In women, there was a less marked association between levels of deprivation and hip fracture incidence with a dose-response pattern (Fig. 1). Age-adjusted hip fracture incidence was 17% higher in the most deprived vs. the least deprived quintile (IRR 1.17 [95% CI 1.16, 1.18], $p < 0.001$).

Whereas age-standardised incidence declined in women across all strata of deprivation from 2001 to 2014, more marked declines in hip fracture incidence were observed among women in the least deprived quintile as compared to the most deprived quintile (deprivation by time interaction, $p < 0.001$). For example, among the least deprived quintile, hip fracture incidence decreased by 60 hip fractures per 100,000 women between 2001 and 2014 equating to an average decline of 1.41% per year, whilst among the most deprived quintile a more modest decline of 31 hip fractures per 100,000 women was seen, equating to an average decline of 0.59% per year (Fig. 2).

Hip fracture admissions among those with high levels of comorbidity

Over the period 2008 to 2014, 46.2% of men and 34.5% of women with a hip fracture admission had high levels of comorbidity. After standardising for age, the proportion of hip fracture admissions rose by 14.2% among men and 12.7% among women between 2008 and 2014. The age-standardised proportion was higher in the most deprived compared with the least deprived quintile in both men and women, and this proportion increased similarly across all strata of deprivation (Fig. 3).

Discussion

This study examined the relationship between area-based deprivation and hip fracture incidence in men and women aged 50 years and older in England over a 14-year period, confirming that whilst age-standardised hip fracture incidence is declining in women, there has been an increase among men. Among men, social deprivation is associated with substantially higher hip fracture rates, and these inequalities have not improved over more than a decade, so that men who are most deprived are 50% more likely to fracture their hip than those who are least deprived. Across England, when averaged over 14 years, this equates to approximately 8546 excess hip fractures per year occurring among men with greater deprivation (quintiles 2 to 5 vs. 1). Among women, the effect of deprivation on hip fracture incidence is weaker: however, owing to the higher incidence of hip fractures in women, the absolute burden of deprivation on hip fractures is greater in women than in men. Differences in hip fracture incidence have become more overt over time, with women who are most deprived benefiting the least from improved secular trends in hip fracture incidence. Comorbidity levels have increased within the hip fracture population over time, and these increases have occurred in women and men across all deprivation strata.

Ours is only the second study in the UK to examine the association between deprivation and hip fracture incidence

Table 2 Characteristics of patients admitted to hospital and sustaining a hip fracture over time from 2001 to 2014

		2001 and 2002	2003 and 2004	2005 and 2006	2007 and 2008	2009 and 2010	2011 and 2012	2013 and 2014	*p* value
N (%)		102,784 (13.8)	103,095 (13.8)	103,828 (13.9)	106,214 (14.2)	108,894 (14.6)	110,510 (14.8)	112,044 (15.0)	
Age (years)	Median (IQR)	82 (77–88)	83 (77–88)	83 (77–88)	83 (77–88)	83 (77–88)	83 (77–89)	83 (77–89)	$p < 0.001$
Age (years), *n* (%)	50–64	5748 (5.6)	6086 (5.9)	6710 (6.5)	7277 (6.9)	7585 (7.0)	7421 (6.7)	7403 (6.6)	$p < 0.001$
	65–74	13,829 (13.5)	13,596 (13.2)	13,020 (12.5)	13,291 (12.5)	14,058 (12.9)	14,429 (13.1)	15,108 (13.5)	
	75–84	40,534 (39.4)	41,800 (40.6)	40,288 (38.8)	39,615 (37.3)	39,385 (36.2)	39,196 (35.5)	39,485 (35.2)	
	≥85	42,673 (41.5)	41,613 (40.4)	43,810 (42.2)	46,031 (43.3)	47,866 (44.0)	49,464 (44.8)	50,048 (44.7)	
Gender, *n* (%)	Female	80,085 (77.9)	79,498 (77.1)	78,283 (75.4)	78,663 (74.1)	78,848 (72.4)	79,909 (72.3)	79,287 (70.8)	$p < 0.001$
IMD score	Median (IQR)	17.3 (10.1–29.9)	17.1 (10.1–29.6)	17.0 (10.0–29.4)	16.7 (9.7–29.1)	16.7 (9.8–28.9)	16.6 (9.8–28.5)	16.4 (9.7–28.2)	$p < 0.001$
Charlson comorbidity score[ab]	0				39,314 (37.1)	35,873 (33.1)	31,855 (28.9)	29,354 (26.2)	$p < 0.001$
	1				34,742 (32.8)	35,311 (32.6)	35,079 (31.8)	34,404 (30.7)	
	2				18,746 (17.7)	20,661 (19.1)	22,876 (20.8)	23,865 (21.3)	
	≥3				13,106 (12.4)	16,543 (15.3)	20,441 (18.5)	24,421 (21.8)	

IQR interquartile range, *IMD* Index of Multiple Deprivation

[a] Restricted to financial years 2008–2014; calculated using comorbidity data derived from the index hip fracture admission and hospital admissions over the previous 3 years

[b] The numerator for year 2008 has been doubled to derive the number of hip fractures stratified by comorbidity for the equivalent of 2007 and 2008

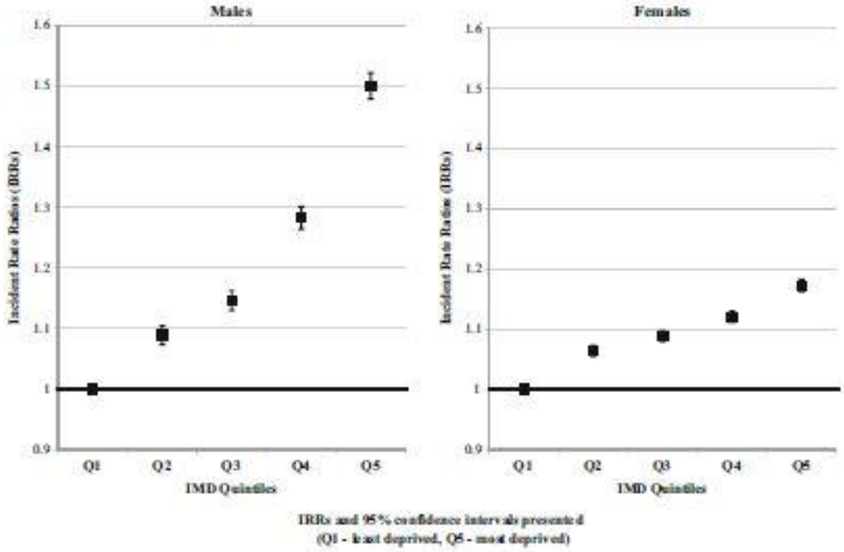

Fig. 1 Association between quintiles of deprivation and age-adjusted hip fracture incidence rates in men and women aged 50+ years residing in England, 2001–2014 (quintile 1 (Q1) (least deprived quintile)—reference category)

over time; a previous analysis (1998–2008) did not identify the clear relationships we have done [13]; however, their analyses were not gender stratified and were based upon the Carstairs deprivation index, an area-based measure of relative material deprivation calculated at the ward level using four census indicators (male unemployment, overcrowding, car ownership and low social class) [32]. We used the IMD which, in contrast, is based on a broader range of deprivation measures across seven domains of deprivation, and therefore is considered to provide a more comprehensive assessment of deprivation at the small-area level. We also measured at a smaller and more homogenous area (LSOAs), which should have reduced exposure misclassification.

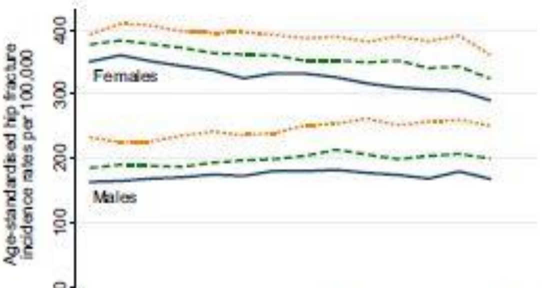

Fig. 2 Annual age-standardised hip fracture incidence rates per 100,000 population by quintile of deprivation in men and women aged 50+ years, 2001–2014 (quintile 1 (Q1)—least deprived quintile, quintile 5 (Q5)—most deprived quintile)

Few studies have examined the relationship between deprivation and hip fracture incidence by gender. Our findings suggest a stronger association between deprivation and hip fracture incidence in men than in women and are consistent with those of a recent UK study, in men and women aged over 18 years, using general practitioner (CPRD) records from 1988 to 2012 [16]; our findings, with the advantage of a larger sample size, confirm a clear association between deprivation and hip fracture risk in men, and determine a previously unidentified association between deprivation and hip fracture risk in women. This association between deprivation and increased hip fracture incidence in both men and women may partly be explained by the social gradient of lifestyle-associated risk factors for fracture. The prevalence of tobacco [33] and heavy alcohol consumption [34] is higher among more deprived populations, with men rather than women having a greater propensity towards these lifestyle habits [19, 20]. Alcohol consumption and tobacco use are associated with an increased risk of hip fracture in men [35]. Similarly, the prevalence of obesity, physical inactivity and poor nutrition increases with greater levels of deprivation [36]. The less marked relationship between deprivation and hip fracture incidence in women may in part be explained by the stronger relationship between deprivation and obesity in women [37], as adiposity over the greater trochanter is thought to protect against hip fracture [38]. Interestingly, a regional study in an urban population in Spain (2009–2012) demonstrated that age- and sex-adjusted hip fracture risk was 10% lower in the most deprived as compared to the least deprived areas [12]. However, this association was attenuated after adjustment for body mass index (BMI), suggesting that a higher prevalence of obesity in more deprived areas may have accounted for the

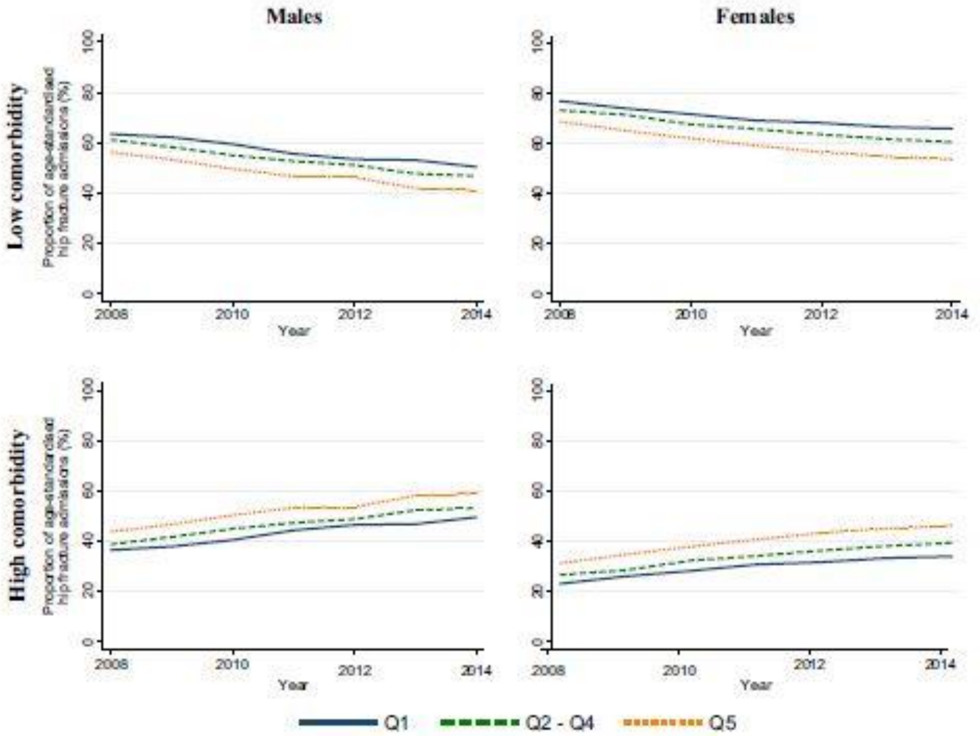

Fig. 3 Proportion of age-standardised hip fracture admissions with low or high comorbidity, by quintile of deprivation in men and women aged 50+ years, 2008–2014 (quintile 1 (Q1)—least deprived quintile, quintile 5 (Q5)—most deprived quintile)

inverse relationship observed. We were unable to adjust for obesity in our analyses due to lack of BMI data in HES; similarly, tobacco use and alcohol consumption data were not available for analysis.

Studies investigating the relationship between deprivation and hip fracture incidence have mostly demonstrated a social gradient with greater levels of deprivation being associated with a higher hip fracture incidence across many high-income countries [6–11], including the UK [14–16]. Despite efforts made over the last decade by the UK Government to reduce health inequalities in England, it is concerning that our findings suggest that disparities in fracture prevention persist and, in some groups, have worsened. The 'Choosing Health: making healthy choices easier' (2004) and 'Healthy Lives, Healthy People' (2010) white papers highlighted the Government's strategy for addressing public health challenges [39, 40], and the 'Marmot Review' (2010) provided evidence-based policy recommendations for addressing health inequalities in England [41]. These efforts coincided with a growing emphasis towards the improved management of individuals at risk of fragility fractures; in 2012, NICE issued guidance on targeted assessment of fracture risk among 'at risk' populations (such as those with comorbidities) using validated tools, namely FRAX and QFracture [42], as well as treatment recommendations to protect bone [43]. Hip fractures commonly follow another index fragility fracture, hence the importance of Fracture Liaison Services (FLS) to promptly identify such fractures and instigate management to reduce future fracture risk (21). Despite this, a significant gap in care for secondary fracture prevention has been reported in several countries [44] as well as in the UK [45]. Several large-scale initiatives aiming to narrow this care gap have been implemented nationally [21, 42, 46] and internationally [47]. Encouragingly, over the last two decades, we have made considerable gains in reducing hip fracture incidence among women in England; however, our findings suggest that greater focus needs to be placed upon addressing the rising hip fracture incidence in men, as well as the inequities in hip fracture incidence observed in those who are most deprived.

The decline in hip fracture incidence rates among women that we report are consistent with studies conducted in Australia [22], Canada [23] and the USA [24]. However, these also reported, albeit to a lesser degree, declining rates in men. Our contrasting observation of increasing hip fracture incidence among men is consistent with an analysis of UK general practitioner (CPRD) records, which showed that hip fracture incidence increased from 108 to 134 hip fractures per 100,000 person-years between 1990-1994 and 2008–2012 [27];

although hip fracture incidence was reported as stable in women, the analyses were not age adjusted. Early HES analyses reported stable age-standardised hospital admission rates for hip fractures in men and women in England between 1989 and 1998 [25], and gender-specific trends similar to those we report were seen in older adults between 2003 and 2013 [26]. Gender differences in secular trends in hip fracture incidence may be partly explained by an under-appreciation of osteoporosis as a disease that affects men. Despite a third of all hip fractures worldwide occurring in men [48], and their higher associated mortality [49], men are less likely to receive osteoporosis treatment than women [24, 45, 50]. A UK study found that women were 50% more likely than men to be initiated on an anti-osteoporosis drug within the year following an incident hip fracture over the period 2000 to 2010 [45]. The use of androgen deprivation therapy to treat prostate cancer has risen in England since the 1980s from 33,000 prescriptions in 1987 to 470,000 prescriptions in 2004 and is a well-established risk factor for fracture [51, 52]. Whilst the frequency of alcohol consumption has decreased considerably from 2005 to 2014, in men alcohol consumption more than three times the daily recommended limit has only marginally decreased from 12% in 2005 to 10% in 2014 [53].

Our findings that the proportion of age-standardised hip fracture admissions in both men and women who have comorbidity has risen from 2008 to 2014 further highlights the importance of hip fracture prevention in those with comorbid conditions; a similar trend has been observed in the USA using Medicare claims data from 1985 to 2005 [24]. Nationally the burden of comorbidity is growing; the number of people with multiple comorbidities is predicted to rise from 1.9 million in 2008 to 2.9 million in 2018 in the UK [54]. Furthermore, deprivation is associated with higher rates of comorbidity [55, 56]. The increasing burden of comorbid disease amidst our growing ageing population is likely to have a significant impact on future hip fracture incidence.

Limitations

We calculated hip fracture incidence rates based on individuals, and therefore, we limited our analyses to the first occurrence of hip fracture for each patient, which is likely to lead to an underestimation of hip fracture incidence (8.7% of hip fractures are thought to be second hip fractures [57]). The vast majority of hip fractures are expected to be managed in an NHS hospital; however, a small proportion may have been admitted directly to privately financed healthcare facilities and hence were not captured in HES, again leading to an underestimation of hip fracture incidence, particularly among those least deprived. The quality of clinical coding in HES is liable to have changed over time in response to changes in health care tariff systems, influencing the recording of comorbidities over our study period and potentially contributing to the apparent increasing burden of comorbid disease. Hence, we may have underestimated the proportion of hip fracture admissions with comorbidity during the earlier years of our analyses. Finally, we used an area-based measure of deprivation as a proxy for an individual's level of deprivation, so this ecological measure will in some cases misclassify individuals.

Conclusion

Our study is the largest UK population-based study of incident hip fracture admissions assessed by levels of deprivation in both men and women for more than a decade. The availability of patient-level data for all hip fracture admissions to English NHS hospitals over a 14-year period allowed us to undertake detailed examination of secular trends in hip fracture incidence, stratified by IMD quintiles and gender, using a valid measure of deprivation specific to the English context. We have demonstrated firstly that, after accounting for age, hip fracture incidence is declining in women, but is rising in men; secondly, deprivation predicts increased hip fracture incidence in both women and men, with a stronger relative impact among men. However, owing to the overall higher incidence of hip fractures in women, deprivation has a greater impact on the number of hip fractures among women. Thirdly, despite UK Government and public health initiatives to both address health inequalities and prevent hip fractures, absolute inequalities in hip fracture incidence have persisted among both men and women over the 14 years studied, with the health inequality gap marginally widening among women. Our findings stress the need for reassessment of current national public health strategies to prevent hip fractures. Particular focus is needed on the development of health policies that address persisting social and gender inequalities.

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Compliance with ethical standards We obtained NHS Research Ethics Committee approval for this study (REC reference: 15/LO/1056).

Conflict of interest None.

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Original Research

Inequalities in hip fracture incidence are greatest in the North of England: regional analysis of the effects of social deprivation on hip fracture incidence across England

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ABSTRACT

Objectives: Hip fracture risk varies by geography and by levels of deprivation. We examined the effect of local area-level deprivation on hip fracture incidence across nine regions in England, using 14 years of hospital data, to determine whether inequalities in hip fracture incidence rates vary across geographic regions in England.
Study design: Sequential annual cross-sectional studies over 14 years.
Methods: We used English Hospital Episodes Statistics (2001/02–2014/15) to identify hip fractures in adults aged 50+ years and mid-year population estimates (2001–2014) from the Office for National Statistics. The Index of Multiple Deprivation was used to measure local area deprivation. We calculated age-standardised hip fracture incidence rates per 100,000 population, stratified by gender, geographic region, deprivation quintiles and time-period, using the 2001 English population as the reference population. Using Poisson regression, we calculated age-adjusted incidence rate ratios (IRRs) for hip fracture, stratified as above.
Results: Over 14 years, we identified 747,369 hospital admissions with an index hip fracture. Age-standardised hip fracture incidence was highest in the North East for both men and women. In North England (North East, North West and Yorkshire and the Humber), hip fracture incidence was relatively higher in more deprived areas, particularly among men: IRR most vs least deprived quintile 2.06 (95% confidence interval [CI] = 2.00–2.12) in men, 1.62 (95% CI 1.60–1.65) in women. A relationship, albeit less marked, between deprivation and hip fracture incidence was observed among men in the Midlands and South, but with no clear pattern among women.

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Conclusions: Regional variation in hip fracture incidence exists across England, with the greatest absolute burden of incident hip fractures observed in the North East for both men and women. Across local areas in North England, absolute and relative inequalities in hip fracture incidence were greater than in other regions. Our findings highlight the need for improved fracture prevention programmes that aim to reduce regional and social inequalities in hip fracture incidence.

Introduction

Hip fractures are an important public health problem, with significant impact on morbidity and mortality. Approximately 60,000 hip fractures occur annually in England,[1] and incidence is predicted to rise as our population ages. Hip fractures are costly with annual hospital costs estimated at £1.1 billion for the United Kingdom (UK).[2]

Worldwide geographic variation in hip fracture incidence is well documented, with the highest rates reported in Northern Europe and the United States (US).[3] Regional variation in hip fracture incidence rates has been demonstrated within New Zealand and the US.[4,5] Considerable regional variation in age-adjusted hip fracture incidence has been observed in the UK based on analysis of primary care data, with the lowest rates in London and the highest rates in the south west of England, Northern Ireland and Scotland.[6]

Greater deprivation has been associated with higher hip fracture rates in many high-income countries, including the UK. Analysing English Hospital Episodes Statistics (HES), we recently found that despite public health efforts to prevent hip fractures, amongst both men and women, greater deprivation predicts higher hip fracture incidence, and that, over the last 14 years, this health inequality gap has not narrowed for men and has marginally widened amongst women.[7] However, it is unknown whether inequalities in hip fracture incidence rates differ between geographic regions in England and whether this has changed over time.

We hypothesised that inequalities in hip fracture incidence are not uniformly distributed across the geographic regions of England and that greater inequalities in hip fracture incidence would be observed in more deprived regions, in part potentially owing to variation in lifestyle risk factors for fracture. Hence, we examined the effect of area-level social deprivation on hip fracture incidence in England, across nine geographic regions, over a 14-year period.

Methods

We used HES data from all National Health Service (NHS) hospitals in England for the period 1st April 2001 to 31st March 2015 to identify patients aged 50 years and older with an index case of hip fracture on or during admission using International Classification of Diseases, Tenth Revision (ICD-10) disease codes for fracture of neck of femur (S72.0), pertrochanteric fracture (S72.1) and subtrochanteric fracture (S72.2). We excluded patients aged below 50 years in whom hip fractures are primarily due to high-impact trauma and those with missing data (n = 4667) for age, gender, Index of Multiple Deprivation (IMD) or region of residence. We used Office for National Statistics annual mid-year population estimates for England from 2001 to 2014 as population denominators, stratified by age, gender, IMD quintiles and nine Government Office Regions (GORs). We categorised the nine GORs into three geographic regions: North of England (North East, North West and Yorkshire and the Humber), the Midlands (East Midlands, West Midlands and East of England) and South of England (South East, South West and London). The IMD is a relative measure of socio-economic deprivation for local areas comprising seven domains of deprivation. We categorised patients into deprivation quintiles based on the national ranking of their local residential area, with quintile 1 being the least deprived and quintile 5 the most deprived group.

We used direct standardisation to calculate age-standardised hip fracture incidence rates per 100,000 population for men and women, stratified by geographic region and IMD quintiles, using the 2001 English population as our reference population structure; age-standardised hip fracture incidence rates, further stratified by time-period, were calculated to assess secular trends. We also calculated age-standardised rates for individual GORs using the same approach. To describe the association between local area deprivation and hip fracture incidence stratified by geographic regions, separately for women and men, we fitted Poisson regression models with the number of hip fractures per group as the dependent variable and IMD quintile and age as independent variables, including the population size as an offset. Associations are presented as incidence rate ratios (IRRs) with 95% confidence intervals. All statistical analyses were conducted using Stata, version 14 IC (StataCorp, College Station, TX, USA).

Results

Over 14 years, we identified 747,369 people admitted to hospital with a hip fracture. Three quarters (74.2%) were women, and the median age was 83 years; 81 in men and 84 in women. A fifth (19.2%) occurred among individuals in the least deprived quintile and just under a fifth (18.8%) among those in the most deprived quintile.

Age-standardised hip fracture incidence was higher in women than in men and was higher among people living in the most deprived compared to the least deprived local areas.

Regional variation in hip fracture incidence

Overall, age-standardised hip fracture incidence was highest in the North East (343 hip fractures per 100,000 population) and lowest in London (279 per 100,000). In men, age-standardised hip fracture incidence was highest in the North East (230 per 100,000) and lowest in the East of England (192 per 100,000), whilst among women, incidence was highest in the North East (414 per 100,000) and lowest in London (330 per 100,000) [Fig. 1].

Regional variation in hip fracture incidence by deprivation

The association of deprivation with age-adjusted hip fracture incidence was strongest in the North of England, with a dose–response pattern observed in both men and women (Fig. 2). A less marked relationship between deprivation and hip fracture incidence was observed among men in the Midlands and the South, with no clear pattern seen among women residing in these regions (Fig. 2). Age-standardised hip fracture incidence was highest in the North compared to the Midlands and the South for both women and men, and particularly in the most deprived local areas (Table 1).

When analysed within the nine individual GORs, greater levels of deprivation were associated with higher hip fracture incidence in the North East, North West, Yorkshire and the Humber, East Midlands, West Midlands and London, for both men and women. Amongst men, patterns in the South East and South West were similar (Supplementary Table 1). In contrast, the opposite association between deprivation and hip fracture incidence was observed amongst women living in the East and South East of England and amongst men in the East of England, where hip fracture incidence was lower among people living in more deprived local areas.

Secular trends in hip fracture incidence by deprivation and region

In men, age-standardised hip fracture incidence increased across all strata of deprivation and all geographic regions between 2001 and 2014, except for more deprived men in the North and the least deprived men in the South among whom hip fracture incidence remained relatively stable (Fig. 3a). The greatest increase in age-standardised hip fracture incidence was observed among the least deprived men in the North and the most deprived men in the South; however, the rate of this increase in hip fracture incidence declined over the study period. For example, among the most deprived men in the South, hip fracture incidence increased by 30 hip fractures per 100,000 men between 2001–2005 and 2006–2010, and by 8 hip fractures per 100,000 men between 2006–2010 and 2011–2014 (Supplementary Table 2).

From 2001 to 2014, age-standardised hip fracture incidence decreased in women of all strata of deprivation and all geographical regions, except for the most deprived women in the Midlands and South in whom hip fracture incidence remained stable over time, and in the least deprived women in the North who showed a paradoxical increase in age-standardised hip fracture incidence over time (Fig. 3b). The greatest absolute decline in age-standardised hip fracture

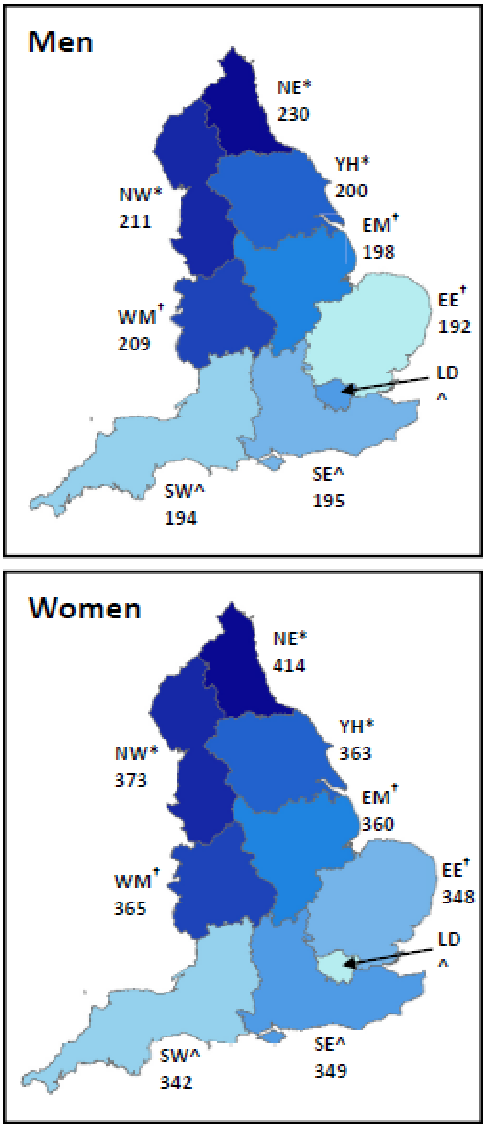

Fig. 1 – Regional variation in age-standardised hip fracture incidence among men and women aged 50+ years residing in England averaged over a 14-year period (numbers are incidence rates per 100,000 population). *North of England: North East (NE), North West (NW) and Yorkshire and the Humber (YH); †Midlands: East Midlands (EM), West Midlands (WM) and East of England (EE); ^South of England: South East (SE), South West (SW) and London (LD).

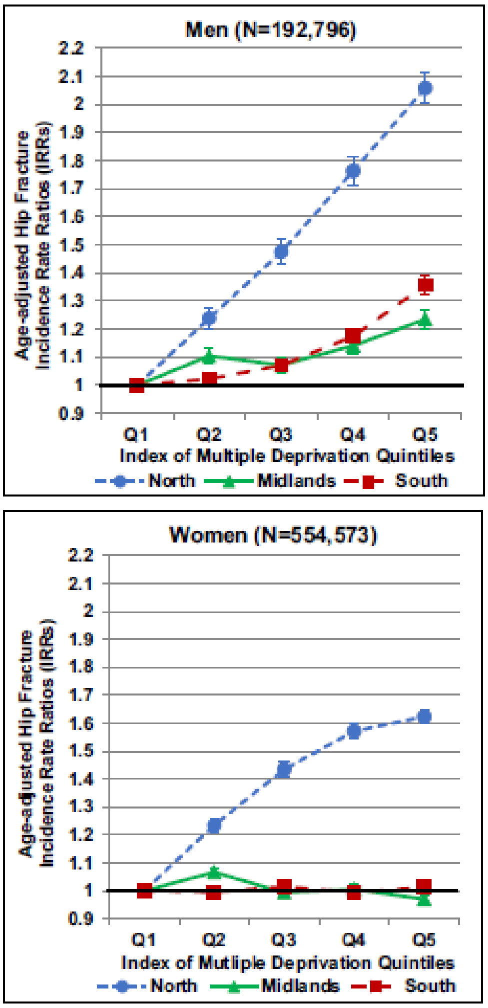

Fig. 2 – Geographical variation in the association between quintiles of deprivation and age-adjusted hip fracture incidence rate ratios in men and women aged 50+ years residing in England between 2001 and 2014 (Quintile 1 [Q1] [Least deprived quintile]—reference category; 95% confidence intervals presented). North (North East, North West and Yorkshire and the Humber); Midlands (East Midlands, West Midlands and East of England); South (South East, South West and London).

incidence was observed among the least deprived women in the South, decreasing from 387 to 296 hip fractures per 100,000 women between 2001–2005 and 2011–2014.

Discussion

This study examined the relationship between local area-based deprivation and hip fracture incidence in men and women aged 50 years and older in England and its geographic regions, analysing data collected over a 14-year period. We found marked geographical variation in age-standardised hip fracture incidence rates across England; the absolute burden of age-standardised hip fracture incidence was greatest in the North East of England for both men and women, whilst hip fracture incidence rates were lowest in the East of England and London for men and women, respectively. If age-standardised hip fracture incidence across all GORs was reduced to the level seen in the East of England in men and London in women, then each year across England, 3248 fewer (738 male and 2510 female) hip fractures would be recorded. Furthermore, for both men and women, the relative effect of deprivation on hip fracture incidence was most marked in the North of England, where absolute inequalities in hip fracture incidence were greatest. There were an additional 129 fractures per 100,000 men and 175 per 100,000 women in the most versus least deprived quintile in the North; this contrasts with an additional 52 per 100,000 male and 11 per 100,000 female hip fractures in the South.

These observed regional patterns in hip fracture incidence are in keeping with the wider body of literature documenting a 'North-South divide' in England, in which the health experiences in northern regions are generally poorer than the average for England, with the reverse being true for southern regions, and where the Midlands is comparable to the 'average for England'.[8]

The clear North-South gradient in hip fracture incidence that we observed in England contrasts with a recent UK study analysing Clinical Practice Research Datalink (CPRD) records from 1988 to 2012, which reported English hip fracture incidence to be highest in the South West and lowest in London for both men and women.[6] Whilst we also observed crude hip fracture incidence to be high in the South West, second only to the North East, this pattern was no longer evident after standardising for age. The CPRD analysis was not age-standardised, which may account for our differing conclusions. In addition, we analysed individual-level data derived from secondary rather than primary care sources and studied a 14-year period from 2001, whilst Curtis et al. studied a 24-year period from 1988. Such earlier data periods used ICD-9 codes to classify hip fractures whilst our analyses used ICD-10 codes. These methodological differences when defining the hip fracture populations may explain the differing findings from both studies.

Regional inequalities in hip fracture incidence across England may partly be explained by regional variation in lifestyle factors. Lifestyle factors such as heavy alcohol consumption and tobacco use are associated with an increased hip fracture risk in both men and women.[9,10] A North-South divide in smoking prevalence was identified in household population survey data (2014–2016) with rates highest in the North East and lowest in the South East.[11] A similar geographic pattern was observed for high-risk alcohol consumption, with the highest prevalence in the North; however, prevalence was lowest in London and the Midlands.

Alternatively, regional inequalities in hip fracture incidence rates may reflect geographic differences in access to fracture prevention services through service delivery models such as Fracture Liaison Services (FLS). CPRD records

Table 1 – Age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation, overall and in men and women aged 50+ years residing in the North, Midlands and South of England, 2001–2014.

IMD quintiles	Overall		Men		Women	
	No. of cases	Rate/100,000 population	No. of cases	Rate/100,000 population	No. of cases	Rate/100,000 population
North						
Q1	26,341	217	6679	142	19,662	267
Q2	36,328	268	8937	174	27,391	331
Q3	40,696	315	9892	204	30,804	384
Q4	48,288	354	12,040	240	36,248	423
Q5	71,125	379	19,220	271	51,905	442
Midlands						
Q1	44,328	283	11,463	185	32,865	352
Q2	53,433	306	13,570	202	39,863	375
Q3	52,453	289	13,398	194	39,055	352
Q4	43,893	298	11,275	205	32,618	357
Q5	36,567	299	10,063	216	26,504	349
South						
Q1	72,514	275	18,437	182	54,077	339
Q2	67,293	277	16,910	185	50,383	338
Q3	65,820	286	16,588	193	49,232	346
Q4	55,752	291	14,918	208	40,834	341
Q5	32,538	308	9406	234	23,132	350

IMD, Index of Multiple Deprivation.
Quintile 1 (Q1)—least deprived quintile, quintile 5 (Q5)—most deprived quintile.

(1990–2012) have shown prescription rates of oral anti-osteoporosis drugs (AODs), which aim to reduce fracture risk, vary across England with the highest prescription rates in the South West in both men and women, and the lowest amongst men in Yorkshire and the Humber and amongst women in the East Midlands.[12] However, AOD prescription does not necessarily translate to medication adherence, and whether adherence varies by region is unknown.

The Royal College of Physician's FLS-Database (RCP FLS-DB) facilities audit systematically appraises the organisation of FLSs in England and Wales with the aim of improving the quality of fragility fracture care.[13] Fewer than 50% of eligible sites in England participated in the first facilities audit in 2016, of which 65% (48/74) reported having a dedicated FLS, of which two-thirds (31/48) of these were in the South of England.

A final explanation could be that area-based deprivation is more closely associated with individual deprivation in the North of England compared to the South or Midlands. This could also explain the unexpected relationship between lower levels of deprivation and higher hip fracture incidence in certain Eastern GORs. Internal migration patterns among older people could lead to a difference in the socio-economic status of individuals over the greater part of their lives, relative to the deprivation of the area they currently live in. The greatest movement among older people is away from London and towards the South East, South West and East of England.[14] Of all English regions, London has the highest percentage of older people living in the most deprived local areas, as defined by the IMD Income Deprivation Affecting Older People Index, that is the proportion of adults aged 60 years and older living in pension credit households.[15] It can be hypothesised that people living in relatively deprived areas within London can afford to migrate later in life to more affluent regions in the South and East of England; however, they convey an increased hip fracture risk due to earlier life exposures to lifestyle risk factors for fracture.

The growing prioritisation of secondary fracture prevention programmes and routine orthogeriatric input into hip fracture care in the UK over the last decade may in part explain the declines in hip fracture incidence seen in women, although our findings would suggest that all men and more deprived women in the Midlands and South may not be realising equal benefit from such services. We have also demonstrated that for both men and women in the North of England, those who are least deprived have seen a progressive increase in age-standardised hip fracture incidence; the explanation for which remains unclear. The development of FLSs was recommended as part of the Department of Health's Prevention Package for Older People (2009) to improve fracture prevention.[16] The implementation of initiatives such as the National Hip Fracture Database in 2007 and the associated Best Practice Tariff in 2010 aimed to improve the quality of hip fracture care;[17] however, we cannot exclude a secondary influence on the quality of clinical HES coding of hip fractures which may in part explain an increase in the number of recorded hip fractures over this period.[7] We reported that hip fracture incidence has decreased over time in women and increased in men;[7] an observation that has been supported by a recent analysis of UK CPRD data, which showed that hip fracture incidence had similarly increased in men but plateaued in women.[18] The differential recording of hip fractures in HES according to gender and deprivation quintile is unlikely to explain the regional inequalities that we have described. Of note, we were unable to determine from HES codes, high vs. low-trauma fractures, nor very rare atypical femoral fractures.[19]

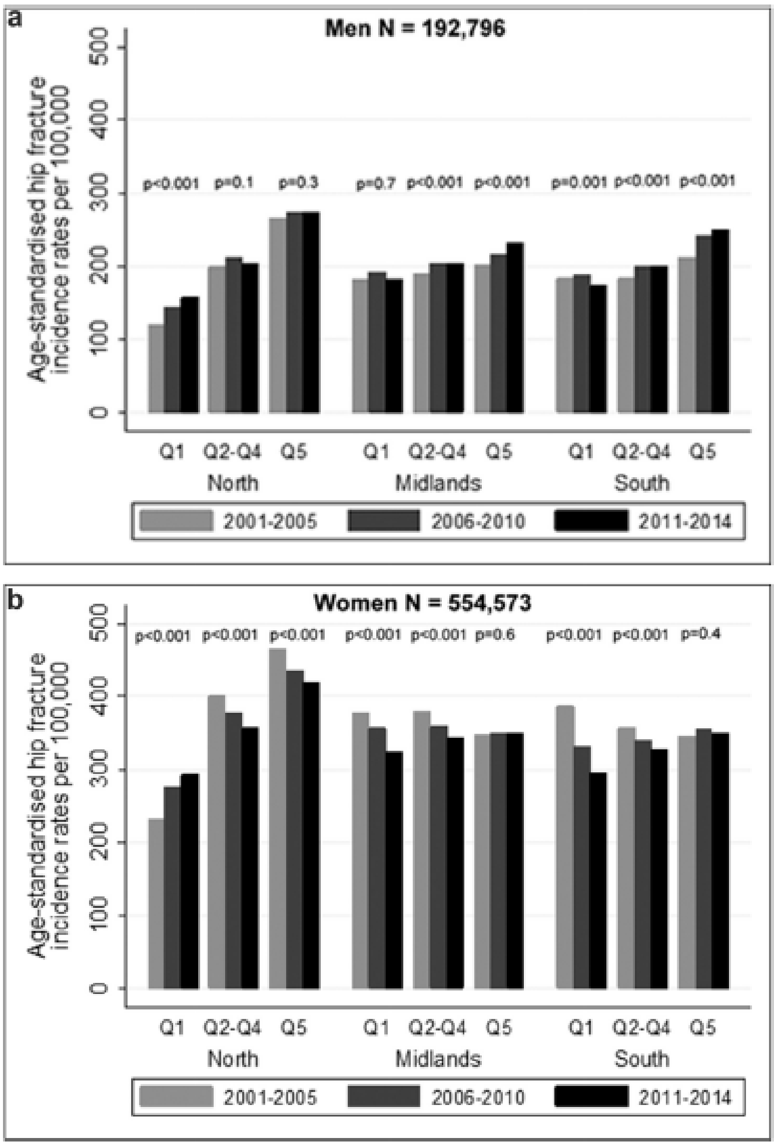

Fig. 3 – Secular trends in age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation, in (a) men and (b) women aged 50+ years residing in England, 2001–2014 (Quintile 1 [Q1]—least deprived quintile, quintile 5 [Q5]—most deprived quintile). North (North East, North West and Yorkshire and the Humber); Midlands (East Midlands, West Midlands and East of England); South (South East, South West and London). Poisson regression was used to assess trends in hip fracture incidence, adjusted for age group.

Conclusion

This is the first population-based study of inequalities in hip fracture incidence between and within geographic regions of England, using hospital administrative data collected over more than a decade. We have demonstrated that, after accounting for age, marked regional variation in hip fracture incidence exists across England, with the greatest absolute burden of incident hip fractures observed in the North East for both men and women. Furthermore, absolute and relative inequalities in hip fracture incidence linked to local area deprivation were greatest in the North of England for both men and women. Our findings highlight the need for fracture prevention programmes that aim to reduce regional and social inequalities in hip fracture incidence, with arguably the greatest need in the North of England. The RCP FLS-DB offers an opportunity to audit regional variation in such fracture prevention programmes.

Author statements

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Ethical approval

The authors obtained the NHS Research Ethics Committee approval for this study (REC reference: 15/LO/1056).

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None declared.

Competing interests

Arti Gauvri Bhimjiyani, Jenny Neuburger, Timothy Jones, Yoav Ben-Shlomo and Celia L Gregson have no disclosures.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.puhe.2018.05.002.

13.2. Systematic review supplementary methods

Systematic review protocol registered on PROSPERO

PROSPERO
International prospective register of systematic reviews

NHS
National Institute for Health Research

What is the effect of deprivation on the incidence of fragility fracture in adults aged 50 years or older?

Arti Bhimjiyani, Celia Gregson, Yoav Ben-Shlomo

Citation

Arti Bhimjiyani, Celia Gregson, Yoav Ben-Shlomo. What is the effect of deprivation on the incidence of fragility fracture in adults aged 50 years or older?. PROSPERO 2016 CRD42016032866 Available from:
http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42016032866

Review question

What is the effect of deprivation on the incidence of fragility fracture in adults aged 50 years or older?

Searches

A systematic search of electronic databases will be undertaken and will include articles published from the commencement of the database to current date. Articles published in any language will be considered for inclusion in this review.
The following electronic databases will be searched to identify relevant published literature:
Medical – MEDLINE, Embase
Social Science – Web of Science, PsycINFO, Cumulative Index to Nursing and Allied Health (CINAHL)
The following organisational websites will be searched to identify relevant grey literature:
Osteoporosis Review (National Osteoporosis Society)
Bone Research Society abstracts
European Calcified Tissue Society (ECTS) abstracts
American Society for Bone and Mineral Research (ASBMR) abstracts
In addition, relevant literature will be identified through snowballing methods and citation searches.

Types of study to be included

We plan to include any study that examines the relationship between deprivation and incidence of fragility fractures, including studies that use an individual and/or ecological measure of deprivation. This will include the following study designs: cohort studies (prospective and retrospective), case-control studies, cross-sectional studies (including registry/database studies) and ecological studies. Studies published in any language will be considered for inclusion in this review. We plan to exclude the following study designs: case reports, case series, qualitative studies and review articles.

Condition or domain being studied

"Fragility fractures are fractures that result from mechanical forces that would not ordinarily result in fracture, known as low-level (or 'low energy') trauma (1). The World Health Organization (WHO) has quantified this as forces equivalent to a fall from a standing height or less."
Source: Osteoporosis: assessing the risk of fragility fracture NICE guidelines [CG146]
https://www.nice.org.uk/guidance/CG146/chapter/Introduction
(1) Kanis JA, Oden A, Johnell O et al. (2001) The burden of osteoporotic fractures: a method for setting intervention thresholds. Osteoporosis International 12: 417–27.

Participants/population

Adults aged 50 years or older who have sustained a fragility fracture.
This excludes adults who have sustained trauma-related fractures defined as any road traffic accident- (RTA) or multi-vehicle accident (MVA)-related fractures, and pathological fractures due to metastases.

Intervention(s), exposure(s)

Studies assessing the effect of deprivation on the incidence of fragility fracture, including individual-based measures of deprivation (e.g. education, income, occupation, socio-economic status and ethnicity) and area-based measures of deprivation (e.g. Index of Multiple Deprivation, Townsend score and Carstairs score).
Studies assessing the effect of deprivation on readmissions of fragility fractures will be excluded.

Comparator(s)/control
Incidence in the most deprived group will be compared with that in the least deprived group.

Context
We plan to include studies that have been conducted in all geographic contexts.

Main outcome(s)
Incidence of fragility fractures of the hip/spine/humerus/wrist.

Additional outcome(s)
None.

Data extraction (selection and coding)
One author (AB) will examine the titles and abstracts of all studies retrieved from the literature searches and assess eligibility for inclusion based on the study inclusion and exclusion criteria outlined. Any studies where it is unclear whether the study meets the review eligibility criteria will be discussed with the review co-authors (CLG and YBS) for final agreement.
We have developed a data extraction form that will be piloted on the first 10% of studies identified from our literature search and will be modified based on any feedback determined from the pilot process.
It is anticipated that one author (AB) will extract data on the following variables and any queries that arise will be discussed with the review co-authors (CLG and YBS) for final agreement:
Study design; study setting: primary and/or secondary care; data source; geographical region (e.g. country) and level (e.g. city, town, village, etc.); population (including overall size, age, gender and ethnicity); type of fracture; time period of study (start and end date); deprivation measure; domains of deprivation measure (e.g. education, income, health, etc.); categorisation of deprivation score (e.g. quintiles, deciles) and deprivation score; incidence as a rate or proportion, including information on the denominator; method(s) of analysis; adjustment (age, gender, co-morbidity, other); stratification (age, gender).

Risk of bias (quality) assessment
We plan to use the Newcastle-Ottawa Scale to assess the methodological quality of included observational studies. We do not intend to assess the methodological quality of ecological studies given that there is no widely accepted quality appraisal tool for this study design, however we plan to include these studies in our review for completeness.

Strategy for data synthesis
We plan to perform a narrative synthesis of the data identified.

Analysis of subgroups or subsets
We plan to analyse data by age, gender and fracture type depending on data availability.

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Type and method of review

Anticipated or actual start date
01 February 2016

Anticipated completion date

30 June 2016

Funding sources/sponsors
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Conflicts of interest
None known

Language
English

Country
England

Stage of review
Review Ongoing

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Adult; Age Factors; Bone and Bones; Bone Density; Fractures, Bone; Humans; Incidence; Osteoporosis; Risk Factors

Date of registration in PROSPERO
02 February 2016

Date of publication of this version
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Details of any existing review of the same topic by the same authors

Stage of review at time of this submission
The review has not started

Stage	Started	Completed
Preliminary searches	No	No
Piloting of the study selection process	No	No
Formal screening of search results against eligibility criteria	No	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Versions
02 February 2016

Systematic search strategy and results retrieved from electronic searches of medical and social science databases conducted in 2016

Line no.	Search terms	No. of records
Individual-level SEP		
1	exp Social Class/ or exp Social Conditions/ or exp Social Mobility/ or exp socioeconomic factors/	647,514
2	((socioeconomic or "socio economic" or socio-economic) adj2 (status or position$ or factor$ or disadvantage$ or condition$ or depriv$ or mobil$ or inequality$ or inequit$)).tw.	130,006
3	(social$ adj2 (mobil$ or condition$ or circumstance$ or class$ or inequalit$ or inequit$)).tw.	60,093
4	(SES or SEP).tw.	58,338
5	((social$ or economic$) adj2 depriv$).tw.	7,454
6	1 or 2 or 3 or 4 or 5	782,233
7	exp Occupations/ or exp Employment/ or exp Income/ or exp Education/ or exp Poverty/ or exp Ethnic groups/	2,694,842
8	(occupation$ or manual or income or educat$ or poverty$ or ethnic$).tw.	2,251,152
9	((educat$ or educational) adj2 attainment).tw.	16,210
10	(employed or employment).tw.	724,234
11	7 or 8 or 9 or 10	4,576,419
12	6 or 11	4,897,414
Area-based deprivation		
13	exp Poverty Areas/ or exp Residence Characteristics/	245,524
14	((poor or poverty or depriv$) adj2 areas).tw.	6,603
15	(residen$ adj2 characteristic$).tw.	2,565
16	("household size" or overcrowd$).tw.	8,779
17	(index adj2 (multiple adj2 deprivation)).tw.	927
18	(IMD or LSOA).tw.	3,396
19	(IMD adj2 (rank or score)).tw.	136
20	(Townsend adj2 (score$ or depriv$ or index or indices)).tw.	697
21	(Carstairs adj2 (score$ or depriv$ or index or indices)).tw.	315
22	(("neighborhood" or "neighbourhood" or "area-level") adj2 (disadvantage$ or depriv$)).tw.	2,496
23	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22	266,913

Individual-level SEP and area-based deprivation combined

24	12 or 23	5,035,637

Fragility fractures

Line no.	**Search terms**	**No. of records**
25	exp Hip Fractures/ or exp Femoral Neck Fractures/	53,053
26	((hip or femur$ or femoral or "femoral neck") adj2 fracture$).tw.	55,175
27	((neck or proximal) adj2 femur$ adj2 fracture$).tw.	2,954
28	NOF.tw.	896
29	25 or 26 or 27 or 28	78,604
30	exp Spinal Fractures/ or exp Fractures, Compression/	30,237
31	((spine or spinal or vertebra$ or wedge or compression) adj2 fracture$).tw.	32,065
32	30 or 31	47,580
33	exp Humeral Fractures/	15,401
34	((humerus or humeral or "upper arm" or "proximal arm") adj2 fracture$).tw.	9,367
35	33 or 34	18,977
36	exp Colles Fracture/ or exp Radius Fractures/	16,643
37	((wrist or colles$ or "distal radius" or radi$ or forearm) adj2 fracture$).tw.	18,105
38	36 or 37	25,979
39	("major osteoporotic fracture" or "MOF").tw.	7,321
40	29 or 32 or 35 or 38 or 39	166,230

Epidemiology

41	exp Incidence/ or exp Prevalence/ or exp Epidemiology/	2,824,092
42	(inciden$ or prevalen$ or epidemiolog$ or (new adj2 cases) or rate).tw.	6,524,258
43	41 or 42	7,923,009

Final search result

44	24 and 40 and 43	4,203

List of systematic review variables for which data were extracted

Data extraction criteria	**Data extraction variable**
Study details	First Author Year of publication Aims and objectives
Methods	
Study design	Study design Data source Study period
Geography	Country National/regional study Rural/urban setting
Study population	Characteristics of study sample, including age and gender criteria Site of fracture occurrence Exclusion criteria
Exposure	Measure used to define individual-level SEP and area-based deprivation Methods used to categorise exposure variable
Statistical analyses	Absolute and relative measures of association e.g. incidence rates, incidence rate ratio Statistical methods Potential confounders
Results	
Description of study population	Descriptive characteristics of study sample
Main findings	Absolute and relative measures of association stratified by fracture site and age/gender if available
Additional information	
Summary	Summary of key findings Study limitations Additional comments

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE
CASE CONTROL STUDIES

Selection (maximum 4 stars)

1) Is the case definition adequate?
   a) yes, with independent validation ✵
   b) yes, e.g. record linkage or based on self reports
   c) no description

2) Representativeness of the cases
   a) consecutive or obviously representative series of cases ✵
   b) potential for selection biases or not stated

3) Selection of Controls
   a) community controls ✵
   b) hospital controls
   c) no description

4) Definition of Controls
   a) no history of disease (endpoint) ✵
   b) no description of source

Comparability (maximum 2 stars)

1) Comparability of cases and controls on the basis of the design or analysis
   a) study controls for ________________ (Select the most important factor.) ✵
   b) study controls for any additional factor ✵ (This criteria could be modified to indicate specific control for a second important factor.)

Exposure (maximum 3 stars)

1) Ascertainment of exposure
   a) secure record (e.g. surgical records) ✵
   b) structured interview where blind to case/control status ✵
   c) interview not blinded to case/control status
   d) written self report or medical record only
   e) no description

2) Same method of ascertainment for cases and controls
   a) yes ✵
   b) no

3) Non-Response rate
   a) same rate for both groups ✵
   b) non respondents described
   c) rate different and no designation

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE
COHORT STUDIES

Selection (maximum 4 stars)

1) Representativeness of the exposed cohort
   a) truly representative of the average _______________ (describe) in the community ❋
   b) somewhat representative of the average ______________ in the community ❋
   c) selected group of users e.g. nurses, volunteers
   d) no description of the derivation of the cohort

2) Selection of the non exposed cohort
   a) drawn from the same community as the exposed cohort ❋
   b) drawn from a different source
   c) no description of the derivation of the non exposed cohort

3) Ascertainment of exposure
   a) secure record (e.g. surgical records) ❋
   b) structured interview ❋
   c) written self report
   d) no description

4) Demonstration that outcome of interest was not present at start of study
   a) yes ❋
   b) no

Comparability (maximum 2 stars)

1) Comparability of cohorts on the basis of the design or analysis
   a) study controls for _____________ (select the most important factor) ❋
   b) study controls for any additional factor ❋ (This criteria could be modified to indicate specific control for a second important factor.)

Outcome (maximum 3 stars)

1) Assessment of outcome
   a) independent blind assessment ❋
   b) record linkage ❋
   c) self report
   d) no description

2) Was follow-up long enough for outcomes to occur
   a) yes (select an adequate follow up period for outcome of interest) ❋
   b) no

3) Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for ❋
   b) subjects lost to follow up unlikely to introduce bias - small number lost - > ____ % (select an adequate %) follow up, or description provided of those lost) ❋
   c) follow up rate < ____% (select an adequate %) and no description of those lost
   d) no statement

MODIFIED NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE CROSS-SECTIONAL STUDIES

Adapted from the systematic review conducted by Herzog et al titled ‘Are Healthcare Workers’ Intentions to Vaccinate Related to their Knowledge, Beliefs and Attitudes? A Systematic Review’

Selection (maximum 4 stars)

1) Representativeness of the sample:
   a) Truly representative of the average in the target population. * (all subjects or random sampling)
   b) Somewhat representative of the average in the target population. * (non-random sampling)
   c) Selected group of users.
   d) No description of the sampling strategy.

2) Sample size:
   a) Justified and satisfactory. *
   b) Not justified.

3) Non-respondents:
   a) Comparability between respondents and non-respondents characteristics is established, and the response rate is satisfactory. *
   b) The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory.
   c) No description of the response rate or the characteristics of the responders and the non responders.

4) <u>Ascertainment of exposure</u>
   a) secure record (e.g. surgical records) ✸
   b) structured interview ✸
   c) written self report
   d) no description

Comparability (maximum 2 stars)

1) The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled.
   a) The study controls for the most important factor (select one). *
   b) The study control for any additional factor. *

Outcome (maximum 3 stars)

1) Assessment of the outcome:
   a) Independent blind assessment. **
   b) Record linkage. **
   c) Self report. *
   d) No description.

2) Statistical test:
   a) The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals and the probability level (p value). *
   b) The statistical test is not appropriate, not described or incomplete.

13.3. Comparison of ONS MYPE data

Table 60: Comparison of population counts derived from two different sources of ONS MYPE data stratified by quintiles of deprivation in men and women aged 50+ years, 2005-2014

	Males		Females	
IMD Quintile	**AB ONS MYPE**	**TJ ONS MYPE**	**AB ONS MYPE**	**TJ ONS MYPE**
Q1 - Least deprived	18,442,660	19,074,594	20,667,675	21,332,733
Q2	17,994,005	18,654,041	20,342,757	21,052,859
Q3	17,336,360	17,678,335	19,704,167	20,098,707
Q4	16,093,928	15,289,155	18,462,124	17,541,547
Q5 - Most deprived	14,457,232	13,628,060	16,398,059	15,548,936
Total	84,324,185	84,324,185	95,574,782	95,574,782

IMD – Index of Multiple Deprivation; ONS – Office for National Statistics; MYPE – mid-year population estimates

13.4. Quality assessment criteria for identifying linked hip fracture admissions in HES-ONS and NHFD datasets

Table 61: Cross-tabulation of difference between HES-ONS and NHFD admission and operation dates

Difference between HES-ONS and NHFD operation dates (days)	Difference between HES-ONS and NHFD admission dates (days) (N (%))		Total (N (%))
	0-10 days	**>10 days[a]**	
0-3	355,235 (94.8)	10,954 (77.4)	366,189 (94.2)
>3	7,712 (2.1)	1,783 (12.6)	9,495 (2.4)
Missing	11,670 (3.1)	1,424 (10.1)	13,094 (3.4)
Total	374,617	14,161	388,778

[a] column percentage does not total to 100% due to rounding error

HES – Hospital Episode Statistics; ONS – Office for National Statistics; NHFD – National Hip Fracture Database

Table 62: Tabulation of difference between patient age recorded in HES-ONS and NHFD datasets

Difference between patient age recorded in HES-ONS and NHFD datasets (years)	N (%)[a]
0 or 1	385,977 (99.3)
>1	2,653 (0.68)
Missing	148 (0.04)
Total	388,778

[a] column percentage does not total to 100% due to rounding error

HES – Hospital Episode Statistics; ONS – Office for National Statistics; NHFD – National Hip Fracture Database

Table 63: Tabulation of difference between patient gender recorded in HES-ONS and NHFD datasets

Patient gender recorded in HES-ONS and NHFD datasets	N (%)[a]
Same gender	385,798 (99.2)
Different gender	2,980 (0.77)
Total	388,778

[a] column percentage does not total to 100% due to rounding error

HES – Hospital Episode Statistics; ONS – Office for National Statistics; NHFD – National Hip Fracture Database

Table 64: Tabulation of difference between hospital provider codes recorded in HES-ONS and NHFD datasets

Hospital provider code recorded in HES-ONS and NHFD datasets	N (%)
Same provider code	374,080 (96.2)
Different provider code	14,698 (3.8)
Total	388,778

HES – Hospital Episode Statistics; ONS – Office for National Statistics; NHFD – National Hip Fracture Database

13.5. Annual age-standardised hip fracture incidence rates by quintiles of deprivation

Table 65: Annual age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation in men and women aged 50+ years, 2001-2014

	Q1 - Least deprived		Q2-Q4		Q5 - Most deprived	
Year	**No. of cases**	**Rate/ 100,000**	**No. of cases**	**Rate/ 100,000**	**No. of cases**	**Rate/ 100,000**
2001/02	9,050	280	31,420	308	10,170	339
2002/03	9,494	288	32,321	314	10,329	345
2003/04	9,453	281	32,048	309	10,166	343
2004/05	9,529	277	31,848	304	10,051	341
2005/06	9,694	274	31,995	300	10,096	342
2006/07	9,640	264	32,417	299	9,986	338
2007/08	10,218	272	32,902	298	9,891	335
2008/09	10,437	270	32,834	294	9,932	338
2009/10	10,669	268	33,757	298	9,994	340
2010/11	10,650	259	33,888	292	9,936	337
2011/12	10,832	254	34,347	290	9,965	336
2012/13	10,948	248	34,439	284	9,979	334
2013/14	11,400	251	35,399	287	10,153	340
2014/15	11,169	238	34,341	272	9,582	317

13.6. Tests for interaction to examine the relationship between deprivation and hip fracture incidence over time and according to patient characteristics

Table 66: Tests for interaction to examine whether secular trends in hip fracture incidence differ according to gender and deprivation quintiles

Covariate	Gender sub-groups	Time x covariate interaction term[a] Age-adjusted IRR (95% CI)[b]	LRT p-value
Female gender (ref – male gender)		0.98 (0.98, 0.98)	<0.001
Deprivation[c]	Overall	1.01 (1.01,1.01)	<0.001
	Men	1.00 (1.00,1.01)	0.11
	Women	1.01 (1.01,1.01)	<0.001

[a] Time was modelled as a continuous term

[b] Age was categorised in 5-yearly age groupings from 50 years to 90+ years

[c] Deprivation was modelled as an ordinal variable; deprivation x covariate interaction term presented for quintile 5 (Q5 – most deprived quintile) with quintile 1 (Q1 – least deprived quintile) as the reference category

IRR – incidence rate ratio; CI – confidence interval; LRT – likelihood ratio test; ref – reference category

Table 67: Tests for interaction to examine whether the effect of deprivation on hip fracture incidence differs according to gender and age group

Covariate	Deprivation x covariate interaction term[a] IRR (95% CI)	LRT p-value
Female gender[b] (ref – male gender)	0.78 (0.77,0.80)	<0.001
Age 85+ years (ref – age group 50-84 years)	0.68 (0.67,0.69)	<0.001

[a] Deprivation was modelled as an ordinal variable; deprivation x covariate interaction term presented for quintile 5 (Q5 – most deprived quintile) with quintile 1 (Q1 – least deprived quintile) as the reference category

[b] Adjusted for age categorised in 5-yearly age groupings from 50 years to 90+ years

IRR – incidence rate ratio; CI – confidence interval; LRT – likelihood ratio test; ref – reference category

Table 68: Tests for interaction to examine whether secular trends in hip fracture incidence differ according to deprivation quintiles in men aged 50-84 years and 85+ years

Covariate	Age groups	Time x covariate interaction term[a] IRR (95% CI)	LRT p-value
Deprivation[b]	50-84 years	0.99 (0.99,1.00)	<0.001
	85+ years	1.01 (1.00,1.02)	0.02

[a] Time was modelled as a continuous term

[b] Deprivation was modelled as an ordinal variable; deprivation x covariate interaction term presented for quintile 5 (Q5 – most deprived quintile) with quintile 1 (Q1 – least deprived quintile) as the reference category

IRR – incidence rate ratio; CI – confidence interval; LRT – likelihood ratio test; ref – reference category

Table 69: Tests for interaction to examine whether secular trends in hip fracture incidence differ according to deprivation quintiles in women aged 50-84 years and 85+ years

Covariate	Age groups	Time x covariate interaction term[a] IRR (95% CI)	LRT p-value
Deprivation[b]	50-84 years	0.99 (0.99,0.99)	<0.001
	85+ years	1.01 (1.01,1.01)	<0.001

[a] Time was modelled as a continuous term

[b] Deprivation was modelled as an ordinal variable; deprivation x covariate interaction term presented for quintile 5 (Q5 – most deprived quintile) with quintile 1 (Q1 – least deprived quintile) as the reference category

IRR – incidence rate ratio; CI – confidence interval; LRT – likelihood ratio test; ref – reference category

13.7. Age-standardised hip fracture incidence rates by quintiles of deprivation and geographic region of residence

Table 70: Age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation, in men and women aged 50+ years residing in the 9 Government Office Regions of England, 2001-2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

	North			
IMD quintiles	Men		Women	
	No. of cases	Rate/ 100,000	No. of cases	Rate/ 100,000
	North East			
Q1	832	113	2,567	231
Q2	1,405	181	4,114	326
Q3	1,751	224	5,477	424
Q4	2,655	245	8,188	451
Q5	4,368	318	11,897	518
	North West			
Q1	3,368	149	9,557	270
Q2	4,148	172	12,614	326
Q3	4,508	205	14,131	384
Q4	5,429	242	16,190	419
Q5	9,237	268	24,626	435
	Yorkshire and Humber			
Q1	2,479	144	7,538	278
Q2	3,384	173	10,663	338
Q3	3,633	196	11,196	367
Q4	3,956	234	11,870	411
Q5	5,615	248	15,382	407

	Midlands			
IMD quintiles	Men		Women	
	No. of cases	Rate/ 100,000	No. of cases	Rate/ 100,000
	East Midlands			
Q1	3,180	183	9,025	344
Q2	3,607	177	10,687	339
Q3	3,473	205	10,073	369
Q4	3,494	215	10,152	387
Q5	2,903	225	7,817	371
	West Midlands			
Q1	2,669	157	7,585	298
Q2	4,264	207	12,361	369
Q3	4,567	205	13,532	370
Q4	4,145	228	12,046	392
Q5	5,632	237	14,528	380
	East of England			
Q1	5,614	204	16,255	390
Q2	5,699	218	16,815	407
Q3	5,358	181	15,450	327
Q4	3,636	177	10,420	304
Q5	1,528	155	4,159	250

	South			
IMD quintiles	Men		Women	
	No. of cases	Rate/ 100,000	No. of cases	Rate/ 100,000
	London			
Q1	2,352	152	6,915	287
Q2	3,313	167	9,810	296
Q3	4,133	186	12,090	331
Q4	5,744	205	14,906	334
Q5	5,140	258	12,080	387
	South East			
Q1	11,786	194	34,896	362
Q2	7,763	184	23,675	345
Q3	6,341	195	18,870	345
Q4	4,629	213	12,996	348
Q5	2,143	212	5,570	317
	South West			
Q1	4,299	171	12,266	314
Q2	5,834	198	16,898	358
Q3	6,114	195	18,272	359
Q4	4,545	207	12,932	343
Q5	2,123	212	5,482	318

13.8. Secular trends in age-standardised hip fracture incidence rates by quintiles of deprivation and geographic region of residence

Table 71: Secular trends in age-standardised hip fracture incidence rates per 100,000 population by quintiles of deprivation, in men and women aged 50+ years residing in England, 2001-2014

(Quintile 1 (Q1) – least deprived quintile, quintile 5 (Q5) – most deprived quintile)

IMD quintiles	Time-period	Males		Females	
		No. of cases	Rate/ 100,000	No. of cases	Rate/ 100,000
North					
Q1	2001-2005	1,662	119	5,432	231
	2006-2010	2,446	144	7,260	276
	2011-2014	2,571	158	6,970	293
Q2-Q4	2001-2005	9,436	199	34,016	401
	2006-2010	11,371	212	33,494	377
	2011-2014	10,062	205	26,933	357
Q5	2001-2005	6,513	265	20,147	465
	2006-2010	6,938	274	18,124	435
	2011-2014	5,769	273	13,634	419
Midlands					
Q1	2001-2005	3,304	181	10,952	377
	2006-2010	4,253	192	11,932	357
	2011-2014	3,906	182	9,981	323
Q2-Q4	2001-2005	11,414	189	39,279	379
	2006-2010	13,972	204	39,641	359
	2011-2014	12,857	205	32,616	344
Q5	2001-2005	3,211	201	9,590	347
	2006-2010	3,613	216	9,387	349
	2011-2014	3,239	232	7,527	350
South					
Q1	2001-2005	5,677	183	20,193	387
	2006-2010	6,795	187	18,928	333
	2011-2014	5,965	174	14,956	296
Q2-Q4	2001-2005	14,719	183	50,768	357
	2006-2010	17,737	200	49,583	339
	2011-2014	15,960	199	40,098	327
Q5	2001-2005	2,948	212	8,403	346
	2006-2010	3,429	242	8,248	355
	2011-2014	3,029	250	6,481	350

13.9. Tests for interaction to examine the effect of individual-level risk factors on the relationship between deprivation and clinical outcomes after hip fracture

Table 72: Tests for interaction to examine the effect of individual-level risk factors (modelled as an ordinal term) on the relationship between deprivation (modelled as a continuous term) and mortality in the year after hip fracture

Age[a]

Mortality time-point	**Deprivation x covariate interaction term** Adjusted OR (95% CI)[b,c]	**LRT p-value**
7-day	1.00 (0.96,1.04)	0.86
30-day	0.98 (0.95,1.00)	0.05
120-day	0.99 (0.97,1.01)	0.27
365-day	0.98 (0.96,0.99)	0.0007

[a] Age was binarised as 60-84 years (reference category) and 85+ years
[b] Adjusted for gender and comorbidity
[c] Comorbidity was defined as no comorbidity, comorbidity that excluded dementia and dementia +/- other comorbidities
OR – odds ratio; CI – confidence interval; LRT – likelihood ratio test

Gender

Mortality time-point	**Deprivation x covariate interaction term** Adjusted OR (95% CI)[a,b]	**LRT p-value**
7-day	0.98 (0.95,1.02)	0.43
30-day	1.00 (0.97,1.02)	0.78
120-day	1.01 (0.99,1.02)	0.56
365-day	1.00 (0.99,1.02)	0.36

[a] Adjusted for age and comorbidity
[b] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia and dementia +/- other comorbidities
OR – odds ratio; CI – confidence interval; LRT – likelihood ratio test

Comorbidity[a]

Mortality time-point	Comorbidity strata	**Deprivation x covariate interaction term** Adjusted OR (95% CI)[b,c]	LRT p-value
7-day	Comorbidity excl. dementia	0.98 (0.91,1.04)	0.07
	Dementia	0.94 (0.87,1.01)	
30-day	Comorbidity excl. dementia	0.97 (0.93,1.01)	<0.001
	Dementia	0.92 (0.88,0.96)	
120-day	Comorbidity excl. dementia	0.98 (0.95,1.01)	<0.001
	Dementia	0.95 (0.92,0.97)	
365-day	Comorbidity excl. dementia	1.00 (0.98,1.02)	<0.001
	Dementia	0.96 (0.93,0.98)	

[a] Comorbidity was defined as no comorbidity (reference category), comorbidity that excluded dementia and dementia +/- other comorbidities

[b] Adjusted for age and gender

[c] Age was categorised in 5-yearly age groupings from 60 years to 90+ years

OR – odds ratio; CI – confidence interval; LRT – likelihood ratio test

Table 73: Tests for interaction to examine the effect of individual-level risk factors (modelled as an ordinal term) on the relationship between deprivation (modelled as a continuous term) and emergency 30-day readmission

Covariate	**Deprivation x covariate interaction term** Adjusted OR (95% CI)[a]	LRT p-value
Age 85+ years[b] (ref – 60-84 years)	0.99 (0.97,1.01)	0.24
Female gender[c] (ref – male gender)	0.99 (0.97,1.01)	0.32
Comorbidity excl. dementia[d] (ref – no comorbidity)	1.02 (0.99,1.04)	0.009
Dementia[d] (ref – no comorbidity)	1.04 (1.01,1.07)	

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia and dementia +/- other comorbidities

[b] Adjusted for gender and comorbidity

[c] Adjusted for age and comorbidity

[d] Adjusted for age and gender

OR – odds ratio; CI – confidence interval; LRT – likelihood ratio test; ref – reference category

Table 74: Tests for interaction to examine the effect of individual-level risk factors (modelled as an ordinal term) on the relationship between deprivation (modelled as a continuous term) and superspell LOS

Covariate	**Deprivation x covariate interaction term** Adjusted β coefficient (95% CI)[a]	LRT p-value
Age 85+ years[b] (ref – 60-84 years)	-0.20 (-0.34,-0.06)	0.004
Female gender[c] (ref – male gender)	0.00 (-0.15,0.15)	0.99
Comorbidity excl. dementia[d] (ref – no comorbidity)	0.05 (-0.12,0.21)	<0.001
Dementia[d] (ref – no comorbidity)	-0.38 (-0.56,-0.19)	

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia and dementia +/- other comorbidities

[b] Adjusted for gender and comorbidity

[b] Adjusted for age and comorbidity

[c] Adjusted for age and gender

LOS – length of stay; CI – confidence interval; LRT – likelihood ratio test; ref – reference category

Table 75: Tests for interaction to examine the effect of individual-level risk factors (modelled as an ordinal variable) on the relationship between deprivation (modelled as a continuous term) and total NHS bed days in the year after hip fracture

Covariate	**Deprivation x covariate interaction term** Adjusted β coefficient (95% CI)[a]	LRT p-value
Age 85+ years[b] (ref – 60-84 years)	-0.38 (-0.58,-0.19)	0.0001
Female gender[c] (ref – male gender)	-0.09 (-0.31,0.13)	0.41
Comorbidity excl. dementia[d] (ref – no comorbidity)	0.11 (-0.14,0.35)	0.24
Dementia[d] (ref – no comorbidity)	-0.09 (-0.37,0.18)	

[a] Age was categorised in 5-yearly age groupings from 60 years to 90+ years; comorbidity was defined as no comorbidity, comorbidity that excluded dementia and dementia +/- other comorbidities

[b] Adjusted for gender and comorbidity

[b] Adjusted for age and comorbidity

[c] Adjusted for age and gender

CI – confidence interval; LRT – likelihood ratio test; ref – reference category

13.10. Histograms summarising the distribution of hospital LOS after hip fracture

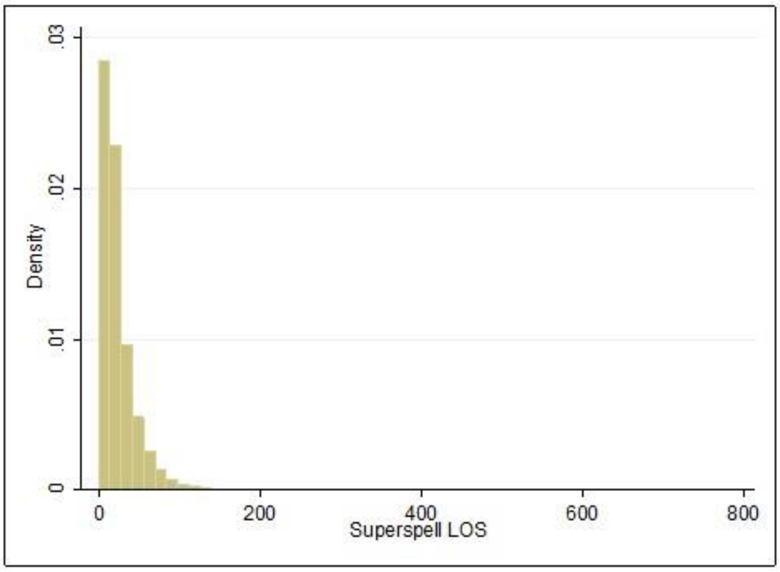

Figure 38: Histogram summarising the distribution of superspell LOS among men and women aged 60+ years admitted to hospital with a hip fracture between 1st April 2011 and 31st March 2015

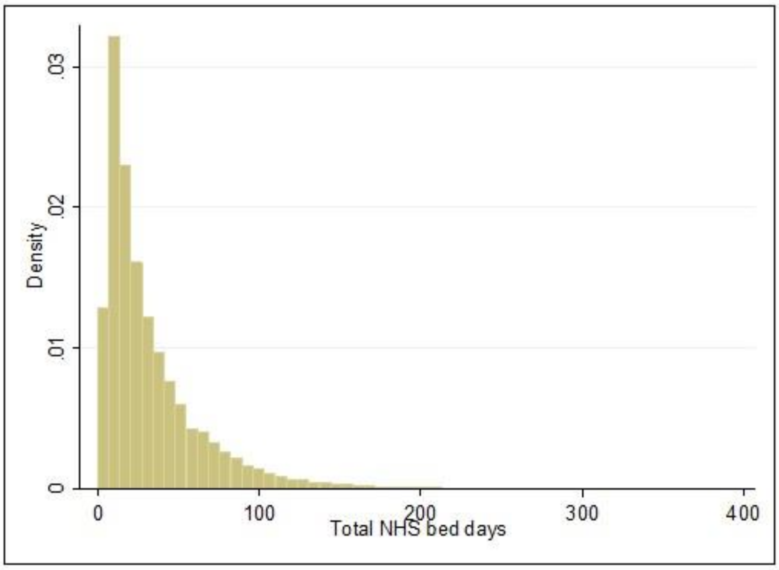

Figure 39: Histogram summarising the distribution of total NHS bed days in the year after hip fracture among men and women aged 60+ years admitted to hospital with a hip fracture between 1st April 2011 and 31st March 2015

13.11. Mean and median hospital LOS after hip fracture by levels of deprivation

Table 76: Mean and median superspell LOS in days by levels of deprivation among men and women aged 60+ years admitted to hospital with a hip fracture between 1st April 2011 and 31st March 2015

IMD quintile	Mean (SD)	Median (IQR)
Q1 (least deprived)	23.3 (22.1)	16 (10-29)
Q2	23.1 (21.1)	16 (10-29)
Q3	23.4 (21.2)	16 (10-30)
Q4	24.2 (22.0)	17 (10-31)
Q5 (most deprived)	24.4 (21.7)	17 (11-31)

LOS – length of stay ; SD – standard deviation; IQR – inter-quartile range

Table 77: Mean and median total NHS bed days in the year after hip fracture by levels of deprivation among men and women aged 60+ years admitted to hospital with a hip fracture between 1st April 2011 and 31st March 2015

IMD quintile	Mean (SD) days	Median (IQR) days
Q1 (least deprived)	32.3 (32.4)	21 (11-43)
Q2	32.2 (32.1)	21 (11-42)
Q3	33.3 (32.7)	22 (11-44)
Q4	34.3 (33)	23 (12-46)
Q5 (most deprived)	34.9 (33.6)	24 (12-46)

IMD – Index of Multiple Deprivation ; SD – standard deviation; IQR – inter-quartile range