UNIVERSITY OF SOUTHAMPTON

FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES

Department of Gerontology

Risk factors for hospital admission in an ageing English cohort: an analysis linking prospectively collected data with Hospital Episode Statistics

by

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ABSTRACT

FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES

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RISK FACTORS FOR HOSPITAL ADMISSION IN AN AGEING ENGLISH COHORT: AN ANALYSIS LINKING PROSPECTIVELY COLLECTED DATA WITH HOSPITAL EPISODE STATISTICS

Shirley Jill Simmonds

The UK has an ageing population in which overall life expectancy is growing faster than healthy life expectancy. The result is that an increasing number of older people are in poor health; these people contribute to rising trends in hospital admission and are commonly associated with the financial crisis in the NHS. Reducing demand on hospitals is enshrined in Government policy, but requires improved understanding of the determinants of service use; these may differ according to the type of admission under consideration. Only when the determinants of admission are clear can effective preventive measures be put in place.

This thesis describes the creation of a novel resource in which to investigate risk factors for hospital admission. This is achieved by combining data from two sources. The first is the Hertfordshire Cohort Study; a group of community-dwelling men and women whose physical, mental and social health were comprehensively characterised in 1998-2004 when they were aged 59-73 years. To these baseline data, routinely collected information about hospital admissions that participants experienced during the following decade has been added. The resulting resource has several advantages over hospital data alone: it includes variables that were prospectively collected; that go beyond those that are clinically relevant; and that cover non-admitted as well as admitted individuals.

Three papers based on the combined dataset are presented. Each takes the same panel of 25 predictor variables - chosen to summarise baseline demography and anthropometry, lifestyle, social circumstances, physical function and morbidity – and compares it with one of three admission outcomes: 30-day readmission, emergency admission or elective admission. Across both sexes, the papers identify six risk factors for 30-day readmission, five for emergency admission and four for elective admission. Two markers of overall burden of disease: poor self-rated health (SRH) and increased number of body systems medicated (NSM); conferred risk for all three outcomes. Poor physical function and history of smoking were associated with risk of two outcomes each. SRH was associated with emergency admission in both sexes and NSM with elective admission in both sexes. The likelihood of each type of admission rose with the number of risk factors an individual had that were specific to it.

The primary implication is that older people at highest risk of admission of any sort could be identified prospectively in a primary care setting by screening for poor SRH and a high number of systems medicated. This is suggested as an area for focus in revising the Quality and Outcomes Framework. Meanwhile, Public Health departments should seek to decrease risk profiles in younger generations and thus to increase healthy life expectancy.

An important additional point relates to the linkage methodology. This PhD has shown that linked data have more value than either cohort or routinely collected data alone; this methodological contribution is arguably as important as the substantive findings. However, the work has been threatened from the outset by changing regulations on data sharing – a problem that urgently needs to be addressed. The Digital Economy Act that is currently progressing through Parliament presents an opportunity for Government to remedy the access problems that beset research of this nature.

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List of Accompanying Materials

The value of the linked dataset described herein is borne out by the publication of three papers in addition to those that constitute Chapters 5-7 of this thesis:

Simmonds, S.J., Syddall, H.E., Walsh, B., Evandrou, M., Dennison, E.M., Cooper, C. and Aihie Sayer, A. (2014) Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study. *Age Ageing,* 43, 653-660 (reproduced in Appendix A).

Simmonds, S.J., Syddall, H.E., Westbury, L.D., Dodds, R.M., Cooper, C. and Aihie Sayer, A. (2015) Grip strength among community-dwelling older people predicts hospital admission during the following decade. *Age Ageing,* 44, 954-959.

Syddall, H.E., Westbury, L.D., **Simmonds, S.J**., Robinson, S., Cooper, C. and Sayer, A.A. (2016) Understanding poor health behaviours as predictors of different types of hospital admission in older people: findings from the Hertfordshire Cohort Study. *J Epidemiol Community Health,* 70 (3), 292-298.

Westbury, L., Syddall, H., **Simmonds, S.,** Cooper, C. and Aihie Sayer, A. (2016) Identification of risk factors for hospital admission using multiple-failure survival models: a toolkit for researchers.
Med Res Methodol, 16, 46.

DECLARATION OF AUTHORSHIP

I, SHIRLEY SIMMONDS declare that this thesis and the work presented in it are my own and have been generated by me as the result of my own original research.

Risk factors for hospital admission in an ageing English cohort: an analysis linking prospectively collected data with Hospital Episode Statistics

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Parts of Chapter 4 have previously been examined to satisfy the dissertation component of the MSc in Gerontology at this University;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Chapters 5, 6 and 7 comprise multi-author papers for which declarations of authorship are supplied;
8. Parts of this work have been published as:

Simmonds, S.J., Syddall, H.E., Walsh, B., Evandrou, M., Dennison, E.M., Cooper, C. and Aihie Sayer, A. (2014) Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study. *Age Ageing,* 43, 653-660.

Signed: ....

Date: ……………………………………………16/01/2018 ....

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Definitions and Abbreviations

A&E	Accident and Emergency
ACSC	Ambulatory Care Sensitive Condition
ADL	Activities of Daily Living
Age effects	Influences attributable to the age of the subject at the time of admission
APC	Age, Period, Cohort effects
Barthel Index	An ordinal scale to measure activities of daily living
Bed day	A length of stay metric used at the population level
BMI	Body Mass Index
Case-control study	A study in which two distinct groups of people are recruited (those with, and those without, the outcome of interest) and risk factors compared retrospectively
Cohort effects	Influences attributable to the generation to which the subject belongs
Cohort study	A longitudinal study in which information on outcomes is collected over time from a group of people selected on the basis of exposure criteria
Cross-sectional study	A study in which information on exposures and outcomes is collected at the same time
C statistic	A summary measure of the performance of a predictive model, ranging in value from 0 to 1
CHD	Coronary Heart Disease
CHKS	Caspe Healthcare Knowledge Systems
CHSEO	Centre of Health Service Economics and Organisation
Comorbidity	See Multimorbidity
COPD	Chronic Obstructive Pulmonary Disease
Day case	Admission and discharge on the same date
ECG	Electro Cardio Gram
Ecological study	A study in which the association between exposures and outcomes is assessed using aggregate, rather than individual, data
Elective admission	An admission arranged in advance of the date of admission
Emergency admission	An admission at short notice because of clinical need

EPIC	European Prospective Investigation of Cancer
FEV1	Forced Expiratory Volume in one minute: a measure of lung function
Frailty	Increased vulnerability resulting from decreased physiological reserves, multi-system dysregulation and limited capacity to maintain homeostasis
Geriatric giants	Immobility, instability, incontinence and intellectual impairment
GP	General Practitioner
GRACE	Geriatric Resources for Assessment and Care of Elders
HA	Health Authority
HAP	Healthy Ageing Phenotype
HbA1C	Glycated haemoglobin – a marker for diabetes
HCS	Hertfordshire Cohort Study
HES	Hospital Episode Statistics
HLE	Healthy Life Expectancy
IADL	Instrumental Activities of Daily Living
ICD-n	International Classification of Disease - revision number; used to code morbidity and mortality
IHD	Ischaemic Heart Disease
Index admission	The admission preceding a readmission
LE	Life Expectancy
Longitudinal study	A study in which information on exposures and outcomes is collected from a group of people over time
MRC	Medical Research Council
Multimorbidity	The co-existence of two or more chronic diseases
NHS	National Health Service
NHSCR	National Health Service Central Register
NSM	Number of Systems Medicated
OA	Osteoarthritis
ONS	Office for National Statistics
OPCS-n	Office of Population Censuses and Surveys - version number; used to code operative procedures
Period effects	Influences attributable to the time at which admission takes place
PHRDF	Public Health Research Data Forum

Polypharmacy	The simultaneous prescription of two or more drugs
PPV	Positive Predictive Value: the proportion of those identified by a model who experience the predicted outcome
Prospective cohort study	A cohort study in which characterisation of exposures is followed by a period during which the development of the outcome of interest is monitored
PRM	Predictive Risk Model
QOF	Quality and Outcomes Framework: a measure of performance in primary care
Randomised controlled trial	A study in which the effect of a treatment or intervention is evaluated by comparing groups of patients who, according to random allocation, do, and do not, receive the treatment of interest
Readmission	A second admission within a defined time of a first; unless otherwise stated, within 30 days
Retrospective cohort study	A cohort study in which pre-existing records are used to identify participants and characterise the exposure
Sensitivity	The proportion of a population who experience a predicted outcome who are identified by a model
SF-36	A 36 item (Short Form) questionnaire tool to measure health-related quality of life
SF-36 PF	Physical function sub-scale of the above
SHS	Scottish Health Survey
SRH	Self-Rated Health
STP	Sustainability and Transformation Plan (Partnership from 2017)
Trend study	A type of ecological study in which time trends in exposures and outcomes are compared
UK	United Kingdom
US	United States
WHO	World Health Organization

Chapter 1: Introduction

1.1 Aims

The aims of the research described in this thesis were twofold: to link data from the baseline characterisation of an ageing English cohort with administrative data on hospital admissions experienced by participants during the following decade; and to investigate associations, within the resulting dataset, between 25 predictor variables from the cohort data and three admission outcome variables, namely elective admission, emergency admission and readmission within 30 days of discharge.

1.2 Rationale

The UK has an ageing population in which overall life expectancy is growing faster than healthy life expectancy. The result is that an increasing number of older people are in poor health; these people contribute to rising trends in hospital admission and are commonly linked with the financial crisis in the NHS (Iacobucci, 2017b). Public concern is high: during the winter of 2016/17, pressures on the NHS led to conditions in hospitals that were described by the Red Cross as an 'humanitarian crisis' (O'Dowd, 2017).

Reducing demand on hospitals is enshrined in Government policy (NHS, 2017). A range of measures have been proposed to achieve this (Oliver, 2016b), prevention being high on the agenda (Alderwick and Ham, 2017). Prevention requires first that risk factors for admission be understood. However, more is known about the determinants of readmission than of the elective or emergency admission that necessarily precedes it, though some admissions of each type have been argued to be potentially avoidable (Sanderson and Dixon, 2000; Blunt *et al.*, 2010; Purdy, 2010; Chauhan *et al.*, 2012; van Walraven *et al.*, 2012). A review of the literature (Section 3.3) suggests that risk factors may differ between elective admission, emergency admission and readmission, but is difficult to interpret because of differences in data sources, study designs and healthcare systems.

This thesis adopts a consistent approach to investigate the risk factors for type-specific admissions in a single dataset. The decision to link cohort and administrative data was prompted by three perceived advantages. First, linkage allows the unit of measurement to be the person rather than the admission. People who have multiple admissions and people who have none contribute equally valuable information; this is not the case using admissions data alone. Secondly, an extensive range of prospectively measured predictor variables exists in cohort data that is not routinely available. Finally, ascertainment of admission outcomes through administrative data is almost attrition-proof; it would be more difficult, more expensive and less successful if contact with cohort members were required.

1.3 Data sources

The cohort data used in this research were from the Hertfordshire Cohort Study (HCS), which comprises 2,997 men and women born in that county between 1931 and 1939 and aged 59-73 at baseline (1998-2004). With reference to published literature on the determinants of admission, a panel of twenty-five predictor variables was selected for this investigation from the extensive range measured at baseline. Briefly, the variables summarised participants' demography and anthropometry, lifestyle, social circumstances, physical function and morbidity (Section 3.4).

The administrative data were routinely collected and supplied by the Hospital Episodes Statistics (HES) Service. Mortality data from the Office for National Statistics were also incorporated.

1.4 Thesis overview

Using linked cohort and HES data, this thesis adopts a lifecourse approach to investigate the predictors of elective admission, emergency admission and readmission within 30 days of discharge amongst participants of the Hertfordshire Cohort Study. It follows a 3-paper format, each paper considering the relative and combined effects of the predictor panel variables on one admission type. The papers are followed by an overarching discussion chapter which compares and contrasts the predictor panel across the three admission types, thus collectively the thesis contributes more than the sum of the three papers to the understanding of the aetiology of hospital admissions in later life.

The thesis comprises eight chapters in total. Following this introduction, Chapter 2 describes population and individual ageing, discusses the distribution of hospital admissions, provides an overview of policy measures intended to manage demand and concludes that such measures require better evidence on risk factors for admission. Chapter 3 therefore reviews the literature on the determinants of hospital admissions among older people. It focuses first on studies using linked cohort and administrative data from the UK, and widens to consider risk factors specific to 30-day readmission, emergency admission and elective admission. On this basis, it develops and outlines the original research questions that underpin the thesis. Chapter 4 describes the Hertfordshire Cohort Study and the linked Hospital Episode Statistics data in detail. It then provides an overview of the cohort's experience of admissions and the analysis strategy common to the three papers.

Chapters 5, 6 and 7 present the three component papers: on 30-day readmissions, emergency admissions and elective admissions respectively. The papers have been prepared by the candidate as lead author, with the intention to submit to a journal that limits original articles to 2500 words, 30 references and 3 tables or figures, though additional material can be included in online appendices. Unfortunately, it has not been possible to submit them to date, due to restrictions on the HES data that are discussed in Sections 4.8.3 and 8.4.4. To preserve the integrity of the papers and of the thesis as a whole; tables, figures and appendices from the papers have dual numbers, and the references cited are repeated in the bibliography of the thesis.

Following the three papers, Chapter 8 comprises the overarching discussion referred to above. After summarising the key findings, this final chapter compares and contrasts the predictor panel across the three admission types, considers the policy implications of the findings, discusses the strengths and limitations of the work, makes suggestions for future research and draws together key conclusions of the thesis.

Chapter 2: Ageing and healthcare

This chapter describes population and individual ageing and the impact they have on hospital admission in older people. Section 2.1 shows that when increases in life expectancy are not matched by increases in healthy life expectancy, the population of older people at greatest risk of admission grows; projections are presented that have worrying implications for future demand on hospitals. Section 2.2, on individual ageing, discusses the development of chronic disease in later life and conceptual approaches to limiting it; these will be important in the context of an ageing population if demand on hospitals is to be managed at source. Section 2.3 outlines the care system that exists in England, and shows that hospital care is its most costly element. Section 2.4 therefore focuses on hospitalisation. After describing the pattern of admissions overall, it differentiates three admission types: elective, emergency and 30-day readmission; and contrasts them according to the burden they impose on the NHS, their epidemiology and their impact on older people. Trends in overall and type-specific admissions highlight the need to manage demand on hospitals; Section 2.5 outlines policy initiatives applied across the care system which seek to do this, both generally and with reference to particular types of admission. It finds that such strategies have limited effectiveness, especially if they depend on routinely collected data to identify those at risk of admission. Section 2.6 therefore concludes that more and better information about risk factors for admission might be obtained from bespoke research studies; a review of the existing scientific literature follows in Chapter 3.

2.1 Population ageing

Population ageing is defined as a rise in the proportion of older people within a population. The process is taking place in nearly all countries of the world, driven by reductions in first, mortality, and then fertility, during the demographic transition (United Nations, 2013). Like most developed countries, the UK already has an aged population in which life expectancies continue to rise (House of Lords Select Committee on Public Service and Demographic Change, 2013). This positive development may be mitigated by failing health in old age, thus a measure of health expectancy is required to evaluate the impact of population ageing (Parliamentary Office of Science and Technology, 2006); particularly in relation to the demand for hospital care.

2.1.1 Life expectancy

In England and Wales, the 2011 census reported that 9.2m usual residents were aged 65 or over (Office for National Statistics, 2013a, 2013b); at that time, remaining life expectancy (LE) at age 65 was 18.2 years for men and 20.8 years for women. The number of older people and the proportion of the population they represent will increase in coming decades as those born during the post-war baby boom reach old age. At the same time, it is projected that LE at age 65 will rise to 23 years for men and 26 years for women by 2030 (House of Lords Select Committee on Public Service and Demographic Change, 2013). The result will be that by 2030, 13.8m residents of England and Wales will be aged 65 or over: a 50% increase on 2011. Increases in the oldest-old will be even more rapid: in 2011, there were 1.25m people aged 85 or more; by 2030 this is expected to have doubled to 2.5m (Office for National Statistics, 2011b).

2.1.2 Health expectancy

Healthy life expectancy (HLE) is calculated from a question on self-rated health (SRH) routinely asked in the General Household Survey and also in the 2011 census (Office for National Statistics, 2011a), which requires respondents to rate their general health during the previous year on a 5-point scale from very good to very bad. The categories are grouped to represent 'good' and 'not good' health and are analysed in combination with mortality data to produce estimates of HLE at the population level (Office for National Statistics, 2014c).

In 2009-2011, HLE at age 65 in England was, for men: 60.0% of remaining life (10.9 years in good health and 7.3 in not good health), and for women: 58.3% of remaining life (amounting to 12.2 years in good health and 8.7 in not good health) (Office for National Statistics, 2014c). Thus, although women had longer life expectancy, a greater proportion of it could be expected to be lived in poor health. By 2012-2014, overall life expectancy at age 65 had risen for both men and women, but the proportion spent in good health had fallen to 56.3% in men (10.6 years in good health and 8.2 years in not good health) and 54.2% in women (11.5 years in good health and 9.7 years in not good health) (Office for National Statistics, 2016).

Notwithstanding worrying suggestions that rises in LE have recently slowed (Iacobucci, 2017a), it is clear that a widening gap exists between LE and HLE. Older people already make greater demands on hospitals than any other age group (Section 2.4); if HLE continues to fall behind LE in an older population swelled by baby boomers, an increasing burden of morbidity will accentuate the impact of population ageing on hospital admissions. One projection suggests that the NHS will need at least 17,000 additional beds in acute hospitals by 2022: this equates to about 22 hospitals with 800 beds each (Smith *et al.*, 2014).

Section 2.2 discusses the theory and practice of individual ageing, approaches to maintaining health into old age and the existing burden of age-related illness; factors closely linked to future and current demand on hospitals.

2.2 Individual ageing

In contrast to population ageing, individual ageing is a continuous, unavoidable process argued by some to begin at or before birth (Franco *et al.*, 2009). There are numerous theories as to why it occurs. The traditional medical model holds it to be the result of physical changes which are largely inevitable, whilst social gerontologists point out that some aspects of ageing (such as lifestyle or retirement age) are socially or culturally determined and may therefore be modifiable (Cox *et al.*, 2014).

2.2.1 The biology of ageing

Biologically, ageing is defined as a gradual loss of function with chronological time, with increasing probability of death (Cox *et al.*, 2014). It is associated with a deterioration in physiological processes, brought about in three interconnected ways (Masoro, 2003). The first of these is intrinsic biological activity, for example by free radicals, which are a product of aerobic metabolism and cause damage which accumulates through life. The second is a range of extrinsic factors particular to lifestyle or the environment, which can accentuate the damaging action of intrinsic factors. The third is age-associated disease which, being an effect as well as a cause of deterioration, can lead to a vicious circle of decline; it has been argued that the majority of physiological deterioration is secondary to this age-associated disease (Masoro, 2003).

2.2.2 The lifecourse perspective on ageing

The loss of function that is definitive of ageing has been shown to follow a similar trajectory through life in many biological systems. This observation underlies the lifecourse perspective (Stein and Moritz, 1999). Typically, capacity increases gradually during early life to reach a peak in early adulthood, plateaus, and then declines (Figure 1). Theoretically, the rate of decline may be related to the intrinsic, extrinsic and disease factors postulated above, such that unavoidable, intrinsic loss is accelerated by extrinsic factors or age-related disease. The lifecourse perspective proposes a disability threshold that is crossed soonest by those with the fastest rate of decline, and not at all by those with the slowest; it has been applied to a variety of tissues, including muscle (Aihie Sayer *et al.*, 2008) and bone (Harvey *et al.*, 2014).

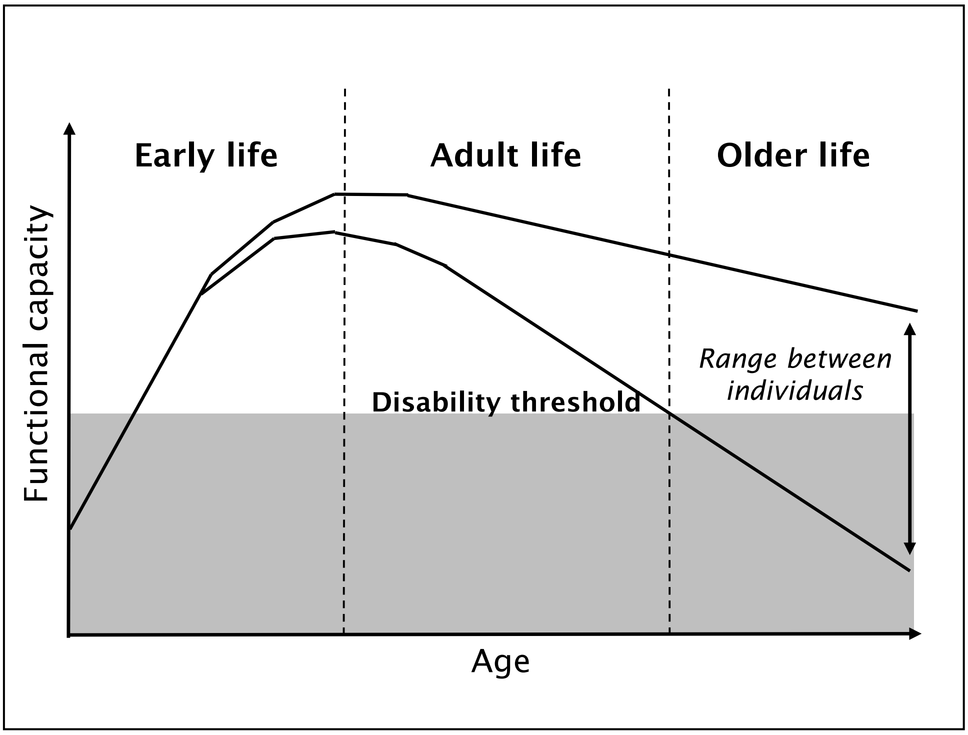


Figure 1 The lifecourse perspective on functional capacity

(Source, author's adaptation of Stein and Moritz, 1999 p4)

The strength of the model is that it combines insights from gerontology on social and cultural processes and social structures (Cox *et al.*, 2014) with the functional perspective from biology, emphasising the opportunity to modify a range of influences on the model at multiple points: first, by promoting growth in early life to maximise the peak attained in adulthood; secondly, by actively maintaining peak capacity, thirdly, by minimising the rate of loss due to extrinsic factors in later life and finally by promoting a supportive environment to modify the disability threshold for older people.

According to the lifecourse model, a favourable trajectory exists that avoids major chronic disease and cognitive or physical impairment (Franco *et al.*, 2009). This has been called the Healthy Ageing Phenotype (HAP). Whilst it is accepted that functional loss is definitive of ageing, on the healthy ageing trajectory such loss is seen to be independent of disease or poor quality of life. Only a small proportion of differences in ageing are thought to be determined genetically (Franco *et al.*, 2009; Cox *et al.*, 2014); the remainder are due to the environment, lifestyle and an element of chance, many of which are modifiable. The HAP has been proposed as a framework for ageing research; first to understand the mechanisms that keep individuals on the favourable trajectory and secondly to develop interventions to help people to return to it. Hospital care may facilitate this: joint arthroplasty or cataract removal, for example, can allow older people to resume an active lifestyle, thus preventing the decline associated with inactivity and improving quality of life.

The HAP is forward looking: it recognises the need to limit risk factors and the continuing importance of therapeutic medicine, healthcare and pharmacological intervention. However, healthy ageing remains an aspiration. The current reality is that age-related disease is the norm; most chronic diseases increase in prevalence with age (Marengoni *et al.*, 2011) and senescence without disease is atypical. The prevalence of common age-related conditions is discussed below.

2.2.3 Age-related conditions

Table 1 presents prevalence estimates for common chronic conditions derived from a number of sources. In general, men are more vulnerable than women to vascular conditions such as ischaemic heart disease and stroke, whilst women have higher rates of degenerative bone conditions and mental health disorders.

Table 1 Percentage of men and women reporting various chronic conditions; England, unless otherwise stated

Condition	**Age**					
	65-74		**75+**		**All ages**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**
Ischaemic Heart Disease (2011)[1]	15.1	7.5	26.7	16.5	5.7	3.5
Stroke (2011)[1]	7.2	4.4	12.2	9.4	2.7	2.1
Hypertension (2012)[1]	59.1	55.8	64.2	75.5	30.9	26.8
Type 2 diabetes (2012)[1]	17.3	11.0	17.5	12.9	6.7	4.9
Osteoporosis (1990s, Europe)[2]	3.7◊	17.9◊	9.2◊	33.9◊	-	-
Osteoarthritis (2015, UK)[3]	35	44	42	49	23*	31*
Depression, age ≥65 (2005)[4]	22	28	-	-	-	-
Bronchitis (2010)[5]	11	10	9	8	4†	5†
Cancer, all sites, age ≥65 (2008, UK)[6]	13.1	12.7	-	-	2.7	3.8
Dementia (UK, 2014)[7]	3.0+	3.1+	10.3+	11.7+	7.1+	
Multimorbidity ≥2 diseases (2007, Scotland)[8]	64.9$		81.5$		20.1	26.2

Sources: 1. (NHS Digital, 2018); **2**. (Kanis, 2007) ◊vertebral fracture, ages 70 and 80 years are shown; **3**. (Arthritis Research UK, 2017) *ages 45-64; **4**. (Craig and Mindell, 2007); **5**. (Hall and Mindell, 2011) †ages ≥16 ; **6**. (Maddams *et al.*, 2009); **7**. (Prince *et al.*, 2014) +ages 70-74, 80-84 and 65+ are shown; **8**. (Barnett *et al.*, 2012) $ages 65-84 and ≥85, sexes combined; - data not available

However, individual disorders are only part of the challenge: a further consideration is that disorders tend to occur together. This phenomenon is called co- or multi- morbidity; Table 1 shows that it is common - indeed normal - in later life. Multimorbidity occurs because many chronic conditions share common underlying pathways and are lifestyle-, as well as age-, dependent. For example, obesity is associated with insulin resistance and vascular inflammation which, through metabolic dysregulation, can result in cardiovascular disease, diabetes or cognitive decline (Franco *et al.*, 2009). Conditions are also interdependent: cardiovascular disease, for example, causes the pH of circulating blood to fall, resulting in altered bone mineralisation and increased risk of osteoporosis (Cox *et al.*, 2014).

The prevalence figures for multimorbidity in Table 1 are from a cross-sectional study of 1.7m people of all ages in Scotland, which defined multimorbidity as having 2 or more of 40 predefined physical or mental diseases (Barnett *et al.*, 2012). However, neither the definition nor the prevalence of multimorbidity is clear cut. A 2011 systematic review (Marengoni *et al.*, 2011) distinguished three approaches to defining the condition: first, a simple count of concurrent diseases; secondly, a summary index incorporating both number and severity of diseases present; and finally, the simultaneous presence not only of disease, but also of symptoms and cognitive or physical limitations. The review was complicated by different age structures in the studies it included, as well as by variation in methods of ascertainment and threshold for classification of disease. It was nevertheless able to conclude that, consistent with the Scottish data presented in Table 1, the prevalence of multimorbidity in later life was between 55% and 98%, rose with age and was higher in women and those from lower social classes.

Members of the British 1946 birth cohort belong to the baby boomer generation; multimorbidity amongst them at age 60-64 (Pierce *et al.*, 2012) was reported to be 39% in men and 38% in women. This is consistent with the younger age at measurement than in the Scottish study, and with the smaller base of conditions considered: only 15 were screened for in this study. The reversal of the sex ratio compared to the findings of Barnett et al (2012) and Marengoni et al (2011) may also result from the young age of the cohort. Because men have shorter average life expectancy, they might be expected to develop multimorbidity sooner than women, with a survival bias keeping those who do not die healthier than women who survive. Thus these figures may represent an earlier stage in the development of multimorbidity, rather than better health of this younger generation.

Population ageing means the number of people living with multiple chronic conditions is growing rapidly. In England, it is expected to increase from 1.9m in 2008 to 2.9m by 2018 (Iacobucci, 2017b). The consequences of multimorbidity include disability, poor quality of life and the development of frailty. It leads to high healthcare utilisation, including polypharmacy (the prescription of increased numbers of medications) and increased rates of hospitalisation (Marengoni *et al.*, 2011).

Section 2.2 has described a heavy burden of disease associated with biological ageing and shown that it will be exacerbated by population ageing. Associations with use of healthcare, including hospitalisation have been noted. Reducing demand for hospital care depends in part on the availability of alternative sources of care. A brief overview of the services which comprise the English care system follows.

2.3 The care system

This section first, describes the services overseen by the Department of Health to provide health and social care, and secondly, considers their financial costs, with particular reference to the NHS.

2.3.1 The structure of the system

Four sectors of the care system interact, under the aegis of the Department of Health, to provide health and social care in England. The first two, primary and secondary care, are the responsibility of the NHS. Primary care is provided by general practitioners, along with dentists, opticians and pharmacists, who are based in the community and act as a first point of contact for NHS patients. Such practitioners are expected to manage mild to moderate conditions themselves, but if more specialised treatment, further investigation or emergency care is required, can refer patients to another healthcare provider. Such secondary care usually means hospital services, which may be provided on an outpatient basis or following admission. Patients may also self-refer to hospitals for emergency care (NHS, 2013).

The remaining sectors of the care system: public health and social care; are provided by local authorities rather than the NHS. The role of public health is to protect people against major health risks, promote healthy lifestyles and improve the health of the local population. Public health departments also provide immunisation and screening services. The final element is social care, the aim of which is to maintain independence and promote wellbeing. Care for older people may be provided in their own homes or may be residential (NHS, 2013); social care is the only sector of the care system for which means-tested charges are levied on older people (NHS, 2013). Alongside the state system a small private healthcare industry exists, largely funded by insurance among working aged people (Commission on the Future of Health and Social Care in England, 2014).

Between hospital care and social care sits intermediate care; an initiative of the National Service Framework for Older People (Department of Health, 2001). The aims of intermediate care include the aversion of admission to hospital and support for timely discharge, though it has been argued by some to represent a lower level of provision that effectively denies older people the clinical or rehabilitation services they need (Evans and Tallis, 2001). NHS funded, bed-based intermediate care is provided in a range of settings, including community hospitals, residential care homes and nursing homes (NHS Benchmarking Network, 2014). Around two thirds of intermediate care beds are outside hospital (NHS Benchmarking Network, 2014), thus not all NHS beds are hospital beds, though hospital beds outnumber intermediate care beds by more than 10:1 (Ewbank *et al.*, 2017).

2.3.2 The cost of care

The budget of the NHS for 2015/16 was £117.2bn (NHS Confederation, 2017). Commissioning models introduced in 2012 make it difficult to differentiate spending by sector in recent years (Addicott, 2014; Arnett, 2016); prior to the introduction of new models, primary care accounted for about 25% of the total NHS budget and acute hospitals for 50%: 27.5% on emergency admissions; 17.5% on elective and maternity admissions, and 5% on outpatients (Mayden, 2011). Local authority spending in 2015/16 amounted to £3.2bn on public health and £17bn on adult social care (The King's Fund, 2017). Hospital care therefore accounts for the largest proportion of the healthcare budget by far.

In the UK, the average annual cost to the NHS of a person aged 85 or more is six times that of a 16-44 year-old and four times that of a 45-64 year old (Grundy, 2003). This excess cost of older people’s NHS services is due in part to their higher likelihood of hospital admission; it has been reported that 65 percent of people admitted to hospital are aged over 65 although this age group makes up only 17 percent of the population (Cornwell *et al.*, 2012). The following section explores hospital admissions among older people in more depth.

2.4 Hospital admissions among older people

Hospital admissions are enumerated by the Hospital Episode Statistics (HES) service. This section describes HES data and the pattern of overall admissions that they show. It then defines the different types of admission which form the basis of this investigation: elective admission, emergency admission and readmission within 30 days. Characteristics of each admission type are examined in turn, and then compared to show that patterns of hospital use differ by age. The section concludes by distinguishing individual level admissions from those at the population level, and briefly examining the effect of admission on older people.

2.4.1 Hospital Episode Statistics

Administrative data on acute hospital activity in England are routinely collected by the Hospital Episode Statistics (HES) Service (NHS Digital, 2017c). The primary purpose of the data is to allow remuneration of hospitals for the treatments they provide. In addition, HES data are used by NHS, government and research organisations to monitor trends, inform choice, support service planning and develop and evaluate policy (NHS Digital, 2017c). The provision of epidemiological data is not an explicitly stated aim of the service.

Each HES record describes one hospital episode, which is a period of care of one patient under one consultant. The information contained includes demographic data about the patient (date of birth, sex, postcode), administrative information about the episode (how admitted and where from; where discharged to; dates of both) and clinical information about the diagnoses reached and clinical procedures carried out. A patient may have two or more episodes consecutively, the sum period between admission to the first and discharge from the last being referred to as a 'spell' or an 'admission' (NHS Digital, 2017d). To link episodes relating to the same patient, each record contains an encrypted identifier, the PSEUDO_HESID, so that records may be combined to generate whole admissions or longer-term patient histories (NHS Digital, 2017g).

Summary information from HES is published in annual 'Admitted Patient Care Summary' reports that are available from the NHS Digital online catalogue (NHS Digital, 2017a). Other standard and bespoke extracts are available via the Data Access Request Service subject to ethical and legal conditions (NHS Digital, 2017f). At their most basic, HES are population-level data: they enumerate episodes of care rather than people cared for. The range of uses and users of HES makes for a variety of approaches to analysis and reporting. One could, for example, report annual hospitalisation of a group of people in terms of a number of episodes accrued, a number of admissions accrued, or a number of individuals among them who were hospitalised during the year. Organisations notable for their analyses of HES data include the Nuffield Trust, the King's Fund, Dr Foster Intelligence and CHKS. The following sections draw on reports from those organisations as well as on Admitted Patient Care Summary reports to describe patterns of overall, elective, emergency and 30-day readmissions.

2.4.2 Overall admissions

The HES summary for 2013/14 reports 18.2m hospital episodes in England for the year, 8.1m in men and 10.1m in women (giving crude rates of 305/1,000 men and 369/1,000 women, based on mid-year population estimates (Office for National Statistics, 2014a)). These episode-level data equate to a total of 15.5m admissions at all ages (NHS Digital, 2017e).

Patients aged 65 or above accounted for 7.3m episodes during 2013/14, 1.6m of which were for patients aged 85 or above (NHS Digital, 2017e). Complex analyses show greater age effects than can be seen in the raw data; for example, the widely quoted King's Fund report cited in Section 2.3.2 finds that 65 per cent of people admitted to hospital are aged over 65 although they represent only 17% of the population (Cornwell *et al.*, 2012).

The number of hospital admissions in England is reported by the Nuffield Trust to have increased by 16% (from 12.6m to 14.6m) during the six years from 2006/7 to 2012/13 (Smith *et al.*, 2014). Figure 2 shows that the increase was concentrated in older people; percentage increase (finely spotted) ranging from under 10% among those younger than 65 to around 25% at ages 65-84 and over 40% in those older than 85. However, the absolute increase in numbers of admissions (striped) accounted for by the oldest group was more modest than the percentage increase, because the number of people of that age is smaller.

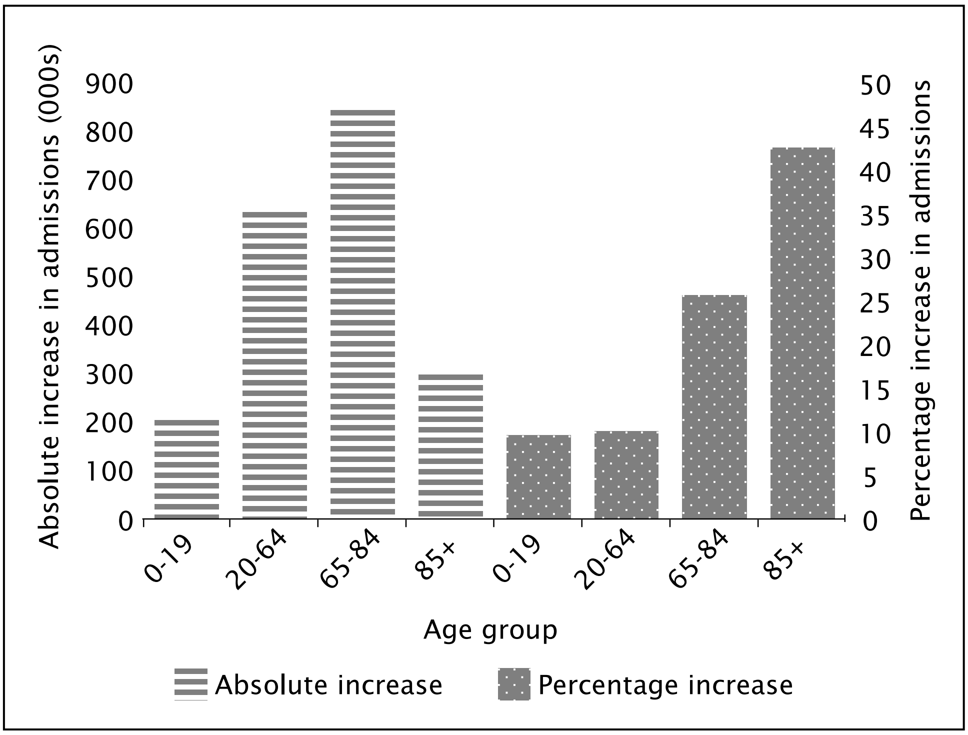


Figure 2 Absolute and percentage increase in hospital admissions, by age group, between 2006/7 and 2012/13 (Source, Smith et al., 2014)

An important measure of the cost and complexity of hospital admissions is length of stay; an indicator of the level of resources consumed (Martin and Smith, 1996). This is frequently dichotomised between admissions treated as day cases, which begin and end on the same day, and those requiring longer stays. Older people are less likely than younger people to be admitted as day cases (Health and Social Care Information Centre, 2014a), and their average length of stay is therefore greater.

2.4.3 Admissions by type

Published summary figures divide hospital admissions into discrete categories according to method of admission: elective, emergency and 'other'. The 'other' category is dominated by maternity cases and will be considered no further here. Elective and emergency admissions have distinct characteristics, as has the third admission type examined by this thesis; namely 30-day readmission. The selected admission types are described in turn by Sections 2.4.3.1-2.4.3.3, with reference to their general description, the administrative burden they impose on the NHS, and their trends.

2.4.3.1 Characteristics of elective admissions

General description: elective admissions are those which are planned in advance (NHS Digital, 2017b). They are usually preceded by a referral from primary care and evaluation at an outpatient appointment, after which the patient attends on a specified day for investigation or treatment. They are the standard route for many common tests and operations including endoscopy, cataract removal and joint replacement (Maguire *et al.*, 2016). Of the 15.5m admissions recorded in 2013/14 (NHS Digital, 2017e), 8.0m (51.8%) were elective.

Administrative burden: the published cost of a day case for 2011/12 was £682, compared with £3,215 for an elective overnight stay (Department of Health, 2012c). 78% of elective admissions were treated as day cases in 2011/12 (NHS Digital, 2017a), therefore the average cost of an elective admission of any length was £1,239. All day cases are single episode admissions, meaning that most elective admissions have low complexity. Advance planning means that elective admissions are, by definition, predictable.

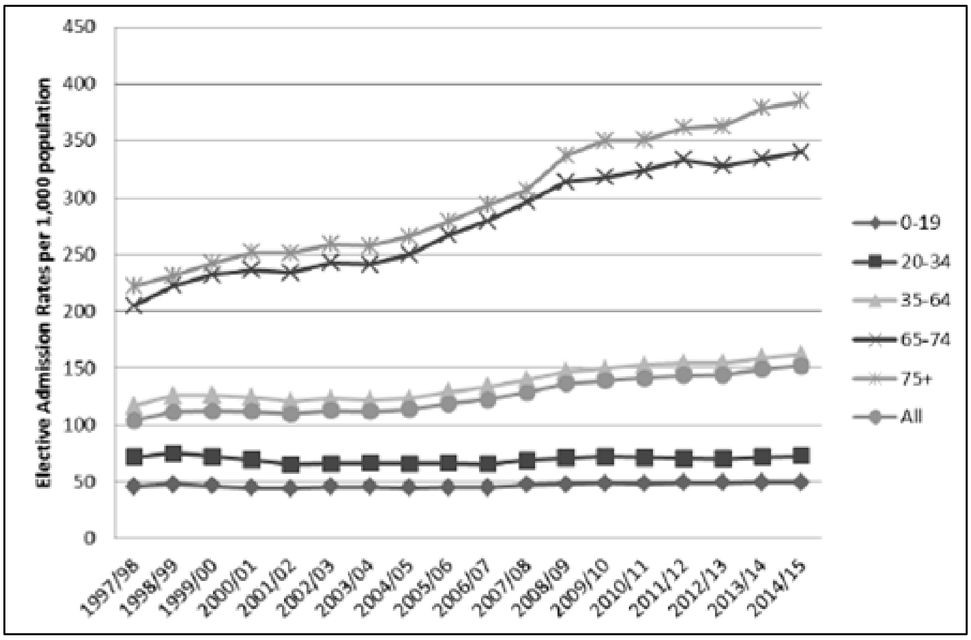


Figure 3 Trends in elective admissions per 1,000 population, 1997/8-2012/13, by age (Source, Wittenberg et al., 2015 pp42)

Trends: Figure 3 shows trends in elective admission by age for the 17 years from 1997/8 to 2014/15, reproduced from a report by the Centre of Health Service Economics and Organisation

(CHSEO) (Wittenberg *et al.*, 2015). Rates of admission were notably higher in the two oldest groups (those aged 65-74 and 75 or above) than in younger people; analyses showed that admission rates rose with age to 78 years and then fell.

2.4.3.2 Characteristics of emergency admissions

General description: emergency admissions are those that are unpredictable and at short notice because of clinical need (NHS Digital, 2017b). Most are made via an accident and emergency (A&E) department (Maguire *et al.*, 2016), to which patients may self-refer or be directed by a general practitioner or consultant outpatient clinic. Around 20% of such admissions are due to worrying signs and symptoms that do not result in a clear diagnosis (Walsh *et al.*, 2011). Summary figures for 2013/14 report 5.4m emergency admissions in England, comprising 35.0% of all admissions (NHS Digital, 2017e).

Administrative burden: the published cost of an emergency admission of any length of stay in 2011/12 was £1,436 (Department of Health, 2012c). The majority of emergency admissions result in an overnight stay: just 28% were treated as day cases in 2009 (Jones, 2006b) and average length of stay was 7.2 days in 2006/7 (National Audit Office, 2013). Overnight admissions may result in several episodes as additional consultants are called upon, meaning that emergency admissions may become quite complex and are, by definition, unpredictable and urgent. They must therefore be prioritised over elective admissions and can disrupt elective care.

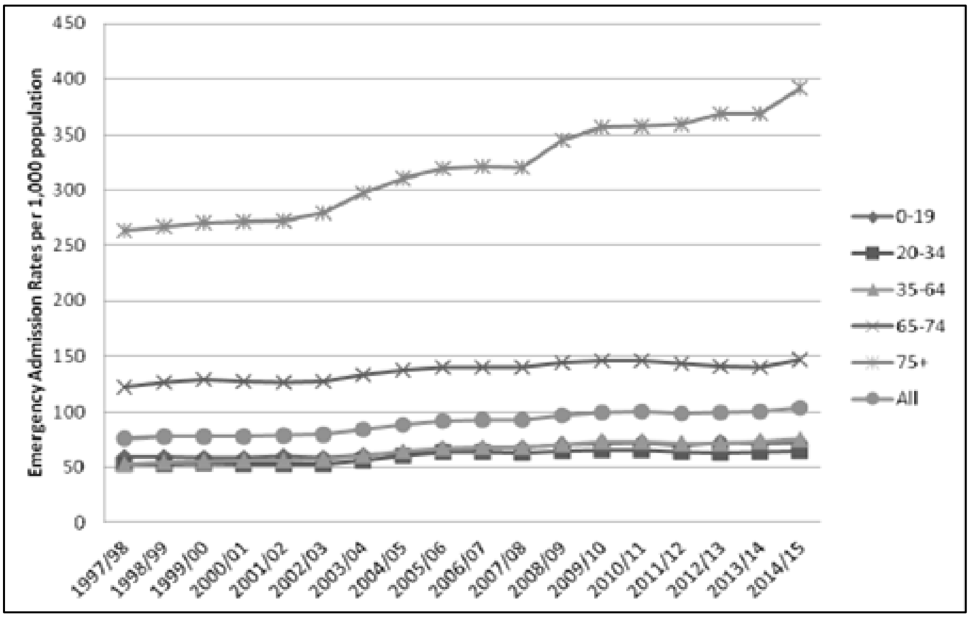


Figure 4 Trends in emergency admissions per 1,000 population, 1997/8-2012/13, by age (Source, Wittenberg et al., 2015 pp12)

Trends: Figure 4 shows trends in emergency admission by age (Wittenberg *et al.*, 2015). In this case, it is only the oldest group (those aged 75 or above) that has notably elevated rates of admission; analyses showed that the rise in admission rates with age had no upper cap.

Emergency admissions are sometimes known as acute admissions, although there is some ambiguity to this term. It may, for example, be used to describe any admission to an acute hospital trust (Information Services Division, 2018), or more specifically, to describe an emergency admission via an A&E department or an Acute Medical Unit (Royal College of Physicians, 2007). The term is not used in Hospital Episode Statistics and is avoided by this thesis.

2.4.3.3 Characteristics of readmissions

General description: following discharge, some patients are admitted to hospital again within a short time: this is known as readmission. Such admissions may be by either elective or emergency routes, thus there is an overlap with the previously described admission categories. The time window that defines readmission is variable, but is most often one month (28, 30 or 31 days): 30 days is the working definition adopted by this thesis. The first admission of a pair is known as the index admission and can itself be classified as elective or emergency. Analyses show that in about 50% of cases, the readmission is diagnosed differently to the preceding index admission (Foundation Trust Network, 2011), suggesting it is for a different problem rather than a continuation of the same one. The study of readmissions is complex: one needs to account for two separate periods of hospitalisation, a variable time-window and a literature heavily (and not always explicitly) skewed towards emergency, rather than any, readmissions. In addition, careful scrutiny is required to determine what, if any, exclusions authors have applied to their analyses. Approximately 10 percent of people aged 16-74 who were discharged from hospital during 2010-11 were readmitted in an emergency within a month. At ages 75 and over, this figure rose to 15.3 percent (Department of Health, 2013). The percentage readmitted electively is less clear.

Administrative burden: readmissions place a heavy demand on healthcare resources; the cost of a readmission is estimated to be at least £1,750-£1,900 (Robinson, 2010b; Foundation Trust Network, 2011), and possibly considerably more (Billings *et al.*, 2012). The cost of the original ‘index’ admission is accounted for separately. Unpredictability is high: in addition to the half that are themselves emergencies, 70% follow an emergency index admission (Foundation Trust Network, 2011). Elective cases among them differ from other elective admissions in that they are typically part of a programme of care such as chemotherapy: even though they are planned and predictable, they take priority over other elective cases if they cannot safely be deferred (NHS Digital, 2017b).

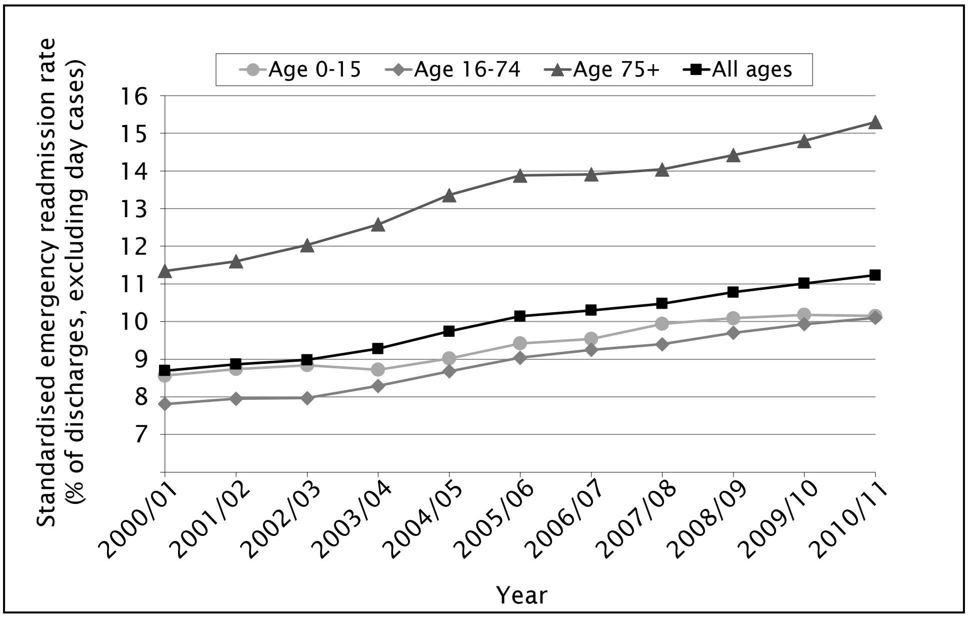


Figure 5 Standardised emergency readmission rate per 100 discharges excluding day cases, by age (Source, author's presentation of Department of Health data)

Trends: Figure 5 shows trends in emergency readmission rates per 100 discharges by age, plotted using published data (Department of Health, 2013), for comparability with figures 3 and 4. The rates are considerably higher than is suggested above, because the denominator excludes day cases. Once again those aged 75 or above have notably elevated rates of admission, although the age bands are less discriminating in these data.

2.4.4 Comparison of admission types

Table 2 summarises the characteristics of overall and type-specific admissions that were described by Sections 2.4.2 and 2.4.3; although not all the targeted information is readily available. For each of cost, complexity and priority, a gradient is demonstrated across the admission types from elective, through emergency to readmission that increases the administrative burden of the admission type to the NHS.

Cost was shown to increase across the admission types, such that elective admission is the least and readmission the most expensive category, after allowing for the cost differential between day and overnight elective cases. As well as costing more per case, emergency admissions also consume a greater proportion of the overall NHS budget than elective admissions (Section 2.3.2) even though there are fewer of them.

Complexity, inferred from length of stay and/or number of episodes, also increased across the admission types. Because elective admissions include a high proportion of day cases, most comprise only one episode; emergency admissions have a lower proportion of day cases, last

Table 2 Summary of differences between admission types

Characteristic	**Admission type**			
	All admissions	**Elective**	**Emergency**	**Readmission**
Number of admissions n(%)	15.5m (100)[1]	8.0m (51.8)[1]	5.4m (35%)[1]	1.2m (8.3%)[2]
Number of episodes (all ages)	18.2m[1]			
Number of episodes (age ≥65)	7.3m[1]			
Administrative characteristics				
Cost (per admission)		£1278[3]	£1436[3]	£1750+[2,4,5]
Complexity				
Day cases (%)	41[1]	High (78)[1]	Low (28)[6]	Very low (11.6 -21.7)[7]
Average length of stay (days)		Mostly day cases	7.2 [8]	6.38 - 13.89[7]
Priority				
Predictability[9]		High	Low	Mixed
Urgency[9]		Low	High	High
Epidemiological characteristics				
Age and sex				
Highest rates at age		65+ [10]	75+[10]	75+[11]
Sex most affected (all ages)	F[1]		F [10]	M[11]
Trends (growth pa, all ages)	~2.6%[12]	2.9%[10]	2.5%[10]	4.6%[11]

Sources: 1. NHS Digital (2017e) *Admitted Patient Care, England 2013-14*; **2.** Foundation Trust Network (2011) *The impact of non-payment for acute readmissions*. London: NHS Confederation, Issue 211; **3.** Department of Health (2012c) *Reference Costs 2011-12*; **4.** Robinson, P. (2010) *Hospital readmissions and the 30 day threshold*. CHKS; **5.** Billings, J., Blunt, I., Steventon, A., Georghiou, T., Lewis, G. and Bardsley, M. (2012) Development of a predictive model to identify inpatients at risk of re-admission within 30 days of discharge (PARR-30). *BMJ Open,* 00, e001667; **6.** Jones, R. (2006b) *Zero day stay 'emergency' admissions in Thames Valley;* **7**. Department of Health (2008) *Emergency readmission rates. Further analysis;* **8.** National Audit Office (2013) *Emergency admissions to hospital: managing the demand*. London: The Stationery Office, HC 739; **9.** NHS Digital (2017b) *HES data dictionary. Admitted patient care*.; **10.** Wittenberg, R., Redding, S., Nicodemo, C. and McCormick, B. (2015) *Analysis of trends in emergency and elective hospital admissions and hospital bed days: 1997/8 to 2014/15*. Oxford: Centre for Health Service Economics and Organisation; **11.** Health and Social Care Information Centre (2013a) *Hospital Episode Statistics, Emergency readmissions to hospital within 28 days of discharge - 2011/12;* **12.** Smith, P., McKeon, A., Blunt, I. and Edwards, N. (2014) *NHS Hospitals under pressure: trends in acute activity up to 2022*. London: Nuffield Trust.

longer on average and are more likely to accrue multiple episodes; whilst 30-day readmissions have the smallest proportion of day cases and the longest length of stay.

Priority was inferred from predictability and urgency; factors that are important to the effective management of NHS workloads. Elective admissions that are booked or called at short notice from a waiting list are predictable and can be timed according to the availability of resources, whereas emergency admissions are driven by clinical need that is difficult to anticipate. Readmissions within 30 days of discharge may be of either type; but, as outlined in Section 2.4.3.3, elective cases among them tend to be clinically (as opposed to resource) driven and cannot safely be deferred (NHS Digital, 2017b). Emergency admissions and readmissions are thus, in general, of higher priority than elective admissions.

For ease, this thesis will consider the gradient across admission types to represent increasing '*seriousness'* of admissions, though no clinical interpretation of this term is implied. Section 2.4.3 presented trends in admission by age for each of the selected admission types (Figures 3, 4 and 5), to show that older people have relatively more admissions of each type than younger people, and that with advancing age, there is an increased tendency towards admissions being of the more administratively demanding or *'serious'* types. This is consistent with evidence that the likelihood of an admission being an emergency rises with age from 30% of admissions at age 65-74 through 42% at age 75-84 to 65% at ages 85 and above (Health and Social Care Information Centre, 2014a), thus the ratio of elective to emergency admission is reversed in the oldest-old. The likelihood of readmission following discharge also rises with age (Health and Social Care Information Centre, 2013a).

Table 2 shows that average length of stay increases across the admission types. Therefore, since older people have proportionately more serious admissions, they would be expected to have longer hospital stays than younger people. There is also evidence that, for a given admission type, length of stay is longer for older people than for those who are younger: for example, in 2006/7 length of stay during an emergency readmission was 6.38 days among those aged 16-74 and 13.89 days among people of 75 and over (Department of Health, 2008).

Sex ratios among those admitted also differ by age. For overall admissions, among patients of all ages, women are more likely to be admitted to hospital than men. The same is true of emergency admission; although CHSEO demonstrate that the higher overall rate of emergency admission among women in 2014/15 (106.4/1000 compared to 100/1000 in men) was entirely due to an excess among women aged 20-34: at all other ages the rate for men was higher (Wittenberg *et al.*, 2015). Among emergency readmissions as a percentage of discharges, men had rates around

7% higher than women at all ages in 2011/12 (11.88% vs 11.08%)(Health and Social Care Information Centre, 2013a).

Table 2 also shows recent trends in the percentage growth of overall and type-specific admissions per annum. Several authors have pointed out that this growth in admissions is only partly explained by population ageing (Smith *et al.*, 2014). Other influences have been explored using age, period, cohort (APC) models. Such models seek to differentiate independent effects of the age of the subject at diagnosis (age), prevailing conditions at the time of diagnosis (period), and the lifetime experiences of the generation to which the subject belongs (cohort) (Blanchard *et al.*, 1977). Applied to admissions, period effects are found to be responsible for the majority of recent growth in elective admissions, which stands at 2.9% per annum (Wittenberg *et al.*, 2015). Such effects may act through improved technology, perhaps by making treatment that once required an overnight stay available on a day case basis and thus increasing the capacity of the system. This is consistent with the finding that increasing trends in elective admissions from 2006/07-2012/13 were due to rising numbers of day cases accompanied by a fall in the number of overnight elective admissions (Smith *et al.*, 2014).

Trends in emergency admissions generally show slightly slower growth than elective admissions (2.5% pa) (Wittenberg *et al.*, 2015), though some authors suggest the opposite is true (Robinson, 2010a). APC analyses show that period effects also dominate growth in emergency admissions, though to a lesser extent than elective admissions (Wittenberg *et al.*, 2015). This may be the result of improved technology making treatments available to older and frailer patients than was previously considered advisable, or to changes in the availability of care elsewhere in the system. Projecting the APC trends for emergency admission into the future, the authors suggest that the suppression of an upward age effect by a downward cohort effect, which allows period effects to dominate, may last only until the end of this decade: thereafter, the size of the baby boomer generation may mean age effects dominate and rates of emergency admission rise even more rapidly (Wittenberg *et al.*, 2014). Growth in readmissions has been more rapid than that in elective or emergency admissions (4.6%pa); suggesting that perhaps age effects already play a greater role here.

The information presented in this section is drawn from hospital episode statistics, or analyses thereof. It is at the population level, enumerating episodes or admissions and calculating annual rates across the population. These facts are useful to policy makers and service planners but do not show whether an individual patient accounts for one admission or many; nor do they provide any information about individuals who experience no admissions, other than their contribution to population denominators. The next section will briefly discuss individual level analyses of HES data, and consider the burden of admission on older people.

2.4.5 The burden of admissions on individuals

Within HES, it is possible to link records by the pseudoHESID to create individual-level admission histories that cover several years and so to demonstrate that hospitalisations are unevenly distributed among older people. This technique has been used to explore increasing hospital use towards the end of life (Dixon *et al.*, 2004), and to study the impact of frequently admitted patients on overall admissions. This latter study reported that 14% of patients had 4 or more admissions over a 12 month period, and accounted for almost a third of all admissions (Williams *et al.*, 2005). HES data showed that these patients were more likely to be male than female, aged over 65 years (with a peak at 75-79), and that their first hospitalisation during the period was more likely to have been an emergency than an elective admission. Rates of hospitalization also vary according to individual's living arrangements, being higher for residents of nursing and residential care homes than for those who are community-dwelling. Rates of emergency admission per 100 population have been reported to be 18.9, 22.3 and 31.2 for the community, nursing homes, and residential care homes respectively; the relative risk of admission for all diagnoses among care home residents being 39% higher than among those who are community-dwelling (Godden and Pollock, 2001).

Hospital admission is stressful. In addition to the symptoms of the presenting illness, it is associated with disruption to sleep, dietary habits and other personal routines; and may cause confusion, especially in older patients (McIntyre, 2013). It has been suggested that the burden of hospitalisation on older individuals is so great that admission should itself be considered a disease, and that in the period immediately after discharge patients should be afforded a diagnosis of 'post-hospital syndrome'; a condition which increases the risk of readmission (McIntyre, 2013). A study carried out in Spain among 200 older people showed that the adverse effects of emergency admission outweighed the effects of elective admission. Functional and cognitive capabilities were assessed on admission to hospital, at discharge and 3 months later. In multivariate analyses, those who had been admitted in an emergency had significantly greater loss of instrumental activities of daily living (IADL) and cognitive test score at discharge than those who were admitted electively; at three months, the association with IADL had disappeared, but cognitive score remained significantly reduced (Merino Martin and Cruz-Jentoft, 2012). Repeated admission is also stressful: a qualitative study carried out for Age UK elucidated feelings of depression and frustration about being back in hospital among older readmitted patients (Lawrie and Battye, 2012). Thus a gradient is apparent in burden to the individual, at least between elective and emergency admission, which mirrors gradient in *'seriousness'* described in Section 2.4.4.

Section 2.4 has shown that demand for hospital admission has increased in recent years due in part to population and individual ageing. Admissions vary by type in the burden they impose on society and the individual; nevertheless, it is in the interests of both that policy measures be put in place to avoid admissions. The next section discusses current policy approaches to the avoidance of admission, and their impact.

2.5 Health policy

An important tenet of health policy is to reduce admissions to hospital and so reduce costs. One justification for this demand-management approach, rather than for a continued expansion of the hospital sector to meet the needs of an increasing number of unhealthy older people, comes from the suggestion that some admissions among older people may be preventable (Blunt, 2013). An additional consideration is Roemer's law, which states that *a hospital bed built is a hospital bed filled*; in other words that demand grows to meet supply, making continued expansion of services unwise (Shain and Roemer, 1959). The concept of the avoidable admission is therefore central to strategies to reduce admission. It is explored below, followed by an overview of current policy.

2.5.1 Avoidable admissions

An avoidable admission is one which could theoretically be averted by better care earlier in the disease process (Care Quality Commission, 2013). The difficulty with the concept is that there is no clear definition of an avoidable admission; nor of its opposite, an appropriate admission. There appears simply to be an assumption that avoidable admissions occur with greater frequency among some admission types than among others. For example, readmissions may be avoidable if one accepts that the second admission reflects a shortcoming in the first; likewise, the fifth of emergency admissions that go undiagnosed (Section 2.4.3.2), if the lack of diagnosis implies that no significant morbidity was present. Even elective admission, though comparatively less researched, has been suggested to include some avoidable cases (Sanderson and Dixon, 2000).

In the same way that some types of admission are thought more avoidable than others, admissions for some diagnoses are believed more likely to be avoidable (Care Quality Commission, 2013). Ambulatory care sensitive conditions (ACSCs), for example, are a group of chronic diseases deemed to be manageable in the community, which are thought to give rise to proportionately more avoidable admissions than other diseases. However, even the definition of an ACSC is inconsistent (Sanderson and Dixon, 2000; Care Quality Commission, 2013).

The potential to provide better care earlier in the disease process extends across the care system. Public health departments, for example, could influence the initial development of disease and public understanding of appropriate consulting behaviour. Primary care could ensure effective treatment in the community, and when necessary, timely referral to elective services so that a problem does not escalate to emergency admission. Social care could help people to manage the effects of disease and, after a period of hospitalisation, provide services that allow a patient to continue their recovery at home free from readmission. Policy initiatives to avert admissions therefore affect the whole care system, not just the hospital sector.

2.5.2 Policy initiatives

In response to the increased demand for healthcare (Section 2.4), the NHS published a Five-Year Forward View in 2014 (NHS, 2014) proposing greater integration across the sectors of the care system with a greater focus on care in the community (Section 2.3.1). Forty-four Sustainability and Transformation Plans (STPs) followed in October 2016, setting out how the balance of care across the system would be changed at the local level and seeking to make avoidance of admission a reality. There has been widespread doubt that the measures proposed will deliver a reduction in admissions or in costs (Oliver, 2017), and a recent Nuffield Trust review found little evidence for their efficacy to date (Imison *et al.*, 2017). STPs were renamed Sustainability and Transformation Partnerships in 2017.

Measures to reduce demand on hospitals are often particular to admission type. Typically, policies target the part of the healthcare system from which the admission originates with penalties and incentives, in the expectation that avoidance is possible. For example, hospitals are penalised for readmission on the grounds that it could be avoided by better care during the index admission. Specifically, since 2011/12 the Department of Health has applied a policy of non-reimbursement for emergency readmissions within 30 days of discharge from an elective admission, alongside locally negotiated thresholds for other readmissions. The specific aim was to achieve a 25% reduction in readmission by preventing discharge until suitable aftercare was in place (Department of Health, 2010). Similar policies have been applied since with some variation (Blunt *et al.*, 2015), though cancer patients are excluded (Foundation Trust Network, 2011). The impact of this policy has been estimated at an annual reduction in hospital income of £790m (Foundation Trust Network, 2011), although its success in reducing readmissions is less clear.

Similar penalties are imposed on hospitals for allowing excess emergency admissions, on the grounds that A&E departments are responsible for them. In this case, the specific policy considers emergency admissions above the 2008/9 level to be excessive, and reimburses hospitals at only

30% of the usual tariff for them (NHS England, 2013). The remaining 70% of the tariff is invested in the Better Care Fund, which aims to redeploy resources elsewhere in the healthcare system in order to reduce emergency admissions by 15% by end of this decade (Wittenberg *et al.*, 2014). This disincentive to admit is counterbalanced by penalties for breaching a 4-hour waiting-time target in A&E, which results in increased pressure to admit and is argued by some to contribute to the upward trend in emergency admissions (Maguire *et al.*, 2016).

Incentives aimed at the prevention of all admissions are targeted towards the primary care sector, where since 2004, the Quality and Outcomes Framework (QOF), has provided GPs with financial rewards for identifying and managing selected ACSCs, discouraging smoking and implementing preventive measures, in the belief that reduced admission rates will follow. Around 25 individual criteria, or 'indicators', are enumerated by QOF with minor variations from year to year (NHS Employers, 2017). There is evidence that, against a backdrop of a 34% increase in rates of all-cause emergency admission, rates specific to incentivised conditions fell by 10% between 1998/9 and 2010/11 (Harrison *et al.*, 2014). Nevertheless, QOF single disease indicators have been criticised for inadequately representing the needs of an increasing population of older people with multiple complex problems (Roland and Guthrie, 2016).

Several interventions have been rolled out to support self-management in those with long term conditions, including the Year of Care, the Expert Patient Programme and Personal Health Budgets. Evaluation of pilot schemes suggests that although they benefit patients' wellbeing, self-efficacy, confidence and motivation, and should be welcomed for this alone, the evidence for an impact on use of health services is less convincing (Molloy *et al.*, 2016).

One strategy by which penalties for excess admissions might be avoided is to identify in advance those few patients who are responsible for a disproportionate number of admissions (Section 2.4.5), in order to more effectively target preventive interventions such as those exemplified above. Ambulatory care sensitive, or QOF incentivised conditions represent a broad-brush approach to the identification of people at risk of admission; a more sophisticated method is the development of predictive risk models (PRMs) using large, historic, routinely collected datasets to observe patterns of admission (Lewis *et al.*, 2011). These models are discussed in the next section.

2.5.3 Predictive risk models

PRMs vary in a number of ways. The first is the type of event they aim to predict, readmissions and emergency admissions being the most common. Some models predict which patients will experience more than one such event. Secondly, models differ in the dataset(s) they use, which affects both the population considered at risk and the range of available predictor variables.

Those that use only hospital data exclude non-admitted individuals from the population at risk and use a limited range of predictors, typically prior service use and a measure of morbidity. Meanwhile, models that add GP data extend the population within which cases are predicted and have the potential to include socioeconomic and lifestyle measures among the predictive variables. Thirdly, models vary in three important time parameters: the period of observed retrospective data; the length of the prediction window; and whether the start of the window is immediate or deferred (Lewis *et al.*, 2011).

Once developed, predictive models require validation in a different, but equivalent cohort. The discrimination, or accuracy, of the model is gauged by three metrics: the positive predictive value (PPV), which measures the proportion of those identified by the model who experience the outcome; the sensitivity, which measures the proportion of the population who experience the outcome who are identified by the model; and the C statistic, which is a summary measure of increasing performance of the model that ranges from 0 to 1 (Lewis *et al.*, 2011).

The effect of adding additional datasets to a model to predict emergency admission was investigated in a population of 1.8m in England (Billings *et al.*, 2013). Initially, the model was constructed using only inpatient data, then modified sequentially by adding accident and emergency, then outpatient, then GP data, to create four discrete models. The C statistic rose from 0.73 in the model using only inpatient data to 0.78 in the model incorporating all four datasets, and the authors concluded that the addition of more detailed datasets led to moderate improvement in the number of patients identified with little or no loss of PPV (Billings *et al.*, 2013). These findings contrast with a systematic review of models published in 2011 (Kansagara *et al.*, 2011): this identified 30 studies which collectively considered 26 unique models predicting readmission. Six of the studies compared different models in the same population, of which only two reported that functional and social variables improved model discrimination. Overall, the C statistic of the 26 models was found to range from 0.55-0.83 (Kansagara *et al.*, 2011). A recent innovation in predictive modelling in the US has been the use of artificial neural networks to model risk of readmission from electronic health records. Using machine-learning technology to update the model in real time led to increased PPV over standard models; nevertheless, the authors acknowledged the limitations inherent in their use of area level social data (Jamei *et al.*, 2017).

In general then, predictive models are limited by the data available to them, and have only modest success in identifying those at risk of admission. Following predictive modelling, preventive interventions are offered to people whose risk of admission is calculated to be high, though evidence for the efficacy of such interventions is equally uncertain (Purdy *et al.*, 2012).

2.6 Conclusion

The UK has an ageing population in which life expectancy is increasing more quickly than healthy life expectancy. This chapter has discussed the prevalence of common age-related conditions and demonstrated an impact of population ageing on rising trends in hospital admissions. Three important categories of hospitalisation, namely elective admission, emergency admission and readmission within 30 days have been distinguished and older people have been shown to experience higher rates than younger groups of each admission type. The types are shown to differ in many ways; these differences are suggested collectively to represent a gradient of *'seriousness'* that runs from elective, through emergency, to readmission; risk of more serious admission types is shown to be particularly elevated amongst the oldest people. Nevertheless, several authors have argued that population ageing explains only part of the overall increase in admissions to date, and APC analyses suggest that the impact of age on rates of admission will increase markedly from 2020/1, as the baby boomers grow older.

Hospitals are the most expensive element of the care system and managing demand for admission is enshrined in Government policy; this will become ever more important from 2020/1. Strategies that aim to deliver a reduction in admissions, such as PRMs or QOF, have limited effectiveness, although this chapter has shown that in the case of PRMs, enrichment of hospital data with GP records may improve performance by adding variables that go beyond individuals' morbidity or recent admission history. It is credible that such influences might impact risk of admission in view of the lifecourse model, which recognises the life-long role of extrinsic factors in ageing. In addition, models that use only hospital data omit valuable information on potentially preventive influences from people who have *not* been admitted to hospital: including GP records in PRMs supplies this.

The implications are threefold. First, research on hospital admissions should focus on individual-level, rather than population-level admissions, perhaps particularly on the few people who are responsible for many admissions. Secondly, more and better information is needed about the determinants of hospital admission if the NHS policy ambition to reduce demand on hospitals is to be realised. Ultimately, all routinely collected health records are limited to data of administrative or clinical relevance, thus additional information should be sought from bespoke research studies. Finally, the differing characteristics of elective admission, emergency admission and readmission suggest that risk factors for the three admission types may not be the same. The next chapter develops this investigation by reviewing research evidence on risk factors for admission, generally and then specific to elective admission, emergency admission and 30-day readmission.

Chapter 3: Risk factors for hospital admission

The previous chapter concluded first, that research on hospital admissions should be at the individual level; secondly, that more and better information is needed about risk factors for hospital admission if the NHS policy ambition to avoid admissions is to be realised; and thirdly, that risk factors for elective admission, emergency admission and readmission are not necessarily the same. This chapter reviews existing literature on risk factors for admission. Section 3.1 provides a brief history of research on the determinants of admission and explains why better evidence might be obtained by linking prospectively collected cohort data with routinely collected data on admissions. The advantages and practice of data linkage are then explored. Section 3.2 reviews English and Scottish cohorts that have been linked to admissions data and examines evidence they have produced. Some cohorts report admissions according to a threshold of severity; however, this threshold differs from cohort to cohort, and only one cohort reports risk factors for admissions below, as well as above, its threshold. Elective and emergency admission comprise separate outcomes in only one paper; readmission is considered by none. Therefore, in Section 3.3, papers investigating the determinants of elective admission, emergency admission and 30-day readmission are reviewed with a wider remit on study type. Section 3.4 draws together the risk factors identified and presents a conceptual framework that underpins the thesis. Section 3.5 concludes the review by outlining the specific contribution of this thesis and stating the research questions that are addressed.

3.1 Background

The Andersen Healthcare Utilization Model is a conceptual framework devised in the US in the 1960s (Andersen and Newman, 1973). It proposes that the uptake of healthcare is promoted or limited by three broad influences: *the healthcare system* itself, which may act through organisational or policy measures such as those exemplified in Section 2.5; *society*, which may act through socially accepted norms such as the tendency to treat increasingly old people; and the *individual* him or herself. Individual influences are further subdivided into three types: *predisposing characteristics*, such as age, sex, marital status or education, that affect a person's propensity to use services; *enabling characteristics*, such as transport or (in the US) income or insurance, that govern access to services; and *need*. This final category encompasses the type and severity of illness that the individual has, his or her recognition of it, and ultimately, clinical confirmation of the need for care. Need factors are recognised by Andersen as having the most direct effect on use of healthcare.

The multiplicity of influences recognised by the Andersen model has three implications for this review. First, because the effects of system and society may differ between countries, the review will focus initially on the UK. Secondly, because publicly funded healthcare within the UK may blunt the effects of system and society, the review will focus on risk factors relating to the individual. Thirdly, because the range of individual factors proposed by Andersen is so broad, the review will seek to identify studies that have adopted multifactorial designs to investigate the relative, as well as the absolute effect of the risk factors that they identify.

The Andersen Model has been widely used in psychology and gerontology: the original article has over 1500 citations listed on Web of Science. One citing paper, which applied the model to the cross-sectional analysis of data from the US Longitudinal Study on Aging (Wolinsky and Johnson, 1991), has been recognised as one of gerontology's most influential papers (Ferraro and Schafer, 2008). Based on self-reported data, this paper included explanatory variables representative of all the Andersen criteria to explore nine measures of healthcare utilisation, two of which related to hospitals. In line with Andersen's assertion, need characteristics, which included self-rated health and markers of physical and cognitive function, were seen to drive demand.

Although the Andersen model has been used extensively, it has been criticised for its US dominance and thus limited external validity. Applications have been found to lack sufficiently interrogative statistical methods such as multivariate analyses (Babitsch *et al.*, 2012), or methodological differentiation between mediation and moderation (von Lengerke *et al.*, 2014), and thus to be unable to identify the relative importance of risk factors identified or a causal pathway between them. Only ten of the papers citing the Andersen Model were published in specialist epidemiology journals. This may be symptomatic of a lack of epidemiological attention to the determinants of service use that has been noted previously:

> *'Epidemiology is the 'study of the distribution and determinants of health-related states and events in populations'. However, within epidemiology, more is known about the aetiology of disease than is understood about some of the determinants of health service utilization' (Hanlon et al., 2007 pp 405).*

It is a regrettable omission, not least because epidemiological resources and methodology could make a positive contribution in this area. This thesis adopts an interdisciplinary approach to investigate the determinants of hospital admission using epidemiological methods.

Whilst evidence hierarchies may be maligned, few doubt that epidemiological questions relating to 'real world' risk factors are best answered by prospective cohort studies that can identify multiple risk factors over time (Petticrew and Roberts, 2003). In a cohort study, a group of people are followed over time, and incidence rates of disease (the 'outcome') are compared in those who do, and do not, have a particular characteristic or 'exposure' at the outset (Ward *et al.*, 2012). A cohort study is described as 'prospective' if characterisation of exposures at baseline is followed by a period during which the development of the outcome of interest is monitored. If the outcome develops too slowly for this to be practical, a retrospective design may be used, in which the cohort is identified and the exposure characterised from pre-existing records (Coggon *et al.*, 2003). A cohort study is a type of longitudinal study in which participants are selected according to a particular criterion, for example, their birth date or occupational group. In other longitudinal studies, participants may be selected randomly from the population (Ward *et al.*, 2012).

The UK is home to a number of large national and local cohort studies in which a wide range of exposure variables has been measured in successive waves. These studies are largely conducted at the public expense and enjoy a high level of public support: it has been calculated that 1 in 30 people are members of a cohort study (Pell *et al.*, 2014). Such inclusivity means that findings from cohort studies are more generalisable to whole populations than are other research findings.

An MRC Strategic Review of the largest UK population cohort studies recommended that the scientific and interdisciplinary potential of cohorts should be enhanced through linkage to routine health records and administrative datasets (Medical Research Council, 2014). Linkage has also been advocated for by the Public Health Research Data Forum (Wellcome Trust, 2015), though their report acknowledges significant statistical, technical, operational and institutional challenges. This is regrettable: the UK is one of few countries to have both excellent cohort resources *and* a publicly funded healthcare system that generates records of almost all hospitalisations. In England, these records are produced by the Hospital Episode Statistics (HES) service (Section 2.4.1); sources vary in the other home nations. Linkage of cohort and admission data would offer a rare opportunity to explore the determinants of hospital admission. Records of admissions of cohort members could be collated at the individual level (Section 2.4.5) and compared with exposures to potential risk factors using data collected earlier in the lifecourse; analyses could relate to admissions in general or, in order to explore potential differences in risk factors between admission types, to elective admission, emergency admission and 30-day readmission. In addition to such investigations of the determinants of admission, linkage would have the potential to provide evidence on the distribution of admissions to supplement that examined in Sections 2.4.2 and 2.4.3.

The next section presents a review of the extent of linkage between cohort and admissions data in the UK, and explores the evidence that linkage has produced.

3.2 Cohort linkage

A total of seven major UK cohort studies have published significant bodies of work resulting from the linkage of prospectively collected study data with routine admissions data (ADLS Administrative Data Liaison Service, 2017b). In one, the Millennium Cohort Study, the admissions data are obstetric records relating to cohort mothers, and this cohort will be considered no further. The six remaining cohort studies have linked data from hospital admissions in mid-late life and are outlined below.

3.2.1 The European Prospective Investigation of Cancer (EPIC)

The European Prospective Investigation of Cancer is a collaborative cohort based in 23 centres across 10 European countries. Two are in England: EPIC Norfolk and EPIC Oxford; both have linked admissions data.

EPIC Norfolk

EPIC Norfolk is run by the University of Cambridge and is restricted to residents of Norfolk. It comprises 25,000 men and women recruited in the 1990s at age 40-79, with linked data on hospitalisations ascertained from a local database rather than through hospital episode statistics (Sinha *et al.*, 2008). A recently published paper examined admissions experienced by cohort members between 1999 to 2009 (Luben *et al.*, 2016), during which time, 72.7% of the cohort had at least one admission. Logistic modelling was used to examine the independent relationships between high hospital use (defined as having seven or more admissions during the follow-up period) and six potential predictor variables: age, male sex, having no educational qualifications, manual social class, current smoking and obesity (BMI>30). Significant associations (p<0.0001) were seen with all six predictors. A risk factor score constructed using all the variables except age demonstrated two- to three-fold differences in risk of admission between people with high and low numbers of risk factors. However, the likelihood of admission was high even among those with low risk factor scores: over half of women who were aged less than 55 at baseline and who had no defined risk factors were admitted during the follow-up period.

Apart from this publication, admissions data in EPIC Norfolk have been used only to ascertain specific diseases as outcomes: for example, a series of papers investigated HES-listed incident stroke in relation to baseline fish consumption (Myint *et al.*, 2006b), physical function (Myint *et al.*, 2007b), HbA1C (Myint *et al.*, 2007a), plasma vitamin C (Myint *et al.*, 2008) and physical activity (Myint *et al.*, 2006a). Disease-specific outcomes will be considered no further.

EPIC Oxford

EPIC Oxford, which is UK wide, is run by the University of Oxford and linked to HES data. Recruitment of the cohort, which is 50 percent vegetarian, ran from 1993-9 (University of Oxford, 2015a). HES linkage has been used to study the effect of diet on risk of admission or death specific to diverticular disease (Crowe *et al.*, 2011), cataracts (Appleby *et al.*, 2011), ischaemic heart disease (Crowe *et al.*, 2013), kidney stones (Turney *et al.*, 2014) and gallstones (McConnell *et al.*, 2017), but there has been no wider investigation into hospital admissions.

3.2.2 The Million Women Study

The Million Women Study is a prospective cohort run by the University of Oxford (University of Oxford, 2015b). Women aged fifty and over were recruited from routine breast screening clinics between 1996-9 with the initial aim of investigating risk factors for breast cancer. Participants are followed-up through HES data as well as through cancer notifications and death registration. The study website lists over 120 publications, around 25% of which derived outcome data from the linked hospital records. Outcomes considered were almost always cause-specific, and the papers address a wide range of conditions. Two papers have investigated overall admissions, reporting first, that during an average 9.2 years' follow-up, 1.25m women collectively experienced 2.83m hospital admissions; 61.7% of the cohort had at least one incident admission (Reeves *et al.*, 2014). Comparing baseline body mass index with these admission data showed a significant increase in both admission rate and length of stay with increasing BMI; the authors conclude that around 1 in 8 hospital admissions was attributable to overweight or obesity. Cause-specific analyses showed particularly marked associations between increased BMI and risk of admission for diabetes, knee-replacement, gallbladder disease, venous thromboembolism, cataracts, carpal tunnel syndrome and diverticulitis. Admission type was not differentiated. A subsequent paper showed that the increase in admissions associated with BMI translated into higher hospital costs for women with excess body weight (Kent *et al.*, 2017).

3.2.3 The Whitehall II Study

The Whitehall II Study is a prospective cohort run by University College London (University College London, 2018). 10,308 participants (2/3 men) were recruited from the civil service in 1985, when they were aged 35-55, with the aim of investigating social inequalities in health. Since then, they have been followed-up through self-completion questionnaires and clinical data, including Hospital Episode Statistics.

As in the Million Women Study, HES data have been used to define cause-specific outcomes, including dementia (Sabia *et al.*, 2017), CVD (Kivimaki *et al.*, 2011; Brunner *et al.*, 2014; Hinnouho *et al.*, 2015) and Type 2 diabetes (Hinnouho *et al.*, 2015). They have also contributed to a classification of ageing phenotypes (Akbaraly *et al.*, 2013a; Akbaraly *et al.*, 2013b). Just one paper has exploited the potential of cohort data to predict hospitalisation, although the aim of this study was actually to validate the individual components of the Fried frailty score (Fried *et al.*, 2001). In doing so, the authors showed that each of exhaustion, low physical activity, slow walking speed, low grip strength and recent weight loss was independently associated with admission (of unspecified sort) over a 28 month follow-up period (Bouillon *et al.*, 2013).

3.2.4 The Midspan Studies

The Midspan Studies are three Scottish cohorts originally screened in middle age in the 1960s and 70s, along with a fourth comprising their offspring (Hart *et al.*, 2005). Three of them: the Renfrew-Paisley Cohort (a general population cohort); the Family Cohort (the offspring of married couples from the Renfrew-Paisley Cohort); and the Collaborative Cohort (an occupational cohort); are linked to hospital records via the SMR1 and SMR4: admissions records from NHS Scotland that are broadly equivalent to HES data.

The Renfrew-Paisley Cohort

The Renfrew-Paisley Cohort comprises around 15,000 men and women recruited at age 45-64 during the early 1970s. During the subsequent 23 years, 79% of the cohort experienced at least one acute admission and 5% experienced a mental health admission (Hanlon *et al.*, 1998). This early paper classified admissions as *any* or *serious* (above the 75^{th} percentile for length of stay), and derived a multifactorial predictor panel of prospectively measured biological, behavioural and social variables. Associations were assessed using Cox Proportional Hazards regression models. Following mutual adjustment, risk of *any* acute admission was predicted by age, sex, FEV1 (a measure of respiratory function), smoking status, blood sugar, blood pressure, deprivation category and cholesterol level. The same variables, and body mass index, predicted *serious* acute admission with greater strength of association (Hanlon *et al.*, 1998). Further analyses of these data investigated the same risk factors in relation to the rising trend in hospitalisations over the follow-up period (Hanlon *et al.*, 2000a) and to specific diagnostic categories (Hanlon *et al.*, 2000b; Hart *et al.*, 2000).

A later study in the Renfrew-Paisley Cohort used an extended period of follow-up to examine the role of obesity as a risk factor for any admission. As in the Million Women Study, rates of admission were increased at higher BMIs; in this case rates were also elevated among women defined as underweight, resulting in a J-shaped curve. In men, admission rates increased with BMI without elevation in the underweight category (Hart *et al.*, 2007). In contrast to these findings for any admission, major psychiatric admissions were found to be associated with lower, rather than higher, BMI (Lawlor *et al.*, 2007).

The only known analysis of linked cohort data to consider elective and emergency admissions as separate outcomes also derives from this cohort. A single predictor, occupational social class, was compared with overall admissions, elective admissions and emergency admissions, with adjustment for other baseline variables (McCartney *et al.*, 2013). When analysed together, overall admissions showed no patterning by social class. However, separate analyses revealed contrasting trends in elective and emergency admissions, such that emergency admission was more common among those of lower social class and elective admission more common among those of higher social class. There were no obvious sex differences. Social gradients were also observed among cause-specific admissions, lower social class being associated with higher risk of admission due to cardiovascular disease, coronary heart disease, stroke, respiratory disease and mental health conditions in one or both sexes. After adjustment for other baseline variables, only the gradient in mental health conditions, including dementia in men and women, remained.

A later study considered occupational social class as a predictor of admission among women after their 80th birthday; men were excluded from this analysis as there were too few survivors (Hart *et al.*, 2015). As before, social class was unrelated to overall admissions. Surprisingly, given the previous findings, no separate analyses were carried out for elective or emergency admissions and the authors do not cite their earlier paper. The increased ratio of emergency to elective admissions at later ages described in Section 2.4.4 might suggest that if the previously observed social gradient in emergency admission remained after the age of 80, it would be more likely to be reflected in overall admissions at advanced ages, but it was not. Social gradients in cause-specific admissions were similar to those previously reported, CHD, stroke and mental health admissions being more common among lower social classes. In this case, cancers were more common among higher social classes. Hospital data from the Renfrew-Paisley Cohort have also been used to define ‘healthy’ and ‘unhealthy’ ageing, in order to investigate the relationship of ageing with deprivation (Gilhooly *et al.*, 2007a; Gilhooly *et al.*, 2007b).

The Collaborative Cohort

The Collaborative Cohort comprises around 6,000 men and 1,000 women recruited from 27 workplaces in central Scotland during the early 1970s and followed-up for over 25 years through admissions data (Hart *et al.*, 2005). HES data have been used to ascertain risk of cause-specific outcomes in relation to job instability (Metcalfe *et al.*, 2001) and stress (Metcalfe *et al.*, 2003;

Metcalfe *et al.*, 2005). No wider analysis of the influence of work on hospital admission has been reported.

Later output from the cohort has focused on the effects of alcohol consumption among men, showing a graded effect of number of units consumed per week on mortality and selected causes of hospital admission (Hart and Smith, 2008). An analysis that considered overall and mental health admissions as outcomes concluded that drinking 22 or more units per week was associated with increased risk of both. For mental health admission, but not for overall admission, there was a J-shaped relationship, non-drinkers having higher rates than light or moderate drinkers (Hart and Smith, 2009).

The Family Cohort

The Family Cohort comprises 2,300 offspring of the Renfrew-Paisley Cohort, recruited in 1998 at age 30-59 and followed-up through admissions data. These data appear to have been used only to ascertain cause-specific outcomes, for example cardiovascular disease, which was investigated in relation to baseline vitamin D deficiency (Welsh *et al.*, 2012).

Scottish Health Survey

An extension of the methods used in the Midspan studies has been applied, by the same authors, to data from the Scottish Health Survey (SHS). This is not a cohort study, nor is it one of the Midspan studies *per se*; rather it is an episodic series of cross-sectional surveys modelled on the annual Health Survey for England. Many modules are identical, allowing comparison between the countries (Scottish Executive, 2005). Both surveys seek consent to data linkage from their respondents. In Scotland, survey records are linked retrospectively to hospital admissions since 1981; in England, negotiations are ongoing (ADLS Administrative Data Liaison Service, 2017a).

The resource created has allowed researchers from the Midspan cohorts to repeat the investigation from the Renfrew-Paisley Cohort in a wider national population cohort (aged 16-74), namely the 1998 SHS respondents (Hanlon *et al.*, 2007). Using similar methodology, behavioural, biological and social risk factors were compared with hospitalisation during a 7.5-year follow-up period. Admissions were defined as serious if above average cost, and in this case only serious admissions were reported. The analyses differed from those in the earlier Renfrew-Paisley study in that each risk factor was assessed independently, with adjustment only for age and sex. More variables therefore achieved significance; hazard ratios were used to assess which had the most important effects. The authors highlight smoking, body mass index and FEV1 as influential risk factors, replicating the results from Renfrew-Paisley. They also note large effects on risk associated with self-rated health, longstanding illness and previous admission that had not been demonstrated previously. Markers of poverty or lower social position were typically associated with a smaller increase in risk of admission, for example, poorer educational achievement, lower social class, not owning a car, renting rather than owning a home or being unemployed were associated with increased risk of between 20 and 40%. Alcohol consumption, physical activity and diet also had small but significant effects on risk of admission.

Other papers using the linked SHS hospital statistics data have related specific disease outcomes to individual risk factors, for instance: admissions for alcohol related disease have been compared with alcohol consumption (McDonald *et al.*, 2009); and those for cardiovascular disease with physical activity (Stamatakis et al., 2009) and adiposity (Hotchkiss *et al.*, 2013).

3.2.5 UK Biobank

UK Biobank is a relatively new study which recruited 500,000 people aged 40 to 69 years between 2006 and 2010. Although it is a longitudinal study rather than a cohort, having obtained consent from each participant for access to HES data, it will develop into a valuable resource with time. As yet, only cause-specific outcomes have been considered (UK Biobank, 2016).

3.2.6 Overview of evidence from cohort linkage

Sections 3.2.1-3.2.3 described six cohorts with linked admissions data for people in mid-late life: EPIC Norfolk and EPIC Oxford; the Million Women Study; and three MIDSPAN cohorts - Renfrew-Paisley, Collaborative and Family. In addition, two non-cohort studies with relevant linked data were highlighted; the Scottish Health Survey and UK Biobank. Most research that has used these data has done so only to ascertain specific disease outcomes. Few papers either report the incidence of all-cause admissions or investigate risk factors for them.

Incidence of all-cause admissions

Three cohorts have reported evidence on the incidence of all-cause admission: EPIC Norfolk (72.7%); Million Women (61.7%); and Renfrew-Paisley (79.0%). These figures relate to different lengths of follow-up (10, 9 and 23 years respectively); during different periods (1999-09, 1997-2008 and 1972-95); from different baseline ages (40-79, 50-64 and 45-64 years); and with different sex ratios (55, 100 and 54% women). They are therefore not comparable; they do however demonstrate a consistently high demand for hospital care in later life.

Risk factors for all-cause admissions

Table 3 presents a summary of risk factors for admission identified by the studies discussed. The symbols denote observed associations between the variables listed and broad classes of admission that were considered across the cohort studies (white triangle for any admission; black triangle for serious admission (defined by frequency in EPIC Norfolk, length in Renfrew-Paisley, and cost in SHS); and grey diamond for emergency admission; the absence of a marker implies that no association was demonstrated, *either* because analysis showed no relationship *or* because no analysis was attempted).

Consistent with the national experience (Section 2.4.2), higher age and male sex were identified as risk factors for admission in two cohorts (Hanlon *et al.*, 1998; Luben *et al.*, 2016). Other studies adjusted their analyses for these variables. Four cohorts provided evidence that higher body mass index was associated with increased risk of hospitalisation, though collectively their findings suggest that risk from BMI may be attenuated in the presence of other risk factors, or may be limited to more serious categories of admission. Two analyses that considered BMI alone (Hart *et al.*, 2007; Reeves *et al.*, 2014) found higher values to be associated with increased risk of *any* admission. Conversely, mutually adjusted multifactorial analyses found BMI to be associated with *serious* admission, but not with *any* admission (Hanlon *et al.*, 1998). Two further studies that reported only relatively more serious admissions similarly found associations with increased BMI (Hanlon *et al.*, 2007; Luben *et al.*, 2016). In contrast to this general increase in risk with BMI, major psychiatric admissions were shown to be associated with lower, rather than higher BMI (Lawlor *et al.*, 2007); there was also a suggestion of a sex-specific increase in risk of admission among underweight women (Hart *et al.*, 2007).

Three lifestyle behaviours were identified as risk factors for admission (Table 3): smoking, alcohol intake and physical activity. Of these, only smoking was consistently associated with risk of overall and serious admission across the cohorts, whether considered among mutually adjusted multifactorial models (Hanlon *et al.*, 1998; Luben *et al.*, 2016) or alone (Hanlon *et al.*, 2007). Evidence on the effect of alcohol intake on risk of admission comes from just two studies and is less convincing. In the Midspan Collaborative study, risk of any admission was raised in men who drank 22 units or more per week with no apparent gradient below this level (Hart and Smith, 2009); in the Scottish Health Survey, the effect of alcohol was limited to ex drinkers, suggesting that their past, rather than their present behaviour underlay their increased risk of serious admission (Hanlon *et al.*, 2007). Physical activity was investigated only in the Scottish Health Survey, where men and women who achieved recommended levels of physical activity were at 21% lower risk of admission than those who did not; meanwhile, those who achieved target levels of fruit and vegetable intake had a 15% reduction in risk of serious admission (Hanlon *et al.*, 2007).

Table 3 Summary of risk factors for all-cause admission ascertained from UK cohort studies (Source, author's analysis of research across UK cohort studies)

	EPIC				MIDSPAN					
	Norfolk	Oxford	Million Women	Whitehall II	Renfrew-Paisley			Collaborative	Family	Scottish Health Survey
Age	▲				△	▲				
Sex	▲				△	▲				
BMI	▲		△			▲				▲
Smoking	▲				△	▲				▲
Alcohol								△		▲
Physical activity										▲
Diet										▲
Deprivation					△	▲				▲
Education	▲									▲
Social class	▲						◆			▲
Housing tenure		Cause-specific analyses only							Cause-specific analyses only	▲
Car ownership										▲
Lung function					△	▲				▲
Blood pressure					△	▲				▲
C-reactive protein										▲
Cholesterol					△	▲				▲
Blood sugar					△	▲				
Self-rated health										▲
Frailty				△						
Previous hospitalisation										▲

Association with: △ any admission; ▲ serious admission; ◆ emergency admission.

Five markers of social circumstances were identified as risk factors for admission (Table 3): deprivation, education, social class, housing tenure and car ownership. Deprivation, measured by the Carstairs Index (Carstairs and Morris, 1990), was associated with any acute admission and (more strongly) with serious acute admission in mutually adjusted multifactorial models in

Renfrew-Paisley (Hanlon *et al.*, 1998); analyses in the Scottish Health Survey confirmed a strong gradient in risk of serious admission across quintiles of the Carstairs score (Hanlon *et al.*, 2007). For other markers of social circumstances (some of which are replicated in the Carstairs index), risk was limited to more serious categories of admission.

Few markers of morbidity were assessed as risk factors for admission (Table 3), in spite of Andersen's recognition of need as the most important determinant of the utilisation of healthcare (Andersen and Newman, 1973). This may reflect a lack of baseline measurements in many of the cohorts identified. The measures reported suggest that lung function (ascertained by FEV1), cardiovascular disease (ascertained by blood pressure and levels of C-reactive protein and cholesterol), type 2 diabetes (ascertained by blood sugar) and frailty act as risk factors for any or serious admission (Hanlon *et al.*, 1998; Bouillon *et al.*, 2013). In addition to these specific markers of disease, the Scottish Health Survey reported a range of markers of general health. These included self-rated health, the metric from which health expectancy is calculated (Section 2.1.2), which showed a clear gradient in risk of serious admission, such that those whose rating was 'very bad' were 5 times more likely to have a serious admission than those whose rating was 'very good'. Previous hospitalisation might also be interpreted as a measure of morbidity; a four-fold increase in risk of subsequent serious admission was seen between those who had four or more admissions during the previous 5 years and those who had none in the Scottish Health Survey (Hanlon *et al.*, 2007).Together, the six cohort studies, augmented by evidence from the Scottish Health Survey, suggest that individual risk factors for hospitalisation derive from a person's demography, anthropometry, lifestyle, social circumstances and morbidity. In addition to the diversity of risk factors identified across the cohorts, evidence from EPIC Norfolk showed that, at the individual level, likelihood of admission accumulates according to the numbers of risk factors an individual has, but that even among those with no risk factors, admissions are common (Luben *et al.*, 2016).

Quality of evidence on risk factors

As suggested above, caveats apply to the interpretation of information collated from several sources as in Table 3, due to differing study designs and analysis strategies. Studies that examine the effect of a single predictor variable, such as BMI in the Million Women Study, or alcohol intake in the Collaborative Study, provide no information on the relative effect of different variables. Those that present a series of analyses adjusted only for age and sex, such as the Scottish Health Survey, do consider relationships between the variables. Of the cohorts identified, only EPIC Norfolk (Luben *et al.*, 2016) and Renfrew-Paisley (Hanlon *et al.*, 1998) present mutually adjusted multifactorial analyses.

This sort of multifactorial study design, with appropriate mutually adjusted analyses, might be considered a 'gold-standard' in the identification and differentiation of risk factors for hospital admission. Another example, recently reported from the Swedish Adoption/Twin Study of Aging, investigated factors associated with hospitalisation risk among 772 community living men and women aged 46-103 in Sweden (Hallgren *et al.*, 2016b). In this case a multifactorial predictor panel comprising markers of physical and psychological health, personality, socioeconomics and lifestyle was derived from a baseline postal questionnaire, and compared with overnight admissions experienced during 9 years' follow-up. Time to first overnight admission was analysed using Cox Proportional Hazards models; first in univariate models to identify significant risk factors, then in multivariate models that included all variables that achieved significance at the first stage. Factors associated with increased risk of admission were older age, male sex and having more support from relatives. Reduced risk of admission was related to being unmarried or widowed and having more support from friends. Interestingly, and apparently in contradiction of both UK evidence and Andersen's assertion, neither number of illnesses nor self-rated health were significant in the final model. A companion paper studying risk factors for hospitalisation among nursing home residents reported that in this frailer population, polypharmacy and multimorbidity were influential, along with history of falls and malnutrition (Hallgren *et al.*, 2016a). Thus the elevated rates of admission among nursing home residents that were discussed in Section 2.4.5 appear to be associated with a different profile of risk factors from those seen among the community dwelling.

Type-specific evidence

Comparison across cohorts is also complicated by differing outcomes, some choosing to report overall admissions, whilst others differentiate according to a measure of severity such as frequency, length, cost, or in the Swedish example above, by limiting the analysis to admissions involving an overnight stay. Only the Renfrew-Paisley study compared *any* and *serious* admission as outcomes against the same, mutually adjusted predictor panel, finding that whilst risk factors for each were similar, their associations with serious admissions were stronger (Hanlon *et al.*, 1998); it was also the only cohort to report elective and emergency admissions as separate outcomes, in just one analysis that considered the role of social class as predictor (McCartney *et al.*, 2013). The analysis revealed opposing trends in emergency and elective admission that were obscured by considering all admissions together. This fact, along with the differences between types of admission demonstrated in Section 2.4.4, provides a strong indication that emergency and elective admissions may have different drivers and justifies further investigation of risk factors specific to each. Since major UK cohorts can provide no further evidence specific to admission type, wider sources are consulted in the following section.

3.3 Risk factors specific to admission type

This section reviews evidence on the determinants of hospitalisation specific to elective admission, emergency admission and readmission. Like Section 3.2, it is limited to individual, rather than societal or systemic risk factors and omits studies whose outcomes were cause-specific admissions. To match the assessments of population-wide risk afforded by the UK cohorts, it also omits studies whose sampling was by specific pre-existing disease. In order to investigate the predictors of elective, emergency and 30-day readmission types as outcomes, the remit of this review is widened beyond that of Section 3.2, to include first, international studies and secondly, those from across the hierarchy of epidemiological evidence.

These specifications reduce a very large body of literature to manageable proportions; nevertheless, this is not intended to be an exhaustive review, but rather to add type-specific evidence to that obtained from UK cohorts. To this end, the framework to which risk factor variables identified were related above: demography and anthropometry; lifestyle; social circumstances; and morbidity; guides the structure of each section. Academic interest in risk factors for 30-day readmission greatly outweighs interest in admissions of other types; therefore, from this point forward, the order in which the three outcomes are considered is reversed, thus: 30-day readmission; emergency admission; elective admission.

3.3.1 30-day readmissions

Although the aim of this review is to elicit evidence on individual risk factors for admission, the influence of system factors must be acknowledged in discussing readmissions; of the three admission types considered, they are most directly linked to the system via the index admission and for this reason they are regarded as most likely to be avoidable, despite involving the sickest people. The policy of non-reimbursement adopted by the NHS (Section 2.5.2) is founded on the belief that the cause of readmission lies within the index admission. If this were so, some emergency readmissions could be prevented by optimal care at this stage (Robinson, 2010b).

There is, however, ample evidence that the influence of patient factors dominates among risk factors for readmission. An analysis that aimed to quantify the relative effects of patient and hospital factors in the US estimated that patient factors explained 56.2% of the variation between hospitals in risk of readmission, whilst hospital factors explained only 9.3% (Singh *et al.*, 2014).

The narrative findings of two systematic reviews of high-quality studies investigating the clinical, demographic, social and other risk factors for readmission among older people are drawn on extensively in the review of patient related risk factors that follows. The original papers are consulted and supplemented by other material as appropriate. The first of the reviews was limited to papers reporting prospective cohort studies among people aged 75 or more. (Garcia-Perez *et al.*, 2011). The outcome of interest was unplanned readmission for any medical problem during follow-up periods that extended from 15 days to 18 months from the date of discharge. Twelve studies meeting the criteria were identified, all from developed countries; information reviewed here relates only to four studies that had follow-up periods of one month or less (Kwok *et al.*, 1999; Lotus Shyu *et al.*, 2004; Cornette *et al.*, 2005; Laniece *et al.*, 2008). The second review included two prospective cohort studies not included in the first (Espallargues *et al.*, 2008; Fisher *et al.*, 2013), four retrospective cohort studies (Pines *et al.*, 2010; Dinescu *et al.*, 2012; Robinson and Kerse, 2012; Spector *et al.*, 2015) and a case-control study (Dombrowski *et al.*, 2012), all in Western populations aged 65 or more. Its outcome of interest was unplanned readmission to an acute care hospital within one month of discharge (Pedersen *et al.*, 2014, 2017).

Demography and anthropometry

Section 2.4.3.3 demonstrated higher rates of readmission at older ages in the UK; it is therefore not surprising that most research into readmission has selected study populations of advanced age. Within these narrow ranges, some, but not all, studies observed an association with higher age (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017). Risk of readmission attributable to sex is also equivocal, most studies showing no effect (Garcia-Perez *et al.*, 2011), though there are reports of higher incidence among men (Pedersen *et al.*, 2017).

Lifestyle

Surprisingly, neither of the systematic reviews reported risk attributable to lifestyle behaviours, perhaps because among a panel of risk factors, they are relatively unimportant. In the US, for example, being an active smoker was unrelated to risk of readmission in mutually adjusted analyses that included a diverse range of potential risk factors (Iloabuchi *et al.*, 2014). The effect of alcohol consumption was similarly vulnerable to adjustment for other factors in a US study of predominantly male Veterans aged 65 or more (Chavez *et al.*, 2016). Although univariate analyses demonstrated an increase in risk of 30-day readmission in both high-risk drinkers and non-drinkers, after adjustment for sociodemographic and health variables, only non-drinkers retained an increased risk of readmission. A small study using accelerometry to assess physical activity among men and women aged 65 or more in the US found that a higher step count during the week after discharge was associated with lower risk of 30-day readmission, but again the relationship was attenuated by adjustment for sociodemographic, functional and healthcare characteristics (Fisher *et al.*, 2013).

Social circumstances

The two systematic reviews both cited risk of readmission accruing from social circumstances, though they found different variables to be influential. Garcia Perez cited a study in Taiwan, showing that discharged patients whose caregivers requested help from social services had a readmission rate 10 times that of those who did not need help, and another in Italy that suggested, surprisingly, that having higher level of education was associated with increased risk (Garcia-Perez *et al.*, 2011). Meanwhile, Pedersen reports deprivation to be important (Pedersen *et al.*, 2017).

Interactions of other risk factors with poverty were explored in the prospective Geriatric Resources for Assessment and Care of Elders study (GRACE) in Indianapolis, among community-dwelling adults aged 65 or more who had annual incomes less than 200% of the federal poverty level. Measurements of health and functional status at baseline were followed by four rounds of data collection in the next two years. Independent risk factors for 30-day readmission included living alone, not having Medicaid, and staying in a nursing home in the past 6 months. There was no association with education (Iloabuchi *et al.*, 2014).

Physical function

The two systematic reviews differed in their classification of variables relating to physical function. One considered them with measures of disease as 'health characteristics' (Pedersen *et al.*, 2017); the other defined separate categories relating to 'functional capacity' and 'morbidity' (Garcia-Perez *et al.*, 2011). Notwithstanding this difference, both reviews concluded that functional characteristics are associated with risk of 30-day readmission: via score on the Barthel index of activities of daily living and dependency in feeding (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017). In the GRACE study cited above, having a new assistive device in the previous six months was an independent predictor of 30-day readmission (Iloabuchi *et al.*, 2014).

Morbidity

The prevalence of age-related conditions in England and their impact on hospital admissions was discussed in Section 2.2.3. Internationally, many studies of readmissions have examined associations between the primary diagnosis of the index admission and likelihood of readmission, with no clear pattern identified. Both systematic reviews recognised aspects of health or morbidity as risk factors for 30-day readmission, but again, there was little consensus over which diagnoses or comorbid conditions were important. Studies included in the first review cited diseases of the respiratory, genitourinary and circulatory systems, cancer and poor overall condition (Garcia-Perez *et al.*, 2011). To this list, the second review added diseases of the gastrointestinal system, number of geriatric giants, injury, and a number of clinical markers during the index admission (Pedersen *et al.*, 2017). Meanwhile, the GRACE study (see above) found no association with any chronic disease from a list that included COPD, congestive heart failure, myocardial infarction, diabetes mellitus, stroke, cancer, depression, and dementia (Iloabuchi *et al.*, 2014), although both dementia (Daiello *et al.*, 2014) and depression (Marcantonio *et al.*, 1999) have been previously linked to risk of 30-day readmission in the US.

The tendency of age-related conditions to cluster was explored in Section 2.2.3, and this phenomenon has been found to predict 30-day readmission, whether defined by number of diagnoses (Chu and Pei, 1999; Marcantonio *et al.*, 1999; Au *et al.*, 2002), or the score from a comorbidity index (Shu *et al.*, 2012; Pugh *et al.*, 2014). In Spain, an analysis of readmissions within an administrative database found that comorbidity was associated with increased risk of readmission at one month but not at one year, possibly due to a mortality bias (Librero *et al.*, 1999).

Finally, the predictive value of patients' subjective appraisal of their health (Section 2.1.2) at discharge from the index admission has been investigated in Hong Kong using a structural equation model. A composite measure that combined 5 indicators including self-rated health was the only variable significantly affecting risk of 28-day readmission among these patients (Wong *et al.*, 2010).

Previous hospitalisation

There is a large literature on prior hospital care in relation to readmission, and both systematic reviews report associations with fact of previous admission, duration of admission(s), or both (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017). Pedersen additionally cites admission by transfer and discharge to a nursing home as risk factors for readmission. However, although previous admissions tend to be regarded as missed opportunities to avert readmission, they do not just represent system factors: it is possible to view them as additional markers of morbidity, as classified by the Scottish Health Survey (Section 3.2.5).

3.3.2 Emergency admissions

Emergency admissions have been relatively less studied than readmission. A review article on risk factors for unplanned admissions in older people found limited evidence from high quality studies and was forced to draw conclusions from studies intended to validate screening or risk stratification tools, whilst sounding appropriate caveats over their interpretation (Walsh, 2014). The findings of the article are discussed below, and supplemented by other relevant evidence.

Demography and anthropometry

The review cited above reports clear evidence of increased risk of emergency admission with higher age (Walsh, 2014). This is confirmed by the findings of two studies in Leicestershire: the first linked admissions data for those aged 65 or more with enumeration district level denominators from the census (Bernard and Smith, 1998); the second, an ecological study, compared the emergency admission rate of GP practices with the percentage of practice populations that were aged 65 or over (Bankart *et al.*, 2011). Conversely, two prospective cohort studies nested within randomised controlled trials reported that the effect of age was unrelated to emergency admission among frail patients aged 50 or more in the US (Damush *et al.*, 2004), and was attenuated once other risks were accounted for in multivariate analyses among those aged 70 or more in Australia (Mallitt *et al.*, 2015).

The effects of sex on risk of emergency admission were not mentioned by the review article; supplementary material consulted has produced conflicting results. Higher risk in men was found in the first of the Leicestershire studies (Bernard and Smith, 1998) and among those aged 70 or over in Sydney (Mallitt *et al.*, 2015). Conversely, the ecological study in Leicestershire found increased risk of emergency admission among practices with higher proportions of women. This may be because it included patients of all ages, though it did not include maternity admissions (Bankart *et al.*, 2011).

The review does not mention anthropometric variables either; one supplementary study has been identified showing that, among frail older patients in the US, lower BMI was associated with increased risk of emergency admission (Damush *et al.*, 2004).

Lifestyle

No markers of lifestyle are considered by the review article. The impact of physical activity specific to emergency admission has been investigated by a small prospective cohort study in Bristol among people aged 70 and above. Univariate analyses of accelerometry data collected over one week showed that decrease in minutes/week of moderate-to-vigorous physical activity was predictive of unplanned admission; however, no significant relationship remained when adjusted for lower-limb function, summarised across measures of the Short Physical Performance Battery (Simmonds *et al.*, 2014a).

Social circumstances

A range of social circumstances have been associated with increased risk of emergency admission. Walsh cites evidence to suggest that living in a nursing home, in an urban environment or alone are detrimental (Walsh, 2014), though this latter relationship was replicated in men, but not women, in Sweden (Pimouguet *et al.*, 2017). Other living arrangements that have been associated with risk include having a live-in carer in Australia (Mallitt *et al.*, 2015).

Walsh also reports deprivation to be associated with risk of emergency admission; this has been confirmed among older people (Bernard and Smith, 1998) and at all ages (Bankart *et al.*, 2011) in Leicestershire and in a population of adults aged 20 or more in a retrospective cohort in Scotland (Payne *et al.*, 2013). In an ecological study in London, the percentage of the patients classified as unskilled was positively associated with emergency admission (Reid *et al.*, 1999).

Physical function

No analyses of risk of emergency admission accruing from physical function are reported by the review article; just one has been found, showing that among frail individuals in the US, rate of emergency admission was reduced among those with better SF-36 physical function (Damush *et al.*, 2004). This relationship was independent of demographic variables, disease status and prior hospitalisation.

Morbidity

A wide range of physical diseases have been associated with increased risk of emergency admission, including heart failure (Damush *et al.*, 2004; Walsh, 2014), diabetes and anaemia (Damush *et al.*, 2004). Risk has also been attributed to mental health conditions (Payne *et al.*, 2013; Walsh, 2014) as well as to more general measures of ill health such as multimorbidity (Payne *et al.*, 2013; Walsh, 2014), and in ecological studies, to the percentage of a practice population classified as chronically ill (Reid *et al.*, 1999). Polypharmacy has been associated with risk even after accounting for comorbidity (Damush *et al.*, 2004): among those aged 80 or more in Belgium, there was an 11% increase in risk of emergency admission per extra medication taken (Wauters *et al.*, 2016).

Previous hospitalisation

Walsh, among others, reports prior hospitalisation, as well as increased numbers of primary care visits to be predictive of emergency admission (Walsh, 2014).

3.3.3 Elective admissions

Little evidence is available on risk factors for all-cause elective admissions, other than from ecological studies that consider whole populations, rather than just older people.

Demography and anthropometry

Risk factors for elective admission have been investigated in a third study in Leicestershire, which showed that higher percentages of practice populations who were aged 65 or more, were of white ethnicity, or were female had significantly increased risk of elective admission in multivariate analyses (Chauhan *et al.*, 2012).

Social circumstances

The association between deprivation and elective admission has been investigated among GP practices in South London using the Jarman UPA8 score (Reid *et al.*, 1999) and in Leicestershire using the index of multiple deprivation (IMD) (Chauhan *et al.*, 2012). Neither study demonstrated a link after adjustment for other variables. In the Thames Valley, at Lower Super Output Area level, relationships between IMD and overnight elective admission were shown to differ by Health Resource Group chapter (ie, by body system), but the author concluded that overall,

'elective admission is relatively insensitive to the effect of increasing IMD' (Jones, 2006a pp7).

Had this study not excluded day cases, it is possible that associations would have been smaller still. This would tally with evidence that links higher social class with increased demand for elective care (Dixon *et al.*, 2007).

Morbidity

Specific diseases have clear associations with elective admission according to their treatment protocols, thus risk of admission follows risk of disease, mediated by the variables above. However, no single disease appears to define risk effectively at the population level; in Leicestershire, coronary heart disease prevalence was used as a marker of chronic disease, but no association was found (Chauhan *et al.*, 2012). Adopting a more general marker of overall health in South London, a positive association was demonstrated between the percentage of the practice population classified as chronically ill and elective admission (Reid *et al.*, 1999).

3.3.4 Comparison of admission types

The evidence presented above is drawn from multiple studies in diverse populations and may not be fully comparable. Populations in which more than one admission type has been studied using a consistent methodology are needed to overcome this problem. Five populations have been identified in which emergency and elective admissions have been studied. The first, the Renfrew-Paisley Cohort (Section 3.2.3), showed opposing associations between social class and admission, such that rates of emergency admission were raised in people of lower, and elective admission in people of higher, occupational social class. In analyses of all admissions combined, these relationships were masked (McCartney *et al.*, 2013). This observation, combined with the differences between admission types outlined in Sections 2.4.3-2.3.4 justified separate consideration of admission types in this review.

Risk factors for elective and emergency admissions were also reported separately in the previously cited ecological studies from London (Reid *et al.*, 1999), Leicestershire (Bankart *et al.*, 2011; Chauhan *et al.*, 2012) and the Thames Valley (Jones, 2006a): in each case, measures of deprivation were associated strongly with emergency admission and minimally or not at all with elective admission. In the Thames Valley study, the relative effect of a 10-unit rise in IMD was compared for overnight elective and emergency admissions by HRG chapter. For emergency admissions, the effect ranged from 6-33%, compared with just 1-9%, for elective admissions (Jones, 2006a).

The effects of other variables have been compared more obliquely in London, where combined census-defined sociodemographic patient factors were estimated to explain 45% of the between-practice variation in rate of emergency admission, compared with 25% for elective admission. The relative contribution of different factors to the combined measure varied, chronic illness being the primary explanatory variable for elective admission, whilst being unskilled dominated risk of emergency admission (Reid *et al.*, 1999).

A range of variables have also been evaluated as potential risk factors for elective and emergency admission at the individual level by a trend study set in The Netherlands. Multiple waves of data collection between 1995 and 2009 in the Longitudinal Aging Study Amsterdam (LASA) were used to define trends in health, demographic and lifestyle characteristics, which were related to trends in admission during the 36 months following each wave of data collection, ascertained by linkage to routine data. Among 2,520 participants aged 65-88 years, trends in admission were seen to differ by type, with a two-fold increase in elective day cases; there was also a slight increase in overnight admissions, due entirely to emergency cases. Increased prevalence of chronic diseases, functional limitations and polypharmacy partly explained the trend in emergency admissions. Policy factors, such as healthcare reform and increasing treatment possibilities, also contributed to the rise in emergency admissions, and were considered to wholly explain the trend in day cases (Galenkamp *et al.*, 2016). This mirrors the greater impact of period effects on elective admission than on emergency admission that was demonstrated in the UK (Wittenberg *et al.*, 2015) (Section 2.4.4).

None of the above studies extended its comparison of admission types to include readmission.

3.3.5 Overview of type-specific evidence

Table 4 presents a summary of type-specific risk factors for admission identified by Sections 3.3.1-3.3.4 above. The symbols denote associations between the variables listed and each admission type: filled symbols represent evidence of an independent association; open symbols represent associations that are confirmed only by univariate evidence or for which direction is unclear; the absence of a marker implies that no association has been demonstrated or that there is no known analysis.

Table 4 Summary of risk factors for all-cause type-specific admission among older people (Source, author's analysis of research across international studies)

	Admission type		
	Readmission	Emergency	Elective
Age	○	◇	□
Sex	○	◇	□
BMI		◇	
Smoking	○		
Alcohol consumption	○		
Physical activity	○	◇	
Social Circumstances	●	◆	□
Physical function	●	◆	
Morbidity	●	◆	■
Previous hospitalisation	●	◆	

Key: filled symbol = strong association; open symbol = univariate or ambiguous association

Evidence on demographic variables is derived from figures 3-5, which show that rates of admission are highest in the oldest age groups, irrespective of admission type. This is confirmed in studies of specific admission types when whole populations are sampled. However, studies that are restricted to older populations often do not detect an effect across a narrow age range, suggesting that biological age may be a more important risk factor than chronological age in later life. The effect of age is therefore considered equivocal. The same is true of sex, though the bulk of evidence seems to suggest that among older populations, males have higher rates of readmission and emergency admission, whilst across all ages, the risk for females is greater.

Little evidence was found on anthropometric variables; a single association between lower BMI and increased risk of emergency admission being considered (Damush *et al.*, 2004). In view of the J shaped curve and the inverse association of BMI with mental health admissions that were reported in the Midspan studies (Hart *et al.*, 2007; Lawlor *et al.*, 2007), this is viewed as incomplete evidence and the association is again considered equivocal.

Associations with lifestyle variables that were demonstrated for readmission and emergency admission were generally vulnerable to adjustment for other factors. A single exception was an elevated risk of readmission among non-drinkers (Chavez *et al.*, 2016), again mirroring reported associations with ex-drinkers in the Midspan studies (Hanlon *et al.*, 2007).

The evidence relating to social circumstances is clearer, particularly in relation to lower social status and deprivation, for which strong links with readmission and emergency admission have consistently been demonstrated (Garcia-Perez *et al.*, 2011; Walsh, 2014). In contrast, elective admission appears to be associated with higher social class (Dixon *et al.*, 2007); this divergent relationship has been demonstrated in most (Reid *et al.*, 1999; Bankart *et al.*, 2011; Chauhan *et al.*, 2012; McCartney *et al.*, 2013) but not all (Jones, 2006a) of the populations in which both elective and emergency admissions have been studied and is noted in *serious*, but not in *all*, admissions reported by the cohort studies (Table 3).

Evidence on the relationship of physical function suggests that measures of severely compromised function, such as ADL limitations, are associated with readmission (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017), whilst a better score on the ordinal SF-36 PF domain is associated reduced risk of emergency admission (Damush *et al.*, 2004). Physical function does not appear to have been considered as a risk factor specific to elective admission, nor in the cohort studies discussed.

A wide range of diseases has been associated with readmission and emergency admission, with no consensus over which is most important (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017); indeed, some studies have reported no association with any specific disease in wide-ranging multivariate models (Iloabuchi *et al.*, 2014). Markers of general disease are perhaps more consistent risk factors across the spectrum of admission types, multimorbidity having been associated with readmission (Chu and Pei, 1999; Marcantonio *et al.*, 1999; Au *et al.*, 2002; Shu *et al.*, 2012; Pugh *et al.*, 2014) and emergency admission (Payne *et al.*, 2013; Walsh, 2014); polypharmacy with emergency admission (Damush *et al.*, 2004; Wauters *et al.*, 2016); and long term limiting illness with both emergency and elective admission in the same population in London (Reid *et al.*, 1999). No disease-specific risk factors for elective admission have been found, although markers for respiratory disease, cardiovascular disease and diabetes were found to predict any admission as well as serious admission in Renfrew-Paisley (Hanlon *et al.*, 1998).

Previous admissions, alongside a range of other measures of healthcare utilisation, have been found to predict readmission and emergency admission. Although they are often regarded as system factors, and may be thought suggestive of system failure, prior admissions can equally be viewed as markers of poor health. Intuitively, although the rise in elective day case admissions is attributed to system factors (Galenkamp *et al.*, 2016), such admissions must also be related to individual factors; the system cannot operate without patients. The likelihood is that the balance between system and individual factors differs by admission type, as do APC effects.

3.4 Summary of risk factors for admission

Overall, UK cohorts and international type-specific studies produce similar findings on risk factors for admission. In cohort studies, more risk factors are apparent when the outcome is a *serious* admission, however defined, than when it is *any* admission. In type-specific studies, more risk factors have been identified for readmission and emergency admission than for elective admission. This may simply be due to preferential academic interest in readmission and emergency admission, perhaps driven by policy incentives; alternatively, it may support the suggestion (Section 2.4.4) that admission type is another proxy for *'seriousness'* of admission.

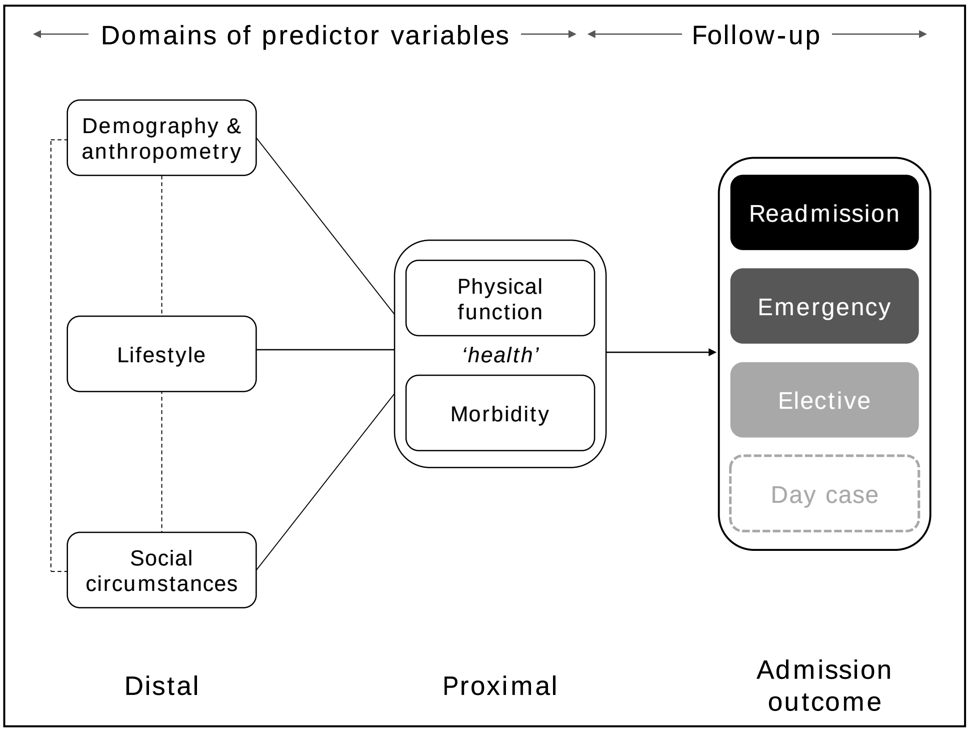


Figure 6 A priori conceptual framework showing relationships between domains of predictor variables and admission outcomes (Source, author)

Figure 6 shows a diagrammatic summary of the combined evidence on risk factors for all cause admission. Risk factors are grouped into five domains, the first of which is *demography and anthropometry;* a disparate group of variables relating to the person which includes age, sex, and body size. The second domain relates to *lifestyle,* and includes health behaviours such as smoking, alcohol consumption, physical activity and diet. The third domain contains a wide range of measures of *social circumstances*; the variables have influences across the lifecourse and include education, relationship status, measures of wealth and social standing, and living arrangements in old age. The fourth domain is *physical function*, typically enumerated using scales of ADL or IADL limitation or the SF-36 tool. *Morbidity* summarises the final domain; many examples of which have been implicated, including several of the age-related diseases listed in Table 1. Measures of self-rated health and previous hospitalisation are also classified to this domain.

The relative placement of the domains on Figure 6 is informed by the evidence shown in Table 4. No admission type has an association with demography and anthropometry or with lifestyle that is informed by consistent, unambiguous, multivariate evidence; thus these domains are considered distal to admission outcomes. Social circumstances are also placed distally, because evidence, though strong, is not consistent for elective admission. The potential for independent effects of each of these domains on admission is nonetheless acknowledged. Demography and anthropometry, for example, could directly affect risk of admission if older or fatter people were denied elective procedures from which they were less likely to benefit than younger, thinner people with the same disease status. Alternatively, such individuals may be more likely to be admitted for procedures that could usually be carried out safely in the community. Lifestyle could independently affect risk of admission if behaviour affected the choice of treatment considered appropriate, (eg smokers may not be suited to thoracic surgery), or if the behaviour itself required supervision to ensure a favourable outcome to a health problem (eg those under the influence of alcohol admitted via A&E after a minor accident). Direct effects of social circumstances on risk of hospital admission could result from difficulties in access to medical care, inadequate domestic environment or lack of a caregiver at home. Figure 6 also recognises, by means of dotted lines, potential interrelationships between these distally placed domains.

The two remaining domains, physical function and morbidity, are grouped, in recognition of their close and bidirectional relationships, and for consistency with other reviewers (Pedersen *et al.*, 2017). Because not all exemplar variables are measures of morbidity *per se*, the two domains together are considered to represent *health*. This composite domain is positioned proximal to admission, due to the relationship with morbidity that is consistent across admission types in Table 4, and in accordance with Andersen's recognition of need as having the most direct impact on admission (Andersen and Newman, 1973). Notwithstanding the capacity for independent effects on admission from anthropometry, demography, lifestyle and social circumstances, the placement of these domains behind health in Figure 6 suggests that their impact on admission may be largely mediated through recognised associations with health (discussed in Section 4.6.1); associations which may be bidirectional.

3.5 Conclusion

In conclusion, this chapter has shown that several UK cohort studies have been successfully linked to Hospital Episode Statistics and have yielded evidence on risk factors for admission. Limited conclusions can be drawn about the relative effects of these risk factors on admissions of differing seriousness; still less is clear about their specific contributions to readmission within 30 days, emergency admission or elective admission (Section 3.2.4). Collectively, the international literature on risk factors for admissions of these types is difficult to interpret, but provides some suggestion that risks vary by type of admission as they do by seriousness of admission in the cohort studies, readmission being the most 'serious' type of admission (Section 3.3.4). This similarity supports the impression of a gradient in *'seriousness'* across the types explored in Section 2.4.4.

The relative contribution of system factors to risk of admission can be seen to differ by admission type. However, the influence of individual factors is unavoidable, and is probably the most difficult for policy makers to modify. This review suggests that the individual determinants of admission can be broadly categorised to five domains: demography and anthropometry; lifestyle; social circumstances; physical function; and morbidity. A conceptual framework is presented in Figure 6.

In the context of this thesis, five criticisms may be levelled at the literature reviewed. First, there is a problem of comparability: between studies that differ in design and quality; and between studies from different populations that are not necessarily applicable to the UK. Secondly, studies that examine only a narrow range of predictor variables produce no evidence on their relative importance. Thirdly, the complexity of individual admission histories has not been addressed: if people have admissions of more than one type, the specificity of risk factors they exhibit to the type of admissions they experience is questionable. Fourthly, few studies have examined the constancy of risk factors across different admission types; nor fifthly, whether there is a gradient in risk between types.

As Pedersen concludes in her systematic review of risk factors for readmission:

'Due to the breadth and diversity of variables examined and the lack of comparability of findings, the impact of these varying factors and their value as risk adjusters and application in different settings and populations are limited' (Pedersen et al, 2017 pp 455).

More consistent information is clearly required.

This thesis makes a unique contribution to the field by exploring the associations, in older people, between a panel of prospectively measured risk factors and three outcomes: 30-day readmission, emergency admission and elective admission. The work uses data from the Hertfordshire Cohort Study and an extract of HES data relating to its members. A multifactorial predictor panel is selected according to the evidence of this review to include variables representative of the domains identified in Figure 6: demography and anthropometry; lifestyle; social circumstances; physical function and morbidity. This allows an evaluation of their relative importance in an at-risk population comprising a community dwelling cohort that includes admitted and non-admitted individuals. Analyses consider broad patterns of hospital admission rather than a single admission as the dependent variable, and examine the constancy of risk factors across admission types. This has not been done before and has the potential to contribute to the existing international literature on the determinants of admission by type. In addition to this work on the determinants of admission, the linked files have contributed to the rather sparse UK literature on the distribution of admissions among older people in the following publication, which is reproduced in Appendix A:

Simmonds, S.J., Syddall, H.E., Walsh, B., Evandrou, M., Dennison, E.M., Cooper, C. and Aihie Sayer, A. (2014) Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study. *Age Ageing,* 43, 653-660.

The formal research questions addressed by this thesis are these:

1. How could Hospital Episode Statistics and Cohort Study data be linked to produce a dataset with added value?
2. In such a dataset, how would demography and anthropometry; lifestyle; social circumstances; physical function; and morbidity; individually and together, affect risk of:
    a) readmission within 30 days?
    b) emergency admission?
    c) elective admission?
3. Are there common drivers of different types of admission at older ages?

The next chapter addresses the first question by describing the cohort and administrative data that are available, ethical considerations governing their use, methods of linkage, and the resulting dataset used by this research. Chapters 5, 6 and 7 focus on the individual parts of Question 2, each presenting a paper that compares a common panel of 25 predictor variables with one of three outcomes: readmission within 30 days of discharge (Chapter 5); emergency admission (Chapter 6); and elective admission (Chapter 7). The final chapter compares and contrasts the findings of the papers to address the third question.

Chapter 4: Data and methods

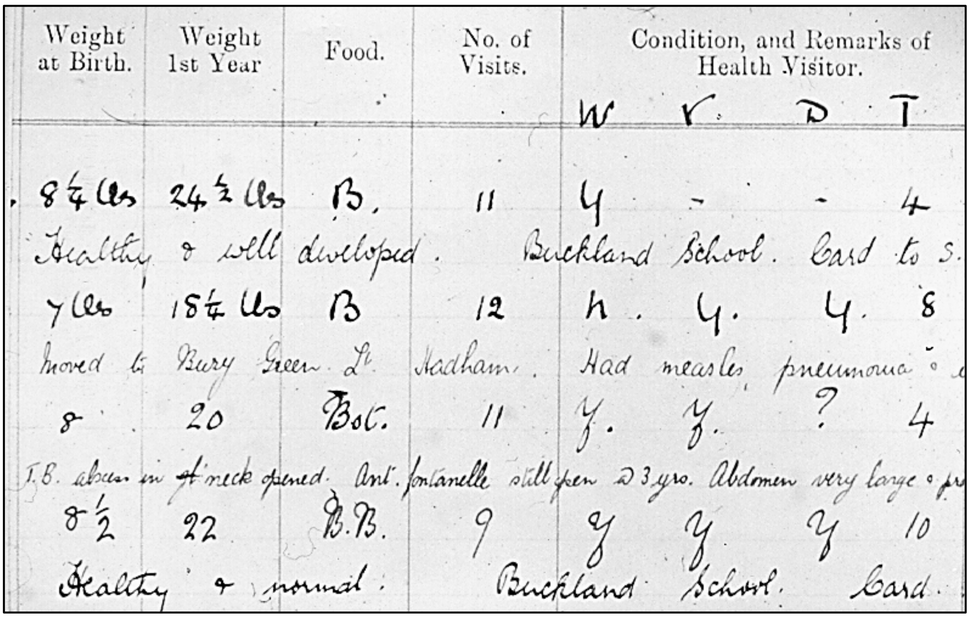
The previous chapter showed that our understanding of risk factors for hospital admission could be supplemented by linking two data sources: first, baseline information from a cohort of community-dwelling older people; and secondly, hospital episode statistics relating to admissions subsequently experienced by cohort members. The initial research question to be addressed was a practical one: *'How could Hospital Episode Statistics and Cohort Study data be linked to produce a dataset with added value?'* In describing the data and methods employed, this chapter begins to provide an answer. Section 4.1 introduces the Hertfordshire Cohort Study (HCS), with reference to the recruitment and tracing of participants and the baseline characterisation that cohort members underwent around the beginning of this century. Section 4.2 describes the routinely-collected follow-up data on hospitalisation and death from which outcome variables for this research were derived. Section 4.3 explains briefly how the data were brought together; more technical information appears in Appendix B. Sections 4.4 and 4.5 discuss the descriptive epidemiology of admissions within the linked file at cohort and individual levels respectively. These sections begin to demonstrate the added value of linked data and provide useful context to the work that follows. However, the real value of the combined data is the potential to examine the effect of prospectively collected baseline information on subsequent admissions. Section 4.6 describes the panel of predictor variables constructed from the information collected at baseline and discusses how the literature reviewed in Chapter 3 guided its design. Section 4.7 defines the three outcome variables: these are compared with the predictor panel by the papers that comprise Chapters 5, 6 and 7. Section 4.8 outlines the statistical methods and analysis strategy that is common to all three papers, and summarises the techniques adopted by each. Sections 4.9 and 4.10 address two important issues in epidemiological research, sample attrition and ethics, and Section 4.11 concludes the chapter. Collectively, the research methods outlined in this chapter comprise a pragmatic strategy to investigate the stated research questions.

4.1 Hertfordshire Cohort Study: background

Ecological studies carried out during the 1980s showed a similarity in the distributions of infant mortality in the early 1900s and death from coronary heart disease (CHD) some 65 years later across the administrative areas of England and Wales (Barker and Osmond, 1986). It was hypothesised that poor conditions in early life, for which infant mortality is a marker, were causally linked to subsequent CHD mortality in the same generation. A nationwide search for records of individual infants or children in whom the association could be tested led to the discovery of a large set of Health Visitors' ledgers in Hertfordshire. These have underpinned the Hertfordshire Cohort Study (HCS), which is run by Medical Research Council (MRC) Lifecourse Epidemiology Unit (LEU) and funded principally by the MRC with additional grants from the British Heart Foundation, Arthritis Research UK, the National Osteoporosis Society, the Wellcome Trust, and the University of Southampton. The following sections describe HCS in detail.

4.1.1 Health Visitors' ledgers

The Hertfordshire health visitors' ledgers are the legacy of a county-wide scheme established in 1911 by Ethel Margaret Burnside, Hertfordshire's 'Chief Health Visitor and Lady Inspector of Midwives'. Her team of nurses attended women during childbirth and recorded the weight of their offspring on a card. Babies were visited regularly for the first year, during which time illnesses, development and method of infant feeding were noted. They were weighed again at one year, and visits continued intermittently until the age of five. The information was transcribed from the cards into ledgers (Figure 7) covering the years from 1911 until 1948, when the NHS was formed; around 100,000 births in all. These summary ledgers were acquired by the Medical Research Council (MRC) and computerised by double-entry, a third person adjudicating over disagreements.



Weight at Birth.	Weight 1st Year	Food.	No. of Visits.	Condition, and Remarks of Health Visitor. W V D T
8¾ lbs	24½ lbs	B.	11	Y - - 4
Healthy & well developed. Buckland School. Card to S.				
7 lbs	18¾ lbs	B	12	N. Y. Y. 8
Moved to Bury Green St Hadham. Had measles, pneumonia [illegible]				
8	20	B&C.	11	Y. Y. ? 4
T.B. abscess in neck opened. Ant. fontanelle still open at 3 yrs. Abdomen very large [illegible]				
8½	22	B.B.	9	Y Y Y 10
Healthy & normal. Buckland School. Card.				

Figure 7 Extract from the health visitors' ledgers (Source, MRC LEU)

4.1.2 Tracing

People detailed in the ledgers were traced through the National Health Service Central Register (NHSCR); a list of everyone enumerated in England and Wales at the 1939 census and those born since. It is maintained by NHS Digital (and forerunning organisations) and used for the administration of primary care records. With appropriate legal authority, it is possible to 'flag' individuals among those listed and when they die, for NHS Digital to forward a copy of death details supplied to them by the Office for National Statistics.

Minimum information needed to trace individuals on NHSCR is full name and date of birth; address at a given date is also helpful. Where these details were unclear or incomplete in the Health Visitors' ledgers, they were confirmed through the national Index of Births, birth certificates being obtained where necessary. Approximately 50,000 individuals whose births were recorded in the ledgers during 1911-39 had sufficient detail and were sent to NHSCR for tracing; 40,000 were successfully traced and flagged for continuous notification of death; over half have died to date. Analyses of mortality from heart disease in the cohort confirmed associations with low birth weight and low weight at one year - markers of intrauterine and postnatal growth respectively, both of which are indicative of generally poor environmental conditions (Barker *et al.*, 1989; Osmond *et al.*, 1993). Associations were also demonstrated between early growth and other causes of death (Syddall *et al.*, 2005b).

To investigate links between early weight and risk factors for heart disease *before* death, three subsets of individuals whose births had been recorded in the ledgers were recruited in life. This was possible because the Central Register indexes each person's entry with their NHS number and lists against it a cipher showing which area health authority the individual is registered with. Both these details were communicated to the MRC, allowing a list of NHS numbers for those registered in Hertfordshire to be compiled and sent to the health authority (HA); the HA to identify responsible General Practitioners (GPs); and GPs to provide consent for an MRC approach to their patients alongside contact details to enable this. The first two subsets identified were small groups of people born before the end of 1930. A third cohort born during 1931-39 was chosen to be young enough to undergo investigations (at the inception of the study in the late 1990s) and likely to survive a follow-up period during which a range of somatic ageing processes, beyond the original focus on heart disease, could be observed. Their later birth meant the ledger address was often still current at the 1939 census, thus the trace rate on the NHSCR was high (87%).

It is this subset that is known as the Hertfordshire Cohort Study (HCS), on which this thesis is based. Potential participants were contacted through their GP and invited to take part in a baseline assessment comprising a nurse administered home interview followed by attendance at a clinic for detailed physiological investigations. Of those registered with a Hertfordshire GP, permission was obtained to contact 6,099 (85%) men and women by letter. 1,684 (54%) men and

1,541 (52%) women aged 59-73 years completed a home interview and 1,579 (94%) men and 1,418 (92%) women subsequently attended clinic. Recruitment is summarised in Figure 8.

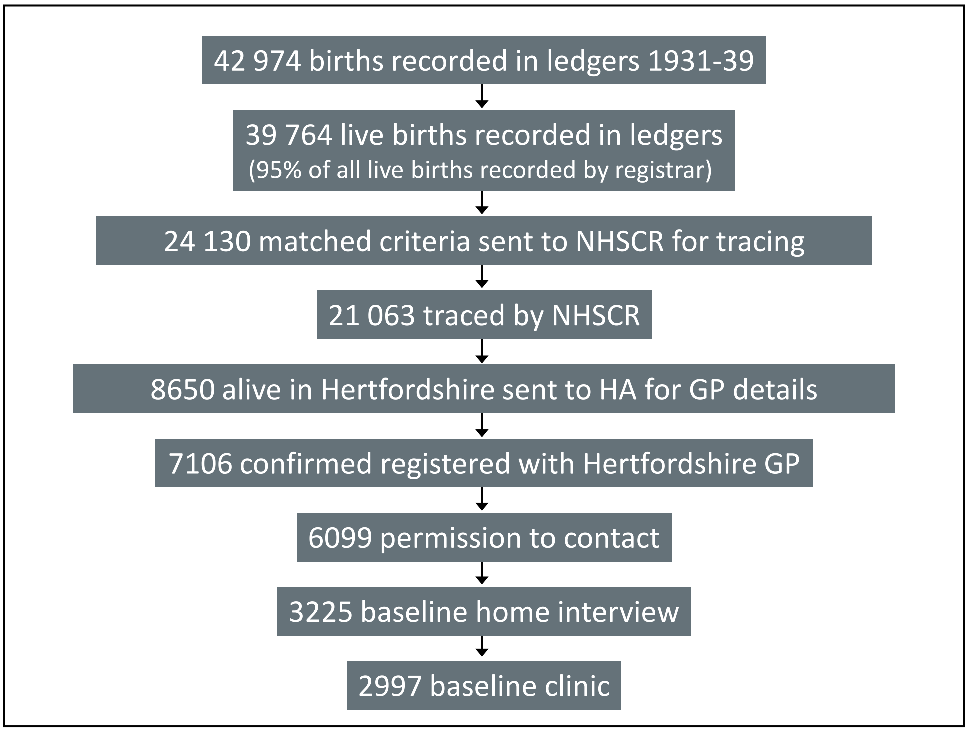


Figure 8 Recruitment of study participants: birth – baseline clinic (Source, MRC LEU)

With the passage of time, these baseline assessments have become a valuable resource for use in the study of ageing. Further details are given below.

4.1.3 Baseline assessments

HCS baseline assessments were carried out between 1998 and 2004, when the participants were aged 59-73 years. Table 5 provides a summary of the data collected at home interview and clinic. Taken together, the data from the health visitors' ledgers, information reported by the participant at the nurse-administered home interview and the measurements made by the research team in clinic, constitute a lifecourse overview of the social, behavioural and biological characteristics of 2,997 people; the study population on whom this thesis is based.

Interviews and physiological investigations were carried out by a trained team of nurses and doctors working to strict protocols. To ensure comparability of measurements obtained over the 5½-year study period, intra- and inter-observer studies were conducted at regular intervals.

Table 5 Baseline assessments in the Hertfordshire Cohort Study (Source, MRC LEU)

Home interview	Clinic Visit
• Marital status • Age left full-time education • Housing tenure • Car availability • Family history including father's social class • Physical activity • Cigarette smoking • Alcohol consumption • Obstetric history • Occupational history • Current Social class • Rose/WHO chest pain and leg pain questionnaires • Severe chest pain and previous coronary surgery • Respiratory symptoms (MRC questionnaire) • Fracture history (own and of parents and siblings) • Lower back pain • Medical history (including stroke and diabetes) • Current medications • Falls • Self-rated general health • SF-36 health related quality of life • Anxiety and depression (HAD) scores • Current diet (administered food frequency questionnaire and 24-hour food diary) • Nutrient intake from dietary supplements • Social support and networks • Job effort-reward and demand- control	• Height; weight; waist, hip, mid-upper arm and thigh circumferences • Triceps, biceps, subscapular and suprailiac skinfold thicknesses (Harpenden callipers) • Blood pressure and pulse rate (Dinamap recorder) • Lung function FEV1 and FVC (Micro Spirometer, Micro Medical) • Standard 12-lead electrocardiography (1982 Minnesota protocol) • Venous blood samples after overnight fast: Glucose Insulin and proinsulin precursors Total, HDL and LDL cholesterol Triglycerides Apolipoprotein A1 and B Vitamin C • Frozen plasma and sera stored for future measurements • Two-hour timed 75g oral glucose tolerance test: Glucose and insulin 30' and 120' post load • DNA extracted from whole blood samples • Timed overnight urine collection • Grip strength (Jamar hand-grip dynamometer) • Quadriceps strength (West Hertfordshire only, Lafayette MMT strength system) • Timed 6m up-and-go test and 3m walk • Chair rises • Timed one-legged stand • Clinical hand examination for pain, swelling and tenderness

4.2 Hertfordshire Cohort Study: follow-up

Since their baseline characterisation, cohort members have been followed-up by postal questionnaires, repeat clinics and through routinely-collected data from NHSCR, the Hospital Episode Statistics (HES) service, and the Office for National Statistics (ONS). Besides maintaining the NHSCR, NHS Digital acts as gatekeeper for HES and ONS. This thesis derives follow-up data exclusively from these administrative sources.

4.2.1 Hospital Episode Statistics

The Hospital Episode Statistics service is described in Section 2.4.1. Briefly, it comprises a regularly updated warehouse of data on hospital admissions in England from which bespoke extracts can be provided by NHS Digital subject to ethical and legal conditions (NHS Digital, 2017f), although since the passage of the 2012 Health and Social Care Act access has become very difficult. In 2011, before these legislative changes (Section 8.4.4), an extract was requested to cover all inpatient episodes experienced during the financial years 1998/9 to 2009/10 by people who had completed an HCS baseline assessment. The extract formed the primary data source for this research; fifteen variables were obtained for each episode, as shown in Table 6 (left and middle columns). Together, these variables supplied sufficient information to link episodes to individual HCS participants (using NHS number, date of birth, sex), differentiate admission types (using date of admission, method of admission, date of discharge), and produce summary data on the clinical characteristics of admissions experienced by cohort members, (using main specialty, primary and other diagnoses, primary and other procedures) consistent with nationally recognised coding systems (ICD-10 and OPCS-4 respectively (World Health Organization, 2011; Health and Social Care Information Centre, 2013b).

Table 6 Follow-up variables (Source, author)

Source (all supplied by NHS Digital)		
Hospital Episode Statistics Service		**Office for National Statistics**
HES id number	Date of discharge	Date of death, with:
NHS number	Destination on discharge	Underlying cause (ICD-10)
Postcode	Main specialty	Multi-cause (ICD-10)
Sex of patient	Primary diagnosis (ICD-10)	
Date of birth	Other diagnoses	**NHSCR**
Date of admission	Primary procedure (OPCS-4)	Emigration
Method of admission	Other procedures	
Source of admission		

4.2.2 Other follow-up

The mechanism by which cohort members were originally traced and flagged (Section 4.1.2) has continued to yield follow-up information from ONS about their deaths, as well as limited information about their current whereabouts from the NHSCR. These data, which are input to the cohort database on receipt, are summarised in Table 6 (right column).

4.2.2.1 Office for National Statistics

Routinely collected mortality data are returned monthly by NHS Digital on behalf of the Office for National Statistics. For each person who has died during the reporting period, date and cause of death are provided, alongside sufficient identifying information to allow verification of correct linkage. For the purposes of this thesis, these data were used to ascertain death as an outcome and to adjust the denominator in assessing rates of admission. Cause coding was not considered.

4.2.2.2 NHSCR

As well as deaths, monthly returns from NHS Digital contain dated notifications of other events that have caused those who are flagged on the NHSCR to cancel their registration with a General Practitioner. Notifiable events include transfer to the long-term care of an armed services medical officer, the mental health service or the prison service, and emigration from England and Wales. These events, which are rare among the Hertfordshire Cohort, are treated as loss to follow-up.

All records from NHS Digital are identified by NHS number (Section 4.1.2); the same identifier is cross referenced in the cohort database with the internal serial number. It was therefore possible to combine HES and cohort data to create an admissions history for each cohort member, as described in the next section.

4.3 Data linkage

Admissions level data are preferable to episode level data for a number of reasons (Aylin *et al.*, 2004). Episode data from the HES extract were therefore combined to describe complete admissions, and linked to mortality and other data from NHSCR to create an admissions history for each participant covering the period between their baseline assessment and 31/03/2010. The end date was adjusted for those who died or were otherwise lost to follow-up, so that the follow-up period during which individuals were considered to be at risk of hospitalisation varied from person to person.

Figure 9 shows how cohort and episode data combined and is described below.

4.3.1 Episodes and admissions

The HES extract contained a total of 12,131 episodes, of which 12,127 were successfully matched to HCS participants by NHS number. 2,250 episodes preceded individuals' baseline home interviews, and these were excluded from the analysis. Of the remaining 9,877 episodes, 8,505 represented single episode admissions that required no further cleaning; 1,372 contributed to multiple episode admissions amongst which concurrent or consecutive episodes were combined to yield a further 243 admissions, making 8,748 admissions in total. Seven were ongoing at the end of the study and were excluded, leaving 8,741 completed admissions by the end of March 2010. Fifty-four admissions were identified that occurred between participants' home interview and clinic dates; a median lag of 27 days (IQR: 14,42). These admissions were excluded from the file to ensure that all variables in the predictor panel (some of which were measured in clinic) had been ascertained prospectively. The number of completed admissions eligible for analysis was therefore 8,687.

4.3.2 Classification of admissions by type

Fields from the HES record (Table 6) were used to classify each admission to type. Elective and emergency admissions were defined by the admission method of their first episode; readmissions were flagged according to the lag between one date of discharge and the next date of admission in an individual's history. Start and end dates were derived from the beginning of the first episode and the end of the last for multiple episode admissions.

4.3.3 Admissions and individuals

Mapping 8,687 admissions to individuals, 2,161 cohort members had one or more admission during the follow-up period (Figure 9, right pathway); 836 (Figure 9, left pathway) had none. Mortality data were added to the file for 275 people who died between baseline and the study end: 21 of those who died had no admissions, whilst 254 were admitted at least once.

Appendix B provides technical details of the file preparation.

The clear distinction between admissions and admitted individuals is an essential strength of this research. Section 4.4, which follows, describes the 8,687 admissions accrued by cohort members during the follow-up period. This serves to contextualise Section 4.5, which describes individual's experience of admissions.

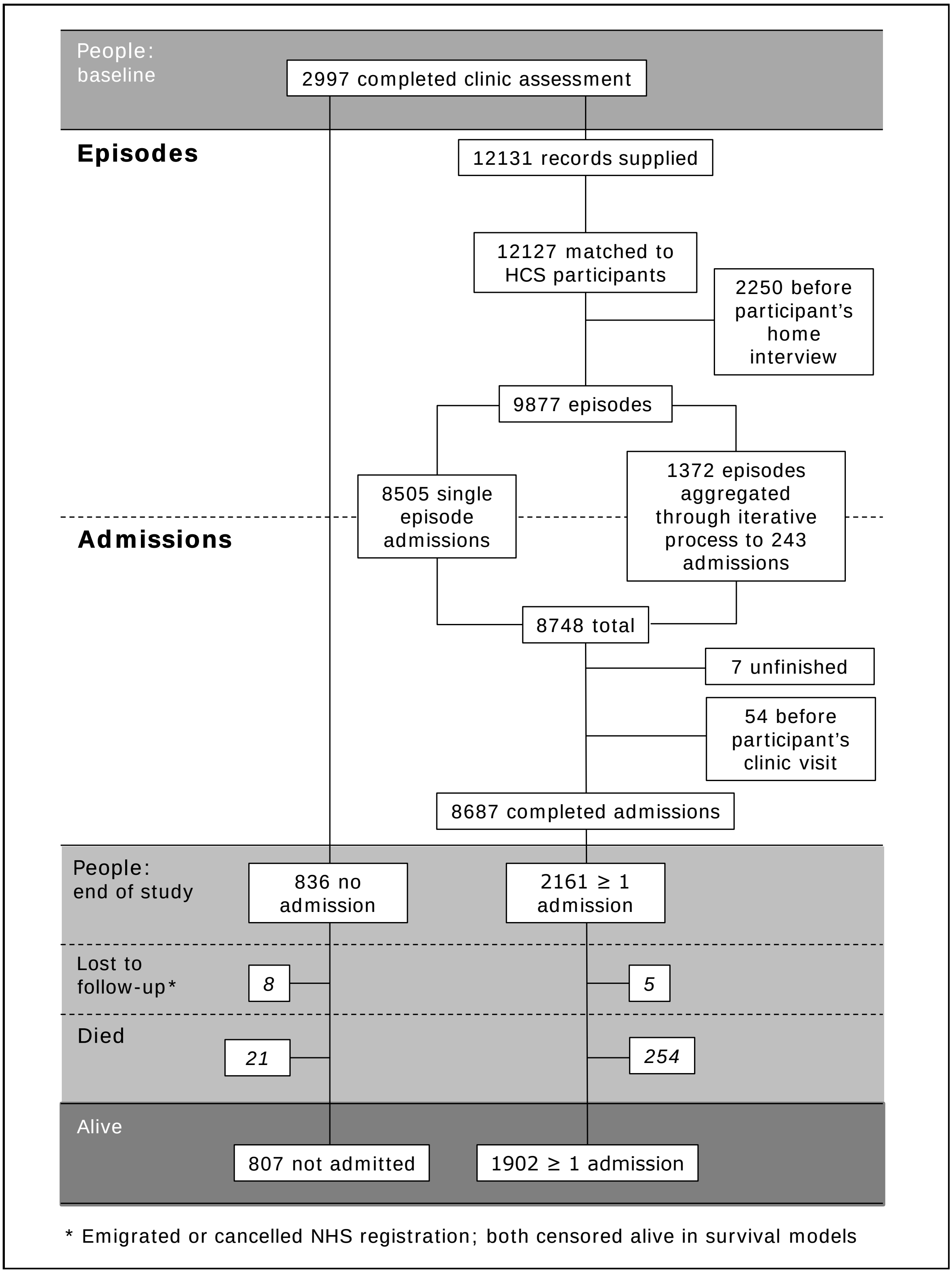


Figure 9 Linkage of admissions data to individuals

(Source, author)

4.4 Descriptive epidemiology of admissions: cohort level

This section describes the 8,687 admissions accrued by the cohort during the follow-up period; overall, and by admission type.

4.4.1 Overall admissions at the cohort level

Among the total 8,687 admissions that occurred during the follow-up period, the majority (8,505 (97.2%)) consisted of a single episode; only 243 admissions comprised multiple episodes. The ratio of admissions to episodes in HCS was 1:1.13; published figures for 2010/11 show that nationally, at all ages, the ratio was 1:1.16 (NHS Digital, 2017a). HCS admissions may therefore be a little less complex than is usual among older people, in accord with the acknowledged healthy participant effect (Syddall *et al.*, 2005a). In more than half of HCS admissions (59.4%) the patient was male, a similar proportion of admissions (58%) were day cases; only 14% lasted more than 7 days (range 1-142 days). Operative procedures were carried out in 75.7% of all admissions.

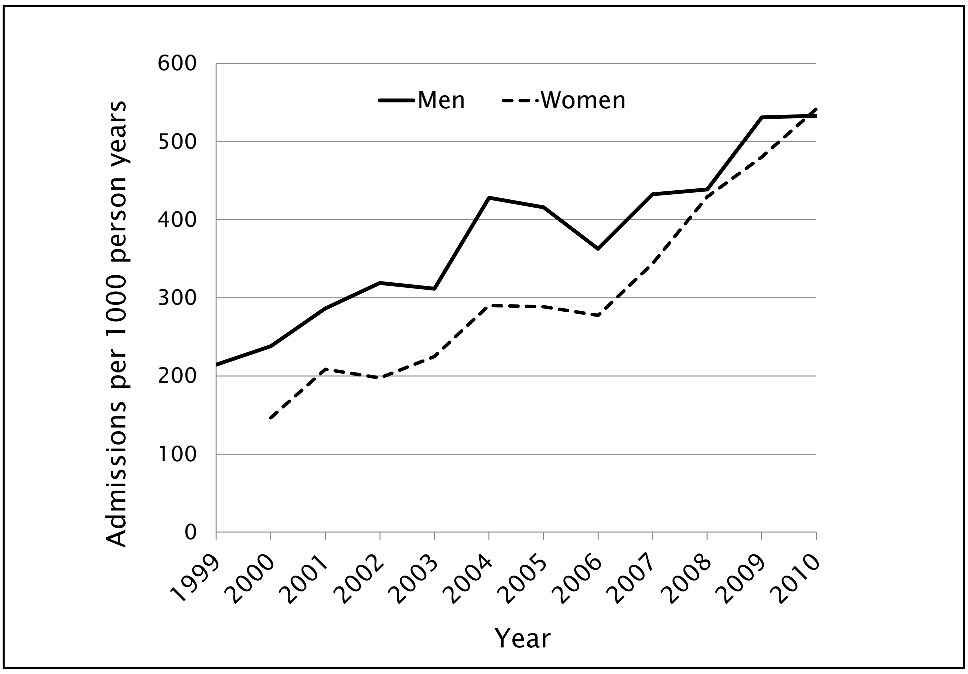


Figure 10 HCS admission rate per 1,000 person years, by sex

(Source, author)

Figure 10 shows that rates of admission were higher among men than women in the cohort and that they more than doubled during the follow-up period. Overall rates were: among men, 392.9/1,000 person-years; and among women, 328.1/1,000 person-years. These rates cover the whole follow-up period and are not comparable with the national data shown in Section 2.4,

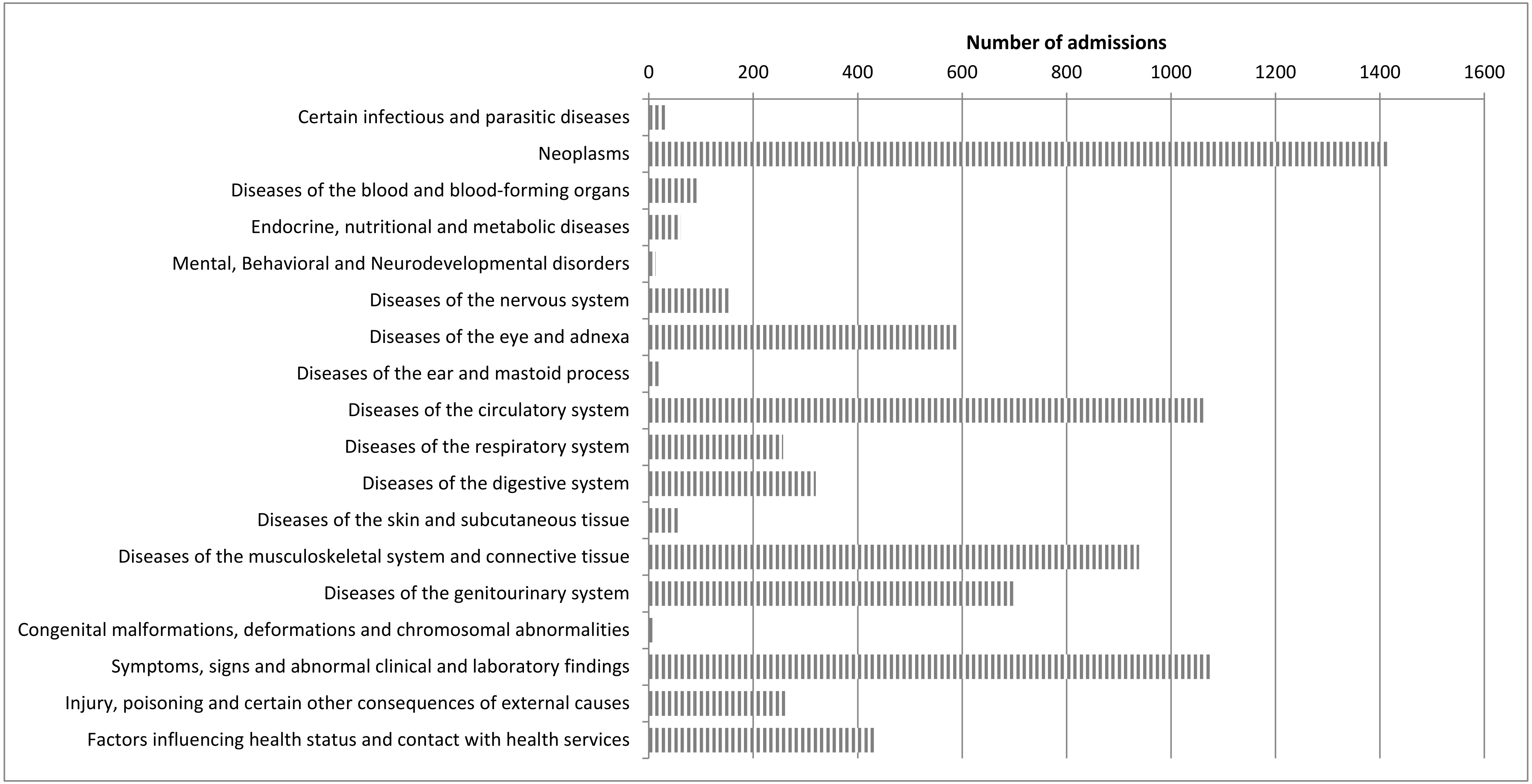


Figure 11 Number of admissions by ICD chapter (Source, author)

because they reflect the ageing of the cohort with time as well as the national rise in admission rates.

ICD-10 codes from each episode (Table 6) were integrated in the records of complete admissions and used to assign each admission to an ICD chapter according to its primary diagnosis; Figure 11 shows the number of admissions per chapter. Six chapters had particularly high numbers of admissions, in decreasing order they were: cancers, abnormal signs and symptoms (admissions during which no clear diagnosis was reached, see Section 2.4.3.2), circulatory diseases, musculoskeletal diseases, genitourinary diseases and eye diseases.

The HES data suggest that almost all admissions in HCS originated from the participant's usual or temporary address: only 4 (0.05%) were recorded as coming from a residential care or nursing home. Although the validity of data in this field has been questioned (Godden and Pollock, 2001), HCS participants were comparatively healthy, were community dwelling at baseline, and were of an age at which care home residence is unusual: just 0.6% of the population of England and Wales aged 65-74 were reported to live in nursing or residential care homes in 2011 (Office for National Statistics, 2014b). Any underestimate is therefore likely to be small.

4.4.2 Admissions by type at the cohort level

Each admission record was classified by method of admission as elective, emergency or transfer (see footnote to Table 7). In addition, a readmission flag was created to show whether or not each admission began within 30 days of a previous discharge. In admissions comprising more than one episode, date of admission was derived from the first episode, and date of discharge from the last. Table 7 shows the number of admissions accrued by the cohort, by admission type.

Table 7 Cohort level admissions, by type (Source, author)

Admission type n (% of total admissions)	Among 1579 men	Among 1418 women	Total
Elective	3798 (73.6)	2664 (75.5)	6462 (74.4)
Emergency	1342 (26.0)	859 (24.3)	2201 (25.3)
Total admissions	*5157*	*3530*	*8687*
Readmissions (≤30days)	993 (19.3)	670 (19.0)	1663 (19.1)

Footnote: 24 admissions were by transfer, ie were classified as neither elective nor emergency

Approximately three-quarters of admissions were elective and one-quarter were emergencies; nearly one in five admissions began within 30 days of a previous discharge. These proportions held for overall admissions and for each sex separately. Operative procedures were carried out in 91.7% of elective admissions but only in 29.0% of emergency admissions. Across all admissions, the most common procedures, with the numbers carried out, were: endoscopy of the bladder

(464), endoscopy of the upper gastrointestinal tract (447), cataract surgery (385), angiography (350), knee replacement (175), and hip replacement (174).

Figure 12 shows rates of admission by type. In common with the national experience (Section 2.4.3) the most rapid rises were seen in elective day cases, which increased threefold over the follow-up period.

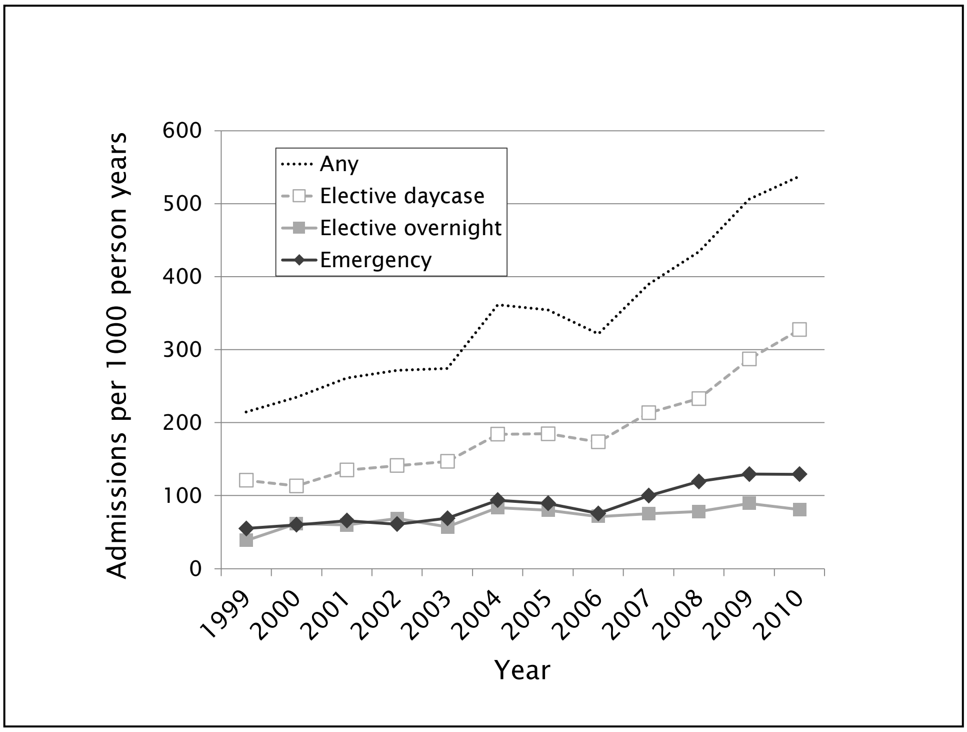


Figure 12 HCS admission rate per 1,000 person years, by admission type (Source, author)

Figure 13 shows the proportion of admissions in each chapter that were treated electively or were emergencies. Not surprisingly, cancers, musculoskeletal disorders and particularly diseases of the eye (predominantly cataracts) were treated primarily as elective cases. Higher proportions of emergencies were seen for injury, and for infectious, respiratory and mental health conditions. 432 admissions, almost all elective, were coded to the final chapter *'Factors influencing contact with health services'.* Such admissions predominantly represent examinations where no abnormality was detected, follow-up after treatment, or screening procedures.

Appendix C tabulates the most common diagnostic conditions and procedures by admission type.

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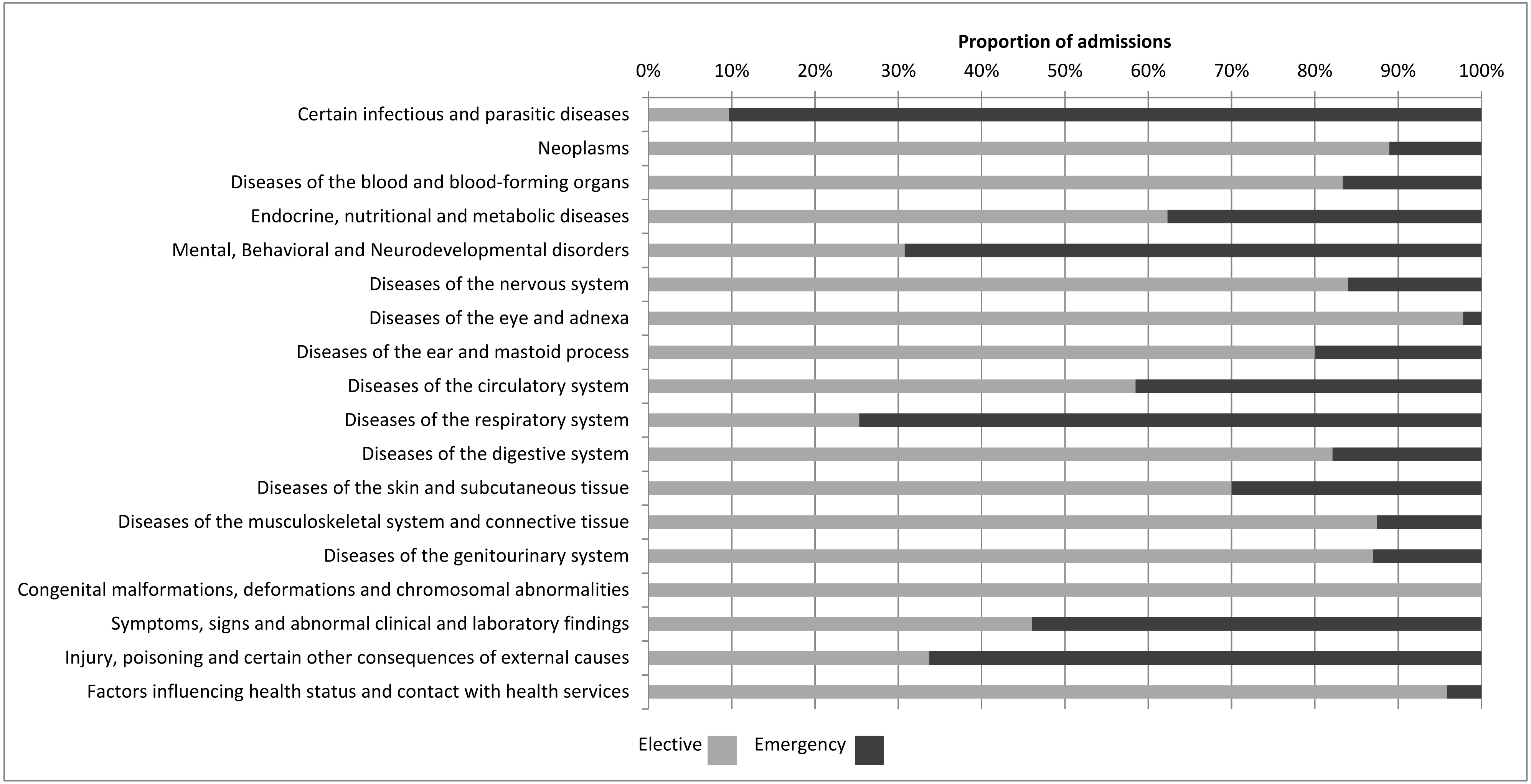

Figure 13 Proportion of elective and emergency admissions, by ICD chapter (Source, author)

4.5 Descriptive epidemiology of admissions: individual level

This section describes individual's experience of admissions overall and by admission type. It then introduces the admission history variables that comprise the outcomes of this research.

4.5.1 Overall admissions at the individual level

Median length of follow-up was 8.1 years. Of the 2,997 members of the Hertfordshire Cohort Study, 836 (28%) had no admissions. The remaining 2,161 (72%) participants were admitted to hospital at least once during the follow-up period: among men, 1,185 (75%) were admitted, and among women, 976 (69%). This is consistent with the high demand demonstrated among other cohorts (Section 3.2.5). Figure 14 shows frequency of admission among cohort members (range 0-56 admissions). Almost half had more than one admission: amongst those who were ever admitted, the median number of admissions was 3 in men (IQR: 1,6) and 2 in women (IQR: 1,5); admitted cohort members spent a median total of 7 (IQR: 2,19) days in hospital across the follow-up period.

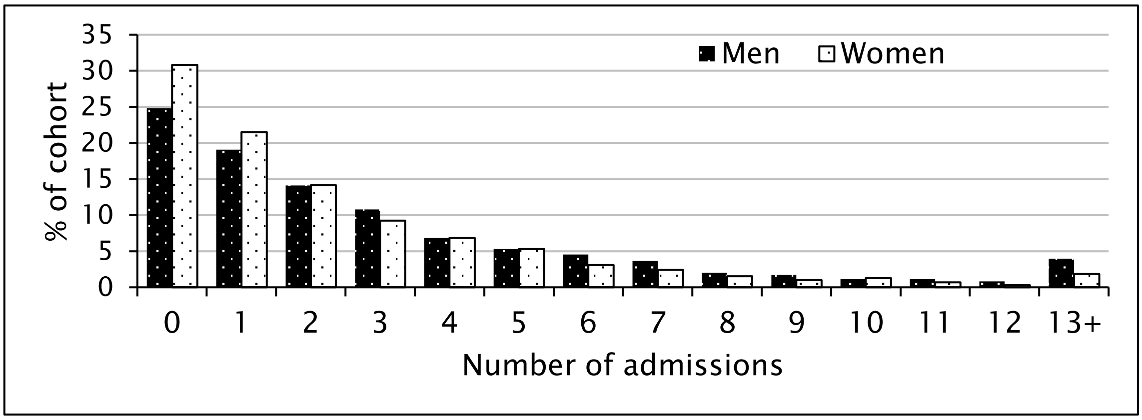

Figure 14 Number of admissions per cohort member (%), by sex (Source, author)

Median time to first admission was 2.6 years from clinic. Among those ever admitted, 70% had stayed overnight. 429 men (36.2% of admitted men) and 316 women (32.4%) had an admission lasting more than 7 days.

4.5.2 Admissions by type at the individual level

Binary variables were created within each person's admission history to indicate whether or not the participant had ever had an elective admission, ever had an emergency admission, and was ever readmitted within 30 days of a previous discharge. In addition, to take account of the curtailment of admission history by death, and to acknowledge that death represents a health outcome *worse* than hospital admission, a further set of variables was derived to indicate whether or not the participant had ever had an elective admission *or died*, ever had an emergency admission *or died*, and ever been readmitted within 30 days of a previous discharge *or died*. Table 8 shows the cohort's experience of these outcomes.

Table 8 Individual level admission outcomes, by type (Source, author)

Outcomes n (%)	**Men (n=1579)**	**Women (n=1418)**	**All (n=2997)**	**P for gender difference#**
Never any admission	394 (25.0)	442 (31.2)	836 (27.9)	<0.001
Never any admission or died	382 (24.2)	433 (30.5)	815 (27.2)	<0.001
Ever any admission	1185 (75.0)	976 (68.8)	2161 (72.1)	<0.001
Ever any admission or died	1197 (75.8)	985 (69.5)	2182 (72.8)	<0.001
Ever elective	1051 (66.6)	882 (62.2)	1933 (64.5)	0.013
Ever elective or died	1105 (70.0)	910 (64.2)	2015 (67.2)	0.001
Ever emergency	608 (38.5)	433 (30.5)	1041 (34.7)	<0.001
Ever emergency or died	638 (40.4)	450 (31.7)	1088 (36.3)	<0.001
Ever readmission (≤30 days)	371 (23.5)	244 (17.2)	615 (20.6)	<0.001
Ever readmission (≤30 days) or died	458 (29.0)	288 (20.3)	746 (25.1)	<0.001
Died	189 (12.0)	86 (6.1)	275 (9.2)	<0.001

Footnote:
Gender differences were assessed using the chi-squared test

Deaths were uncommon and most were preceded by admissions, thus relatively few people were considered positive for a given admission or death outcome only because they died. For example, whilst 38.5% of men ever had an emergency admission, 40.4% ever had an emergency admission or died. Men were more likely to be admitted, had more admissions, stayed longer in hospital, and were more likely to die than women. They were also significantly more likely to experience each specific type of admission than women.

Many participants had admissions of more than one type. The next section describes inter-relations between the admission types, to summarise admission histories for the cohort.

4.5.3 Admission histories

Figure 15 shows the overlap between the ever elective, ever emergency and ever readmitted groups from Table 8. Experiencing only emergency admissions was unusual; amongst those who *ever* had an emergency admission (bottom left circle), *only* emergency admissions were experienced by 198 people and a further 29 who were ever readmitted. Conversely, 363 of those who ever had an emergency admission *also* had an elective admission, alongside 451 who also had an elective admission *and* were ever readmitted (by either route). Thus, most people (78.2%) who had an emergency admission also had an elective admission. Of the group who ever had an elective admission (bottom right circle), *only* elective admissions were experienced by 984 people and a further 135 who were ever readmitted. The majority (58%) had no emergency admission. By definition, all of the 615 who were ever readmitted (top circle) had experienced either elective or emergency admission or both. Twenty-nine had only emergency admissions, 135 only elective admissions and 451 admissions of both sorts. Thus the majority (73%) had both elective and emergency admissions.

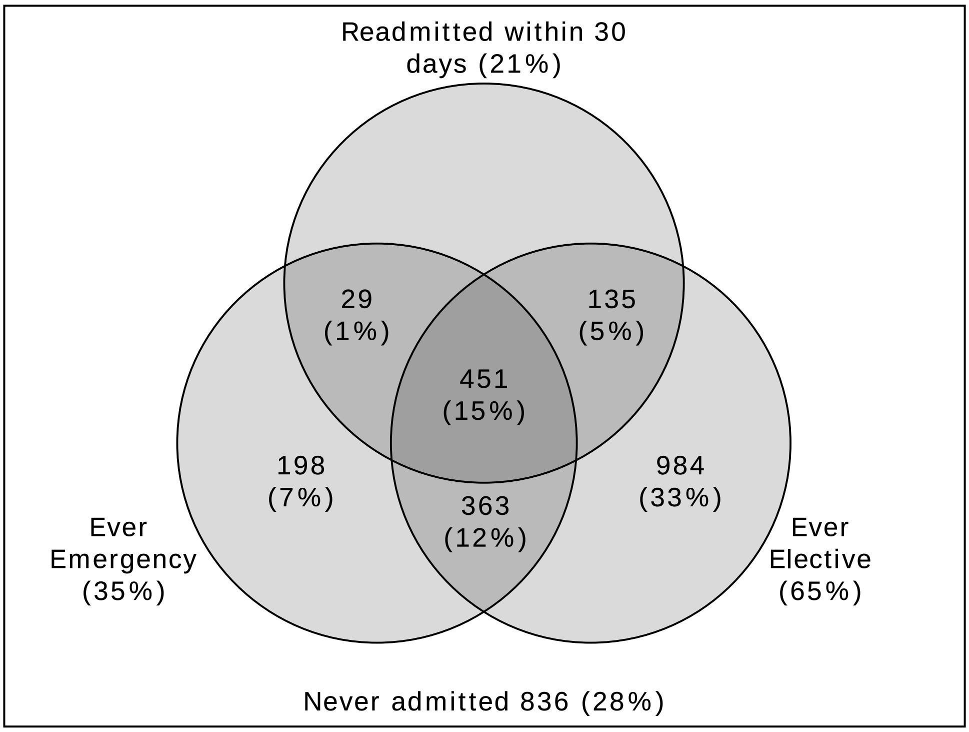

Figure 15 Summary of admission histories of HCS participants.

Percentages refer to total sample of 2,997 participants (Source, author)

Thus far, Chapter 4 has addressed the first of the research questions posed by Section 3.5: it has shown how cohort and administrative data can be linked together and, by describing the epidemiology of hospital admissions within the cohort, demonstrated that this adds value to both datasets. However, the real value of the combined file derives from the potential to investigate associations between the prospective measurements made at baseline and participants' admission histories. Section 4.6 describes how a predictor panel was assembled from the baseline data to reflect influences on admission identified by Chapter 3; Section 4.7 then defines the admission outcome variables with which the predictor panel will be compared.

4.6 Predictor Variables

The UK and international literature synthesised in Chapter 3 suggested that the determinants of hospital admission can be broadly classified to five domains: demography and anthropometry; lifestyle; social circumstances; physical function and morbidity. Of these, only morbidity has been unequivocally linked to each of 30-day readmission, emergency admission and elective admission; even then, no specific disease has been linked to all admission types (Section 3.3.5). This role of morbidity or *'need'* as the primary risk factor for the utilisation of healthcare has long been acknowledged (Andersen and Newman, 1973) and is intuitively believable; demography and anthropometry; lifestyle; social circumstances; and physical function are known influences on healthy ageing that the literature review suggests may have an effect on hospitalisation independent of their effect on morbidity (Section 3.4). To investigate their individual and combined effects, a panel of 25 predictor variables was selected from the HCS database that included measures representative of each domain.

4.6.1 The predictor panel

Table 9 lists the variables selected from those available in HCS and is followed by a justification for including each in turn. A brief outline is also provided of how each was ascertained; more technical information is given in Section 4.8.1 and Table 11.

Table 9 Predictor panel domains and variables (Source, author)

Demography and anthropometry	Lifestyle	Social circumstances
Age	Smoking history	Social class
Height	Alcohol intake	Relationship status
Weight	Physical activity	Housing tenure
Body mass index		

Physical function	Morbidity
Grip strength	Ischaemic heart disease
Physical function (SF-36)	Stroke
Walking speed	Hypertension
Fall history	Diabetes
	Fracture history
	Osteoarthritis (hand)
	Self-rated health
	Depression
	Anxiety
	Bronchitis
	Medication

4.6.1.1 Demography and anthropometry

Variables selected for inclusion in this domain were age, height, weight, and BMI; all were analysed as continuous variables. Sex was not included; instead, separate analyses were carried out for men and women.

Age

Section 3.3.5 noted that, among older cohorts such as HCS, chronological age is not consistently associated with risk of admission: this may be due to a mismatch between chronological and biological ageing (Cox *et al.*, 2014). Age was nevertheless included in the predictor panel to control for any potential confounding influence.

Measures of body size: height, weight, body mass index

BMI combines measures of height and weight to provide a marker of adiposity; a recognised risk factor for chronic disease, notably Type 2 Diabetes and cardiovascular disease (Melzer *et al.*, 2012). Increased BMI has been associated with all admissions in women (Reeves *et al.*, 2014) and serious admissions in both sexes (Hanlon *et al.*, 2007; Luben *et al.*, 2016); *low* BMI has also been linked to increased risk of admission (Damush *et al.*, 2004; Hart *et al.*, 2007; Lawlor *et al.*, 2007). Evidence specific to admission type is sparse; BMI was therefore included in the predictor panel although recognised as an imperfect marker of adiposity, especially among older people in whom declining muscle mass may change the ratio of lean mass to fat (St-Onge, 2005).

Given the limitations of BMI, its components, height and weight, were also included in the predictor panel, although Chapter 3 found no previous evidence that either act as direct risk factors for admission. In addition to the variables described, a sex-specific standardised residual of weight-adjusted-for-height was calculated for inclusion with height in regression models, in order to avoid complications resulting from collinearity between height and weight (correlations between height and weight were $r=0.44$, $p<0.001$ for men and $r=0.32$, $p<0.001$ for women in the HCS baseline clinic sample (Sayer *et al.*, 2006)). The height and weight of each participant were measured once in clinic using a Harpenden stadiometer and portable Seca scale respectively.

4.6.1.2 Lifestyle

Selected markers were smoking, alcohol intake and physical activity.

Smoking

As the literature review shows, smoking has been linked to risk of any and of serious admission in a number of cohort studies (Hanlon *et al.*, 1998; Hanlon *et al.*, 2007; Luben *et al.*, 2016), but may be outweighed by other risk factors (Iloabuchi *et al.*, 2014). Smoking was first linked to lung cancer and heart disease in the 1950s and since then unequivocal evidence has accrued that it is harmful to health. Although those aged 60 and over have the lowest smoking prevalence of any age group (Health and Social Care Information Centre, 2014b), many are ex-smokers rather than never smokers (Melzer *et al.*, 2012); indeed because of their age, many have had long exposures. Investigation of smoking as a risk factor specific to elective admission, emergency admission and 30-day readmission is therefore justified. Smoking status was ascertained during the HCS home interview and included in the predictor panel as a dichotomised variable: a history of ever versus never having smoked regularly. Although this approach under-used information about the amount and duration of exposure to smoking, it was taken because of perceived inconsistencies in the self-reported information about cessation of smoking.

Alcohol

Health risks associated with alcohol are more nuanced. High consumption is undoubtedly hazardous to health, but opinion differs over whether a J-shaped curve sometimes observed with mortality suggests moderate amounts are beneficial or represent a 'healthy drinker' effect (Melzer *et al.*, 2012). The findings of the literature review accord with this uncertainty: only heavy (Hart and Smith, 2008), ex- (Hanlon *et al.*, 2007), and non- (Chavez *et al.*, 2016) drinkers were found to be at increased risk of admission. It has been argued that changed body composition at older ages should lead to a lowering of recommended limits among older people (Melzer *et al.*, 2012), although they are the group least likely to report exceeding the current recommendations. Inclusion of alcohol consumption in the predictor panel could help to inform this debate. It was ascertained in HCS at home interview and categorised to high or not high according to the UK guidelines that were advised at that time: high was defined as 22 or more units per week for men and 15 or more units per week for women.

Physical activity

There is strong evidence that people aged 65 years and over who are physically active have higher levels of cardio-respiratory fitness and physical function, improved disease risk-factor profiles and lower incidence of numerous chronic non-communicable diseases than those who are inactive (Department of Health, 2011). Evidence linking a failure to reach recommended levels of physical activity to increased risk of admission (Hanlon *et al.*, 2007) has been contradicted by mutually adjusted analyses (Simmonds *et al.*, 2014a; Fisher *et al.*, 2016); thus the inclusion of a physical activity variable in the predictor panel could provide additional evidence. Objective measures, such as accelerometry, are difficult to implement in large cohorts (Hills *et al.*, 2014); physical activity was therefore assessed cohort-wide in HCS by incorporating the Dallosso customary physical activity instrument (Dallosso *et al.*, 1988) in the home interview questionnaire. This tool classifies current customary level of productive activity, indoors and outdoors, by a score in the range 0-100, higher values representing more active lifestyles. The score was treated as a continuous variable.

4.6.1.3 Social circumstances

Variables selected to characterise social circumstances were social class, relationship status and home ownership.

Social class

Chapter 3 reported strong evidence that social status and deprivation are associated with hospitalisation, with a suggestion that the direction of association differed by admission type; more serious categories of admission being predicted by low socioeconomic status and elective admission by higher status (McCartney *et al.*, 2013). As previously in HCS, occupational social class was selected as a predictor panel variable (Syddall *et al.*, 2005a). Occupation affects health through multiple mechanisms: income, which determines material living standards; social standing, which may affect access to healthcare; social networks and hierarchies, through their impact on psychosocial processes; and environmental exposures, which may directly cause disease (Galobardes *et al.*, 2006). Although occupationally-based social class is widely used, whether it adequately indexes current social circumstances among the retired has been questioned (Galobardes *et al.*, 2006). It was included in the predictor panel to further investigate its relative effect on hospitalisations of different types. Occupation was ascertained during the HCS home interview and coded from the 1990 OPCS Standard Occupational Classification (SOC90) unit group for occupation (Office of Population Censuses and Surveys, 1990) using computer assisted standard occupational coding (Elias *et al.*, 1993). Current social class was obtained from own current or most recent full-time occupation for men and never-married women, and from husband’s occupation for ever-married women (Arber and Ginn, 1993). Social classes I, II and IIIN were considered to represent non-manual; and IIIM, IV and V manual occupations.

Relationship status

Differing life expectancies between men and women result in divergent marital status in later life: at age 80-84 more than half of men but only 1 in 5 women remain married as widowhood becomes more common in both sexes (Arber and Ginn, 2005). Marriage and other forms of partnership are advantageous to the living arrangements, financial wellbeing and social relationships of older people; those who are married have a mortality rate half that of the widowed and divorced, and one third that of the never-married (Gjonca and Marmot, 2005).

Increased rates of hospitalisation have been reported among those who are unmarried (Hu *et al.*, 2014), but may not apply equally to both sexes (Walsh, 2014). In HCS, relationship status was ascertained at home interview and a dichotomous variable was created to distinguish those who had ever married from those who had not. Although more detailed information was available at baseline, it may not have reflected experience across the lifecourse, and was liable to change during the follow-up period. Therefore, although being never-married is unusual (under 10% of older people fall into this group (Arber and Ginn, 2005)), it was considered a more meaningful prospective variable than baseline relationship status.

Housing tenure

Owning, rather than renting, one's home is known to predict favourable longevity and health independent of age, sex, income and social class (Macintyre *et al.*, 2001). Few studies have considered housing tenure as a risk factor for hospitalisation, though univariate analyses among working-age people in Scotland reported an association with serious admission (Hanlon *et al.*, 2007). Being an owner-occupier may be less discriminatory in old age if people move into residential or sheltered housing (Robards *et al.*, 2014); nevertheless from a lifecourse perspective, and among young-old cohorts such as HCS, tenure provides a useful indication of accumulated advantage through life (Galobardes *et al.*, 2006). Housing tenure was ascertained at home interview in HCS and dichotomised for analysis to owned/mortgaged versus not.

4.6.1.4 Physical function

Grip strength, walking speed, self-reported capability and history of falls were selected to characterise varying aspects of physical function.

Grip strength

Grip strength is strongly associated with ageing; it is normal to lose muscle mass and strength in later life (Dodds *et al.*, 2014). Grip is a powerful, independent predictor of disability, morbidity and mortality (Sayer and Kirkwood, 2015), and whilst none of the studies reviewed in Chapter 3 considered it as a potential predictor, low grip strength has been associated with self-reported hospitalisation in the US and Europe (Cawthon *et al.*, 2009; Chan *et al.*, 2014; Legrand *et al.*, 2014). The associations of grip strength with hospitalisation in HCS have been reported separately (Simmonds *et al.*, 2015); it was included in the predictor panel to assess its effect relative to other risk factors. It was measured 3 times for each hand at the HCS baseline clinic using a Jamar handgrip dynamometer (Roberts *et al.*, 2011); the maximum value was treated as a continuous variable in analyses.

Physical function (SF-36 PF)

Difficulties in performing activities of daily living increase with age and are common in later life: for example, amongst those aged 65 or more who took part in the 2001/2 wave of the General Household Survey, 22% of men and 39% of women reported that they found it difficult or impossible to manage stairs without help (Evandrou, 2005). Literature examining the risk of admission attributable to physical function has typically been concerned with severely compromised function, such as ADL limitations (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017). A more discriminatory approach is required to assess the range of physical function in young-old community-dwelling populations such as HCS: the short-form 36 (SF-36) instrument was therefore included in the home interview questionnaire (Ware et al. 2000) and the degree to which health limits a range of activities was derived from its physical function subscale (SF-36 PF). Scores were dichotomised for analysis, participants in the lowest sex-specific fifth of the overall distribution of SF-36 PF at baseline (≤75 for men, ≤60 for women) being classified as having 'poor' physical function. Higher SF-36 PF scores have been associated with reduced rates of emergency admission in the US (Damush *et al.*, 2004).

Walking speed

Walking without difficulty is important to independence. In the UK 39% of men and 47% of women aged 65 or over report difficulty in walking ¼ mile, the main causes being pain in the leg or foot, shortness of breath and (among the oldest groups) balance problems and fatigue (Melzer *et al.*, 2012). Slow measured gait speed (<1m/s) has been associated with risk of overnight admission or major day case procedure in the US (Cesari *et al.*, 2009). In HCS, walking speed was ascertained in two ways: by objective measurement in clinic and by self-report. The self-reported ordinal variable was preferred for inclusion in the predictor panel because it was available for all participants, whilst gait speed measurement, which was introduced mid-way through the fieldwork, was not. The subjective measure has been validated against measured gait speed in those for whom both metrics were available (Syddall *et al.*, 2015).

History of falls

Falls become more common with advancing age: in the English Longitudinal Study of Ageing 27% of those aged 60 or more reported having one or more in the previous year (Melzer *et al.*, 2012). Whilst falls may be a cause of admission in their own right, most commonly among women aged over 65 (Health and Social Care Information Centre, 2011), they do not always result in serious injuries and may go unreported. History of falls was included in the predictor panel to identify failing physical function. Falls were ascertained at the HCS baseline home interview, but the question, like gait speed measurement, was introduced in mid-study and data are available for only 866 men and 1,282 women.

4.6.1.5 Morbidity

Baseline markers of disease were selected for inclusion in the predictor panel to reflect the common chronic conditions listed in Table 1, whether or not they had been previously associated with admission. The markers chosen, described below, were IHD, stroke, hypertension, diabetes, history of fracture, hand osteoarthritis, depression, anxiety and bronchitis, all of which were analysed as binary variables according to their presence or absence. In addition, self-rated health, and number of body systems for which medication was taken, were included as measures of overall health. Due to the relatively young age of the cohort at baseline, neither frailty nor cognitive function was assessed.

Ischaemic heart disease

Ischaemic heart disease is an umbrella term covering acute events such as myocardial infarction (MI) and chronic forms including angina and atherosclerotic disease. It is also known as coronary heart disease (CHD). Its prevalence increases sharply with age (Table 1). Those who survive with IHD frequently require revascularisation procedures such as percutaneous coronary intervention or coronary artery bypass graft: IHD accounted for 3.4% of all inpatient episodes in men and 1.4% in women in England in 2010/11, among patients of all ages (Townsend *et al.*, 2012). Markers for IHD have been associated with any and serious admission in Scotland (Hanlon *et al.*, 1998; Hanlon *et al.*, 2007). HCS participants were considered to have IHD at baseline if major Q waves were identified on the ECG examination conducted in clinic (Prineas *et al.*, 1982), if they reported typical angina on the Rose Chest Pain questionnaire administered at home interview (Rose, 1965), or had had a previous coronary artery bypass graft.

Stroke

Stroke is the consequence of an interruption to the flow of blood to the brain either by blockage or bleeding. The effects vary in severity from a passing weakness or tingling of a limb to paralysis or coma. As with IHD, case fatality is high: 17.1% of men and 24.7% of women of all ages died within 60 days of suffering a stroke in England in 2006 (Townsend *et al.*, 2012). In addition to emergency care aimed at optimising outcomes, stroke survivors frequently require lengthy periods of rehabilitation, ideally in a specialist unit. Stroke accounted for 1.3% of all inpatient episodes in men and 1.1% in women in England in 2010/11, among patients of all ages (Townsend *et al.*, 2012). Previous history of doctor-diagnosed stroke was ascertained at home interview in HCS.

Hypertension

Blood pressure generally increases through life and is strongly related to cardiovascular disease (which includes IHD and stroke) and mortality (Melzer *et al.*, 2012). It was shown to be a risk factor for any and serious admission in Scotland (Hanlon *et al.*, 1998; Hanlon *et al.*, 2007). Participants whose blood pressure in clinic was 160/100 or higher, and those who reported taking regular antihypertensive medication were considered to be hypertensive at baseline.

Diabetes

Susceptibility to Type 2 diabetes increases with advancing age as declining physiological function impairs regulation of blood sugar (Townsend *et al.*, 2012). The condition is widely underdiagnosed, with evidence suggesting that 2% of those aged 70-84 and 5% aged 85 or more have undiagnosed diabetes (Melzer *et al.*, 2012). Prospectively measured raised blood sugar levels have been associated with risk of any and serious admission in Scotland (Hanlon *et al.*, 1998). In HCS, participants who reported that they suffered from diabetes *and* gave evidence of medication to control it were considered to be diabetic at baseline, along with those in whom the fasting oral glucose tolerance test carried out in clinic reported a 2h plasma glucose level of ≥11.1 mmol/l.

History of fracture

Risk of fracture depends on the strength of bones and the forces applied to them, weaker bones breaking with lower levels of trauma. Bone strength and density decline from the age of around 35 as part of the normal ageing process (Harvey *et al.*, 2014); osteoporosis is defined as a bone density of 2.5 standard deviations below that of a young adult, measured by Dual-energy X-ray Absorptiometry (DXA) (NHS Choices, 2017). It characteristically results in fractures at the wrist, hip and spine, although other bones may be affected. Osteoporosis is very common: diagnostic imaging shows 50% of people to be affected by the age of 75, though not all will sustain fractures as a result. Women are at greater risk than men, because their bones are smaller overall, and loss is accelerated around the menopause due to hormonal change. The healthcare burden resulting from fractures is substantial: wrist (or Colles') fractures occurring in middle-age tend to be the first indication of osteoporosis, and although they heal successfully, should be followed by bone densitometry assessment and preventive treatment. Spine and hip fractures tend to occur at older ages, and can result in dramatically increased care needs (National Osteoporosis Society, 2014). DXA scanning is available for only around one third of HCS participants, whilst history of fracture since 45 years of age was ascertained cohort-wide at the HCS baseline home interview. Minor trauma fractures were identified from the information provided and the variable was included in the predictor panel.

Osteoarthritis (hand)

Osteoarthritis (OA) of the hand is characterised by bony swellings in the finger joints called Bouchard's and Heberden's nodes. They result primarily from an inflammatory form of the disease, although swelling at the base of the thumb can have degenerative origins. The condition is more common in women than men (Arthritis Research UK, 2015). Although the hand is the affected site in only one sixth of those seeking treatment for arthritis, it is of interest because hand OA in middle age is known to be associated with later knee OA, and because of a known correlation between Heberden's nodes and generalised OA (Arthritis Research UK, 2015). It was included in the predictor panel as a marker of bone health because, unlike other forms of the disease, ascertainment of hand OA requires no medical imaging. In HCS the hands were examined by a physician at the baseline clinic, and osteoarthritis diagnosed if Heberden's or Bouchard's nodes were present, or there was any squaring at the base of the thumb. Observations were available on the whole cohort, whereas diagnostic imaging for knee OA was limited to a subset.

Self-rated health

Self-rated health is assessed using a single, subjective, non- time-specific question about health status that invites a graded response, very similar to the question used to calculate healthy life expectancy at the population level (Section 2.1.2). Quite what is captured is debatable: it is known that people habitually overestimate their own health in relation to others' and that women rate their health lower, on average, than men (Pinquart, 2001). A weak correlation with age suggests that individuals adjust for age in considering their response (Fayers and Sprangers, 2002). International research shows SRH to be independently associated with specific health problems, use of health services, changes in functional status, recovery from episodes of ill health, mortality, sociodemographic characteristics and multimorbidity (Pinquart, 2001; Bowling, 2005). Specific associations of low SRH have been demonstrated with serious (Hanlon *et al.*, 2007) and multiple (Kennedy *et al.*, 2001) admissions. Self-rated health was derived from the first question of the SF-36 instrument in HCS. The five response categories (Poor, Fair, Good, Very good and Excellent) were analysed either as an ordinal scale or dichotomised by combining the top 3 categories (good or better health) and the bottom 2 (not good health). It was included in the predictor panel as a marker of overall health status.

Depression and Anxiety

Depression and anxiety both decline in prevalence with increasing age, though there is some evidence of a cohort effect, with higher prevalence in later-born generations (Melzer *et al.*, 2012). Social isolation is common in the older population and may be an independent risk factor for depression. Other psychiatric disorders are rare among older people (Melzer *et al.*, 2012). The relation between depression and readmission is unclear (Marcantonio *et al.*, 1999; Iloabuchi *et al.*, 2014; Davydow *et al.*, 2015), though collectively, mental health conditions have been found to have a smaller effect on risk of emergency admission than do physical conditions (Payne *et al.*, 2013). Mental health was assessed in HCS using the Hospital Anxiety and Depression Scale (HAD). This produces scores in the range 0-21 for each condition; probable or definite anxiety or depression were defined as a score of 8 or more on the appropriate scale. (Bjelland *et al.*, 2002)

Bronchitis

Chronic bronchitis is defined as the presence of cough and sputum production for at least 3 months in each of the past two consecutive years. For epidemiological purposes, it is a proxy for Chronic Obstructive Pulmonary Disease (COPD). In the UK COPD is directly related to the prevalence of tobacco smoking, though other air pollutants may contribute. Age is a recognised risk factor, but this likely results from cumulative exposure through life rather than the ageing process *per se* (Vestbo, 2013). Bronchitis at HCS baseline was ascertained from the home interview questionnaire and the variable was included in the predictor panel to ensure a range of disease coverage.

Medication

The use of medication among older people is associated with prevalence of chronic disease and with multimorbidity; a linear relationship has been described between number of medications and risk of emergency admission (Wauters *et al.*, 2016). HCS participants were asked to present prescribed and over-the-counter medications they were taking at baseline to the nurse-interviewer; the latter were included to capture conditions that had not yet come to clinical attention. Details were transcribed from the packaging and subsequently coded to body system using the British National Formulary, to create a count of number of systems medicated. This avoided double-counting conditions which require multiple medications. The continuous variable was included in the predictor panel to stand proxy for overall burden of disease.

4.6.2 Cohort characteristics

Table 10 shows summary measures of the 25 predictor panel variables in HCS participants at baseline. The mean age of men was slightly lower than that of women: 65.7 (SD 2.9) years compared with 66.6 (SD 2.7); first because the tracing process took longer in women who had changed their name at marriage; and secondly, because fieldwork was phased to provide single-sex clinics.

Table 10 Characteristics of Hertfordshire Cohort Study participants at baseline (Source, author)

Variable n (%)		Men (n=1579)	Women (n=1418)	P for gender difference[#]
Demography and anthropometry				
Age (yrs)[+]		65.7 (2.9)	66.6 (2.7)	<0.001
Height (cm)[+]		174.2 (6.5)	160.8 (5.9)	<0.001
Weight (kg)[+]		82.4 (12.7)	71.4 (13.4)	<0.001
BMI (kg/m^2)[+]		27.2 (3.8)	27.6 (4.9)	0.998
Lifestyle				
Ever smoked regularly		1059 (67.1)	553 (39)	<0.001
High alcohol intake[++]		340 (21.5)	68 (4.8)	<0.001
Activity score[+]		60.9 (15.3)	59 (15.7)	<0.001
Social circumstances				
Social class (manual)		908 (59.3)	827 (58.4)	0.602
Relationship status (never married)		109 (6.9)	74 (5.2)	0.054
Housing tenure (not homeowner)		299 (18.9)	313 (22.1)	0.033
Physical function				
Grip strength (kg)[+]		44.0 (7.5)	26.5 (5.8)	<0.001
Low physical function SF36[+++]		316 (20.0)	301 (21.2)	0.417
Walking speed (self-reported)	Very slow	76 (4.8)	97 (6.8)	
	Stroll	375 (23.8)	285 (20.1)	
	Normal	625 (39.6)	638 (45)	<0.001
	Brisk	432 (27.4)	319 (22.5)	
	Fast	69 (4.4)	79 (5.6)	
Fall in past year[++++]		124 (14.3)	289 (22.5)	<0.001
Morbidity				
Ischaemic heart disease		225 (14.6)	127 (9.2)	<0.001
Stroke		79 (5.1)	39 (2.8)	0.001
Hypertension		630 (40)	577 (40.8)	0.644
Diabetes		232 (14.9)	199 (14.3)	0.675
Any fracture since 45yrs age		213 (13.5)	298 (21)	<0.001
Osteoarthritis (hand)		389 (28)	741 (53.6)	<0.001
Self-rated health	Poor	20 (1.3)	21 (1.5)	
	Fair	162 (10.3)	196 (13.9)	
	Good	600 (38)	620 (43.9)	<0.001
	Very good	593 (37.6)	455 (32.2)	
	Excellent	202 (12.8)	120 (8.5)	
HAD-depression (probable/definite)		76 (4.8)	85 (6.0)	0.152
HAD-anxiety (probable/definite)		232 (14.7)	355 (25.1)	<0.001
Bronchitis		92 (5.8)	69 (4.9)	0.244
Number of systems medicated*		1.0 (0.0, 2.0)	1.0 (1.0, 2.0)	0.004

Footnotes:

[+] Mean (SD) of normally distributed variables * Median (lower quartile, upper quartile) of skewed variables

[++] ≥ 22 units/week in men; ≥ 14 units/week in women (guidelines at baseline)

[+++] ≤75 for men, ≤60 for women on SF-36 PF domain (lowest sex-specific fifth of distribution)

[++++] The question on falls was introduced mid-study; data are available for 2148 people

[#] Gender differences were assessed using the chi-squared test for binary and categorical variables; t-tests for normally distributed continuous variables; the Wilcoxon rank-sum test for age; and Poisson regression with robust variance estimation for number of systems medicated

Key characteristics among the cohort have been compared with data collected by the nationally representative Health Survey for England (HSE) during the late 1990s, contemporaneous with the HCS baseline (Syddall *et al.*, 2005a). HCS participants were found to be broadly comparable to those in HSE, with some notable differences. In particular, HCS participants were taller, were less likely to be in the extremes of the socioeconomic distribution, had better self-rated health (SF-36), and the women were less likely to be current smokers or heavy drinkers than women in HSE (Syddall *et al.*, 2005a). This healthy participant effect is usual among cohort studies and is acknowledged (Section 4.9.1). As well as the question over the representativeness of HCS to people of their generation in England, the existence of cohort effects (Section 4.2.2) also raises questions over the representativeness of the HCS generation to those that follow it.

Some gender differences are apparent in Table 10. Among the physical function variables, men were stronger than women, had better physical function and were less likely to have fallen, all of which would be expected. Baseline morbidity data demonstrate sex differences consistent with those shown in Table 1 for most of the variables considered: higher rates of IHD, stroke, and good or better SRH were seen in men; conversely, women had higher rates of fracture, hand OA, depression and anxiety. Rates of hypertension and diabetes were similar in cohort men and women, though Table 1 suggests that nationally, these conditions are more common in men at ages 65-74. These differences may result from between-study variations in method of ascertainment or classification of the disorders; there is no evidence that the healthy participant effect in HCS differs by sex (Syddall *et al.*, 2005a).

4.7 Outcome variables

Section 2.4 of this thesis described a number of differences between 30-day readmission, emergency admission and elective admission, and suggested that these amount to a gradient in *'seriousness'* across the admission types. Section 3.3 reviewed evidence suggesting that risk factors for admission also vary by type. To investigate the determinants of type-specific admission within HCS, the admission histories of participants that were outlined in Section 4.5.3 were grouped to identify three admission outcomes for study (Figure 16): *ever* readmitted within 30 days of a previous discharge (striped); emergency admission (dark grey) and *only* elective admission (light grey). Each of these is addressed by a separate scientific paper (Chapters 5-7).

Deaths were a complicating factor, because they were considered a more serious outcome than admission of any type. Incorporation of deaths within each analysis was guided by this concept of seriousness and is discussed in Sections 4.8.2.1 - 4.8.2.3.

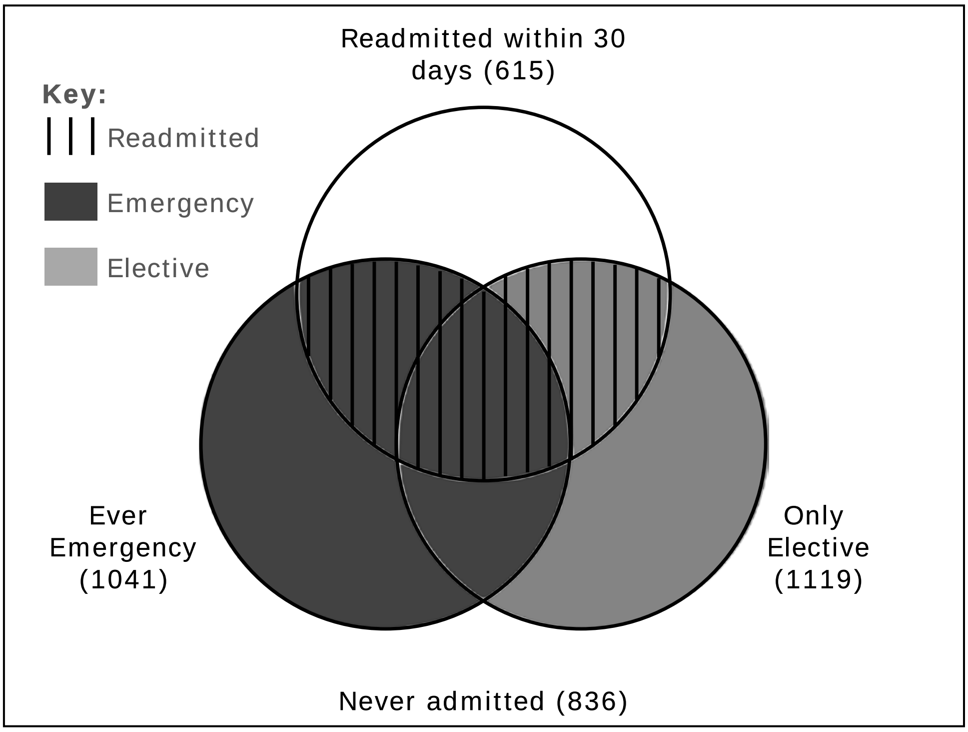

Figure 16 Admission outcomes

(Source, author)

4.8 Statistical methods

This section provides an overview of the statistical methods employed by this thesis; for predictor panel variables, these were consistent throughout (Section 4.8.1). Associations with each outcome were investigated using a common analytical strategy (Section 4.8.2); thereafter, different methods were necessitated for each admission outcome. Similarities and differences between them are summarised in Section 4.8.2.1 - 4.8.2.3; the papers themselves should be consulted for full details of each analysis.

To take account of sex differences in the predictor panel variables (Table 10), all analyses were carried out for men and women separately, using Stata (Release 13) (StataCorp, 2013).

4.8.1 Predictor variables

Table 11 summarises how the variables selected for inclusion in the predictor panel (Section 4.6) were measured and prepared for analysis.

The normality of continuous predictor variables was assessed using visual inspection of histograms. Age, height, weight, BMI, activity score and grip strength were normally distributed;

Table 11 Ascertainment and categorisation of predictor variables

Domain/variable	Ascertainment		Categorisation
Demography and anthropometry			
Age	Clinic	Self-reported, confirming detail from birth register	
Height	Clinic	Harpenden pocket stadiometer	
Weight	Clinic	SECA floor scale	Recorded to the nearest 0.5kg
Weight for height			Derived for inclusion in regression models with height
BMI (kg/m^2)			Derived for inclusion in predictor panel
Lifestyle			
Smoking history	Home	Self-reported	Dichotomised to ever vs never smoked regularly
Alcohol intake	Home	Self-reported	Dichotomised to high (≥22 units per week in men and ≥15 units per week in women) or not high
Physical activity	Home	Self-reported using Dallosso customary physical activity questionnaire[1]	Score coded to range 0-100
Social circumstances			
Social class	Home	Self-reported occupation(s), coded to 1990 Standard Occupational Classification[2] using computer assisted standard occupational coding[3]	Own current or most recent occupation; husband's current or most recent occupation for ever-married women. Dichotomised to non-manual (I,II,IIIN) vs manual (IIIM,IV,V)
Relationship status	Home	Self-reported	Dichotomised to ever vs never married
Housing tenure	Home	Self-reported	Dichotomised to owned/mortgaged home vs not
Physical function			
Grip strength	Clinic	Jamar handgrip dynamometer, 3x per hand using Southampton protocol[4]	Best of 6 measurements used to characterise maximum muscle strength
SF36 physical function	Home	Self-reported using SF-36 HRQoL questionnaire[5]	Dichotomised to low (bottom 1/5 of HCS sex-specific distribution; ≤75 for men and ≤60 for women) or not low
Walking speed	Home	Self-reported ordinal measure of walking speed	
Fall in past year	Home	Self-reported; data are available for 2148 people	

Continued...

…Table 11 continued

Domain/variable	Ascertainment		Definition /categorisation
Morbidity			
Ischaemic heart disease	Clinic Home Home	ECG, graded to Minnesota protocol[6] Self-reported using Rose chest-pain questionnaire[7] Self-reported history of coronary revascularisation	Presence of major Q waves – OR -IHD defined by report of typical angina – OR -IHD defined by history of coronary artery bypass graft or angioplasty
Stroke or TIA	Home	Self-reported	
Hypertension	Clinic Home	Dinamap model 8101, mean of 3 resting BP readings Self-reported prescribed and over-the-counter medications	Measured BP ≥160/100 mmHg - OR - Prescribed medication known to affect BP
Diabetes	Clinic Home	2h fasting oral glucose tolerance test Self-reported diabetes diagnosis	2h plasma glucose ≥11.1mmol/l (WHO criteria[8]) - OR - Existing diet, tablet or insulin treatment regime
Fracture since age 45y	Home	Self-reported	
Osteoarthritis (hand)	Clinic	Clinical examination	Heberden's or Bouchard's nodes present, or squaring at base of thumb
Self-rated health	Home	Self-report using SF-36 HRQoL questionnaire[5]	
Depression	Home	Self-report using Hospital Anxiety and Depression survey instrument[9]	Score ≥8 = probable or definite
Anxiety	Home	Self-report using Hospital Anxiety and Depression survey instrument[9]	Score ≥8 = probable or definite
Bronchitis	Home	Self-reported symptoms	Productive cough most days for > 3 months of the year
Number of systems medicated	Home	Self-reported prescribed and over-the-counter medications	Coded to physiological system using the British National Formulary

Footnotes: 1. Dallosso, H.M., Morgan, K., Bassey, E.J., Ebrahim, S.B.J., Fentem, P.H. and Arie, T.H.D. (1988) Levels of customary physical activity among the old and the very old living at home. *J Epidemiol Community Health*, 42, 121-127; **2**. Office of Population Censuses and Surveys (1990) *Standard occupational classification, Vol 1 structure and definition of major, minor and unit groups*. London: HMSO; **3**. Elias, P., Halstead, K. and Prandy, K. (1993) *Computer assisted standard occupational coding.* H.M. Stationery Office; **4**. Roberts, H.C., Denison, H.J., Martin, H.J., Patel, H.P., Syddall, H., Cooper, C. and Sayer, A.A. (2011) A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing*, 40 (4), 423-429; **5**. Ware, J.E. (2000) SF-36 health survey update. *Spine*, 25 (24), 3130-3139; **6**. Prineas, R.J., Crow, R.S. and Blackburn, H.W. (1982) *The Minnesota code manual of electrocardiographic findings: standards and procedures for measurement and classification,* 2nd ed. London: Springer; **7**. Rose, G.A. (1965) Chest pain questionnaire. *Milbank Mem Fund Q*, 43 (2), 32-39; **8**. World Health Organization (1999) *Definition, Diagnosis and Classification of Diabetes Mellitus and its Complications: Report of a WHO Consultation. Part 1: Diagnosis and Classification of Diabetes Mellitus*. Geneva; **9**. Zigmond, A.S. and Snaith, R.P. (1983) The hospital anxiety and depression scale. *Acta Psychiatr Scand*, 67 (6), 361-370.

positive skewness was detected in number of systems medicated (data heaped at lower number of systems medicated). Normally distributed continuous variables were summarised using means and standard deviations; for those that were skewed, medians and inter-quartile ranges (IQR) were used. Categorical variables were summarised by frequency and percentage distributions (Altman, 1999).

4.8.2 Analysis strategy

Each of the following three chapters comprises a freestanding scientific paper that compares the predictor panel with one admission history outcome using a common four stage regression modelling process, the design of which was informed by the conceptual framework proposed by Figure 6. The first stage explores univariate associations between the admission outcome and variables representing demography and anthropometry; lifestyle; and social circumstances; variables which were placed distal to admission by Figure 6. Significant variables are carried forward to a second, mutually adjusted stage, allowing for interrelationships represented by dotted lines in Figure 6. The third stage examines associations between the admission outcome and variables representing physical function and morbidity; variables that were placed proximal to admission by Figure 6, with adjustment for variables found to be significant at stage 2. Finally, the physical function and morbidity characteristics most strongly associated with the admission outcome at stage 3 are included in a mutually adjusted model with the variables representing demography and anthropometry; lifestyle; and social circumstances that were influential at stage 2. Thus the most important risk factors for each admission type are identified. In each paper, McFadden's pseudo R-squared (McFadden, 1974) is calculated for the mutually adjusted models presented at stages 2 and 4, to contrast the extent of variance explained.

Whilst the four-stage process is replicated across the three papers, the statistical technique applied to derive estimates of association and the method of accounting for death differs from paper to paper. Although rates were low (12% of men and 6.1% of women died during follow-up), the inclusion of mortality data for cohort members required careful consideration. Death during follow-up ended the possibility of admission in people whose risk would otherwise have been high; clearly such individuals were different from people whose risk was low due to favourable health. It was important in all analyses to avoid including these high risk individuals who had not experienced an admission *because they died* in a comparator group with others who had not experienced that type of admission; because differing risk factor profiles within the comparator group could mask associations with the outcome of interest. It was also important to account for any reduction in admissions due to mortality. Treatment of death in the analyses is elaborated in Sections 4.8.2.1 - 4.8.2.3

4.8.2.1 Readmissions paper

The readmissions paper takes ever having a 30-day readmission or dying as its outcome. The analysis contrasts those who were ever readmitted (striped section of Figure 16) or died and those who were not (ie the rest of the cohort, regardless of admission history) by applying Poisson regression models with a robust variance estimator to the common analysis strategy. This technique produces an estimate of relative risk, and is particularly suitable when the measured outcome is not rare (Barros and Hirakata, 2003). Multiple-failure survival modelling techniques were unsuited to this outcome due to difficulties in defining time at risk of 30-day readmissions after the first.

4.8.2.2 Emergency admissions paper

The emergency admissions paper considers time to emergency admission or death as its outcome. This is analysed by applying the Prentice Williams and Peterson total time (PWP-TT) model to the common analysis strategy. This technique was chosen because it captures information from every emergency admission that a cohort member experiences rather than just the first; reflects increasing risk with accumulated admissions for an individual; excludes time spent in hospital as time at risk of admission and recognises that times to admission are correlated within an individual's admission history. The estimate of association produced is a hazard ratio (Castaneda and Gerritse, 2010). In many ways this multiple-failure survival technique represents a gold-standard for the analysis of hospital admisions within a defined period (Westbury *et al.*, 2016). It was particularly suited to the analysis of the emergency admission or death outcome, because whilst time spent in hospital during elective admissions in an individual's history was excluded from time at risk of emergency admission, being less *'serious',* elective admissions could be otherwise ignored.

4.8.2.3 Multinomial paper

The final paper, in which predictors of elective admission are explored, is referred to in shorthand as the multinomial paper. It compares risk of three outcomes: never being admitted; having only elective admissions (light grey section of Figure 16), and ever having an emergency admission (dark grey section of Figure 16) or dying. It applies multinomial logistic regression models to the common analysis strategy in recognition that elective admission represents an outcome intermediate in *'seriousness'* to the other two. The estimate of association produced is a relative risk ratio. The PWP model was less suited to the elective admission outcome because many people who had elective admissions also had more *'serious'* emergency admissions; background emergency admissions could not be ignored, because their risk factor profile might dominate the analysis making it unclear whether associations identified resulted from emergency or elective admission.

The relative strengths and weaknesses of the three techniques are discussed in Section 8.5.3.

4.9 Sample attrition

4.9.1 Healthy participant effect

Section 4.6.2 acknowledged the existence of a healthy participant effect in HCS, showing that cohort members were less likely than HSE participants to be in the extremes of social class, were taller and had better self-rated health; HCS women were also less likely to be current smokers or heavy drinkers, although the absolute differences were small (Syddall *et al.*, 2005a).

The effect of attrition between births listed in the ledgers and baseline clinic (Figure 8) has been addressed by comparing people who progressed at each stage with those who did not. For example, birthweight and weight at one year were shown to be similar in those who had a home interview and those who were invited to do so but declined; men and women who attended clinic were shown to smoke less, and have better self-reported physical function and general health than those who participated in the home interview but declined the invitation to clinic (Syddall *et al.*, 2005a)..

This healthy responder effect is apparent in the generally lower rates of admission in the cohort than in England (Chapter 2), and by the lower ratio of episodes to admissions (Section 4.4.1). Patterns also differ by type: for example, the finding that approximately one quarter of admissions were classified as emergencies among HCS participants contrasts with the national figure of 35% at all ages; especially since older people (such as the HCS participants) are known to have *higher* rates of emergency admission on average (Blunt *et al.*, 2010). However, the associations described in this thesis are based on internal comparisons and, notwithstanding the caveat that they may not be generalisable to the national level, are unlikely to be affected by a healthy responder effect.

4.9.2 Loss to follow-up

Reliable certification of death has a long history in the UK (Devis and Rooney, 1999); figure 9 shows that just 13 participants were lost to follow-up for reasons other than death. Minimal attrition was assured by using only routinely collected data for follow-up: no further contact with cohort members was necessary after their initial characterisation. Hospital Episode Statistics report all admissions to NHS hospitals in England, along with admissions to private hospitals funded by the NHS. Only privately funded admissions to private hospitals are excluded, and these are likely to be rare among the cohort (Section 8.5.1).

4.10 Ethical considerations

Separate ethical considerations apply to participant tracing, baseline investigations and follow-up stages of this project. They will be addressed separately below, alongside more general requirements implicit in handling personal data.

4.10.1 Participant tracing

Section 4.1.2 describes how HCS participants were selected from a wider cohort of individuals born in Hertfordshire who were traced and flagged for continuous notification of death. Because this occurred without contact for most people, and before contact for HCS participants, ethical permission to obtain information about individuals without their consent was required. This was originally sought from the Chief Medical Statistician in 1987 and has recently been updated with exemption from Section 251 of the NHS Act 2006 granted by the Health Research Authority's Confidentiality Advisory Group (CAG), in compliance with Regulation 5 of the Health Service (Control of Patient Information) Regulations 2002 (NHS Health Research Authority, 2016) (Appendix D(i); see also Section 8.4.4).

4.10.2 Baseline investigations

Home interviews and clinics are described in Section 4.1.3. Prior to the formation of the Hertfordshire and Bedfordshire Local Research Ethics Committee the study area was covered by two smaller Health Authority committees. Approval for fieldwork was therefore granted by East and North Hertfordshire and West Hertfordshire authorities separately (Appendix D(ii,iii,iv)). Investigations were carried out by qualified personnel in accordance with the RCUK Code of Conduct, which follows the principles expressed in the Declaration of Helsinki (World Medical Association, 2016). Given the prevalence of age-related disease (Section 2.2.3), clinical investigations in older adults risk the discovery of abnormal results in participants who may be unaware of a problem. In the small number of instances where this happened, participants and their usual healthcare providers were informed. All participants gave written informed consent for the investigations carried out in clinic and for follow-up through their GP records.

4.10.3 Follow-up

The follow-up outcomes considered in this thesis are solely derived from two sources of routinely collected data: HES and ONS (Section 4.2).

At the outset of this study, consent was obtained from clinic participants which granted researchers future access to their GP records. When the HES data were obtained in 2010, this was accepted as implicit consent for access to the brief, anonymous coded summaries extracted from their hospital records for linkage to the HCS database, since all the fields it contained would be obtainable from the discharge summary stored in the GP record. The original data sharing agreement and two routine renewals governing use by the Lifecourse Epidemiology Unit are reproduced in Appendix D(v,vi,vii).

Both renewals were issued without question, but when the second of them expired in 2015, a third was refused by NHS Digital's Data Access Advisory Group because, according to their interpretation of the Health and Social Care Act 2012, the consent held did not satisfy changed legal requirements. By that time a substantial proportion of the cohort had died or been otherwise lost to follow-up and could not be re-consented. It was therefore necessary to obtain an opinion from an ethical committee on the validity of the consent, to support an application to CAG for Section 251 exemption. This would allow the processing of data on the presumption of no consent, as for the mortality data (Section 4.10.1). Whilst the application was processed the LEU was permitted to retain but not to process the data.

A very favourable response was received from the Cambridge and East of England REC (dated 22/09/2016): *'the Committee is of the opinion to not allow linkage would undermine the consent of participants and further it would be unethical not to allow this study to continue'.* Section 251 exemption was granted by CAG after protracted delays and a new application was submitted to NHS Digital in May 2017. This is still pending in January 2018.

Mortality and other NHSCR data for HCS participants continue to be covered by the cohort-wide Section 251 exemption referred to in Section 4.10.1, though participants' consent to follow-up through GP records could be argued to cover this also.

4.10.4 General ethical considerations

Ethical considerations in addition to consent (above) include the duty of confidentiality to participants. Very strict standards are imposed by the MRC, such that breach of confidentiality constitutes grounds for automatic dismissal. Identifiers such as name, address and NHS number are stored separately from clinic data and few members of staff have access to both files. These highly sensitive fields are never output to analysis files, which are anonymised. All members of staff who have access the records are ONS Accredited Researchers.

The Data Protection Act 1998 requires people to be informed of the uses to which their personal data are put; this is achieved in HCS through regular newsletters to cohort members alongside a dedicated website. Articles on the research described in this thesis have appeared in the 2015 newsletter and on the website (www.mrc.soton.ac.uk/herts/findings/hospital-care).

The University of Southampton acts as sponsor to HCS and provides indemnity insurance; this is facilitated by the Research Governance Office through its ERGO system. The relevant documentation is reproduced in Appendix D(viii,ix).

Finally, routine statistics are collected at the public expense. They form an inexpensive source of follow-up in a cohort study which is also publicly funded. It is surely in the public interest to exploit the full value of data as in this project; indeed, as the Cambridge and East of England REC suggest above (Section 4.10.3), it would be unethical *not* to do so.

4.11 Conclusion

This chapter describes the data sources that are drawn on by this research, and shows that they can be linked together. To demonstrate the added value of the combined data, the descriptive epidemiology of hospital admissions within the cohort is explored by Sections 4.4 and 4.5. However, the real value of the combined dataset derives from the prospective measurements made at baseline. From these, a predictor panel has been assembled to reflect influences on admission identified by Chapter 3 (Section 4.6). This will be compared with 30-day readmission (Chapter 5), emergency admission (Chapter 6) and elective admission (Chapter 7), to address the second research question: *In (this) dataset, how would anthropometry, lifestyle, social circumstances, physical function and morbidity, individually and together, affect risk of: a) readmission within 30 days? b) emergency admission? c) elective admission?*

The papers that comprise Chapters 5-7 have multiple authors, whose individual contributions are detailed by signed declarations of authorship at the end of each paper. As first author, the candidate obtained the HES data, conducted the literature review, designed the strategy for statistical analyses, designed the tables and figures and drafted all versions of the manuscript of each paper. Statistical analyses were conducted with two statisticians and the work was overseen by supervisors from two faculties. The candidate's wider contribution to HCS has also been significant. Having set up the study with Professor David Barker in the 1980s, she has been responsible for participant tracing and the acquisition, processing and reporting of cohort-wide mortality data from the outset, and has latterly assumed responsibility for research governance, particularly in matters related to data sharing and linkage.

Chapter 5: Risk factors for 30-day readmission to hospital among older people: Evidence from data linkage

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Abstract

Background: Models aiming to identify those at risk of 30-day readmission have met with only partial success. They are typically limited in the range of variables they include, the timescale over which these are collected, and the population considered at risk.

Objective: To investigate the individual and combined importance of diverse prospectively measured risk factors for 30-day readmission among a community-dwelling cohort of older people.

Design: Prospective cohort study.

Setting: Hertfordshire UK.

Participants: 1,579 men and 1,418 women aged 59 to 73 at baseline.

Methods: Participants' demography and anthropometry, lifestyle, social circumstances, physical function and morbidity were characterised at baseline (1998-2004). Hospital admissions and deaths from baseline-2010 were ascertained by linkage with administrative data.

Results: The cohort experienced 8,687 admissions and 275 deaths during follow-up. 1,663 admissions (19.1%) were within 30 days of a previous discharge. Mutually adjusted Poisson regression models identified poor self-rated health and increased number of systems medicated as dominant risk factors for readmission or death in both sexes. History of smoking, not owning one's home, slow self-reported walking speed and history of fracture were sex-specific risks. Probability of 30-day readmission or death, estimated from the model, increased steeply with number of risk factors present; from 0.19 (95%CI: 0.14,0.24) among men with none, to 0.51 (95%CI: 0.43,0.60) among men with four or more. Corresponding probabilities for women were 0.11 (95%CI: 0.08,0.16) and 0.49 (95%CI: 0.41,0.57).

Conclusion: Multimorbidity, ascertained by self-rated health and number of systems medicated, is a key risk factor for 30-day readmission; additional risks derive from unhealthy lifestyle, socioeconomic disadvantage and poor physical function. These risk factors could be detected in a general practice population before the index admission.

Key words: Risk factors; Hospital Episode Statistics; Hospitalization; Readmission; Older people; Multimorbidity.

Introduction

Approximately 10 percent of people aged 16-74 who were discharged from hospital during 2010-11 were readmitted in an emergency within a month. At ages 75 and over, this figure rose to 15.3 percent (Department of Health, 2013). The percentage readmitted electively is less clear. The causes of readmission are variously thought to lie in the hospital care during the first (or 'index') admission, the community care that followed it, or individual patient characteristics; debate often centres on apportionment of blame (Oliver, 2015). In 2011, the UK Department of Health introduced a policy of non-payment for selected readmissions within 30 days of discharge, as an incentive to hospitals to improve care and discharge planning (Department of Health, 2010). The aim was to reduce emergency readmission by 25 percent alongside locally agreed targets for other readmissions; the effect has been a loss of income estimated to average £5m per hospital trust (Foundation Trust Network, 2011). Similar financial penalties were introduced in the US in 2012 (Drozda Jr, 2013). In both countries, predictive models have been developed to identify high-risk patients in whom preventive intervention might avoid readmission. These models usually draw on variables routinely available from the hospital record, typically age, admissions history and a measure of morbidity (Lewis *et al.*, 2011). This is in part pragmatic - they are the most readily available data; and in part design – if the hospital is responsible they are also the most relevant data.

However, such models ignore the likely contribution of community and patient factors to readmission. In the US it has been estimated that patient characteristics explain 56.2% of between-hospital variation in readmission rate (Singh *et al.*, 2014); meanwhile in the UK, models that incorporate records from primary care as well as hospitals have been shown to perform better than those based on hospital data alone. This approach extends the range of predictive variables (for example, to include smoking), the timescale over which they are measured and the population considered at risk (Billings *et al.*, 2013), demonstrating that patient characteristics beyond those routinely recorded in the hospital record are important. However, studies examining their association with readmission have been predominantly small, disease-specific and US-based. All but one (Iloabuchi *et al.*, 2014) ascertained predictive variables at the time of the index admission.

Using data from a UK cohort of community-dwelling men and women aged 59-73 at recruitment, linked with hospital episode statistics (HES) relating to their admissions over the following decade, we investigated a range of prospectively measured, patient-centred, potential risk factors for 30-day readmission. Risks were categorised into five domains that had been previously linked with readmission: demography and anthropometry, lifestyle, social circumstances, physical function and morbidity (Garcia-Perez *et al.*, 2011; Walsh, 2014; Pedersen *et al.*, 2017).

Methods

Study population The Hertfordshire Cohort Study (HCS) comprises 1,579 men and 1,418 women born during 1931 to 1939, whose birth, infancy and early childhood were documented by Health Visitors. Between 1998 and 2004, they were interviewed at home and subsequently attended clinics for detailed physiological investigations across a range of body systems. Together, the home interview and clinic constitute the baseline characterisation. The study had ethical approval from the Hertfordshire and Bedfordshire Local Research Ethics Committee and has been described in detail previously (Syddall *et al.*, 2005a).

Linkage with administrative data At baseline, cohort members gave informed consent for future access to their medical records by the research team. An extract of Hospital Episode Statistics (HES) data was obtained listing 15 variables for each episode experienced by participants between 01/04/98 and 31/03/10. These episode data, including start and end dates and method of admission, were collapsed into records of completed admissions and combined with cohort data to create a personal admissions history for each individual. The cohort is flagged by NHS Digital for continuous notification of death, details of which were appended to the admissions history where appropriate. Admissions before the date of clinic attendance were discounted, so that the follow-up period differed by person, from an individual baseline (identified by the date of HCS clinic) to a common end-date of 31/03/2010. These methods have been described in detail previously (Simmonds *et al.*, 2014b).

Statistical methods The outcome variable, indicating whether or not a participant had experienced at least one 30-day readmission or died during the follow-up period, was coded from the personal admissions history. No distinction was made between elective and emergency readmissions.

A panel of predictor variables was selected from the information collected at baseline, reflecting domains of risk for hospital admission. Variables included were: in the demography/anthropometry domain, age, height, weight, and two markers of adiposity (weight-adjusted-for-height and body mass index (BMI)); in the lifestyle domain, history of smoking, alcohol intake, and physical activity; in the social circumstances domain, social class, relationship status and housing tenure; in the physical function domain, grip strength, SF-36 physical function, self-reported walking speed and history of falls; and in the morbidity domain, history of ischaemic heart disease, stroke, hypertension, diabetes, fracture since age 45, hand osteoarthritis, depression, anxiety or bronchitis, along with self-rated health and number of physiological systems medicated. Methods of ascertainment and preparation of these data are described in Table 12.

Data were described using means and standard deviations, medians and inter-quartile ranges and frequency and percentage distributions. Associations between the risk of readmission or death and the panel of predictor variables were explored in four stages using univariate, then mutually adjusted Poisson regression models with a robust variance estimator; a suitable technique for estimation of relative risks when an outcome is not rare (Barros and Hirakata, 2003). To enable presentation of comparable effect sizes, sex-specific standard deviation scores were coded for continuous characteristics. To take account of known sex differences in health in later life (Arber and Ginn, 1993), all analyses were carried out for men and women separately, using Stata (Release 13) (StataCorp, 2013).

Results

During the median 8.1-year follow-up period, the cohort collectively experienced 8,687 admissions, of which 1,663 (19.1%) were within 30 days of previous discharge. Men accounted for 993 readmissions and women for 670. There were 275 deaths, 189 among men and 86 among women. This paper presents a combined outcome variable ‘ever readmitted within 30 days or died’. Individually, 458 (29.0%) men and 288 (20.3%) women had at least one readmission or died during the follow-up period (p for gender difference <0.001). Amongst them, 269 men and 202 women had at least one readmission and did not die; 102 men and 42 women had at least one readmission and also died; 87 men and 44 women died without having a readmission. The participants’ characteristics are shown in Table 13.

The first two stages of analysis examined univariate, then mutually adjusted associations between readmission or death and demography/anthropometry, lifestyle and social circumstances. In univariate analyses, increased adiposity (weight-for-height or BMI), history of smoking, low current customary physical activity levels and not being a homeowner were associated with increased risk of readmission in one or both sexes. Only the association with increased adiposity was attenuated by mutual adjustment (Table 14).

The third stage of analysis explored the associations between risk of readmission or death and variables in the physical function and morbidity domains. Adjustment was made for age, smoking history, physical activity and housing tenure, given the associations described above. Increased risk of readmission or death was associated, in one or both sexes, with: weaker grip strength, low SF-36 physical function and slower self-reported walking speed (markers of physical function);

ischaemic heart disease, stroke or hypertension (markers of cardiovascular disease); fracture since 45 years of age; poor self-rated health and increased levels of depression and anxiety (markers of health perception and mental health); bronchitis; and having a greater number of systems medicated (Table 15).

Finally, the physical function and morbidity characteristics that were most strongly associated with risk of readmission or death at stage 3 were included with lifestyle and social characteristics identified at stage 2 in a mutually adjusted model (Table 16). To ensure a parsimonious model fit and to avoid inclusion of highly correlated variables from the same risk factor domain, we used preliminary models to identify which markers of physical function, cardiovascular disease, and health perception/mental health were most strongly associated with risk of readmission or death, and should therefore be included in the mutually adjusted model. On this basis, low SF-36 physical function, slow self-reported walking speed, ischaemic heart disease, hypertension and poor self-rated health were included as potential predictors along with age, smoking history, physical activity, housing tenure, history of fracture, bronchitis and number of systems medicated. This final model identified history of smoking, not owning one's home, slow self-reported walking speed, history of fracture, poor self-rated health and increased number of systems medicated as strong determinants of increased risk of readmission or death in one or both sexes.

To illustrate the combined impact of these baseline characteristics, we devised a risk factor score (Robinson *et al.*, 2013). Individuals were allocated one point for each risk factor they had, yielding a score between zero and six for each person. Figure 17 shows that the probability of readmission or death, as estimated from the Poisson model, increased steeply with greater score among men and women; from 0.19 (95%CI: 0.14,0.24) among men with a score of 0, to 0.51 (95%CI: 0.43,0.60) among men with a score of four or more (corresponding probabilities for women were 0.11 (95%CI: 0.08,0.16) and 0.49 (95%CI: 0.41,0.57)).

Discussion

We have identified six dominant patient-related risk factors for 30-day readmission or death among community-dwelling older people who participated in an English cohort study: poor self-rated health and increased number of systems medicated were strong determinants in both men and women; history of smoking, slow self-reported walking speed and history of fracture were specific to men, whilst not owning one's home (a marker of material deprivation) was significant only in women. There was a striking increase in the probability of readmission or death with number of risk factors present, such that around half of those with four or more risk factors at baseline experienced a readmission or died during the follow-up period, compared with fewer than 1 in 5 who had no risk factors.

Our approach systematically and objectively distinguished the most important risk factors for readmission. The individual and combined impact of number of systems medicated and self-rated health, and their attenuation of markers of single disease as risk factors in our model, suggests that total burden of disease, or multimorbidity (Marengoni *et al.*, 2011), is the primary driver of 30-day readmission in later life. Individually, the two variables describe distinct dimensions of health status: objective (number of systems medicated) and subjective (self-rated health); they should not be regarded simply as proxies for each other (Pinquart, 2001). In the context of predicting readmission, these holistic indicators of multimorbidity may be preferable to measures that sum (or weight) the existence of listed clinical conditions, particularly when poor self-rated health and increased number of systems medicated occur together.

Risk of readmission increases further when unhealthy lifestyle, compromised physical function or unfavourable social circumstances coexist with multimorbidity. The risk factors identified require no clinical testing and could be determined using a short screening questionnaire. Given that the predictive variables were ascertained before either admission, such a questionnaire would be most applicable to a general practice population.

Prospective cohort studies into risk factors for readmission in older people are unusual. A systematic review of those published to 2010 identified 12 (Garcia-Perez *et al.*, 2011), of which just four reported results specific to 30 day readmission (Kwok *et al.*, 1999; Lotus Shyu *et al.*, 2004; Cornette *et al.*, 2005; Laniece *et al.*, 2008). A second review with an overlapping remit (Pedersen *et al.*, 2017) identified two more published by 2013 (Espallargues *et al.*, 2008; Fisher *et al.*, 2013), and we are aware of few since (Iloabuchi *et al.*, 2014; Dong and Simon, 2015). Five of the studies (Kwok *et al.*, 1999; Cornette *et al.*, 2005; Espallargues *et al.*, 2008; Laniece *et al.*, 2008; Iloabuchi *et al.*, 2014) aimed, like us, to discriminate between a diverse range of variables; a multifactorial approach such as this is important in identifying risk factors for admission (Hallgren *et al.*, 2016b). Although the studies commonly reported associations with morbidity and physical function, consensus was lacking over which disease or disability was most influential (Garcia-Perez *et al.*, 2011). All but one of the studies (Iloabuchi *et al.*, 2014) were prospective only insofar as recruitment took place during the index admission.

Thus only one previous study was designed like ours, to include both index admission and readmission within the follow-up period (Iloabuchi *et al.*, 2014). Set within the Geriatric Resources for Assessment and Care of Elders (GRACE) randomised controlled trial, it followed 951 low-income adults aged 65 and over for 2 years after a baseline interview. As in our study, successive regression models first identified univariate risk factors and then derived a multivariate model defining those that were most important. They were: living alone, poor or fair satisfaction with healthcare provider, not having Medicaid, and having a new assistive device or a nursing home stay within the past 6 months.

The panels of potential predictors differed between GRACE and HCS, as did the context within which the studies were set. The GRACE study, by design, covered only a limited socioeconomic range whilst in the wider distribution of HCS, not being an owner-occupier was a predictor of readmission. Similarly, HCS participants were all covered by a single healthcare system (the NHS) whilst in GRACE, insurance status varied and not having Medicaid was predictive. There are areas, however, where the lack of consensus is surprising, such as smoking (*ever* smoking was significant in HCS; *active* smoking was not in GRACE), and burden of disease (number of systems medicated was significant in HCS; having more than two chronic diseases was not in GRACE). Overall, three of the five US predictors were classified by the authors as 'social', whereas in the UK markers of overall morbidity dominated. There were, conversely, some points of agreement between the studies: both reported a role for physical function (defined by a new assistive device in GRACE and slow walking speed in HCS), and the existence of a combined effect among the risk factors identified. Together, the studies imply that risk is multifaceted and context-specific.

Our study has some justifiable limitations. First, we chose to define a binary outcome variable combining readmission with death, in order to include individuals whose health outcome was *worse* than readmission and to account for any reduction in readmissions due to mortality. However, relatively few people were considered positive for the outcome only because they died: 23.5% of men were ever readmitted whilst 29.0% were readmitted or died. Equivalent figures for women were 17.2% and 20.3%, thus we are confident that including deaths does not impact greatly on modelling readmissions. The binary variable also under-used information from those who had multiple readmissions (1663 readmissions were attributable to 615 people); such patterns of frequent readmission are thought to be typical (Black, 2014). Secondly, unlike many previous authors, we chose not to distinguish between emergency and elective readmissions. Although UK policy primarily penalises emergency readmission, elective readmissions are not exempt (Department of Health, 2010), and we wished to address the overall burden of readmission. Moreover, sensitivity analyses (not shown) suggested that the predictors of elective and emergency admission did not differ greatly. Thirdly, our aim was not to produce a validated predictive model; but rather to investigate which variables might most usefully contribute to such a model.

The study also has advantages, particularly due to its novel methodology. It is the first in the UK to use linked cohort and administrative data prospectively to predict readmission; we have mutually adjusted for the combined impact of risk factors from different domains; avoided confounding by acute ill-health at the time of admission by using predictive variables measured *before* the index admission; avoided loss to follow-up resulting from self-report or treatment in more than one hospital by deriving outcome data from routinely collected statistics; and, by incorporating mortality data, we have accounted for deaths.

Conclusion

Unfavourable self-rated health and increased number of systems medicated in early old age increase the risk of having at least one 30-day readmission during the next decade, particularly when they occur together. This is true in both sexes. Additional, sex-specific, risks derive when unhealthy lifestyles, socioeconomic disadvantage and poor physical function coexist with these markers of multimorbidity. This information could be used in General Practice prospectively to identify those at risk of readmission(s). Intervention at this stage would contrast with the current focus on hospital discharges; it could prevent not only the readmission, but the index admission that precedes it.

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References

Arber, S. and Ginn, J. (1993) Gender and inequalities in health in later life. *Soc Sci Med,* 36 (1), 33-46.

Barros, A. and Hirakata, V. (2003) Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. *BMC Med Res Methodol,* 3, 21.

Billings, J., Georghiou, T., Blunt, I. and Bardsley, M. (2013) Choosing a model to predict hospital admission: an observational study of new variants of predictive models for case finding. *BMJ Open,* 3, e003352.

Black, J.T. (2014) Learning about 30-day readmissions from patients with repeated hospitalizations. *Am J Manag Care,* 20 (6), E200-E207.

Cornette, P., D'Hoore, W., Malhomme, B., Van Pee, D., Meert, P. and Swine, C. (2005) Differential risk factors for early and later hospital readmission of older patients. *Aging Clin Exp Res,* 17 (4), 322-328.

Department of Health (2010) *The Operating Framework for the NHS in England 2011/12.* London. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216187/dh_122736.pdf [Accessed 07/01/18].

Department of Health (2013) *Emergency readmissions data.* Available from: https://www.gov.uk/government/publications/emergency-readmissions-data. [Accessed 10/01/18].

Dong, X. and Simon, M.A. (2015) Elder self-neglect is associated with an increased rate of 30-day hospital readmission: findings from the Chicago Health and Aging Project. *Gerontology,* 61 (1), 41-50.

Drozda Jr, J.P. (2013) Readmission rates. *BMJ,* 347, f7478.

Espallargues, M., Philp, I., Seymour, D.G., Campbell, S.E., Primrose, W., Arino, S., Dunstan, E., Lamura, G., Lawson, P., Mestheneos, E., Politynska, B. and Raiha, I. (2008) Measuring case-mix and outcome for older people in acute hospital care across Europe: the development and potential of the ACMEplus instrument. *QJM,* 101 (2), 99-109.

Fisher, S.R., Kuo, Y.F., Sharma, G., Raji, M.A., Kumar, A., Goodwin, J.S., Ostir, G.V. and Ottenbacher, K.J. (2013) Mobility after hospital discharge as a marker for 30-day readmission. *J Gerontol A Biol Sci Med Sci,* 68 (7), 805-810.

Foundation Trust Network (2011) *The impact of non-payment for acute readmissions.* London: NHS Confederation, Issue 211. Available from: http://www.chks.co.uk/userfiles/files/The%20impact%20of%20non-payment%20for%20acute%20readmissions%20FINAL%20FOR%20WEB.pdf [Accessed 07/01/18].

Garcia-Perez, L., Linertova, R., Lorenzo-Riera, A., Vazquez-Diaz, J.R., Duque-Gonzalez, B. and Sarria-Santamera, A. (2011) Risk factors for hospital readmissions in elderly patients: a systematic review. *QJM,* 104 (8), 639-651.

Hallgren, J., Fransson, E.I., Kareholt, I., Reynolds, C.A., Pedersen, N.L. and Aslan, A.K.D. (2016) Factors associated with hospitalization risk among community living middle aged and older persons: Results from the Swedish Adoption/Twin Study of Aging (SATSA). *Arch Gerontol Geriatr,* 66, 102-108.

Iloabuchi, T.C., Mi, D., Tu, W. and Counsell, S.R. (2014) Risk factors for early hospital readmission in low-income elderly adults. *J Am Geriatr Soc,* 62 (3), 489-494.

Kwok, T., Lau, E., Woo, J., Luk, J.K., Wong, E., Sham, A. and Lee, S.H. (1999) Hospital readmission among older medical patients in Hong Kong. *J R Coll Physicians Lond,* 33 (2), 153-156.

Laniece, I., Couturier, P., Drame, M., Gavazzi, G., Lehman, S., Jolly, D., Voisin, T., Lang, P.O., Jovenin, N., Gauvain, J.B., Novella, J.L., Saint-Jean, O. and Blanchard, F. (2008) Incidence and main factors associated with early unplanned hospital readmission among French medical inpatients aged 75 and over admitted through emergency units. *Age Ageing,* 37 (4), 416-422.

Lewis, G., Curry, N. and Bardsley, M. (2011) *Choosing a predictive risk model: a guide for commissioners in England*. London: Nuffield Trust. Available from: https://www.nuffieldtrust.org.uk/files/2017-01/choosing-predictive-risk-model-guide-for-commissioners-web-final.pdf [Accessed 07/01/18].

Lotus Shyu, Y.I., Chen, M.C. and Lee, H.C. (2004) Caregiver's needs as predictors of hospital readmission for the elderly in Taiwan. *Soc Sci Med,* 58 (7), 1395-1403.

Marengoni, A., Angleman, S., Melis, R., Mangialasche, F., Karp, A., Garmen, A., Meinow, B. and Fratiglioni, L. (2011) Aging with multimorbidity: A systematic review of the literature. *Ageing Res Rev,* 10 (4), 430-439.

Oliver, D. (2015) Who is to blame for older people’s readmission? *BMJ,* 351, h4244.

Pedersen, M.K., Meyer, G. and Uhrenfeldt, L. (2017) Risk factors for acute care hospital readmission in older persons in Western countries: a systematic review. *JBI Database System Rev Implement Rep,* 15 (2), 454-485.

Pinquart, M. (2001) Correlates of subjective health in older adults: a meta-analysis. *Psychol Aging,* 16 (3), 414-426.

Robinson, S.M., Jameson, K.A., Syddall, H.E., Dennison, E.M., Cooper, C., Sayer, A.A. and Hertfordshire Cohort Study Group (2013) Clustering of lifestyle risk factors and poor physical function in older adults: The Hertfordshire Cohort Study. *J Am Geriatr Soc,* 61 (10), 1684-1691.

Simmonds, S.J., Syddall, H.E., Walsh, B., Evandrou, M., Dennison, E.M., Cooper, C. and Aihie Sayer, A. (2014b) Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study. *Age Ageing,* 43, 653-660.

Singh, S., Lin, Y.L., Kuo, Y.F., Nattinger, A.B. and Goodwin, J.S. (2014) Variation in the risk of readmission among hospitals: the relative contribution of patient, hospital and inpatient provider characteristics. *J Gen Intern Med,* 29 (4), 572-578.

Statacorp (2013) Stata statistical software: release 13. College Station, TX: StataCorp LP.

Syddall, H.E., Aihie Sayer, A., Dennison, E.M., Martin, H.J., Barker, D.J. and Cooper, C. (2005a) Cohort profile: the Hertfordshire Cohort Study. *Int J Epidemiol,* 34 (6), 1234-1242.

Walsh, B. (2014) Unplanned admissions and readmissions in older people: a review of recent evidence on identifying and managing high-risk individuals. *Rev Clin Gerontol,* 24 (3), 228-237.

Table 12 Ascertainment and categorisation of predictor variables (Readmissions paper, Appendix 1)

Domain/variable	Ascertainment		Categorisation
Demography and anthropometry			
Age	Clinic	Self-reported, confirming detail from birth register	
Height	Clinic	Harpenden pocket stadiometer	
Weight	Clinic	SECA floor scale	Recorded to the nearest 0.5kg
Weight for height			Derived for inclusion in regression models with height
BMI (kg/m^2)			Derived for inclusion in predictor panel
Lifestyle			
Smoking history	Home	Self-reported	Dichotomised to ever vs never smoked regularly
Alcohol intake	Home	Self-reported	Dichotomised to high (≥22 units per week in men and ≥15 units per week in women) or not high
Physical activity	Home	Self-reported using Dallosso customary physical activity questionnaire[1]	Score coded to range 0-100
Social circumstances			
Social class	Home	Self-reported occupation(s), coded to 1990 Standard Occupational Classification[2] using computer assisted standard occupational coding[3]	Own current or most recent occupation; husband's current or most recent occupation for ever-married women. Dichotomised to non-manual (I,II,IIIN) vs manual (IIIM,IV,V)
Relationship status	Home	Self-reported	Dichotomised to ever vs never married
Housing tenure	Home	Self-reported	Dichotomised to owned/mortgaged home vs not
Physical function			
Grip strength	Clinic	Jamar handgrip dynamometer, 3x per hand using Southampton protocol[4]	Best of 6 measurements used to characterise maximum muscle strength
SF36 physical function	Home	Self-reported using SF-36 HRQoL questionnaire[5]	Dichotomised to low (bottom 1/5 of HCS sex-specific distribution; ≤75 for men and ≤60 for women) or not low
Walking speed	Home	Self-reported ordinal measure of walking speed	
Fall in past year	Home	Self-reported; data are available for 2148 people	

Continued...

…Table 12 continued

Domain/variable	Ascertainment		Definition /categorisation
Morbidity			
Ischaemic heart disease	Clinic	ECG, graded to Minnesota protocol[6]	Presence of major Q waves – OR -IHD defined by report of typical angina – OR -IHD defined by history of coronary artery bypass graft or angioplasty
	Home	Self-reported using Rose chest-pain questionnaire[7]	
	Home	Self-reported history of coronary revascularisation	
Stroke or TIA	Home	Self-reported	
Hypertension	Clinic	Dinamap model 8101, mean of 3 resting BP readings	Measured BP ≥160/100 mmHg
	Home	Self-reported prescribed and over-the-counter medications	- OR - Prescribed medication known to affect BP
Diabetes	Clinic	2h fasting oral glucose tolerance test	2h plasma glucose ≥11.1mmol/l (WHO criteria[8]) - OR -
	Home	Self-reported diabetes diagnosis	Existing diet, tablet or insulin treatment regime
Fracture since age 45y	Home	Self-reported	
Osteoarthritis (hand)	Clinic	Clinical examination	Heberden's or Bouchard's nodes present, or squaring at base of thumb
Self-rated health	Home	Self-report using SF-36 HRQoL questionnaire[5]	
Depression	Home	Self-report using Hospital Anxiety and Depression survey instrument[9]	Score ≥8 = probable or definite
Anxiety	Home	Self-report using Hospital Anxiety and Depression survey instrument[9]	Score ≥8 = probable or definite
Bronchitis	Home	Self-reported symptoms	Productive cough most days for > 3 months of the year
Number of systems medicated	Home	Self-reported prescribed and over-the-counter medications	Coded to physiological system using the British National Formulary

Footnotes:
1. Dallosso, H.M., Morgan, K., Bassey, E.J., Ebrahim, S.B.J., Fentem, P.H. and Arie, T.H.D. (1988) Levels of customary physical activity among the old and the very old living at home. *J Epidemiol Community Health*, 42, 121-127; **2**. Office of Population Censuses and Surveys (1990) *Standard occupational classification, Vol 1 structure and definition of major, minor and unit groups*. London: HMSO; **3**. Elias, P., Halstead, K. and Prandy, K. (1993) *Computer assisted standard occupational coding.* H.M. Stationery Office; **4**. Roberts, H.C., Denison, H.J., Martin, H.J., Patel, H.P., Syddall, H., Cooper, C. and Sayer, A.A. (2011) A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing*, 40 (4), 423-429; **5**. Ware, J.E. (2000) SF-36 health survey update. *Spine*, 25 (24), 3130-3139; **6**. Prineas, R.J., Crow, R.S. and Blackburn, H.W. (1982) *The Minnesota code manual of electrocardiographic findings: standards and procedures for measurement and classification,* 2nd ed. London: Springer; **7**. Rose, G.A. (1965) Chest pain questionnaire. *Milbank Mem Fund Q*, 43 (2), 32-39; **8**. World Health Organization (1999) *Definition, Diagnosis and Classification of Diabetes Mellitus and its Complications: Report of a WHO Consultation. Part 1: Diagnosis and Classification of Diabetes Mellitus*. Geneva; **9**. Zigmond, A.S. and Snaith, R.P. (1983) The hospital anxiety and depression scale. *Acta Psychiatr Scand*, 67 (6), 361-370.

Table 13 Participant characteristics (Readmissions paper, Table 1)

Variable n (%)		Men (n=1579)	Women (n=1418)	P for gender difference[#]
Anthropometry				
Age (yrs)[+]		65.7 (2.9)	66.6 (2.7)	<0.001
Height (cm)[+]		174.2 (6.5)	160.8 (5.9)	<0.001
Weight (kg)[+]		82.4 (12.7)	71.4 (13.4)	<0.001
BMI (kg/m^2)[+]		27.2 (3.8)	27.6 (4.9)	0.998
Lifestyle				
Ever smoked regularly		1059 (67.1)	553 (39)	<0.001
High alcohol intake[++]		340 (21.5)	68 (4.8)	<0.001
Activity score[+]		60.9 (15.3)	59 (15.7)	<0.001
Social circumstances				
Social class (manual)		908 (59.3)	827 (58.4)	0.602
Relationship status (never married)		109 (6.9)	74 (5.2)	0.054
Housing tenure (not homeowner)		299 (18.9)	313 (22.1)	0.033
Physical function				
Grip strength (kg)[+]		44.0 (7.5)	26.5 (5.8)	<0.001
Low physical function SF36[+++]		316 (20.0)	301 (21.2)	0.417
Walking speed (self-reported)	Very slow	76 (4.8)	97 (6.8)	
	Stroll	375 (23.8)	285 (20.1)	
	Normal	625 (39.6)	638 (45)	<0.001
	Brisk	432 (27.4)	319 (22.5)	
	Fast	69 (4.4)	79 (5.6)	
Fall in past year[++++]		124 (14.3)	289 (22.5)	<0.001
Morbidity				
Ischaemic heart disease		225 (14.6)	127 (9.2)	<0.001
Stroke		79 (5.1)	39 (2.8)	0.001
Hypertension		630 (40)	577 (40.8)	0.644
Diabetes		232 (14.9)	199 (14.3)	0.675
Any fracture since 45yrs age		213 (13.5)	298 (21)	<0.001
Osteoarthritis (hand)		389 (28)	741 (53.6)	<0.001
Self-rated health	Poor	20 (1.3)	21 (1.5)	
	Fair	162 (10.3)	196 (13.9)	
	Good	600 (38)	620 (43.9)	<0.001
	Very good	593 (37.6)	455 (32.2)	
	Excellent	202 (12.8)	120 (8.5)	
HAD-depression (probable/definite)		76 (4.8)	85 (6.0)	0.152
HAD-anxiety (probable/definite)		232 (14.7)	355 (25.1)	<0.001
Bronchitis		92 (5.8)	69 (4.9)	0.244
Number of systems medicated*		1.0 (0.0, 2.0)	1.0 (1.0, 2.0)	0.004
Outcomes				
Ever any admission		1185 (75.0)	976 (68.8)	<0.001
Ever any admission /died		1197 (75.8)	985 (69.5)	<0.001
Ever readmission (<30 days)		371 (23.5)	244 (17.2)	<0.001
Ever readmission (<30 days) / died		458 (29.0)	288 (20.3)	<0.001
Died		189 (12.0)	86 (6.1)	<0.001

Footnotes:

[+] Mean (SD) * Median (lower quartile, upper quartile)

[++] ≥ 22 units/week in men; ≥ 14 units/week in women (guidelines at baseline)

[+++] ≤75 for men, ≤60 for women on SF-36 PF domain (lowest sex-specific fifth of distribution)

[++++] The question on falls was introduced mid-study; data are available for 2148 people

[#] See Table 10

Table 14 Associations between anthropometric, lifestyle and social characteristics and risk of 30-day readmission or death (Readmissions paper, Appendix 2)

Association between each characteristic and the risk of readmission within 30 days or death[+]	**Men**				**Women**			
	Unadjusted		**Adjusted[†]**		**Unadjusted**		**Adjusted[†]**	
	Relative risk (95% CI)	P-value	Relative risk (95% CI)	P-value	Relative risk (95% CI)	P-value	Relative risk (95% CI)	P-value
Age**	1.08 (1.00,1.16)	0.056	1.07 (0.99,1.16)	0.087	1.10 (0.99,1.21)	0.073	1.08 (0.98,1.20)	0.122
Height**	1.00 (0.92,1.08)	0.906	1.00 (0.92,1.08)	0.995	1.02 (0.92,1.13)	0.771	1.03 (0.93,1.14)	0.569
Weight**	1.05 (0.97,1.14)	0.235			1.16 (1.05,1.28)	0.004		
Weight for height residual**	1.04 (0.96,1.13)	0.326	1.02 (0.94,1.10)	0.646	1.16 (1.04,1.29)	0.007	1.08 (0.97,1.19)	0.167
BMI**	1.05 (0.97,1.14)	0.199			1.17 (1.06,1.29)	0.002		
Ever smoked regularly*	1.34 (1.12,1.60)	0.001	1.35 (1.12,1.61)	0.001	1.38 (1.12,1.69)	0.002	1.27 (1.03,1.56)	0.022
High alcohol intake*[++]	0.90 (0.74,1.10)	0.306			1.01 (0.63,1.64)	0.953		
Activity score**	1.12 (1.04,1.21)	0.002	1.12 (1.04,1.21)	0.003	1.29 (1.17,1.42)	<0.001	1.21 (1.09,1.34)	<0.001
Social class (manual)*	1.02 (0.87,1.19)	0.831			1.07 (0.86,1.32)	0.547		
Relationship status (never married)*	1.08 (0.81,1.44)	0.600			0.93 (0.57,1.51)	0.762		
Housing tenure (not homeowner)*	1.09 (0.90,1.32)	0.370	0.98 (0.81,1.19)	0.813	1.71 (1.38,2.11)	<0.001	1.47 (1.18,1.83)	0.001
Pseudo R2			*0.0084*				*0.0256*	

Footnotes:

[+] Estimates of associations are relative risks (95% CI) from Poisson regression models where the outcome variable is whether or not the participant had a readmission within 30 days / died during the follow-up period and the predictor variable is each characteristic in turn.

[†] A regression fitted with age, height, weight for height residual, activity score, housing tenure and whether the participant had ever smoked regularly as predictor variables to mutually adjust for the most important characteristics in either sex

* Relative risk for presence vs absence

** Relative risk (95% CI) per sex-specific SD increase (estimates for activity score are per sex-specific SD decrease)

[++] High weekly alcohol intake of ≥22M; ≥15F units per week

Table 15 Associations between physical function and health characteristics and risk of 30-day readmission or death (Readmissions paper, Appendix 3)

Association between each characteristic and the risk of readmission within 30 days or death+	**Men**		**Women**	
	Relative risk (95% CI)	P-value	Relative risk (95% CI)	P-value
Grip strength**	1.11 (1.03,1.20)	0.008	1.19 (1.08,1.30)	<0.001
Low Physical Function SF36* +++	1.70 (1.44,2.01)	<0.001	1.78 (1.43,2.22)	<0.001
Waking speed (self-reported)***	1.25 (1.15,1.35)	<0.001	1.33 (1.19,1.48)	<0.001
Fall in past year*	1.08 (0.81,1.44)	0.609	1.02 (0.80,1.31)	0.856
Ischaemic heart disease*	1.41 (1.17,1.69)	<0.001	1.24 (0.93,1.67)	0.145
Stroke or TIA*	1.15 (0.84,1.57)	0.382	1.92 (1.30,2.83)	0.001
Hypertension*	1.26 (1.08,1.48)	0.003	1.35 (1.10,1.66)	0.004
Diabetes*	1.11 (0.91,1.36)	0.318	1.19 (0.92,1.53)	0.188
Fracture since 45yrs age*	1.31 (1.08,1.60)	0.007	0.89 (0.69,1.15)	0.359
Osteoarthritis (hand)*	0.91 (0.76,1.11)	0.353	0.94 (0.77,1.16)	0.590
Self-rated health ***	1.32 (1.21,1.44)	<0.001	1.60 (1.42,1.80)	<0.001
HAD-Depression (prob/definite)*	1.52 (1.18,1.96)	0.001	1.64 (1.22,2.19)	0.001
HAD-Anxiety (prob/definite)*	1.19 (0.98,1.44)	0.088	1.34 (1.08,1.65)	0.008
Bronchitis*	1.26 (0.95,1.66)	0.103	1.81 (1.30,2.51)	<0.001
Number of systems medicated++	1.21 (1.14,1.27)	<0.001	1.24 (1.17,1.31)	<0.001

Footnotes:

+ Estimates of associations are relative risks (95% CI) from Poisson regression models where the outcome variable is whether or not the participant had a readmission within 30 days / died during the follow-up period and the predictor variable is each characteristic in turn. All associations were adjusted for age, housing tenure, physical activity and whether the participant had ever smoked: variables that were significant in either sex in the mutually adjusted model (Appendix 2).

* Relative risk for presence vs absence

** Relative risk per sex-specific SD decrease

++ Relative risk per unit increase

*** Relative risk per band decrease (ie slower walking speed and poorer self-rated health)

+++ Sex-specific score of ≤75M, ≤60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

Table 16 Combined regression model using the most influential participant characteristics to predict risk of 30-day readmission or death (Readmissions paper, Table 2)

Association between each characteristic and the risk of readmission within 30 days or death[+]	**Men**		**Women**	
	Relative risk (95% CI)	P-value	Relative risk (95% CI)	P-value
Age**	1.03 (0.95,1.11)	0.437	1.05 (0.95,1.16)	0.362
Ever smoked*	1.23 (1.03,1.47)	0.021	1.14 (0.93,1.40)	0.215
Activity score**	1.02 (0.95,1.09)	0.656	1.04 (0.94,1.16)	0.392
Housing tenure (not homeowner)*	0.89 (0.74,1.08)	0.239	1.32 (1.07,1.64)	0.010
Low physical function SF36* [+++]	1.20 (0.99,1.45)	0.071	1.12 (0.86,1.46)	0.403
Walking speed (self-reported)***	1.11 (1.01,1.21)	0.023	1.11 (0.98,1.25)	0.098
Ischaemic heart disease*	1.18 (0.98,1.43)	0.073	0.93 (0.70,1.23)	0.603
Hypertension*	1.01 (0.86,1.19)	0.885	1.03 (0.82,1.28)	0.819
Fracture since 45yrs age*	1.37 (1.13,1.66)	0.001	0.85 (0.66,1.11)	0.239
Self-rated health ***	1.16 (1.06,1.27)	0.002	1.36 (1.18,1.57)	<0.001
Bronchitis*	1.07 (0.82,1.39)	0.628	1.24 (0.86,1.78)	0.255
Number of systems medicated [++]	1.11 (1.04,1.18)	0.001	1.12 (1.05,1.20)	0.001
Pseudo R2	*0.0351*		*0.0651*	

Footnotes:

[+] Estimates of associations are relative risks (95% CI) from Poisson regression models where the outcome variable is whether or not the participant had a readmission within 30 days / died during the follow-up period. All predictors were included simultaneously in this mutually adjusted model.

* Relative risk for presence vs absence

[++] Relative risk per unit increase

** Relative risk per sex-specific SD increase (estimates for activity score represent SD decreases)

*** Relative risk per band decrease (ie slower walking speed and poorer self-rated health).

[+++] Sex-specific score of ≤75M, ≤60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

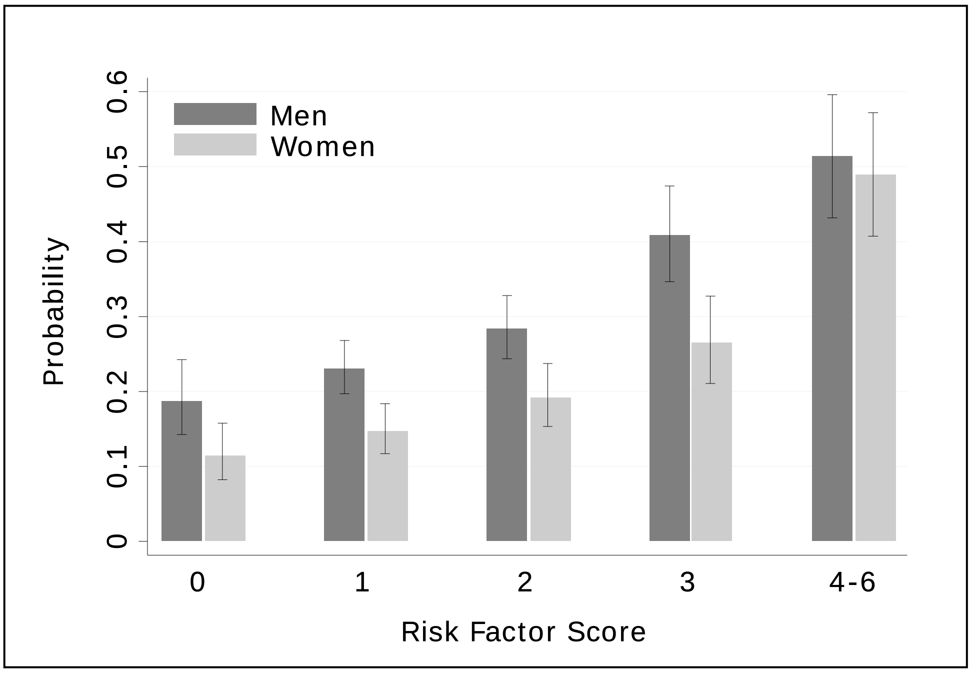

Figure 17 Probability of 30-day readmission or death for different score categories (Readmissions paper, Figure 1)

The risk factor score was derived by allocating one point for the presence of each risk factor (characterised as participant characteristics which were associated (p<0.05) with risk of 30-day readmission/death in either sex in the final mutually-adjusted model: ie having poor or fair self-rated health, two or more systems medicated, history of fracture, not owning one's home, history of smoking and having a self-reported walking speed of very slow or stroll). Participants scored zero if they had none of the risk factors, to a maximum of six if all were present.

Chapter 5: Risk factors for 30-day readmission to hospital

Declaration of authorship

Risk factors for 30-day readmission to hospital among older people: Evidence from data linkage

Shirley Simmonds: obtained the HES data, conducted the literature review, designed the strategy for statistical analyses, designed the tables and figures and drafted all versions of the manuscript.

Holly Syddall: iterated strategy for statistical analyses and presentation of results and reviewed all versions of the manuscript.

Leo Westbury: iterated strategy for statistical analyses and presentation of results, prepared the tables and figures and reviewed all versions of the manuscript.

Maria Evandrou: provided feedback on early drafts of the manuscript and reviewed the final version.

Cyrus Cooper: took overall responsibility for the Hertfordshire Cohort Study and reviewed the final version of the manuscript.

Avan Aihie Sayer: jointly applied for the HES data, provided feedback on early drafts of the manuscript and reviewed the final version.

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Chapter 6: Risk factors for emergency admission to hospital among older people: Evidence from data linkage

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Abstract

Background: Emergency admissions to hospital are a major burden on the NHS. Improved understanding of risk factors for these admissions is needed if effective preventive strategies are to be devised.

Objective: To investigate the individual and combined importance of diverse prospectively measured risk factors for emergency admission among a community dwelling cohort of older people.

Design: Prospective cohort study.

Setting: Hertfordshire UK.

Subjects: 1,579 men and 1,418 women aged 59-73 at baseline.

Methods: Participants' demography and anthropometry, lifestyle, social circumstances, physical function and morbidity were characterised at baseline (1998-2004). Hospital admissions and deaths from baseline-2010 were ascertained by linkage with administrative data.

Results: The cohort experienced 8,687 admissions and 275 deaths during follow-up. 2,201 admissions (25.3%) were by the emergency route. Mutually adjusted survival models identified history of smoking, low physical function and poor self-rated health as dominant risk factors for emergency admission in both sexes. Ischaemic heart disease and number of systems medicated conferred risk only in men. The hazard ratio (HR) for emergency admission or death was 3.24 (95% CI 2.47,4.24) among men and 3.27 (95% CI 2.41,4.45) among women who had four or more of the risk factors we identified, compared with the reference group who had none.

Conclusions: Poor self-rated health is a key risk factor for emergency admission in early old age. Additional risks derive from unhealthy lifestyle and poor physical function. It would be possible to screen for these risks in a general practice population in advance of admission.

Keywords: Risk factors; Hospital Episode Statistics; Hospitalization; Emergency; Unplanned; Older people.

Introduction

Emergency admissions to hospital are those that are unpredictable and at short notice because of clinical need (NHS Digital, 2017b). They account for around 35 percent of all admissions to NHS hospitals and cost approximately £11bn each year in England (Blunt *et al.*, 2010). Rates of emergency admission are highest, and are expanding most rapidly, in those aged 65 and over: in the eleven years from 2001/2 to 2012/13 the emergency admission rate among them increased by 26% (Wittenberg *et al.*, 2014). In this group, emergency admissions are associated with clinical and psychological risks, increased dependency and disruption of usual care; they are thus particularly distressing to patients (Imison *et al.*, 2012).

It has long been argued that some emergency admissions could be avoided by optimising care in the community (Blunt *et al.*, 2010; Purdy, 2010). Transfer of care away from hospitals has been adopted as a key strategy of the Sustainability and Transformation Partnerships that are tasked with addressing the NHS deficit (Oliver, 2017). Practical measures to target emergency admissions include closing hospital beds (Oliver, 2016b), preventive programmes such as supported self-management (Oliver, 2016b), and early interventions (Loder, 2017). However, identifying people who would benefit from preventive programmes is challenging. Although a number of predictive risk models exist, evidence for their effectiveness is mixed (Wallace *et al.*, 2014). A recent review of evidence on identifying and managing high-risk individuals finds few national or population level studies exploring risk factors for emergency admission (Walsh, 2014). Such studies are essential to the accurate identification of vulnerable individuals.

Using data from a UK cohort aged 59-73 at recruitment, linked with hospital episode statistics (HES) relating to their admissions over the following decade, we investigated a range of prospectively measured, patient-centred risk factors for emergency admission. Risks were categorised into five domains that had been previously linked with hospitalisation: demography and anthropometry; lifestyle; social circumstances; physical function; and morbidity, to investigate their relative and combined effect.

Methods

The baseline characterisation of the Hertfordshire Cohort Study (HCS) population and linkage to Hospital Episode Statistics have been described previously (Chapter 5).

Statistical methods Emergency admissions were identified from the admission method of the first or only episode of each admission in the personal history, and defined as the failure event of interest. Death was considered an alternative failure event, thus the outcome considered was emergency admission or death.

A panel of predictor variables was selected as previously reported (Chapter 5).

Data were described using means and standard deviations (SD), medians and inter-quartile ranges and frequency and percentage distributions. Associations between the risk of emergency admission or death and the panel of predictor variables were analysed by fitting univariate and mutually adjusted Prentice Williams and Peterson total time (PWP-TT) models (Castaneda and Gerritse, 2010; Westbury *et al.*, 2016) in four stages. To enable presentation of comparable effect sizes, sex-specific standard deviation scores were coded for continuous variables. To take account of known sex differences in health in later life (Arber and Ginn, 1993), all analyses were carried out for men and women separately using Stata, release 13 (StataCorp, 2013).

Results

During a median 8.1-year follow-up, the cohort collectively experienced 8,687 admissions, of which 2,201 (25.3%) were by the emergency route. Men accounted for 1,342 emergency admissions and women for 859. There were 275 deaths, 189 among men and 86 among women. This paper presents a combined outcome variable of time to emergency admission or death. Individually, 638 (40.4%) men and 450 (31.7%) women had at least one emergency admission or died during the follow-up period (p for gender difference <0.001). Amongst them, 449 men and 364 women had an emergency admission and did not die; 159 men and 69 women had an emergency admission and also died; and 30 men and 17 women died without having an emergency admission. The participants' characteristics are shown in Table 17.

The first two stages of analysis examined univariate, then mutually adjusted associations between emergency admission or death and demography/anthropometry, lifestyle and social circumstances. In one or both sexes, age, greater weight and body mass index, history of smoking, low current customary physical activity and not owning one's home (a marker of material deprivation) were associated with increased risk in univariate models. All but BMI were robust in mutually adjusted analyses (Table 18).

The third stage explored the associations between risk of emergency admission or death and physical function and morbidity. Analyses are presented for each variable individually, each with adjustment for age, smoking history, physical activity and housing tenure, given the associations described above. Increased risk of emergency admission or death was associated, in one or both sexes, with: weaker grip strength, poor SF-36 physical function and slower self-reported walking speed (markers of physical capability); ischaemic heart disease, stroke and hypertension (markers of cardiovascular disease); diabetes; depression, poor self-rated health; bronchitis; and having a greater number of systems medicated (Table 19).

Finally, the physical function and morbidity characteristics that were most strongly associated with risk of emergency admission or death at stage 3 were included with lifestyle and social characteristics in a mutually adjusted model (Table 20). To ensure a parsimonious model fit and avoid inclusion of highly correlated variables from the same risk factor domain, we used separate models to identify which markers of physical capability, cardiovascular disease and health perception/mental health were most strongly associated with risk of emergency admission or death, and should therefore be included in the mutually adjusted model. On this basis, low SF-36 physical function, ischaemic heart disease and hypertension were included as potential predictors, along with age, smoking history, physical activity, housing tenure, diabetes, self-rated health, bronchitis and number of systems medicated. This model identified history of smoking, low physical function, ischaemic heart disease, poor self-rated health and number of systems medicated as strong determinants of increased risk of emergency admission or death during the follow-up period in one or both sexes.

To illustrate the combined impact of these baseline characteristics, we devised a risk factor score (Robinson *et al.*, 2013). Cohort members were assigned one point for each risk factor they had, yielding a score between zero and five for each person. Figure 18 shows that the hazard ratio (HR) for emergency admission or death was more than three times greater among men (HR 3.24 (95% CI 2.47,4.24)) and women (HR 3.27 (95% CI 2.41,4.45)) who had four or more risk factors compared with the reference group who had none.

Discussion

We have identified five dominant risk factors for emergency admission or death among community-dwelling older people who participated in an English cohort study: history of smoking, low physical function and poor self-rated health were strong determinants in both sexes; ischaemic heart disease and number of systems medicated were significant only among men. No predictors were unique to women. There was a threefold rise in likelihood of emergency admission or death between people who had none of the risk factors we identified and those who had four or more.

Our study shows, systematically and objectively, that risk of emergency admission: is best predicted by measures of overall burden of disease rather than by single conditions; derives also from lifestyle and physical function; increases in the presence of multiple risk factors; and differs by sex in relation to some risk factors. For example, we included two measures of total burden of disease in our model: self-rated health and number of systems medicated. Whilst self-rated health, a subjective measure, was significant in both sexes, number of systems medicated, which is more objective, was significant only in men. Thus, it appears that how individuals feel about their health is associated with future emergency admission in both sexes, and is a better predictor than tangible measures of health in women. This is an important finding given that emergency admission is often by self-referral (National Audit Office, 2013), and suggests that those whose self-rated health is poor have most to gain from initiatives such as shared decision making (Foot *et al.*, 2014) and supported self-management (NHS England, 2015).

Existing knowledge on risk factors for emergency admission derives from three sources. First, ecological studies have demonstrated differences in the rates of emergency admission between enumeration districts (Bernard and Smith, 1998), between primary care groups (Majeed *et al.*, 2000) and between general practices (Reid *et al.*, 1999; Bankart *et al.*, 2011); and have consistently reported an association between area level deprivation and increased rates of emergency admission. Although we replicated these findings in the early stages of our model using housing tenure as an individual-level marker of deprivation, the effect was attenuated by adjustment for lifestyle and morbidity.

Secondly, validation studies, which test the performance of predictive risk models (Lewis *et al.*, 2011), have demonstrated the importance of diversity in predictor variables. As well as recent service use, models derived from hospital data often incorporate a measure of morbidity and a surrogate measure of deprivation such as patient's postcode. Improved performance results if external datasets such as those from general practice are included, in part because they contribute additional variables such as smoking status (Bottle *et al.*, 2006; Billings *et al.*, 2013; Wallace *et al.*, 2014). Regional models also improve results in specific populations (Chenore *et al.*, 2013), though this is not a consistent finding (Billings *et al.*, 2013). An additional advantage of external datasets is that they expand the population considered at-risk. This is important because regression to the mean, together with mortality, causes admission rates to fall naturally over time in high-risk older groups (Roland *et al.*, 2005), thus the majority of older people admitted to hospital in an emergency come from lower-risk groups (Roland and Abel, 2012). Our study demonstrates long-term associations between five explanatory variables and emergency admission in a community-based cohort.

Finally, cohort and case-control studies have identified a number of risk factors for emergency admission among individuals with or without previous admissions. The findings of these studies are often inconsistent and are difficult to interpret due to differences in design, especially in terms of confounding influences that are considered. Two studies have adopted a multifactorial approach similar to ours to discriminate between a diverse range of variables (Damush *et al.*, 2004; Mallitt *et al.*, 2015). Both included potential predictor variables that could be loosely classified across each of our five domains, though the precise nature of the metrics was different. In the first study, among a cohort of 308 frail and older primary care patients in the US, higher risk of emergency admission was associated with lower BMI, worse SF-36 physical functioning, previous diagnoses of congestive heart failure, diabetes or anaemia, and higher numbers of prescribed medications (Damush *et al.*, 2004). In the second, a cohort of 1,041 chronically ill patients in Australia, being of male sex, having a live-in carer, diagnoses of respiratory or musculoskeletal disease and number of previous admissions were significant risk factors for emergency admission (Mallitt *et al.*, 2015). Of these findings, only the effects of poor physical function and number of medications are replicated by our study. The fact that risks attributable to lower BMI, specific diagnoses, living arrangements and previous service use were not seen in HCS may be explained by the better physical condition of HCS participants. Self-rated health was reported by the US study and found to be associated with emergency admission over the 12-month follow-up period in univariate, but not multivariate analyses (Damush *et al.*, 2004). Although self-rated health is known to decline with age, it has been found to be less closely correlated with objective measures of health in the old-old than in the young-old (Pinquart, 2001). This divergence may explain its attenuation among older, frailer people, though methodological differences limit the comparability of the studies.

We are aware that our study has some limitations. First, our findings may not be representative of the national situation: Hertfordshire has a low age-sex standardised emergency admission ratio (Blunt *et al.*, 2010) and in our dataset, 25.3% of admissions were emergencies compared with a national rate of 35% over the same time period (Blunt *et al.*, 2010). Secondly, we report a combined outcome variable of time to emergency admission or death, in order to include individuals whose health outcome was *worse* than admission and account for reduction in admissions due to mortality. However, since just 30 men and 17 women were considered positive for the outcome exclusively because they died, we are confident that including deaths does not impact greatly on modelling emergency admissions. Finally, although we have shown that lifestyle and physical function both affect risk of emergency admission, we have not tested the extent to which this is due to their known role in predisposing to morbidity, nor have we explored possible alterations in the relationship between morbidity and hospitalisation when an acute condition develops. These are areas for further work.

Conversely, our study has a number of advantages. First, HCS comprises a well characterised, community-dwelling sample of older people; it enabled us to adopt a lifecourse approach to provide a longer period of follow-up than most other studies; and linkage with HES minimised loss to follow-up by capturing data from every hospital in England. Secondly, after investigating a number of approaches to the analysis of admissions data, we chose to use survival modelling techniques, specifically the PWP-TT model. This sophisticated approach captures information from every emergency admission a cohort member experiences rather than just the first, reflects increasing risk with accumulated admissions for an individual, excludes time spent in hospital from time at risk of admission and recognises that times to admission are correlated within an individual's admission history (Westbury *et al.*, 2016). We are not aware of any other cohort study that used this approach. Damush et al, in their analysis of emergency admissions among a frail cohort over 12 months, experimented with survival models to examine time to first admission, but chose instead to report the results of logistic regression analysis which they found were similar (Damush *et al.*, 2004).

Conclusion

Self-rated health is a key influence on emergency admission in early old age. Additional risks deriving from unhealthy lifestyle (specifically history of smoking) and poor physical function combine with total burden of disease to increase risk of emergency admission.

A simple measure of self-rated health could be ascertained in general practice and used to target supported self-management programmes, thus improving their potential to reduce rates of emergency admission.

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References

Arber, S. and Ginn, J. (1993) Gender and inequalities in health in later life. *Soc Sci Med,* 36 (1), 33-46.

Bankart, M.J.G., Baker, R., Rashid, A., Habiba, M., Banerjee, J., Hsu, R., Conroy, S., Agarwal, S. and Wilson, A. (2011) Characteristics of general practices associated with emergency admission rates to hospital: a cross-sectional study. *Emergency Med J,* 28 (7), 558-563.

Bernard, S. and Smith, L.K. (1998) Emergency admissions of older people to hospital: a link with material deprivation. *J Public Health Med (Oxf),* 20 (1), 97-101.

Billings, J., Georghiou, T., Blunt, I. and Bardsley, M. (2013) Choosing a model to predict hospital admission: an observational study of new variants of predictive models for case finding. *BMJ Open,* 3, e003352.

Blunt, I., Bardsley, M. and Dixon, J. (2010) *Trends in emergency admissions in England 2004-2009*: The Nuffield Trust for Research and Policy Studies in Health Services. Available from: https://www.nuffieldtrust.org.uk/research/trends-in-emergency-admissions-in-england-2004-2009 [Accessed 10/01/18]

Bottle, A., Aylin, P. and Majeed, A. (2006) Identifying patients at high risk of emergency hospital admissions: a logistic regression analysis. *J R Soc Med,* 99, 406-414.

Castaneda, J. and Gerritse, B. (2010) Appraisal of several methods to model time to multiple events per subject: modelling time to hospitalizations and death. *Revista Colombiana De Estadistica,* 33 (1), 43-61.

Chenore, T., Gray, D.J.P., Forrer, J., Wright, C. and Evans, P.H. (2013) Emergency hospital admissions for the elderly: insights from the Devon Predictive Model. *J Public Health (Oxf)*, 35 (4), 616-623.

Damush, T.M., Smith, D.M., Perkins, A.J., Dexter, P.R. and Smith, F. (2004) Risk factors for nonelective hospitalization in frail and older adult, inner-city outpatients. *Gerontologist,* 44 (1), 68-75.

Foot, C., Gilburt, H., Dunn, P., Jabbal, J., Seale, B., Goodrich, J., Buck, D. and Taylor, J. (2014) People in control of their own health and care. The state of involvement. London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/people-in-control-of-their-own-health-and-care-the-state-of-involvement-november-2014.pdf [Accessed 07/01/18].

Imison, C., Poteliakhoff, E. and Thompson, J.L. (2012) *Older people and emergency bed use. Exploring variation.* London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/older-people-and-emergency-bed-use-aug-2012.pdf [Accessed 07/01/18].

Lewis, G., Curry, N. and Bardsley, M. (2011) *Choosing a predictive risk model: a guide for commissioners in England*. London: Nuffield Trust. Available from:

https://www.nuffieldtrust.org.uk/files/2017-01/choosing-predictive-risk-model-guide-for-commissioners-web-final.pdf [Accessed 07/01/18].

Loder, E. (2017) The great NHS debate. *BMJ,* 357, j1729.

Majeed, A., Bardsley, M., Morgan, D., O'Sullivan, C. and Bindman, A.B. (2000) Cross sectional study of primary care groups in London: association of measures of socioeconomic and health status with hospital admission rates. *BMJ*, 321, 1057-1060.

Mallitt, K.A., Kelly, P., Plant, N., Usherwood, T., Gillespie, J., Boyages, S., Jan, S. and Leeder, S. (2015) Demographic and clinical predictors of unplanned hospital utilisation among chronically ill patients: a prospective cohort study. *BMC Health Serv Res,* 15, 136.

National Audit Office (2013) *Emergency admissions to hospital: managing the demand.* London: The Stationery Office, HC 739. Available from: https://www.nao.org.uk/wp-content/uploads/2013/10/10288-001-Emergency-admissions.pdf [Accessed 07/01/18].

NHS Digital (2017b) *HES data dictionary. Admitted patient care*. Health and Social Care Information Centre. Available from: http://content.digital.nhs.uk/hesdatadictionary [Accessed 07/01/18].

NHS England (2015) *How much do clinicians support patient activation?* Available from: https://www.england.nhs.uk/wp-content/uploads/2015/11/cspam-report.pdf [Accessed 07/01/18].

Oliver, D. (2016b) Wishful thinking won't save the NHS. *BMJ*, 354, i4544.

Oliver, D. (2017) David Oliver: Reducing acute admissions - a timely reality check. *BMJ,* 357, j2082.

Pinquart, M. (2001) Correlates of subjective health in older adults: a meta-analysis. *Psychol Aging,* 16 (3), 414-426.

Purdy, S. (2010) *Avoiding hospital admissions. What does the research evidence say?* London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/Avoiding-Hospital-Admissions-Sarah-Purdy-December2010.pdf [Accessed 07/01/18].

Reid, D.A., Cook, D.G. and Majeed, A. (1999) Explaining variation in hospital admission rates between general practices: cross sectional study. *BMJ,* 319, 98-103.

Robinson, S.M., Jameson, K.A., Syddall, H.E., Dennison, E.M., Cooper, C., Sayer, A.A. and Hertfordshire Cohort Study Group (2013) Clustering of lifestyle risk factors and poor physical function in older adults: The Hertfordshire Cohort Study. *J Am Geriatr Soc,* 61 (10), 1684-1691.

Roland, M. and Abel, G. (2012) Reducing emergency admissions: are we on the right track? *BMJ,* 345, e6017.

Roland, M., Dusheiko, M., Gravelle, H. and Parker, S. (2005) Follow up of people aged 65 and over with a history of emergency admissions: analysis of routine admission data. *BMJ,* 330 (7486), 289-292.

Statacorp (2013) Stata statistical software: release 13. College Station, TX: StataCorp LP.

Wallace, E., Stuart, E., Vaughan, N., Bennett, K., Fahey, T. and Smith, S.M. (2014) Risk prediction models to predict emergency hospital admission in community-dwelling adults. A systematic review. *Med Care,* 52 (8), 751-765.

Walsh, B. (2014) Unplanned admissions and readmissions in older people: a review of recent evidence on identifying and managing high-risk individuals. *Rev Clin Gerontol,* 24 (3), 228-237.

Westbury, L., Syddall, H., Simmonds, S., Cooper, C. and Aihie Sayer, A. (2016) Identification of risk factors for hospital admission using multiple-failure survival models: a toolkit for researchers. *BMC Med Res Methodol,* 16, 46.

Wittenberg, R., Sharpin, L., McCormick, B. and Hurst, J. (2014) *Understanding emergency hospital admissions of older people.* Centre for Health Service Economics & Organisation. Available from: https://www.chseo.org.uk/downloads/report6-emergencyadmissions.pdf [Accessed 07/01/18].

Table 17 Participant characteristics (Emergencies paper, Table 1)

Variable n (%)		Men (n=1579)	Women (n=1418)	P for gender difference[#]
Anthropometry				
Age (yrs)[+]		65.7 (2.9)	66.6 (2.7)	<0.001
Height (cm)[+]		174.2 (6.5)	160.8 (5.9)	<0.001
Weight (kg)[+]		82.4 (12.7)	71.4 (13.4)	<0.001
BMI (kg/m^2)[+]		27.2 (3.8)	27.6 (4.9)	0.998
Lifestyle				
Ever smoked regularly		1059 (67.1)	553 (39)	<0.001
High alcohol intake[++]		340 (21.5)	68 (4.8)	<0.001
Activity score[+]		60.9 (15.3)	59 (15.7)	<0.001
Social circumstances				
Social class (manual)		908 (59.3)	827 (58.4)	0.602
Relationship status (never married)		109 (6.9)	74 (5.2)	0.054
Housing tenure (not homeowner)		299 (18.9)	313 (22.1)	0.033
Physical function				
Grip strength (kg)[+]		44.0 (7.5)	26.5 (5.8)	<0.001
Low physical function SF36[+++]		316 (20.0)	301 (21.2)	0.417
Walking speed (self-reported)	Very slow	76 (4.8)	97 (6.8)	<0.001
	Stroll	375 (23.8)	285 (20.1)	
	Normal	625 (39.6)	638 (45)	
	Brisk	432 (27.4)	319 (22.5)	
	Fast	69 (4.4)	79 (5.6)	
Fall in past year[++++]		124 (14.3)	289 (22.5)	<0.001
Morbidity				
Ischaemic heart disease		225 (14.6)	127 (9.2)	<0.001
Stroke		79 (5.1)	39 (2.8)	0.001
Hypertension		630 (40)	577 (40.8)	0.644
Diabetes		232 (14.9)	199 (14.3)	0.675
Any fracture since 45yrs age		213 (13.5)	298 (21)	<0.001
Osteoarthritis (hand)		389 (28)	741 (53.6)	<0.001
Self-rated health	Poor	20 (1.3)	21 (1.5)	<0.001
	Fair	162 (10.3)	196 (13.9)	
	Good	600 (38)	620 (43.9)	
	Very good	593 (37.6)	455 (32.2)	
	Excellent	202 (12.8)	120 (8.5)	
HAD-depression (probable/definite)		76 (4.8)	85 (6.0)	0.152
HAD-anxiety (probable/definite)		232 (14.7)	355 (25.1)	<0.001
Bronchitis		92 (5.8)	69 (4.9)	0.244
Number of systems medicated*		1.0 (0.0, 2.0)	1.0 (1.0, 2.0)	0.004
Outcomes				
Ever any admission		1185 (75.0)	976 (68.8)	<0.001
Ever any admission/died		1197 (75.8)	985 (69.5)	<0.001
Ever emergency admission		608 (38.5)	433 (30.5)	<0.001
Ever emergency admission /died		638 (40.4)	450 (31.7)	<0.001
Died		189 (12.0)	86 (6.1)	<0.001

Footnotes:

[+] Mean (SD) * Median (lower quartile, upper quartile)
[++] ≥ 22 units/week in men; ≥ 14 units/week in women (guidelines at baseline)
[+++] ≤75 for men, ≤60 for women on SF-36 PF domain (lowest sex-specific fifth of distribution)
[++++] The question on falls was introduced mid-study; data are available for 2148 people
[#] See Table 10

Table 18 Associations between anthropometric, lifestyle and social characteristics and risk of emergency admission or death (Emergencies paper, Appendix 1)

Association between each characteristic and the risk of emergency admission or death[+]	Men				Women			
	Unadjusted		Adjusted[†]		Unadjusted		Adjusted[†]	
	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Age (yrs)*	1.09 (1.02,1.06)	0.007	1.08 (1.02,1.16)	0.016	1.09 (1.02,1.18)	0.018	1.08 (1.00,1.16)	0.042
Height (cm)*	0.97 (0.91,1.03)	0.293			1.01 (0.95,1.08)	0.697		
Weight (kg)*	1.04 (0.98,1.10)	0.236			1.08 (1.00,1.16)	0.043		
Weight for height residual*	1.05 (0.98,1.12)	0.154			1.07 (0.99,1.16)	0.085		
BMI (kg/m^2)*	1.06 (1.00,1.13)	0.066	1.04 (0.98,1.11)	0.208	1.08 (1.00,1.16)	0.047	1.02 (0.95,1.09)	0.677
Ever smoked regularly	1.30 (1.12,1.51)	<0.001	1.28 (1.10,1.49)	0.002	1.42 (1.23,1.64)	<0.001	1.36 (1.17,1.58)	<0.001
High alcohol intake[++]	1.04 (0.90,1.21)	0.554			1.00 (0.74,1.34)	0.980		
Activity score*	1.12 (1.06,1.18)	<0.001	1.10 (1.04,1.16)	0.001	1.24 (1.14,1.34)	<0.001	1.19 (1.10,1.29)	<0.001
Social class (manual)	1.09 (0.96,1.24)	0.200			1.14 (0.98,1.32)	0.087		
Relationship status (never married)	1.13 (0.90,1.41)	0.296			0.75 (0.55,1.02)	0.069		
Housing tenure (not homeowner)	1.23 (1.07,1.41)	0.003	1.14 (1.00,1.31)	0.051	1.34 (1.15,1.56)	<0.001	1.18 (1.01,1.37)	0.035
Pseudo R2			*0.0034732*				*0.00797466*	

Footnotes:

[+] Estimates of associations are hazard ratios (95% CI) from PWP-TT models where the failure event is an emergency admission/death and the predictor variable is each characteristic in turn

* Hazard ratio (95% CI) per unit increase in the characteristic (estimates for activity score correspond to SD decreases). For the remaining characteristics, the hazard ratio for the presence versus absence of the attribute is given

[†] A model fitted with age, BMI, activity score, housing tenure and whether the participant had ever smoked regularly as predictor variables to mutually adjust for the most important characteristics

[++] High weekly alcohol intake of ≥22M; ≥15F units per week

Table 19 Associations between physical function and health characteristics and risk of emergency admission or death (Emergencies paper, Appendix 2)

Association between each characteristic and the risk of emergency admission or death[+]	**Men**		**Women**	
	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Grip strength	1.06 (0.99,1.13)	0.083	1.13 (1.05,1.21)	0.001
Low Physical Function SF36[+++]	1.48 (1.29,1.69)	<0.001	1.56 (1.32,1.84)	<0.001
Waking speed (self-reported)*	1.10 (1.03,1.17)	0.007	1.16 (1.07,1.26)	<0.001
Fall in past year	1.09 (0.87,1.37)	0.432	1.00 (0.85,1.18)	0.968
Ischaemic heart disease	1.38 (1.19,1.61)	<0.001	1.22 (1.00,1.50)	0.049
Stroke or TIA	1.16 (0.95,1.42)	0.145	1.36 (1.04,1.79)	0.026
Hypertension	1.23 (1.08,1.39)	0.002	1.27 (1.08,1.48)	0.003
Diabetes	1.19 (1.02,1.38)	0.027	1.20 (1.00,1.45)	0.055
Fracture since 45yrs age	1.18 (1.00,1.39)	0.050	1.08 (0.91,1.29)	0.358
Osteoarthritis (hand)	0.95 (0.81,1.11)	0.504	1.04 (0.89,1.21)	0.606
Self-rated health *	1.24 (1.15,1.33)	<0.001	1.33 (1.20,1.47)	<0.001
HAD-Depression	1.31 (1.03,1.67)	0.027	1.06 (0.82,1.37)	0.659
HAD-Anxiety	1.07 (0.92,1.24)	0.400	1.09 (0.93,1.27)	0.291
Bronchitis	1.29 (1.05,1.59)	0.014	1.41 (1.10,1.80)	0.007
Number of systems medicated	1.18 (1.12,1.23)	<0.001	1.14 (1.09,1.20)	<0.001

Footnotes:

[+] Estimates of associations are hazard ratios (95% CI) from PWP-TT models where the failure event is an emergency admission/death and the predictor variable is each characteristic in turn. All associations were adjusted for age, housing tenure, physical activity and whether the participant had ever smoked

* Hazard ratio per lower band of the characteristic. The hazard ratio per unit increase in the number of systems medicated and per sex-specific SD decrease in grip strength given and for the remaining characteristics, the relative risk for the presence versus absence of the attribute is given

[+++] Sex-specific score of ≤75M, ≤60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

Table 20 Combined regression model using the most influential participant characteristics to predict the risk of emergency admission or death (Emergencies paper, Table 2)

Association between each characteristic and the risk of emergency admission or death[+]	**Men**		**Women**	
	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Age (yrs)*	1.06 (0.99,1.14)	0.079	1.07(0.99,1.16)	0.091
Ever smoked	1.19 (1.02,1.39)	0.028	1.27 (1.08,1.48)	0.003
Activity score*	1.03 (0.97,1.08)	0.347	1.08 (0.99,1.17)	0.086
Housing tenure (not homeowner)	1.03 (0.90,1.18)	0.680	1.11 (0.94,1.30)	0.213
Low physical function SF36* ++	1.24 (1.06,1.44)	0.006	1.29 (1.06,1.57)	0.012
Ischaemic heart disease	1.22 (1.04,1.43)	0.014	1.03 (0.83,1.27)	0.802
Hypertension	1.03 (0.90,1.17)	0.701	1.10 (0.92,1.31)	0.318
Diabetes	1.02 (0.86,1.20)	0.846	1.01 (0.81,1.26)	0.944
Self-rated health**	1.12 (1.03,1.22)	0.006	1.18 (1.06,1.32)	0.003
Bronchitis	1.14 (0.93,1.40)	0.197	1.23 (0.92,1.65)	0.158
Number of systems medicated***	1.11 (1.05,1.18)	<0.001	1.05 (0.99,1.12)	0.089
Pseudo R2	*0.01001141*		*0.01433998*	

Footnotes:

+ Estimates of associations are hazard ratios (95% CI) from PWP-TT models where the failure event is an emergency admission/death. All predictors were included simultaneously in this mutually adjusted model.

* Hazard ratio per sex-specific SD increase (estimates for activity score correspond to SD decreases)

** Hazard ratio per lower band of characteristic

*** Hazard ratio per unit increase. For the remaining estimates, hazard ratios for the presence vs absence of the characteristic are given

++ Sex-specific score of ≤75M, ≤60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

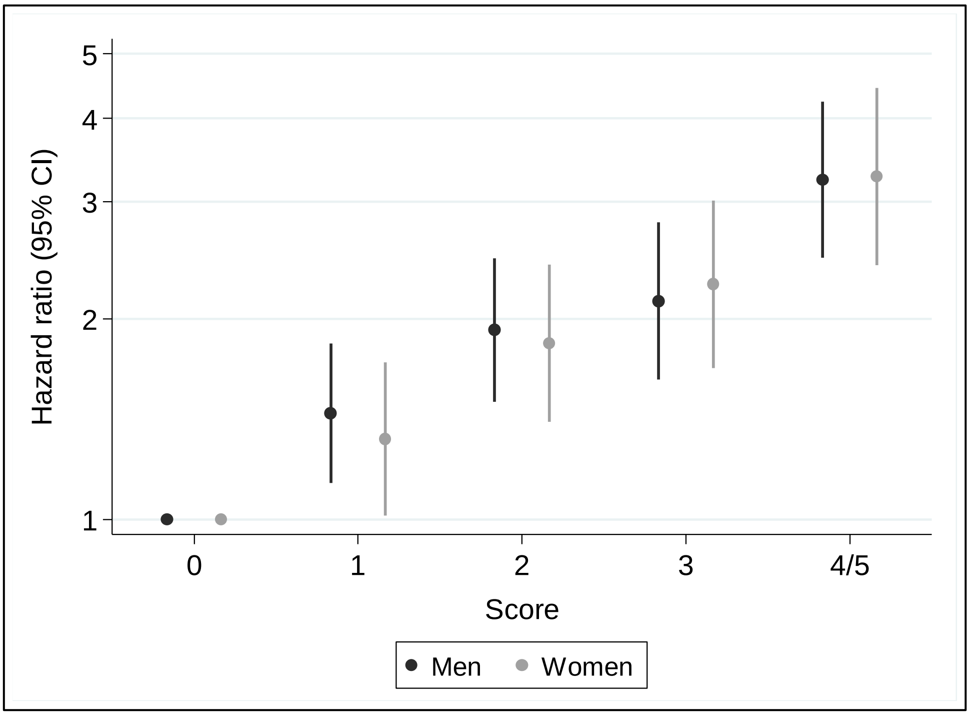

Figure 18 Risk of emergency admission or death for different score categories (Emergencies paper, Figure 1)

The risk factor score was derived by allocating one point for the presence of each risk factor (characterised as participant characteristics which were associated ($p<0.05$) with risk of emergency admission/death in either sex in the final mutually-adjusted model: ie having poor or fair self-rated health, two or more systems medicated, history of smoking, SF-36 PF in the bottom fifth of the sex-specific distribution and baseline ischemic heart disease). Participants scored zero if they had none of the risk factors, to a maximum of five if all were present.

Declaration of authorship

Risk factors for emergency admission to hospital among older people: Evidence from data linkage

Shirley Simmonds: obtained the HES data, conducted the literature review, designed the strategy for statistical analyses, designed the tables and figures and drafted all versions of the manuscript.

Holly Syddall: iterated strategy for statistical analyses and presentation of results and reviewed all versions of the manuscript.

Leo Westbury: iterated strategy for statistical analyses and presentation of results, prepared the tables and figures and reviewed all versions of the manuscript.

Maria Evandrou: provided feedback on early drafts of the manuscript and reviewed the final version.

Cyrus Cooper: took overall responsibility for the Hertfordshire Cohort Study and reviewed the final version of the manuscript.

Avan Aihie Sayer: jointly applied for the HES data, provided feedback on early drafts of the manuscript and reviewed the final version.

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Chapter 7: Do elective admissions to hospital among older people share the same risk factors as emergency admissions? Evidence from data linkage

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Abstract

Background: Although some elective admissions to hospital are thought to be avoidable, less research has investigated risk factors for elective than emergency admission.

Objective: To contrast prospectively measured risk factors for elective and emergency admission among a sample of community-dwelling older people.

Design: Prospective cohort study.

Setting: Hertfordshire UK.

Subjects: 1,579 men and 1,418 women aged 59-73 at baseline.

Methods: Participants' demography and anthropometry, lifestyle, social circumstances, physical function and morbidity were characterised at baseline (1998-2004). Hospital admissions and deaths from baseline-2010 were ascertained by linkage with administrative data. A categorical outcome variable divided the cohort into three groups according to their admission history.

Results: There were 8,687 admissions and 275 deaths during follow-up. One woman was excluded from the analysis because her only admission contained insufficient information to classify her. Of the remaining individuals, 815 (27.2%) survived with no admissions and were treated as the reference group; 1,093 (36.5%) survived with only elective admissions; 1,088 (36.3%) ever had an emergency admission or died. Mutually adjusted multinomial regression models identified increased number of systems medicated (NSM) as the dominant risk factor for elective admission in both sexes; ever having married, low physical function and worse self-rated health (SRH) were sex-specific risks. By contrast, history of smoking, low physical function, worse SRH and increased NSM were leading risk factors for emergency admission or death in both sexes; renting one's home and history of bronchitis were specific to women. Larger effect sizes were observed for emergency admission or death than for elective admission.

Conclusions: Multimorbidity, as indicated by SRH and NSM, is a common influence on elective and emergency admission; NSM is a consistently good marker that could be considered for risk profiling in primary care.

Keywords: Risk factors; Hospital Episode Statistics; Hospitalization; Elective; Emergency; Older people.

Introduction

Recent research into the use of hospital services has focused on admissions that happen in an emergency or within 30 days of previous discharge. Driven in part by policies that penalise healthcare providers, studies have aimed to develop predictive risk models and preventive interventions specific to these types of admission. Elective admissions (those that are planned in advance) have received more limited attention.

Elective admissions account for a bigger proportion of NHS hospitalisations than emergencies (half versus one third) (NHS Digital, 2017e) and, if they involve an overnight stay, cost more than twice as much on average (£3215 versus £1436) (Department of Health, 2012c). During the 17 years from 1997/8 to 2014/5, average annual growth in number of elective admissions outstripped that in emergencies (2.9% versus 2.5% (Wittenberg *et al.*, 2015)). Growth has been driven by an increase in day cases alongside a small fall in overnight admissions (Smith *et al.*, 2014), so that day cases now account for two thirds of all elective admissions (NHS Digital, 2017e). The steepest rises in elective admission rates have been among those aged 65 and over (Wittenberg *et al.*, 2015), perhaps because advances in technology are extending opportunities for intervention to increasingly older people (Oksuzyan *et al.*, 2013).

Why then, if elective admissions are such an important component of NHS activity, has the same attention not been paid to investigating the predictors of day and overnight elective admissions as to admissions of other types, particularly among older people? Whilst it is recognised that planned elective procedures do not disrupt NHS services in the way that emergency admissions do, and that some procedures have immense potential to improve quality of life at older ages, it has nevertheless been suggested that a proportion of elective admissions, particularly those for ambulatory care sensitive conditions (ACSCs), could be avoided (Sanderson and Dixon, 2000; Chauhan *et al.*, 2012).

Using data from a UK cohort aged 59-73 at recruitment, linked with hospital episode statistics (HES) relating to their admissions over the following decade, we investigated the hypothesis that baseline demography and anthropometry, lifestyle, social circumstances, physical function and morbidity might be differentially associated with subsequent elective and other admissions.

Methods

The baseline characterisation of the Hertfordshire Cohort Study (HCS) population and linkage to Hospital Episode Statistics have been previously described (Chapter 5).

Statistical methods In order to differentiate the determinants of elective admissions from those of other outcomes, we defined an ordinal variable that divided the cohort into three groups according to their admission history during the follow-up period. The groups were: people who survived without admissions; people who survived with one or more elective but no emergency admissions; and everybody else. This latter group included those who ever had an emergency admission, whether or not they also had elective admission(s) and also those who died, regardless of their admission history. In an additional analysis, we further divided the group who had only elective admissions to distinguish people who had only day case admissions from those who ever stayed in hospital overnight.

A panel of predictor variables was selected as reported previously (Chapter 5)

Data were described using means and standard deviations; medians and inter-quartile ranges; and frequency and percentage distributions. Associations between the admission history variable and the panel of predictor variables were analysed by fitting univariate and mutually adjusted multinomial logistic regression models in four stages. The first two stages examined univariate, then mutually adjusted associations between the admission history variable and characteristics representing demography and anthropometry, lifestyle and social circumstances. The third stage explored associations of the admission history variable with characteristics representing physical function and morbidity, adjusted for age and the characteristics associated with increased risk of admission at stage 2. Finally, the physical function and morbidity characteristics that were most strongly associated with admission at stage 3 were included with significant lifestyle and social characteristics in a mutually adjusted model. At each stage, those who had only elective admissions and, separately, those who ever had emergency admissions or died were compared with the reference group, who had no admissions. To take account of known sex differences in health in later life (Arber and Ginn, 1993), all analyses were carried out for men and women separately using Stata, release 13 (StataCorp, 2013).

Results

During a median 8.1-year follow-up, the cohort collectively experienced 8,687 admissions. One woman whose only admission was of unknown type was excluded, leaving an analysis sample of 1,579 men and 1,417 women who together accrued 8,686 admissions. Each of these individuals was allocated to one of three groups according to their personal admission history during the follow-up period: 815 (382 men and 433 women) survived with no admissions, 1,093 (559 men and 534 women) survived with only elective admissions and the remaining 1,089 (638 men and 451 women) had at least one emergency admission or died during the follow-up period. Many members of this latter group experienced multiple types of event: 814 had elective as well as emergency admissions (Figure 19). Of the 275 who died, most (228) had at least one emergency admission, 26 had elective but no emergency admissions and 21 had no admissions at all. Women were more likely than men to belong to the never admitted group ($p<0.001$); the opposite was true of the ever emergency or died group ($p<0.001$). There were no sex differences in membership of the elective only group. The participants' characteristics are shown in Table 21.

Associations of the admission history variable with demography and anthropometry, lifestyle and social circumstances (stage 1 and 2), and with physical function and morbidity (stage 3) are shown by Tables 22 and 23 respectively. The final mutually adjusted model brought together the characteristics that were most strongly associated with the admission history variable in the preliminary stages. To ensure a parsimonious model fit and avoid inclusion of highly correlated variables from the same risk factor domain, we used separate models to identify which marker of physical capability, which marker of cardiovascular disease and which marker of self-rated general health status was most strongly associated with the admission history variable, and should therefore be included in the mutually adjusted model. On this basis, low SF-36 physical function, hypertension and self-rated health (SRH) were included as potential predictors, along with age, height, weight-for-height residual, smoking history, physical activity, relationship status, housing tenure, diabetes, bronchitis and number of systems medicated. For each of these variables, Table 24 shows first, risk of being in the 'elective only' group, and then (on the row below) risk of being in the 'ever emergency or died' group, relative to the non-admitted reference group.

Risk factors for elective admission identified in one or both sexes by this model were: ever having married; low physical function; worse SRH; and higher number of systems medicated. Risk of emergency admission in one or both sexes was associated with: history of smoking; renting one's home; low SF-36 physical function; worse SRH; history of bronchitis; and having more systems medicated. To demonstrate the combined impact of risk factors, a further multinomial regression analysis was carried out, treating the number of risk factors as an ordinal variable. This showed that each additional risk factor increased the risk of only elective admission in men by 25% (RRR 1.25; 95%CI 1.09-1.44) and in women by 60% (RRR 1.60; 95%CI 1.39-1.83). The equivalent relative risk ratios for those who ever had an emergency admission or died were in men, 1.91 (CI 1.66-2.19) per additional risk factor, and in women, 2.41 (CI 2.08-2.80).

To explore the predictors of elective day cases, we further divided the group who had only elective admissions according to whether or not they ever stayed in hospital overnight, creating 4 groups in all. Following the same 4-stage analysis, the final model showed greater number of systems medicated to predict higher risk of elective day case admission in both sexes. Worse SRH was similarly predictive in women (analyses are shown in Appendix E).

Discussion

In this study, increased number of systems medicated was the only variable to confer risk for elective admission as well as emergency admission in both sexes. All other risk factors for elective admission (relationship status, SF-36 physical function and SRH) were sex-specific. Other risk factors for emergency admission or death (history of smoking, housing tenure, SF-36 physical function, SRH and bronchitis) broadly overlapped with risk factors for elective admission, but were more numerous and more often affected both sexes. Where a risk factor was associated with both types of admission, size of effect was consistently larger for emergency admission or death.

The Quality and Outcomes Framework (QOF) (NHS Digital, 2016) aims to optimise primary care by paying general practitioners for achieving agreed standards against a range of clinical conditions, in the belief that reduced admission rates will follow. Although there is some evidence that it has led to a small reduction in the rate of increase of emergency admissions (Marshall and Roland, 2017), concern has been expressed that indicators of single diseases do not adequately represent the needs of an increasing population of older people with multiple complex problems (Roland and Guthrie, 2016). Our findings support this view, and suggest that number of systems medicated, which is a more holistic marker of multimorbidity (Marengoni *et al.*, 2011), would be a useful addition (or alternative) to QOF indicators. It is readily quantifiable from electronic clinical records, and may have the potential to identify those at greatest risk of admission. This simple measure is a component part of the recently described electronic Frailty Index (Clegg *et al.*, 2016), but our work suggests that it has value in isolation, even before clinical frailty has developed.

Number of systems medicated is an objective marker of general health; by contrast, SRH is more subjective: both have strong links with multimorbidity. The two measures are known to represent distinct dimensions of health (Pinquart, 2001), and to correlate more closely in men than women (Mavaddat *et al.*, 2014). It is therefore interesting that whilst elective admission was predicted by number of systems medicated in both sexes, it was associated with SRH only in women. This suggests that SRH may incorporate subtle aspects of physiological and psychological health or help-seeking behaviour that are unique to women and have particular relevance to elective admission.

Previous studies comparing risk factors for elective and emergency admissions have focused on two themes, the first being morbidity. In the Netherlands, the Longitudinal Aging Study Amsterdam (LASA) considered the extent to which trends in admission could be explained by the changing characteristics of cohort members. The results showed that whilst increases in emergency admission were partly explained by concomitant increases in polypharmacy of ≥5 drugs, number of chronic diseases (self-reported from a list of 9) and functional limitations (self-reported from a list of 6); increases in elective admission bore little relation to individual characteristics and were considered to result from changing health policy (Galenkamp *et al.*, 2016). Ecological studies comparing the characteristics of general practices or other administrative groups with their admission rates have typically included a population-level marker of health, and findings have differed according to the marker chosen. In London, the proportion of a practice population reporting a long-term limiting illness at census was associated with both elective and emergency admissions (Reid *et al.*, 1999); in Leicestershire, the proportion diagnosed with coronary heart disease (CHD) showed no association with elective admissions (Chauhan *et al.*, 2012) and was associated with emergency admission only in univariate analyses (Bankart *et al.*, 2011). Thus it seems that only holistic measures, such as long-term limiting illness in London, or number of systems medicated in our study, are associated with elective admission. More specific measures, such as chronic illness from a predefined list or numerically defined polypharmacy in LASA are predictive only of emergency admission, whilst single-disease indicators bear little relation to admissions of either type in Leicester or in our study.

The other prominent theme in studies comparing risk factors for elective and emergency admission has been deprivation, an interest due in part to concerns that GPs working in deprived areas are disadvantaged by a reduced capacity to meet QOF indicators (Saxena *et al.*, 2006). In Scotland, among individuals from the Renfrew-Paisley Cohort, opposing associations were seen between occupational social class and admission, such that rates of emergency admission were raised in people of lower, and rates of elective admission in people of higher, social class (McCartney *et al.*, 2013). Ecological studies have broadly confirmed the link between deprivation and emergency admission: at practice level, neither the proportion in unskilled occupations in London (Reid *et al.*, 1999), nor the index of multiple deprivation in Leicestershire (Chauhan *et al.*, 2012) was associated with elective admissions, though in both cases associations were evident with emergency admissions (Reid *et al.*, 1999; Bankart *et al.*, 2011). In the Thames Valley, the rate of elective admission was less affected by the index of multiple deprivation than emergency admission (Jones, 2006a), though the reversal of risk demonstrated for social class in Scotland was not apparent. We found no effect of social status on elective admission using social class and home ownership as markers of socioeconomic position, though living in rented accommodation was associated with modest risk of emergency admission in women. We note that the QOF was introduced in 2005, mid-way through our follow-up period, and is known to have lessened inequalities in the delivery of care (Roland and Guthrie, 2016). It is therefore possible that associations between deprivation and admission were diluted in our data, though attenuation by other factors in our multifactorial model seems more likely.

Overall, our individual-level findings broadly confirm previous evidence that markers of general health predict admission better than more specific markers of disease, and that health and deprivation have a greater impact on emergency than elective admission. In addition, we show that lifestyle markers have little effect on elective admission, though smoking predicts emergency admission or death. We also confirm the association reported by LASA between emergency admission and physical function; in our study physical function also conferred risk of elective admission in women.

We are aware that our study has some limitations. First, 840 people who had elective admissions were assigned to the 'ever-emergency or died' group on the basis of their mixed admission histories. Our conclusions about the predictors of elective admission therefore exclude admissions experienced by these people. To address this problem, we examined the association between the same set of participant characteristics and time to elective admission using the Prentice Williams and Peterson total time model (Castaneda and Gerritse, 2010; Westbury *et al.*, 2016). This sophisticated approach to survival analysis captures information from every elective admission a cohort member experiences rather than just the first, reflects increasing risk with accumulated admissions for an individual, excludes time spent in hospital from time at risk of admission and recognises that times to admission are correlated within an individual's admission history. However, because of the number of people who had both types of admission, this model identified predictors more similar to our linked paper on emergency admissions (Chapter 6). It is possible that the predictors we identify in this paper may relate primarily to the less serious end of the spectrum of elective admissions, though this does not undermine our findings; these may actually be the most avoidable admissions. Some might also question our aggregation of death with emergency admission, though since only 47 people from the group (4.3%) died without experiencing an emergency admission, any effect of this strategy is likely to be small.

Our study also had a number of unique advantages. It is one of few to use linked administrative data, a method advocated for by researchers (Wellcome Trust, 2015) but increasingly difficult to achieve in practice (Gilbert *et al.*, 2015). Hospital Episode Statistics are particularly helpful in an ageing cohort; because they capture data from every hospital in England they minimize loss to follow-up that can result from failing health and changing care patterns. A further advantage of linkage is that it provides individual level data and so produces stronger evidence than ecological studies described earlier (Reid *et al.*, 1999; Jones, 2006a; Bankart *et al.*, 2011; Chauhan *et al.*, 2012). Finally, by combining admissions into personal histories we summarise individual experiences; we are not aware of any other study that used this approach to compare risk factors for elective and emergency admission.

Conclusion

In this study, increased number of systems medicated was the only variable to confer risk for elective admission as well as emergency admission in both sexes. All other risk factors for elective admission were sex-specific. Additional risk factors for emergency admission or death broadly overlapped with risk factors for elective admission, but were more numerous and more often affected both sexes. Where risk was associated with both types of admission, size of effect was consistently larger for emergency admission.

We conclude that multimorbidity, as indicated by SRH and NSM, is an important driver of both elective and emergency admission. Of the two markers of multimorbidity considered here, number of systems medicated was the more consistent determinant of admission, and could be used for risk profiling in primary care.

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References

Arber, S. and Ginn, J. (1993) Gender and inequalities in health in later life. *Soc Sci Med,* 36, 33-46.

Bankart, M.J.G., Baker, R., Rashid, A., Habiba, M., Banerjee, J., Hsu, R., Conroy, S., Agarwal, S. and Wilson, A. (2011) Characteristics of general practices associated with emergency admission rates to hospital: a cross-sectional study. *Emergency Med J,* 28 (7), 558-563.

Castaneda, J. and Gerritse, B. (2010) Appraisal of several methods to model time to multiple events per subject: modelling time to hospitalizations and death. *Revista Colombiana De Estadistica,* 33 (1), 43-61.

Chauhan, M., Bankart, M.J., Labeit, A. and Baker, R. (2012) Characteristics of general practices associated with numbers of elective admissions. *J Public Health (Oxf),* 34 (4), 584-590.

Clegg, A., Bates, C., Young, J., Ryan, R., Nichols, L., Teale, E.A., Mohammed, M.A., Parry, J. and Marshall, T. (2016) Development and validation of an electronic frailty index using routine primary care electronic health record data. *Age Ageing,* 45 (3), 353-360.

Department of Health (2012c) *Reference costs 2011-12.* Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213060/2011-12-reference-costs-publication.pdf [Accessed 15/10/2015].

Galenkamp, H., Deeg, D.J.H., De Jongh, R.T., Kardaun, J. and Huisman, M. (2016) Trend study on the association between hospital admissions and the health of Dutch older adults (1995-2009). *BMJ Open,* 6, e011967.

Gilbert, R., Goldstein, H. and Hemingway, H. (2015) The market in healthcare data. *BMJ,* 351, h5897.

Jones, R. (2006a) *Overnight stay elective admissions in Thames Valley*. Available from: http://www.hcaf.biz/Forecasting%20Demand/Benchmark_elective_admission.pdf [Accessed 07/01/18].

Marengoni, A., Angleman, S., Melis, R., Mangialasche, F., Karp, A., Garmen, A., Meinow, B. and Fratiglioni, L. (2011) Aging with multimorbidity: A systematic review of the literature. *Ageing Res Rev,* 10 (4), 430-439.

Marshall, M. and Roland, M. (2017) The future of the Quality and Outcomes Framework in England. *BMJ,* 359, j4681.

Mavaddat, N., Valderas, J.M., Van Der Linde, R., Khaw, K.T. and Kinmonth, A.L. (2014) Association of self-rated health with multimorbidity, chronic disease and psychosocial factors in a large middle-aged and older cohort from general practice: a cross-sectional study. *BMC Fam Pract,* 15, 185.

McCartney, G., Hart, C. and Watt, G. (2013) How can socioeconomic inequalities in hospital admissions be explained? A cohort study. *BMJ Open,* 3 (8), e002433.

NHS Digital (2016) *Quality and Outcomes Framework* Available from: http://content.digital.nhs.uk/qof [Accessed 04/08/2016].

NHS Digital (2017e) *Hospital Episode Statistics. Admitted patient care, England 2013-14.* Available from: https://digital.nhs.uk/catalogue/PUB16719.

Oksuzyan, A., Jeune, B., Juel, K., Vaupel, J.W. and Christensen, K. (2013) Changes in hospitalisation and surgical procedures among the oldest-old: a follow-up study of the entire Danish 1895 and 1905 cohorts from ages 85 to 99 years. *Age Ageing,* 42 (4), 476-481.

Pinquart, M. (2001) Correlates of subjective health in older adults: a meta-analysis. *Psychol Aging,* 16 (3), 414-426.

Reid, D.A., Cook, D.G. and Majeed, A. (1999) Explaining variation in hospital admission rates between general practices: cross sectional study. *BMJ,* 319, 98-103.

Roland, M. and Guthrie, B. (2016) Quality and Outcomes Framework: what have we learnt? *BMJ,* 354, i4060.

Sanderson, C. and Dixon, J. (2000) Conditions for which onset or hospital admission is potentially preventable by timely and effective ambulatory care. *J Health Serv Res Policy*, 5 (4), 222-230.

Saxena, S., George, J., Barber, J., Fitzpatrick, J. and Majeed, A. (2006) Association of population and practice factors with potentially avoidable admission rates for chronic diseases in London: cross sectional analysis. *J R Soc Med*, 99 (2), 81-89.

Smith, P., McKeon, A., Blunt, I. and Edwards, N. (2014) *NHS hospitals under pressure: trends in acute activity up to 2022.* London: Nuffield Trust. Available from: https://www.nuffieldtrust.org.uk/resource/nhs-hospitals-under-pressure-trends-in-acute-activity-up-to-2022 [Accessed 07/01/18].

Statacorp (2013) Stata statistical software: release 13. College Station, TX: StataCorp LP.

Wellcome Trust (2015) *Enabling linkage to maximise the value of public health research data.* London. Available from: https://wellcome.ac.uk/sites/default/files/enabling-data-linkage-to-maximise-value-of-public-health-research-data-summary-phrdf-mar15.pdf [Accessed 07/01/18].

Westbury, L., Syddall, H., Simmonds, S., Cooper, C. and Aihie Sayer, A. (2016) Identification of risk factors for hospital admission using multiple-failure survival models: a toolkit for researchers. *BMC Med Res Methodol,* 16, 46.

Wittenberg, R., Redding, S., Nicodemo, C. and McCormick, B. (2015) *Analysis of trends in emergency and elective hospital admissions and hospital bed days: 1997/8 to 2014/15*. Oxford: Centre for Health Service Economics and Organisation. Available from: https://www.chseo.org.uk/downloads/report9-admission-and-bed-day-trends.pdf [Accessed 07/01/18].

Table 21 Participant characteristics (Multinomial paper, Table 1)

Variable n (%)		Men (n=1579)	Women (n=1418)	P for gender difference#
Anthropometry				
Age (yrs)+		65.7 (2.9)	66.6 (2.7)	<0.001
Height (cm)+		174.2 (6.5)	160.8 (5.9)	<0.001
Weight (kg)+		82.4 (12.7)	71.4 (13.4)	<0.001
BMI (kg/m^2)+		27.2 (3.8)	27.6 (4.9)	0.998
Lifestyle				
Ever smoked regularly		1059 (67.1)	553 (39)	<0.001
High alcohol intake++		340 (21.5)	68 (4.8)	<0.001
Activity score+		60.9 (15.3)	59 (15.7)	<0.001
Social circumstances				
Social class (manual)		908 (59.3)	827 (58.4)	0.602
Relationship status (never married)		109 (6.9)	74 (5.2)	0.054
Housing tenure (not homeowner)		299 (18.9)	313 (22.1)	0.033
Physical function				
Grip strength (kg)+		44.0 (7.5)	26.5 (5.8)	<0.001
Low physical function SF36+++		316 (20.0)	301 (21.2)	0.417
Walking speed (self-reported)	Very slow	76 (4.8)	97 (6.8)	<0.001
	Stroll	375 (23.8)	285 (20.1)	
	Normal	625 (39.6)	638 (45)	
	Brisk	432 (27.4)	319 (22.5)	
	Fast	69 (4.4)	79 (5.6)	
Fall in past year++++		124 (14.3)	289 (22.5)	<0.001
Morbidity				
Ischaemic heart disease		225 (14.6)	127 (9.2)	<0.001
Stroke		79 (5.1)	39 (2.8)	0.001
Hypertension		630 (40)	577 (40.8)	0.644
Diabetes		232 (14.9)	199 (14.3)	0.675
Any fracture since 45yrs age		213 (13.5)	298 (21)	<0.001
Osteoarthritis (hand)		389 (28)	741 (53.6)	<0.001
Self-rated health	Poor	20 (1.3)	21 (1.5)	<0.001
	Fair	162 (10.3)	196 (13.9)	
	Good	600 (38)	620 (43.9)	
	Very good	593 (37.6)	455 (32.2)	
	Excellent	202 (12.8)	120 (8.5)	
HAD-depression (probable/definite)		76 (4.8)	85 (6.0)	0.152
HAD-anxiety (probable/definite)		232 (14.7)	355 (25.1)	<0.001
Bronchitis		92 (5.8)	69 (4.9)	0.244
Number of systems medicated*		1.0 (0.0, 2.0)	1.0 (1.0, 2.0)	0.004
Outcomes				
Ever any admission		1185 (75.0)	976 (68.8)	<0.001
Died		189 (12)	86 (6.1)	<0.001
No admissions, alive		382 (24.2)	433 (30.5)	<0.001
Only electives, alive		559 (35.4)	534 (37.7)	0.195
Ever emergency or died		638 (40.4)	450 (31.7)	<0.001

Footnotes:

+ Mean (SD) * Median (lower quartile, upper quartile)
++ ≥ 22 units/week in men; ≥ 14 units/week in women (guidelines at baseline)
+++ ≤75 for men, ≤60 for women on SF-36 PF domain (lowest sex-specific fifth of distribution)
++++ The question on falls was introduced mid-study; data are available for 2148 people
# See Table 10

Table 22 Associations between anthropometric, lifestyle and social characteristics and admission history (Multinomial paper, Appendix 1)

Association between each characteristic and the admission history variable⁺	**Men**				**Women**			
	Unadjusted		**Adjusted⁺⁺**		**Unadjusted**		**Adjusted⁺⁺**	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Age (yrs)*	1.01 (0.88,1.15)	0.928	0.99 (0.87,1.13)	0.937	0.95 (0.83,1.07)	0.390	0.94 (0.83,1.07)	0.343
	1.06 (0.94,1.21)	0.345	1.04 (0.91,1.18)	0.582	1.05 (0.92,1.20)	0.427	1.04 (0.90,1.19)	0.618
Height (cm)*	0.96 (0.84,1.09)	0.537	0.96 (0.84,1.09)	0.503	1.03 (0.91,1.17)	0.658	1.03 (0.90,1.17)	0.683
	0.98 (0.86,1.11)	0.744	1.00 (0.88,1.14)	0.955	1.03 (0.90,1.18)	0.659	1.04 (0.91,1.20)	0.534
Weight (kg)*	0.93 (0.82,1.07)	0.309			1.27 (1.11,1.45)	<0.001		
	1.05 (0.93,1.20)	0.413			1.40 (1.22,1.60)	<0.001		
Weight for height residual*	0.94 (0.82,1.07)	0.325	0.93 (0.81,1.06)	0.264	1.26 (1.11,1.43)	0.001	1.23 (1.08,1.41)	0.002
	1.04 (0.92,1.18)	0.541	1.01 (0.88,1.14)	0.932	1.38 (1.20,1.58)	<0.001	1.26 (1.10,1.45)	0.001
BMI (kg/m^2)*	0.94 (0.83,1.07)	0.373			1.27 (1.11,1.45)	<0.001		
	1.06 (0.93,1.20)	0.361			1.41 (1.23,1.62)	<0.001		
Ever smoked regularly	1.04 (0.79,1.36)	0.792	1.04 (0.79,1.36)	0.800	1.29 (0.99,1.68)	0.060	1.21 (0.93,1.59)	0.163
	1.67 (1.27,2.18)	<0.001	1.58 (1.20,2.08)	0.001	1.76 (1.34,2.32)	<0.001	1.56 (1.18,2.07)	0.002
High alcohol intake**	0.89 (0.65,1.22)	0.460			0.80 (0.44,1.47)	0.477		
	1.00 (0.74,1.36)	0.998			1.05 (0.58,1.91)	0.866		

Continued…

…Table 22 continued

Association between each characteristic and the admission history variable[+]	Men				Women			
	Unadjusted		Adjusted[++]		Unadjusted		Adjusted[++]	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Activity score*	1.02 (0.89,1.16)	0.780	1.03 (0.90,1.18)	0.643	1.15 (1.01,1.31)	0.040	1.11 (0.97,1.28)	0.123
	1.19 (1.05,1.35)	0.008	1.15 (1.01,1.32)	0.034	1.51 (1.32,1.73)	<0.001	1.39 (1.21,1.61)	<0.001
Social class (manual)	1.17 (0.89,1.53)	0.253			0.86 (0.67,1.12)	0.261		
	1.33 (1.02,1.73)	0.033			1.02 (0.78,1.34)	0.868		
Relationship status (never married)	0.56 (0.33,0.94)	0.029	0.54 (0.31,0.92)	0.023	1.21 (0.68,2.14)	0.513	1.18 (0.66,2.10)	0.583
	0.93 (0.59,1.48)	0.764	0.81 (0.50,1.30)	0.378	1.01 (0.55,1.86)	0.979	0.83 (0.44,1.58)	0.576
Housing tenure (not homeowner)	1.04 (0.72,1.49)	0.846	1.07 (0.73,1.56)	0.732	1.39 (1.00,1.94)	0.051	1.23 (0.87,1.73)	0.246
	1.85 (1.32,2.58)	<0.001	1.64 (1.16,2.33)	0.005	2.30 (1.66,3.19)	<0.001	1.81 (1.29,2.55)	0.001
Pseudo R2			*0.0147*				*0.0269*	

Footnotes:

[+] Estimates of association are odds ratios (95% CI) from multinomial logistic regression models where the outcome was the variable representing admission history and the predictor variable was each characteristic in turn.

[++] A model fitted with age, weight-for-height residual, whether the participant had ever smoked regularly, activity score and housing tenure as predictor variables to mutually adjust for the most important characteristics.

* Relative risk ratio (95% CI) per sex-specific SD increase in the characteristic (estimates for activity score correspond to SD decreases). For the remaining characteristics, the relative risk ratio for the presence versus absence of the attribute is given

** High weekly alcohol intake of ≥22 (Men); ≥15 (Women) units per week

Admission history variable has the following categories: no admissions, alive (reference group); only electives, alive; ever emergency, dead.

First odds ratio: Odds of being in (only electives, alive) v (reference group)

Second odds ratio: Odds of being in (ever emergency, dead) v (reference group)

Table 23 Associations between physical function and health characteristics and admission history

(Multinomial paper Appendix 2)

Association between each characteristic and the admission history variable⁺	**Men**		**Women**	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Grip strength	0.95 (0.82,1.10)	0.466	1.22 (1.05,1.41)	0.008
	1.17 (1.02,1.36)	0.030	1.41 (1.21,1.65)	<0.001
Low Physical Function SF36 ⁺⁺⁺	1.52 (1.01,2.29)	0.044	2.52 (1.66,3.85)	<0.001
	2.87 (1.96,4.20)	<0.001	4.18 (2.75,6.36)	<0.001
Waking speed (self-reported)*	1.02 (0.88,1.18)	0.811	1.41 (1.21,1.65)	<0.001
	1.33 (1.15,1.55)	<0.001	1.67 (1.42,1.97)	<0.001
Fall in past year	1.46 (0.84,2.51)	0.176	0.79 (0.57,1.11)	0.174
	1.68 (0.98,2.86)	0.058	1.17 (0.84,1.63)	0.360
Ischaemic heart disease	1.48 (0.95,2.30)	0.082	1.11 (0.68,1.81)	0.684
	2.34 (1.55,3.54)	<0.001	1.50 (0.93,2.45)	0.100
Stroke or TIA	1.02 (0.52,1.99)	0.964	0.97 (0.38,2.48)	0.941
	1.52 (0.82,2.82)	0.184	2.40 (1.03,5.59)	0.043
Hypertension	1.17 (0.88,1.55)	0.274	1.39 (1.06,1.84)	0.019
	1.67 (1.27,2.20)	<0.001	1.64 (1.23,2.20)	0.001
Diabetes	1.20 (0.80,1.81)	0.374	1.32 (0.88,1.99)	0.175
	1.49 (1.02,2.20)	0.042	1.42 (0.93,2.16)	0.102
Fracture since 45yrs age	1.10 (0.74,1.64)	0.627	0.79 (0.57,1.09)	0.157
	1.31 (0.89,1.92)	0.167	1.19 (0.86,1.65)	0.288

Continued…

…Table 23 continued

Association between each characteristic and the admission history variable[+]	**Men**		**Women**	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Osteoarthritis (hand)	1.16 (0.85,1.58)	0.354	1.10 (0.85,1.43)	0.465
	0.85 (0.62,1.17)	0.317	0.99 (0.75,1.31)	0.962
Self-rated health *	1.23 (1.05,1.43)	0.012	1.58 (1.35,1.86)	<0.001
	1.63 (1.39,1.90)	<0.001	2.20 (1.84,2.63)	<0.001
HAD-Depression	1.05 (0.48,2.29)	0.901	1.40 (0.75,2.62)	0.294
	2.17 (1.10,4.31)	0.026	1.91 (1.03,3.55)	0.040
HAD-Anxiety	1.38 (0.91,2.11)	0.131	1.58 (1.16,2.15)	0.004
	1.99 (1.34,2.97)	0.001	1.52 (1.10,2.10)	0.012
Bronchitis	0.90 (0.46,1.75)	0.752	1.42 (0.69,2.93)	0.344
	2.03 (1.14,3.62)	0.016	2.99 (1.51,5.93)	0.002
Number of systems medicated	1.30 (1.13,1.50)	<0.001	1.39 (1.24,1.55)	<0.001
	1.68 (1.46,1.92)	<0.001	1.62 (1.44,1.81)	<0.001

Footnotes:

[+] Estimates of associations are relative risk ratios (95% CI) from multinomial logistic regression models where the outcome was the variable representing admission history and the predictor variable was each characteristic in turn. All associations were adjusted for age, height, weight-for-height residual, whether the participant had ever smoked regularly, physical activity, whether the participant had ever been married and housing tenure.

* Relative risk ratio per lower band of the characteristic. The relative risk ratios per unit increase in the number of systems medicated and per sex-specific SD decrease in grip strength are given. For the remaining characteristics, the relative risk ratio for the presence versus absence of the attribute is given.

[+++] Sex-specific score of ≤75 (Men), ≤60 (Women) on SF-36 PF domain (lowest sex-specific fifth of distribution)

Admission history variable has the following categories: no admissions, alive (reference group); only electives, alive; ever emergency, dead.

First relative risk ratio: risk of being in (only electives, alive) v (reference group)

Second relative risk ratio: risk of being in (ever emergency, dead) v (reference group)

Table 24 Combined regression model using the most influential participant characteristics to predict admission history (Multinomial paper, Table 2)

Association between each characteristic and the admission history variable[+]	**Men**		**Women**	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Age (yrs)**	0.96 (0.84,1.10)	0.575	0.91 (0.80,1.04)	0.169
	0.96 (0.84,1.10)	0.566	0.98 (0.85,1.14)	0.814
Height (cm)**	0.95 (0.83,1.09)	0.467	1.10 (0.96,1.25)	0.184
	1.02 (0.89,1.16)	0.803	1.16 (1.00,1.34)	0.048
Weight for height residual**	0.88 (0.76,1.01)	0.075	1.10 (0.95,1.27)	0.200
	0.89 (0.78,1.03)	0.114	1.05 (0.90,1.24)	0.522
Ever smoked*	1.01 (0.76,1.34)	0.942	1.16 (0.87,1.53)	0.308
	1.40 (1.05,1.87)	0.021	1.43 (1.06,1.93)	0.020
Activity score**	0.98 (0.85,1.13)	0.753	1.00 (0.87,1.16)	0.959
	1.01 (0.88,1.17)	0.849	1.11 (0.95,1.30)	0.198
Relationship status	0.51 (0.30,0.89)	0.017	1.19 (0.65,2.17)	0.577
(never married)*	0.81 (0.49,1.33)	0.399	0.81 (0.41,1.60)	0.538
Housing tenure*	1.02 (0.69,1.49)	0.934	1.08 (0.75,1.54)	0.683
(not homeowner)	1.37 (0.95,1.97)	0.092	1.45 (1.00,2.11)	0.049
Low physical function SF36* [+++]	1.14 (0.73,1.76)	0.566	1.74 (1.11,2.71)	0.015
	1.67 (1.11,2.52)	0.014	2.48 (1.58,3.89)	<0.001
Hypertension*	0.92 (0.67,1.26)	0.613	1.01 (0.74,1.38)	0.954
	1.08 (0.80,1.47)	0.607	1.03 (0.74,1.44)	0.850
Diabetes*	1.02 (0.67,1.55)	0.917	1.06 (0.70,1.62)	0.772
	1.01 (0.67,1.52)	0.969	1.07 (0.69,1.67)	0.762
Self-rated health ***	1.14 (0.96,1.35)	0.142	1.38 (1.16,1.65)	<0.001
	1.30 (1.10,1.55)	0.002	1.69 (1.39,2.06)	<0.001
Bronchitis*	0.76 (0.38,1.51)	0.433	1.35 (0.61,2.97)	0.455
	1.55 (0.84,2.83)	0.157	2.30 (1.06,5.01)	0.036
Number of systems medicated	1.28 (1.09,1.51)	0.002	1.27 (1.11,1.44)	<0.001
	1.47 (1.26,1.72)	<0.001	1.37 (1.20,1.57)	<0.001
Pseudo R2	*0.0448*		*0.0714*	

Footnotes:

[+] Estimates of associations are relative risk ratios (95% CI) from multinomial logistic regression models where the outcome was the variable representing admission history. All predictors were included simultaneously in this mutually adjusted model

* Relative risk ratio for the presence vs absence of the characteristic

** Relative risk ratio per sex-specific SD increase in characteristic (estimates for activity score correspond to SD decreases). Relative risk ratio per unit increase in number of systems medicated is shown

***Relative risk ratio per lower band of characteristic

[+++] Sex-specific score of ≤75 (Men), ≤60 (Women) on SF-36 PF domain (lowest sex-specific fifth of distribution)

Admission history variable has the following categories: no admissions, alive (reference group); only electives, alive; ever emergency or died.

First relative risk ratio: risk of being in (only electives, alive) v (reference group)

Second relative risk ratio: risk of being in (ever emergency, dead) v (reference group)

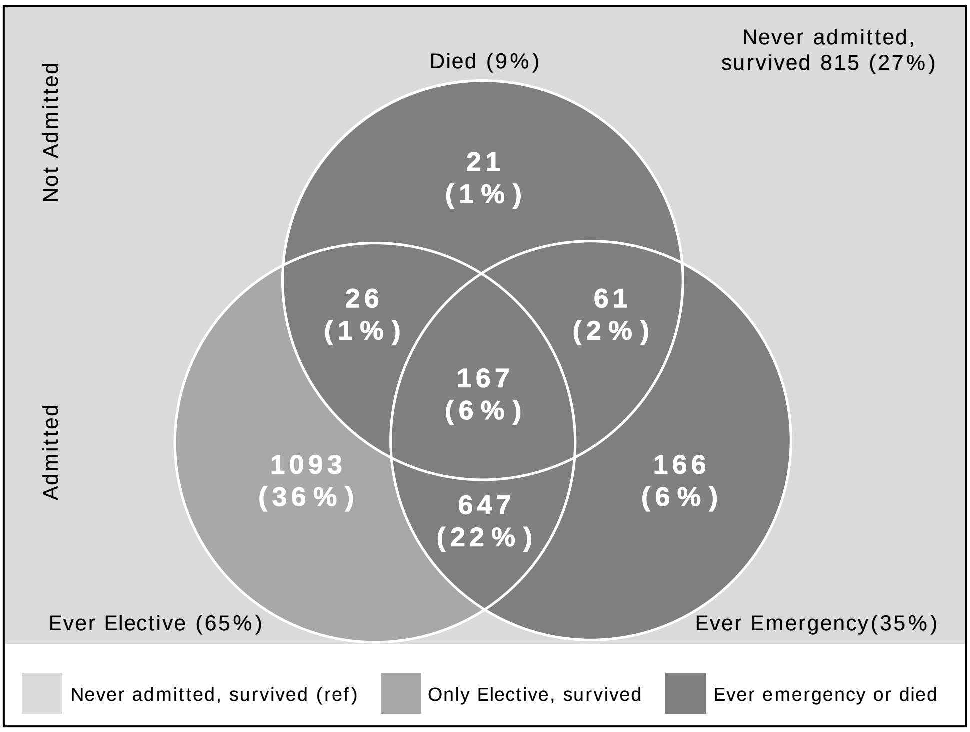

Figure 19 Classification of HCS participants by admission history (Multinomial paper Figure 1)

Declaration of authorship

Do elective admissions to hospital among older people share the same risk factors as emergency admissions? Evidence from data linkage

Shirley Simmonds: obtained the HES data, conducted the literature review, designed the strategy for statistical analyses, designed the tables and figures and drafted all versions of the manuscript.

Holly Syddall: iterated strategy for statistical analyses and presentation of results and reviewed all versions of the manuscript.

Leo Westbury: iterated strategy for statistical analyses and presentation of results, prepared the tables and figures and reviewed all versions of the manuscript.

Maria Evandrou: provided feedback on early drafts of the manuscript and reviewed the final version.

Cyrus Cooper: took overall responsibility for the Hertfordshire Cohort Study and reviewed the final version of the manuscript.

Avan Aihie Sayer: jointly applied for the HES data, provided feedback on early drafts of the manuscript and reviewed the final version.

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Chapter 8: Discussion and conclusions

8.1 Introduction

The National Health Service is struggling to cope with current demand for hospital care, especially from older people (Iacobucci, 2017b). Although it is believed that some admissions may be avoidable, research into the causes of hospitalisation among individuals is patchy, disease-specific and biased towards the antecedents of readmission within 30 days of discharge. A wider understanding is required, especially related to other, earlier, categories of admission. This thesis therefore proposed three overarching research questions, to be explored by combining routinely collected statistics and cohort data:

1 How could Hospital Episode Statistics and Cohort Study data be linked to produce a dataset with added value?
2 In such a dataset, how would demography and anthropometry; lifestyle; social circumstances; physical function; and morbidity; individually and together, affect risk of:
    d) readmission within 30 days?
    e) emergency admission?
    f) elective admission?
3 Are there common drivers of different types of admission at older ages?

The first of these was addressed by Chapter 4, which discussed the cohort and administrative data that are available, ethical considerations concerning their use, methods of linkage and the resulting dataset used by this research. Chapters 5, 6 and 7 focussed on the individual parts of Question 2, each presenting a paper that compared a common panel of 25 predictor variables with a different outcome variable. This discussion chapter compares and contrasts the findings of the papers to address the third question: ‘Are there common drivers of different types of hospital admission at older ages’.

Key findings of the three papers are brought together in Section 8.2 and explored in the context of known literature in Section 8.3. Policy implications of the findings are considered in Section 8.4 and the strengths and limitations of the work discussed in Section 8.5. Suggestions for the future development of the work follow in Section 8.6 and conclusions are drawn in Section 8.7.

8.2 Key findings

Two datasets were successfully linked and a panel of baseline predictor variables from the Hertfordshire Cohort Study was compared with admission data derived from Hospital Episode Statistics. Table 25 shows, by means of colour-coded symbols, the existence of relationships identified by Chapters 5-7. Associations with readmission (from Chapter 5) are shown by black circles; those with emergency admission (from Chapter 6) by dark grey diamonds; and with elective admission (from Chapter 7) by filled grey squares. In addition, associations identified by a subgroup analysis of people who only ever had elective day case admissions (Appendix E) are shown by open grey squares. For completeness, all four stages of the regression modelling process are shown, demonstrating how the predictor panel was systematically and objectively refined until in the final (stage 4) model, in either or both sexes:

- Readmission was associated with six baseline variables: history of smoking, housing tenure, walking speed, fracture since age 45, self-rated health (SRH) and number of systems medicated (NSM)
- Emergency admission was associated with five baseline variables: history of smoking, SF-36 physical function, ischaemic heart disease (IHD), SRH and NSM
- Elective admission was associated with four baseline variables: relationship status, SF-36 physical function, SRH and NSM
- Elective day case admission was associated with three baseline variables: weight for height residual, SRH and NSM

Therefore, ten variables retained associations with at least one category of admission in the final models and can be defined as drivers of admission. They were drawn from all five of the domains considered. Four of them (history of smoking, SF-36 physical function, SRH and NSM) were associated with more than one category of admission and can be considered common drivers of admission. Just two variables, poorer SRH and higher NSM, were associated with increased risk of all four types of admission; they will be referred to as key common drivers of admission.

The remaining sixteen variables from the original predictor panel bore no associations with admission in the final models.

Table 25 Summary of relationships at each stage of the modelling process, all admission types, sexes combined

	Model stage			
Baseline predictor variables	**Stage 1***	**Stage 2***	**Stage 3***	**Stage 4***
Demography/anthropometry				
Age	◆	◆		
Height				
Weight	● ◆ ■			
Weight for height residual	● ■ □	■		□
BMI	● ◆ ■ □			
Lifestyle				
Smoking history	● ◆	● ◆		● ◆
Alcohol intake				
Activity score	● ◆ ■	● ◆		
Social circumstances				
Social class				
Relationship status	■	■		■
Housing tenure	◆	● ◆		●
Physical function				
Grip strength			● ◆ ■	
SF-36 physical function			● ◆ ■ □	◆ ■
Walking speed			● ◆ ■ □	●
Fall history				
Morbidity				
Ischaemic heart disease			● ◆	◆
Stroke			● ◆	
Hypertension			● ◆ ■	
Diabetes			◆ □	
Fracture history			●	●
Osteoarthritis (hand)				
Self-rated health			● ◆ ■ □	● ◆ ■ □
Depression			●	
Anxiety			● ■	
Bronchitis			● ◆	
Medication			● ◆ ■ □	● ◆ ■ □

Footnotes:

● readmissions model; ◆ emergency admissions model; ■ elective only group in mutinomial model; □ elective day case only group in mutinomial model

*Model stages:

1: Demo & anthro/Lifestyle/Social circs (univariate association);

2: Demo & anthro/Lifestyle/Social circs (adjusted for age and variables p<0.05 at stage 1);

3: Physical function/Morbidity (adjusted for age and variables p<0.05 at stage 2);

4: Final mutually adjusted model

The findings presented thus far have been for the sexes combined. Table 26 shows that some of the associations in the final (stage 4) models were sex-specific. In the case of the key common drivers, SRH was a more consistent predictor of risk in women than in men, and the opposite was true of NSM. At the same time, SRH was a more consistent predictor of emergency admission and NSM of elective admission. Both variables were associated with readmission in both sexes. Appendix F extends Tables 25 and 26 to show all four stages of the modelling process by sex.

In addition to the individual effects of predictor panel variables shown in Tables 25 and 26, combined effects on risk of admission were identified in each of the papers, such that having more risk factors conferred higher risk of admission among individuals (Figures 17 and 18).

In summary, this thesis has six key findings.

- Hospital Episode Statistics and Cohort Study data have been linked to produce a dataset with added value. Within these data:
- There was a gradient across the admission types such that six variables were significantly associated with readmission, five with emergency admission, four with elective admission, and three with elective day case admission
- Two variables, SRH and NSM, acted as key common drivers of all admission types; in addition, SF-36 physical function and history of smoking were common drivers of two admission types each
- SRH was more consistently associated with emergency admission and NSM with elective admission
- Likelihood of each type of admission rose with the number of risk factors an individual had specific to that admission type
- SRH and NSM are markers of total burden of disease that could be documented in primary care to flag up those at risk of hospitalisation. Effective public health strategies are required to prevent risk in future generations

These findings are discussed in the following section.

Table 26 Summary of relationships in final (Stage 4) models,

all admission types, by sex

Predictor variables	**Men**				**Women**			
Demography/anthropometry								
Age								
Height								
Weight								
Weight for height residual				□				
BMI								
Lifestyle								
Smoking history	●	◆				◆		
High alcohol intake								
Activity score								
Social circumstances								
Social class								
Relationship status			■					
Housing tenure					●			
Physical function								
Grip strength								
Low physical function		◆				◆	■	
Walking speed	●							
Fall history								
Morbidity								
Ischaemic heart disease		◆						
Stroke								
Hypertension								
Diabetes								
Fracture history	●							
Osteoarthritis (hand)								
Self-rated health	●	◆			●	◆	■	□
Depression								
Anxiety								
Bronchitis								
Medication	●	◆	■	□	●		■	□

Footnotes:

● readmissions model

◆ emergency admissions model

■ elective only group in mutinomial model

□ elective day case only group in mutinomial model

8.3 Discussion of key findings

8.3.1 Data linkage

Routinely collected Hospital Episode Statistics have been combined with cohort data to create a dataset with added value. Linkage of this sort has been advocated for by the Public Health Research Data Forum (PHRDF) (Wellcome Trust, 2015), although their report outlines significant practical challenges (Section 3.1). The experience gained during the project described here would suggest that it is not the technical, statistical or operational issues cited by PHRDF that limit work of this sort: it is the imposition of increasingly restrictive policies on the use of identifiable personal data for medical research (Sections 4.10.3 and 8.4.4). This opinion is shared by other researchers (Gilbert *et al.*, 2015).

8.3.2 Gradient across admission types

A gradient was demonstrated across admission types, such that the number of risk factors identified decreased as follows: six variables were significantly associated with readmission, five with emergency admission, four with elective admission and three with elective day case admission. This is consistent with the variation in number of type-specific risk factors summarised in Table 4, and with greater numbers of explanatory variables for emergency over elective admission in single populations in Leicester (Bankart *et al.*, 2011; Chauhan *et al.*, 2012), London (Reid *et al.*, 1999), the Thames Valley (Jones, 2006a) and Amsterdam (Galenkamp *et al.*, 2016). No previous study has extended the comparison to include readmissions or day cases, but if these admission types represent the top and bottom of a spectrum of '*seriousness*' (Section 2.4.4), it seems reasonable that they should have the highest and lowest numbers of identifiable risk factors.

8.3.3 Drivers of admission, by risk factor domain

8.3.3.1 Morbidity

The variables included in the morbidity domain were history of nine specific conditions, namely ischaemic heart disease, stroke, hypertension, diabetes, fracture since age 45, hand osteoarthritis, depression, anxiety, and bronchitis; alongside SRH and NSM: two markers of overall burden of disease. Amongst these variables, in the final model, poorer SRH and higher NSM were key common drivers of admission; history of ischaemic heart disease and history of fracture were drivers of emergency admission and readmission respectively; no other associations were found. SRH and NSM were included in the model as proxies for overall burden of disease. To understand the associations of these factors with admission, it is necessary to explore them in more detail than was considered in Section 4.6.1.5.

Self-rated health and number of systems medicated: background

SRH is known to be surprisingly accurate in predicting mortality (Idler and Benyamini, 1997), long-term patterns of hospitalisation (Kennedy *et al.*, 2001), and more general health-service use and help-seeking behaviour (Bowling, 2005). Chapter 3 showed that it had at least univariate associations with 'serious' admissions in Scotland (Hanlon *et al.*, 2007), emergency admission in the US (Damush *et al.*, 2004) and readmission in Hong Kong (Wong *et al.*, 2010). In the Netherlands, trends in emergency admission were partly explained by SRH and polypharmacy of 5 prescribed drugs or more (Galenkamp *et al.*, 2016).

Although the replicability of response is not assured in SRH (nearly one third of people change their response if questioned twice in a short time (Crossley and Kennedy, 2002)), the measure has been assessed by psychometric theory and found to be robust. In her 2005 review of single question markers of health, Bowling considers that this robustness has

'at last achieved authoritative acknowledgement' (Bowling, 2005 pp 344).

There has been much debate over what SRH really measures; what respondents consider when making a simple evaluation of their health. In general, authors agree that self-rated health has two distinct components: one is an objective measure of somatic state; the other a more subjective filter conditioned by the context in which health is evaluated and reported.

The first component, somatic state, incorporates both physical and mental health, which have strong, demonstrable associations with self-rated health (Pinquart, 2001). The strength of association depends on the method by which somatic state is ascertained, but is known to be strongest when number of chronic conditions is the gold-standard. This observation is consistently true across Europe (Singh-Manoux *et al.*, 2006; Verropoulou, 2009). The method by which number of chronic conditions is ascertained is also important, medication use having lower validity than symptom checklists (Pinquart, 2001). The mechanism by which somatic state impacts SRH may be direct, for example through a diagnosis communicated to, or drugs prescribed for, the respondent; or indirect, through signs and symptoms experienced by him or her. Clinical measures not necessarily known to the respondent, including inflammatory markers, have been shown to correlate with SRH, and it has been suggested that unconscious bodily sensations or 'interoception' may partly explain such links (Jylha, 2009). Beyond specific health problems, objective physical function may also be considered by individuals in self-rating their health, although smaller associations are typically seen with physical function than with markers of disease.

The existence of a second component can be inferred because SRH remains a reliable predictor of survival even after objective indicators of health are controlled for (Putcha *et al.*, 2013). The literature suggests that this second component is contextual; broadly summarising the characteristics that affect a respondent's understanding of health and their expectation of it (Jylha, 2009). These include, but are not limited to, age, gender, education, social class and family history; the contextual component is therefore particularly mutable. This is demonstrated by variations across European countries in the association of SRH with factors such as age, gender and smoking, in contrast to the similarity in the association with number of chronic conditions described above (Verropoulou, 2009).

In general, the literature suggests that older people have lower health expectations and instinctively adjust for age in their evaluation of SRH. This results in an overestimate of health in relation to younger cohorts, and means that SRH does not decline as fast as objective measures suggest it should (Fayers and Sprangers, 2002). It also explains an observed weakening of the associations of SRH with mortality (Layes *et al.*, 2012) and with objective health (Pinquart, 2001) among oldest-old individuals. Conversely, younger cohorts are known to understand and account for health behaviours as risk factors in evaluating their health in a way that older cohorts do not (Jylha, 2009).

The number of systems medicated broadly reflects the number of clinical conditions present (Syddall *et al.*, 2016), loosely mirroring the somatic component of SRH. It is a more objective measure than overall SRH, because a physician must assess each condition before medication is prescribed. In HCS, regular over-the-counter medicines were included in NSM to capture somatic conditions that had not yet come to clinical attention. Since both choosing to consult a physician and acquiring over-the-counter medication require a degree of subjective motivation, NSM is not wholly objective.

Table 27 shows associations between SRH and other variables from the predictor panel in HCS participants. In keeping with the literature, SRH did not significantly differ by age in HCS; although given the narrow age range of the participants this is not surprising. Of the domains considered, physical function and morbidity might arguably define the somatic component, and lifestyle and social circumstances the contextual one. As might be expected, influences on SRH are apparent in variables representative of both, though the greatest relative risks derive from the physical function and morbidity domains.

Table 27 Association between participant characteristics and risk of having low self-rated health+ in the Hertfordshire Cohort Study

Participant characteristic	Men (n=1579)		Women (n=1418)	
	Relative risk (95%CI)	P-value	Relative risk (95%CI)	P-value
Demography and anthropometry				
Age*	1.13 (0.99,1.29)	0.060	1.05 (0.93,1.18)	0.451
Height*	0.87 (0.75,1.00)	0.046	0.83 (0.73,0.94)	0.003
Weight*	1.16 (1.01,1.33)	0.031	1.31 (1.17,1.46)	<0.001
Weight for height residual*	1.25 (1.08,1.44)	0.002	1.43 (1.26,1.61)	<0.001
BMI*	1.25 (1.11,1.42)	<0.001	1.42 (1.29,1.58)	<0.001
Lifestyle				
Ever smoked regularly	1.64 (1.18,2.27)	0.003	1.50 (1.18,1.92)	0.001
High alcohol intake	0.90 (0.64,1.27)	0.534	0.77 (0.40,1.49)	0.436
Activity score**	1.51 (1.33,1.71)	<0.001	1.57 (1.42,1.73)	<0.001
Social circumstances				
Social class (manual)	1.42 (1.05,1.91)	0.021	1.18 (0.91,1.52)	0.209
Relationship status (never married)	1.50 (0.96,2.34)	0.074	1.15 (0.69,1.92)	0.586
Housing tenure (not homeowner)	2.15 (1.63,2.85)	<0.001	1.83 (1.43,2.35)	<0.001
Physical function				
Grip strength**	1.31 (1.13,1.51)	<0.001	1.59 (1.45,1.74)	<0.001
Low Physical Function (SF-36)	4.45 (3.42,5.80)	<0.001	5.38 (4.24,6.82)	<0.001
Waking speed (self-reported)***	1.98 (1.70,2.31)	<0.001	2.19 (1.93,2.48)	<0.001
Fall in past year	1.58 (1.04,2.40)	0.033	1.20 (0.90,1.60)	0.213
Morbidity				
Ischaemic heart disease	2.34 (1.75,3.13)	<0.001	2.47 (1.86,3.28)	<0.001
Stroke or TIA	2.01 (1.28,3.13)	0.002	1.87 (1.12,3.13)	0.018
Hypertension	2.34 (1.77,3.10)	<0.001	2.05 (1.59,2.63)	<0.001
Diabetes	2.56 (1.92,3.41)	<0.001	1.91 (1.44,2.53)	<0.001
Fracture since 45yrs age	0.71 (0.44,1.12)	0.143	1.11 (0.83,1.49)	0.483
Osteoarthritis (hand)	1.00 (0.71,1.40)	0.985	0.82 (0.64,1.05)	0.114
HAD-Depression	3.18 (2.73,3.70)	<0.001	2.72 (2.34,3.16)	<0.001
HAD-Anxiety	2.13 (1.82,2.49)	<0.001	2.17 (1.91,2.47)	<0.001
Bronchitis	2.84 (2.00,4.04)	<0.001	2.65 (1.90,3.69)	<0.001
Number of systems medicated****	1.65 (1.54,1.78)	<0.001	1.56 (1.48,1.65)	<0.001

Footnotes:
+ Defined by poor or fair categories of SRH variable
Relative risks are obtained from Poisson regression models where the outcome is having low self-rated health
* Estimates per higher sex-specific SD score
** Estimates per lower sex-specific SD score
*** Estimates per lower band of characteristic
**** Estimate per unit increase
All other estimates represent the presence vs absence of the characteristic

Table 28 Association between participant characteristics and number of systems medicated in the Hertfordshire Cohort Study

Participant characteristic	Men (n=1579)		Women (n=1418)	
	Estimate (95%CI)	P-value	Estimate (95%CI)	P-value
Demography and anthropometry				
Age*	1.17 (1.12,1.23)	<0.001	1.07 (1.03,1.12)	0.002
Height*	0.96 (0.92,1.01)	0.134	0.93 (0.89,0.98)	0.003
Weight*	1.10 (1.05,1.16)	<0.001	1.15 (1.10,1.20)	<0.001
Weight for height residual*	1.13 (1.07,1.19)	<0.001	1.19 (1.14,1.25)	<0.001
BMI*	1.13 (1.08,1.19)	<0.001	1.20 (1.14,1.25)	<0.001
Lifestyle				
Ever smoked regularly	1.19 (1.07,1.32)	0.002	1.18 (1.07,1.29)	0.001
High alcohol intake	0.91 (0.81,1.03)	0.127	1.09 (0.87,1.37)	0.443
Activity score**	1.17 (1.11,1.23)	<0.001	1.20 (1.15,1.26)	<0.001
Social circumstances				
Social class (manual)	1.03 (0.93,1.14)	0.557	1.09 (0.99,1.20)	0.066
Relationship status (never married)	0.94 (0.77,1.16)	0.585	1.06 (0.85,1.32)	0.596
Housing tenure (not homeowner)	1.21 (1.08,1.36)	0.001	1.38 (1.24,1.53)	<0.001
Physical function				
Grip strength**	1.15 (1.09,1.21)	<0.001	1.20 (1.15,1.26)	<0.001
Low Physical Function (SF-36)	2.13 (1.95,2.34)	<0.001	1.93 (1.76,2.11)	<0.001
Waking speed (self-reported)***	1.32 (1.25,1.39)	<0.001	1.27 (1.21,1.34)	<0.001
Fall in past year	1.28 (1.09,1.51)	0.003	1.14 (1.03,1.27)	0.014
Morbidity				
Ischaemic heart disease	1.60 (1.44,1.78)	<0.001	1.44 (1.27,1.63)	<0.001
Stroke or TIA	1.93 (1.69,2.20)	<0.001	1.64 (1.36,1.98)	<0.001
Hypertension	2.16 (1.96,2.37)	<0.001	2.09 (1.91,2.29)	<0.001
Diabetes	1.87 (1.67,2.08)	<0.001	1.56 (1.40,1.74)	<0.001
Fracture since 45yrs age	1.02 (0.88,1.19)	0.782	1.12 (1.00,1.25)	0.044
Osteoarthritis (hand)	1.12 (1.00,1.25)	0.05	0.98 (0.90,1.08)	0.738
Self-rated health***	1.47 (1.39,1.55)	<0.001	1.49 (1.41,1.56)	<0.001
HAD-Depression	1.67 (1.50,1.86)	<0.001	1.47 (1.31,1.65)	<0.001
HAD-Anxiety	1.37 (1.27,1.47)	<0.001	1.21 (1.14,1.29)	<0.001
Bronchitis	1.46 (1.21,1.76)	<0.001	1.45 (1.21,1.75)	<0.001

Footnotes:
Estimates are derived from Poisson regression models with robust variance estimation where the outcome is number of systems medicated and the predictor is each variable in turn. Estimates represent the multiplicative increase in number of systems medicated.
*Estimates per higher sex-specific SD score
** Estimates per lower sex-specific SD score
***Estimates per lower band of characteristic
All other estimates represent the presence vs absence of the characteristic

Table 28 shows associations between NSM and other variables from the predictor panel in HCS participants. In contrast to SRH, NSM shows small but significant associations with age, notwithstanding the narrow range in HCS. This supports NSM as a more sensitive marker of objective health than SRH. Influences on NSM, like those on SRH (Table 27), are drawn from all domains.

Tables 27 and 28 also show strong associations between SRH and NSM. This might be expected from the known overlap between the somatic component of SRH and NSM, and it could be argued that including both in the model represents over-fitting. However, there is ample evidence that subjective and objective measures capture distinct dimensions of health. In his 2001 review of correlates of SRH, Pinquart reports common variance between subjective and objective health of only 5-30%, suggesting that they are not good proxies for each other and leading him to recommend that the two should be measured together in gerontological research (Pinquart, 2001). Including both in the models described here is therefore justified.

The dominance of SRH and NSM as key common drivers of admission (Table 25) provides a clear and unsurprising signal that overall burden of disease, whether objectively or subjectively assessed, is fundamental to the demand for hospital care. Table 26 shows sex differences in the associations of the two variables with admission that will be discussed below.

Sex differences in self-rated health and number of systems medicated

The literature shows that sex differences in SRH result from both somatic and contextual components. Clearly, biological differences result in objectively different experiences, but there is abundant evidence of contextual differences also. Men are thought primarily to consider physical health in making their assessment (Brunner, 2006), so that SRH is a closer representation of objective health, and correlates more closely with NSM (Mavaddat *et al.*, 2014) in men than in women. Meanwhile women's SRH, whilst slightly worse than men's (Brunner, 2006), especially at younger ages (Fayers and Sprangers, 2002), is less impacted by worsening physical condition (Arber and Cooper, 1999). It may therefore be concluded that the subjective element of SRH makes a greater contribution to the overall assessment in women than it does in men.

The dominance of physical health in men's assessments may explain why the predictive power of SRH for mortality is usually better in men, though sex differences are small and inconsistent (Brunner, 2006). Contextual influences in women may be more likely to include emotional and psychological factors that temper SRH but do not contribute directly to mortality. Indeed, women's assessments have been argued to have greater associations with events other than mortality, and over a longer timescale than men's (Brunner, 2006).

Table 26 showed that in HCS, SRH was the only baseline variable to predict all admission types in women. In men SRH was associated with readmission and emergency admission, but not with elective or elective day case admission. By contrast, NSM was the only variable to predict all admission types in men. In women, NSM was associated with readmission, elective admission and elective day case admission, but not with emergency admission.

Table 29 reproduces the estimates of association on which Table 26 was based. Although the differences are small, estimates of association for SRH were greater in women for each admission type; for NSM, they were more similar. Several plausible explanations exist for them. First, the greater subjective influence of SRH in women might render it a more fluid measure than in men, with gradations that drive an association with admissions of all types; meanwhile in men, a threshold might exist in SRH that creates a more binary assessment, the lower level being associated with the generally more serious conditions that result in readmission or emergency admission but not with those that are treated electively. Secondly, women's greater readiness to engage in help-seeking behaviour (Galdas *et al.*, 2005) could underlie the association of SRH with elective admissions, if it led to an increase in the number of elective admissions in women relative to men at the same level of SRH. It could also explain the absence of an association between NSM and emergency admission in women if earlier consultation led to treatment that inflated both NSM and elective admission and simultaneously averted emergency admission.

Table 29 Estimates of association in the final model between self-rated health, number of systems medicated and all admission outcomes

	Men		**Women**	
	Estimate* (95% CI)	P-value	Estimate* (95% CI)	P-value
Self-rated health (SRH)				
Readmission	1.16 (1.06,1.27)	0.002	1.36 (1.18,1.57)	<0.001
Emergency	1.12 (1.03,1.22)	0.006	1.18 (1.06,1.32)	0.003
Elective	1.14 (0.96,1.35)	0.142	1.38 (1.16,1.65)	<0.001
Day case	1.07 (0.88,1.30)	0.515	1.35 (1.10,1.65)	0.005
Number of systems medicated (NSM)				
Readmission	1.11 (1.04,1.18)	0.001	1.12 (1.05,1.20)	0.001
Emergency	1.11 (1.05,1.18)	<0.001	1.05 (0.99,1.12)	0.089
Elective	1.28 (1.09,1.51)	0.002	1.27 (1.11,1.44)	<0.001
Day case	1.26 (1.05,1.51)	0.015	1.21 (1.04,1.40)	0.011

Footnote:
Estimates of association are per band increase in SRH and per unit increase in NSM.
Relative risks were derived from Poisson regression models for the readmission outcome (Chapter 5); hazard ratios were derived from PWP-TT models for the emergency admission outcome (Chapter 6) and relative risk ratios were derived from multinomial logistic regression models for elective (Chapter 7) and day case (Appendix E) admission outcomes.

A third possible explanation for the association of all admission types with SRH in women but not in men relates to the length of the follow-up period, since, as stated earlier, SRH is predictive over a longer timescale in women than in men, and is associated with a wider range of outcomes (Brunner, 2006). This superior predictive power could underlie the association of SRH with all admission types in women, but with only the serious outcomes that happen closer to death in men. Finally, differences in methodology could mean potential excess mortality among men has not been adequately accounted for in the elective admission results. This possibility is discussed in Section 8.5.3

Whether these sex differences are reproducible, and whether they reflect differing sensitivities of SRH and NSM, variation in help-seeking behaviour, differential length of prediction or a combination of influences, and notwithstanding the caveat of a possible mortality bias, the findings do not undermine the clear message that together, these two markers of overall burden of disease at baseline in HCS were strongly associated with subsequent hospital admissions of all types.

Associations of other morbidity variables

In contrast to the powerful associations of SRH and NSM across admission types and sexes, the limited influence of single markers of disease was striking. Only two other associations were found: between baseline IHD and increased risk of emergency admission; and between history of fracture since age 45 and increased risk of readmission. Both were specific to men.

The first, between baseline IHD and subsequent emergency admission may simply reflect the high prevalence of acute events among men with IHD. The lack of an association in women could result from sex differences in presentation: first, women with IHD are less likely to suffer acute events than men, so may be more likely to be referred electively; secondly, the onset of IHD in women is typically 10 years later than in men (Douglas, 2017). If women diagnosed with IHD at baseline were at an earlier stage of the disease process, the follow-up period may have been too short to detect an association with emergency admission among them. This finding demonstrates the improved discernment of individual level data over ecological studies: previous work that used practice-level prevalence of coronary heart disease as a measure of chronic ill health in Leicestershire showed no association with emergency admission (Chauhan *et al.*, 2012).

The other association to withstand mutual adjustment was between fracture since age 45 and readmission in men. A probable explanation is the attenuation of fracture risk among women, but not among men, by NSM. Table 28 confirms that prior fracture is associated with baseline NSM in women but not in men, suggesting that women who fracture bones in later life receive medication whilst men do not. This is consistent with women's fractures leading to a diagnosis of early, treatable osteoporosis whilst trauma is considered a more likely cause in men of the same age. Why the association is limited to subsequent readmission is unclear.

Overview of morbidity domain

Collectively, the findings from the morbidity domain show that SRH and NSM are dominant predictors of hospital admission of all types. Other morbidity domain predictors have little impact beyond sex-specific effects of IHD (on emergency admission) and fracture since age 45 (on readmission). Together, poor SRH and increased NSM summarise disease status. Thus it is concluded that, among community dwelling older people, generalised morbidity predicts hospital admission more effectively than any specific morbidity. This concurs with the evidence summarised by the literature review, which suggested that markers of general disease were more consistent risk factors across the spectrum of admission types (Section 3.3.5).

If generalised morbidity results from an accumulation of diverse single conditions, SRH and NSM could stand proxy for multimorbidity, notwithstanding the complex relationships between the three. Pinquart argues that, although SRH is conceptually separate from multimorbidity, the preferential prediction of SRH by number of chronic conditions over single conditions is explained by an age associated increase in multimorbidity (Pinquart, 2001). This is supported by associations between SRH and multimorbidity that have been reported among middle-aged and older people in EPIC-Norfolk (Mavaddat *et al.*, 2014) and the 1946 Birth Cohort (Pierce *et al.*, 2012). In both cases, multimorbidity was characterised by a chronic disease count, of which NSM is an example. However, NSM is a substitute for neither SRH (which has an important contextual component; see page 157/8), nor multimorbidity (which is impacted by severity of conditions, simultaneous presence of symptoms and functional limitation; Section 2.2.3). Moreover, the work described here shows that NSM has associations with hospital admission in men beyond those identified by SRH. This justifies the use of SRH and NSM *together* to stand for multimorbidity.

8.3.3.2 Physical Function

The variables included in the physical function domain were grip strength, SF-36 Physical Function score (SF-36PF), self-reported walking speed and history of falls during the past year. Amongst them, in the final model, only SF-36PF was a common driver of admission; slow walking speed was a driver of readmission; no other associations were found.

SF-36 Physical function: background

SF-36PF determines capability to perform a range of everyday tasks: an important part of older people's definition of health (Morgan, 2003). Although it has been suggested as a marker of current and future health (Cooper *et al.*, 2011), poor physical function does not constitute illness *per se*. Rather than including it with the morbidity variables, this thesis has therefore considered it as a discrete domain, whilst recognising close links with morbidity (Figure 6).

The finding in HCS that low SF-36PF was associated with increased risk of emergency and elective admission in the final, mutually adjusted model, shows that it had a contribution to the risk of admission over and above its recognised action through SRH (Pinquart, 2001). This suggests that aspects of physical function that do not impact SRH nevertheless contribute to risk of admission. In the case of emergency admission, independent effects might act through increased risk of accident, though the lack of association between falls and any admission outcome is noted. For elective admission, such influences might act through procedures that improve physical function such as arthroplasty or removal of cataracts. A further explanation for the independent effect might be a differential decline in predictive validity over the follow-up period, such that more rapid decline in physical function increases risk of admission above that conferred by baseline SRH. The absence of association between physical function and readmission is noteworthy, and may be an unintended consequence of the methods adopted (See discussion of walking speed below).

SF-36 Physical function: sex differences

Physical function declines faster among women than among men in later life, first because women's smaller size endows them with less muscle and bone, and secondly because hormonal changes at the menopause accelerate the rate of loss (Kanis and Pitt, 1992; Shaw *et al.*, 2017). In addition, women's longer lifespan means they survive longer with diminished physical function, leading to proportionately lower health expectancy (Section 2.1.2).

In HCS, low SF-36PF was associated with emergency admission in both sexes, and with elective admission only in women. The more rapid decline in physical function in women might explain the association with elective admissions that was seen in women but absent in men if women required earlier (elective) intervention to improve physical function, but both sexes were at risk of accident, and thus of emergency admission. In addition, the suggested explanations for sex differences in the associations between SRH and admission (a threshold effect, help-seeking behaviour, a mortality bias) might apply differentially to associations with physical function, which was also self-rated.

Associations of other physical function variables

Variables within the physical function domain are known to correlate closely; the pattern of significant associations with admission at stage 3 reflected this (Table 25). Variables that were significantly associated at this stage were therefore subjected to an intermediate model to determine which should progress to the final stage. On this basis, low SF-36PF was included in all three final models and in addition, walking speed was included in the model for readmission. The inclusion of two physical function variables in the final model for readmission may have weakened the association with each of them, and thus explain why walking speed, rather than physical function, was identified as a risk factor for readmission among men, whilst among women, neither variable was associated with readmission.

Overview of physical function domain

Collectively, the findings from this domain show that physical function has an independent effect on all but elective day case admissions. The optimal marker for physical function in this context may be dependent on admission type, or on the overall condition of the study population. In frail populations, the literature review identified associations between readmission and more extreme markers of physical function, such as the Barthel Index of ADL limitations (Garcia-Perez *et al.*, 2011; Pedersen *et al.*, 2017); this thesis shows that risk is discernible in non-frail populations also. Markers of capability, as exemplified by SF-36PF, and markers of lower limb function such as walking speed have stronger associations with admission than markers of upper limb function (for example grip strength), confirming previous work from the USA (Cawthon *et al.*, 2009).

8.3.3.3 Social circumstances

The variables included in the social circumstances domain were social class, relationship status and housing tenure. Amongst them, in the final model, there were no common drivers of admission; housing tenure and relationship status were drivers of readmission and elective admission respectively; no association was found with social class.

Background

Social inequalities in health are well recognised (Marmot, 2011) and clearly contribute to the burden of hospital admissions through their effect on morbidity. Variations have been described in equity of access to hospital services, such that whilst deprivation is associated with increased risk of emergency admission, there is a bias towards higher socioeconomic groups among elective admissions (Dixon *et al.*, 2007; McCartney *et al.*, 2013).

Associations

Not being a home owner was associated with increased risk of 30-day readmission among women; in men there was no effect. No association was found with any other admission type in women or with any admission type in men. Proportionately more women than men lived in rented homes at baseline in HCS (22.1% vs 18.9%)(Table 10); combined with generally poorer pension provision and higher prevalence of widowhood (Vlachantoni, 2012), this failure to accumulate wealth across the lifecourse confers a particular disadvantage on women who rent their homes. Nevertheless, independent effects were seen only for readmission in this most disadvantaged group.

Never having married, although unusual in HCS, (6.9% of men and 5.2% of women had not married (Table 10)) was associated with a halved risk of elective admission among men in the multinomial analysis (Chapter 7). No association was seen with any other admission type in men or with any admission type in women. This negative association could reflect a mortality bias that has not been accounted for in the analysis of the 'elective only' group in the multinomial analysis (see Section 8.5.3): never married people have a mortality rate three times greater than those who are currently married (Gjonca and Marmot, 2005), with reports of larger differences in men (Lillard and Panis, 1996). If this were the explanation, one might expect never-married status to be associated with increased membership of the 'emergency admission or died' group in this analysis, but it was not; the estimate of association, although non-significant, was still below one. An alternative, and therefore more likely, explanation is that never having married is associated with reduced help-seeking behaviour among never-married men (compared to other men). There is ample evidence to suggest that men are generally less ready than women to seek help from a healthcare provider when they are ill, and that this behaviour varies with social factors, such that, for example, men of lower social class are least likely to consult a doctor (Galdas *et al.*, 2005). Intuitively, one might expect help-seeking behaviour for routine problems that would present electively to be reduced among older men who had never married compared to those who had; one might also expect that more urgent problems which could not be overlooked would continue to present as emergencies. This would explain the discrepancy between admission types demonstrated here, which build on the findings of a study in Sweden that compared admitted with non-admitted middle-aged and older people, and showed that unmarried or widowed men were at lower risk of any admission than married men (Hallgren *et al.*, 2016b). There was no analysis by admission type.

Overview of social circumstances domain

In contrast to the literature previously reviewed, this research found no evidence of opposing (or indeed *any*) effects of social class on elective and emergency admission (McCartney *et al.*, 2013), even in univariate (stage 1) models. The other measure of deprivation considered was housing tenure; this had some early associations, but they were largely attenuated by mutual adjustment. Together with the single association of marital status with elective admission, this suggests that, at least in HCS, the effect of social circumstances on hospital admission is largely mediated through inequalities in health, rather than by direct independent effects.

8.3.3.4 Lifestyle

The variables included in the lifestyle domain were ever having smoked regularly, having an alcohol intake above sex-specific limits that were, at baseline, recommended by the Department of Health, and having low levels of customary physical activity. Amongst them, in the final model, history of smoking was a common driver of admission; no other associations were found.

Background

There is overwhelming evidence that smoking is harmful to health (Doll *et al.*, 2004); an effect on risk of admission mediated through morbidity is therefore expected. In the final mutually adjusted models, history of regular smoking was shown to be associated with increased risk of readmission and emergency admission; it was not associated with membership of the ‘elective only’ group in the multinomial model. Effects of smoking on admission, independent of those mediated through morbidity (as assessed by SRH and NSM at HCS baseline), might be explained in two ways. First, the lag between baseline assessment and admission could attenuate the effect of morbidity if smoking related disease was slow to develop, though this seems unlikely as smoking histories were typically long. Alternatively, denial among smokers of the effect of the habit on their health could lead to a mismatch between SRH and admission outcomes, in keeping with literature that suggests older people do not account for health behaviours in assessing their SRH (Jylha, 2009). The lack of association of smoking with elective admissions in either sex may result from smokers being more likely to belong to the ‘ever emergency or died’ group in the multinomial model; a bias that in this case affected both sexes.

Sex differences

The association of smoking with readmission that was unique to men contrasts with associations between smoking and emergency admission in both sexes. This suggests that the sex difference in readmission may be explained by excess male mortality, rather than differing exposures to smoking masked by the binary variable used to separate those who had ever smoked from those who had not.

Overview of lifestyle domain

The effect of lifestyle behaviours on hospital admission was mixed. Smoking had independent effects on hospital admissions other than electives, over and above effects that were mediated through morbidity. Alcohol consumption and physical activity did not. These findings broadly mirror evidence from UK cohorts (Section 3.2.5), which suggested that, of the three behaviours, only smoking was consistently associated with risk of overall or serious admission across the cohorts.

8.3.3.5 Demography and anthropometry

Men were significantly more likely than women to be admitted to hospital, to experience readmission or emergency admission, and to die. There were no sex differences in membership of the elective only group in the multinomial model. All analyses of association with predictor panel variables were conducted for men and women separately. The variables included in the demography/anthropometry domain were age, height and three measures of adiposity. Amongst them, in the final model, there were no common drivers of admission; weight for height residual was a driver of day case elective admissions; no other associations were found.

Associations

Associations with admissions were limited to a single finding relating to weight for height residual: thinner men (those with lower weight for height residual) were at increased risk of elective day case admission. This variable was carried forward to the final stage in the multinomial model and its 4-group extension (Appendix E) due to increased risks of elective and emergency admission at stage 2 among women with *higher* weight for height residual; there was no relationship among men at this stage. The relationship among women was eradicated by mutual adjustment in both final models, with the appearance of an opposing relationship in men specific to the day case elective group. Although negative confounding could have masked a true association in men until the final stage, it seems more likely that this unprecedented finding is due to chance. The literature review (Section 3.2.5) found risk of admission generally to increase with BMI; associations with lower BMI were reported only for psychiatric admission in either sex (Lawlor *et al.*, 2007) and for any admission among women categorised as underweight (Hart *et al.*, 2007).

Overview of demography and anthropometry domain

Risk of admission was generally higher among men; no convincing associations were observed between age or any anthropometric variable and hospital admission.

8.3.3.6 Summary, all domains

The findings described show that the key common driver underlying all admission outcomes in both sexes was multimorbidity, defined collectively by NSM and SRH. Apart from NSM and SRH, no single variable retained associations with all admission outcomes in the final, mutually adjusted models, though each of the domains had at least some influence on admission. The physical function domain was associated with increased risk of all outcomes except elective day cases through either poor SF-36PF or slow self-reported walking speed; the lifestyle domain was associated with increased risk of readmission/death and emergency admission/death through history of ever smoking; and the social circumstances domain was associated with increased risk of readmission/death through renting, rather than owning one's home and with elective admission through never having married. Men were at higher risk of admission than women, but otherwise, relationships with the demography/anthropometry domain were more tenuous, as described in Section 8.3.3.5.

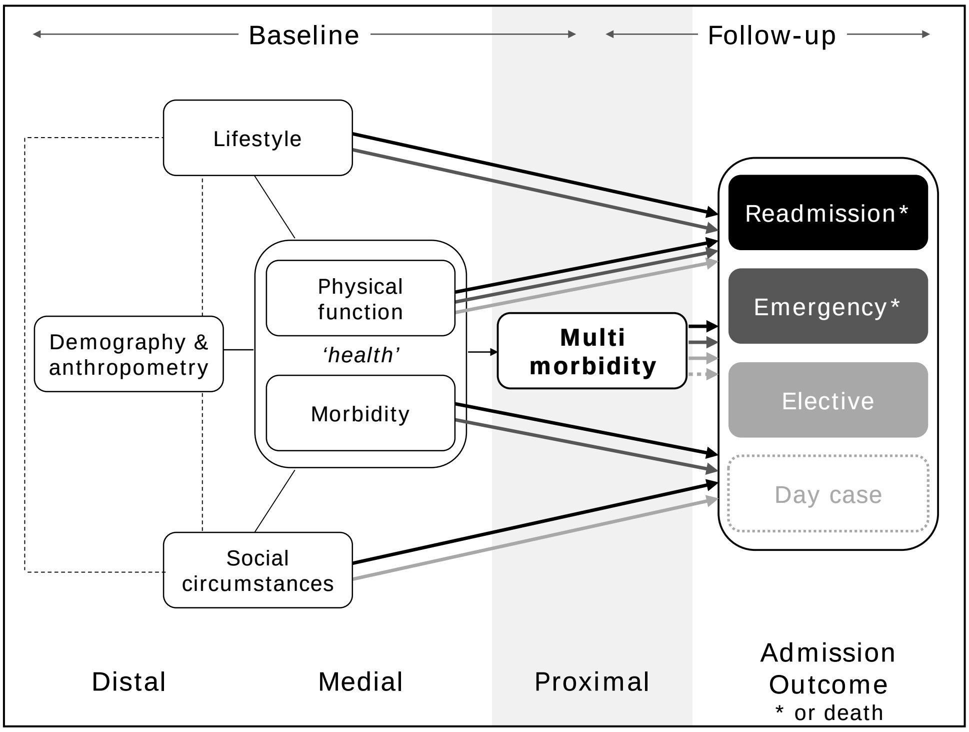

Figure 20 A posteriori update of conceptual framework showing relationships between domains of predictor variables and admission outcomes (Source, author)

These findings inform a redrafting of the conceptual framework proposed earlier (Figure 6). Figure 20 introduces an additional category at baseline representing multimorbidity, which now occupies a position proximal to the admission outcomes, pushing the 'health' category into a medial position. Associations between predictor domains and admission outcomes are shown by arrows colour-coded as in Tables 25 and 26, demonstrating that associations with all outcomes act through multimorbidity whilst all other mutually adjusted associations are specific to admission type. The lifestyle and social circumstances domains, whilst still distal to the outcomes, have been moved somewhat closer to them, on the basis of the associations shown.

This positioning of multimorbidity on the causal pathway between morbidity and admission outcome is purely pragmatic: it represents recognition that the development of multimorbidity requires first that there should be morbidity. It is not indicative of later measurement; all baseline variables were measured contemporaneously, though arguably it could represent a more advanced state (of any given variable or variables) at baseline.

Moreover, the identification of independent predictors of admission does not diminish the importance of other domains in their contribution via morbidity and multimorbidity (Table 27, Table 28), nor the possibility of reverse causation between ill health and other domains. It does not tell us what causes what. This causal sequence is important: if differences in SRH and NSM are ultimately due to variation in the other predictors, SRH and NSM could be used to understand current demand, but prevention ultimately depends on intervening earlier in the lifecourse in the most important predictors of SRH and NSM.

8.3.4 Drivers of admission, by admission type

It is apparent from Table 26 that associations of SRH and NSM were seen in both sexes for elective and elective day case admission with NSM; for emergency admission with SRH; and for readmission with both SRH and NSM. Associations between the elective admission outcomes and SRH, and between emergency admission and NSM were sex-specific.

Although caveats apply regarding the magnitude of the differences (Section 8.3.3.1; Table 29), these subtle and hitherto unknown variations in association by admission type suggest that elective admission was most widely associated with objectively poor health (NSM), emergency admission with more subjectively poor health (SRH), and 30-day readmission (which included both admission methods) was associated with globally poor health as defined by both SRH and NSM. These observations could reflect the role of a common arbiter: the individual who rates his or her health poorly also, in many cases, refers him or herself for emergency treatment either directly or via the ambulance service (National Audit Office, 2013). Conversely, the fact that NSM was the only variable associated with elective admission in both sexes could be explained by citing the physician as common arbiter, since acquiring medication and referral for elective treatment both require a medical opinion, excepting a few over-the-counter medications. Readmissions included both elective and emergency cases and were associated with SRH and NSM in both sexes, suggesting that the two arbiters agreed in identifying those whose health was unequivocally poor.

8.3.5 Accumulation of risk

The combined impact of risk factors was demonstrated graphically for readmission in Chapter 5 (Figure 17) and emergency admission in Chapter 6 (Figure 18). Chapter 7 presented a statistical estimate of the increase in risk of 'only elective' admission associated with each additional risk factor; this was harder to dissect from the multinomial model because individuals with multiple risk factors were more likely to belong to the 'ever emergency or died' group. In all cases, a gradient existed among cohort members such that risk of admission increased steadily with the number of type-specific risk factors an individual had. This was consistently so for men and women.

Figure 21 shows the impact of increasing numbers of risk factors on a range of outcomes across individuals' admission histories. Considering just the four common drivers of admission that have been elucidated (history of smoking, low SF-36 physical function, SRH and NSM), each of the panels shows the percentage of men and women who experienced a given outcome according to the number of risk factors they had. The figure demonstrates a particularly marked accumulation of effect for more adverse admission histories; for example, 62% of women in the highest risk factor category had 3 or more admissions, compared to 20% of those who had no risk factors. Although greater proportions died among people with more risk factors (bottom right), the effect of death is barely discernible between outcomes representing admission alone and those that combine it with death, due to high admission rates in those who died.

Even among those with no risk factors, high proportions of people were admitted: 67% of men and 56% of women with no risk factors had at least one admission during the follow-up period (top left). This high use of health services, even in the absence of known risk factors, has been noted previously in EPIC Norfolk (Luben *et al.*, 2016)(Section 3.2.1). Interestingly, the authors of that study found the association between number of risk factors and hospitalisation to diminish after the age of 75; perhaps because the risk factors they identified (male sex, manual social class, low education, current smoking and BMI>30) excluded any measure of (multi)morbidity or physical function. It is these variables that, with smoking, drive the associations described here.

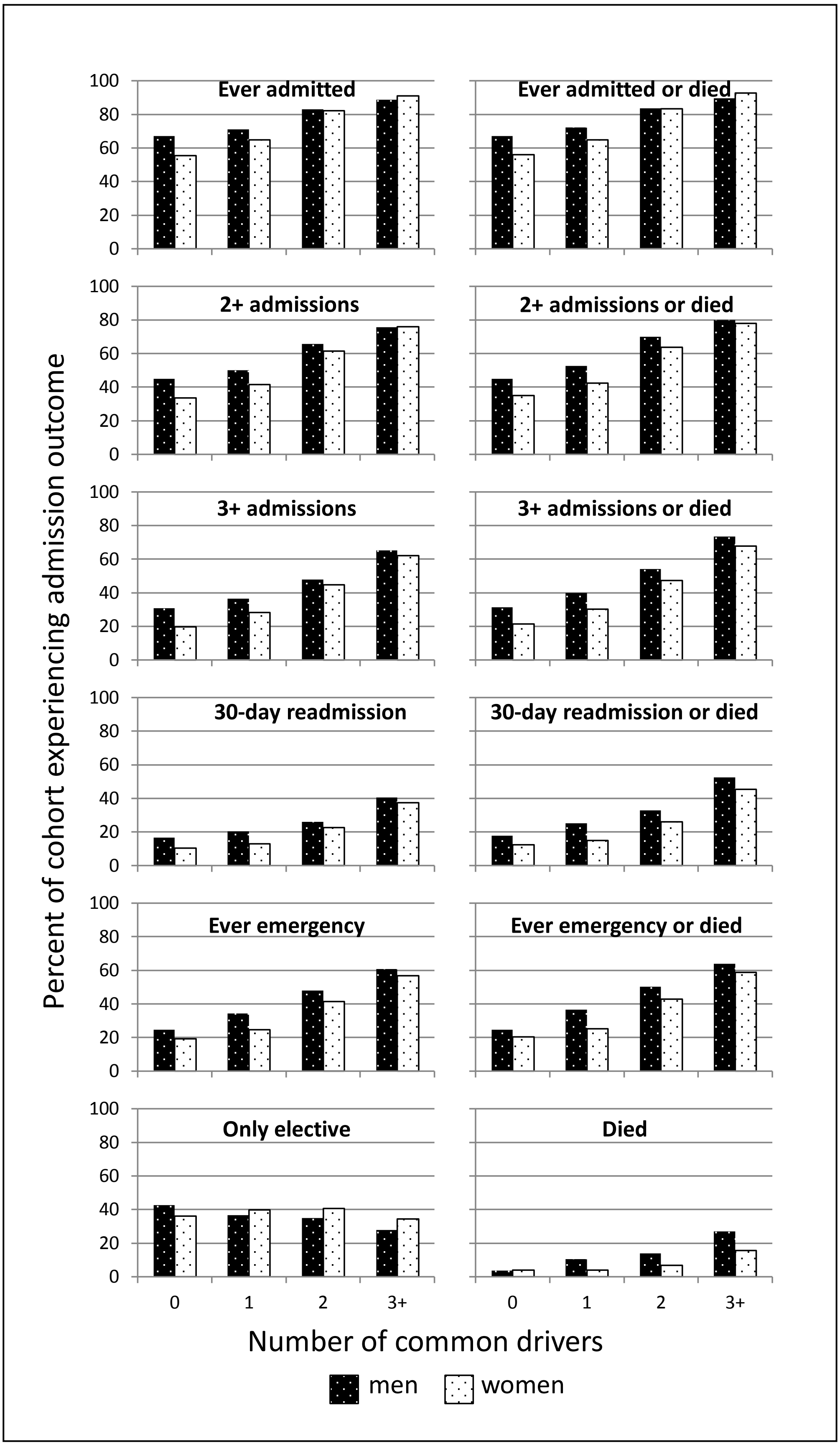

Figure 21 Burden of admissions among individuals according to number of common drivers (history of smoking, low SF-36 physical function, SRH and NSM) (Source, author)

8.4 Policy Context

The research described in this thesis was conducted in a cohort followed-up through early old age. They lived in the affluent south east of England and were known to exhibit a healthy participant effect. Their need for hospital services was nevertheless high, even among those who had none of the risk factors that were identified. Older and poorer populations have higher admission rates (Health and Social Care Information Centre, 2014a) associated with higher prevalence of risk factors (Melzer *et al.*, 2012); in addition, demographic pressures from ageing baby boomers are predicted to impact on hospital admissions from 2020 (Section 2.4.4). Policy measures to address the need for healthcare are therefore paramount, but must be considered against the background of constraints on health and social care expenditure and political uncertainty surrounding Brexit.

An important tenet of health policy is to reduce admissions to hospital and so reduce costs (Section 2.5). The most recent initiative with this aim, local Sustainability and Transformation Plans, were published in October 2016, describing measures to develop new care models and use resources more effectively. It is widely believed that in reality, many of these plans actually propose to cut services (Oliver, 2016a; Ham *et al.*, 2017). Preventing unnecessary admissions has never been more important.

Policies which seek to avoid admission are specific to the type of admission they target and/or to the sector where intervention might be effective. The implications of the findings of this PhD to policy are discussed by sector below:

8.4.1 Secondary care

Measures aimed at the prevention of 30-day readmission are targeted towards acute hospitals, where a policy of non-payment for selected readmission within 30 days of discharge has been in operation since 2011 (Section 2.5.2). This is intended to provide an incentive to hospitals to improve care and discharge planning with the aim of reducing emergency readmission following elective admission by 25 percent, alongside locally agreed targets for other readmissions (Department of Health, 2010). The effect has been a loss of income estimated to average £5m per hospital trust (Foundation Trust Network, 2011), with no obvious reduction in rates of readmission (Health and Social Care Information Centre, 2013a). This is unsurprising; risk of readmission stems from factors related to the individual and to community care as well as to the hospital, in addition, many index admission/readmission pairs have unrelated diagnoses (Conroy *et al.*, 2013); suggesting that readmission may be a marker of vulnerability rather than an inadequately treated specific morbidity.

Chapter 5 identified six patient-related risk factors for readmission; self-rated health and number of systems medicated conferred risk in both sexes, whilst history of smoking, home ownership, walking speed and fracture since age 45 each affected one sex or the other. Baseline measurements were always made before the index admission, sometimes many years earlier. The implications are twofold: first, the impact of patient-related risk factors suggests that the policy of penalising hospitals for readmissions is unjust, and secondly that identification of those at risk of readmission might be possible in a primary care setting, with the potential to prevent not only the readmission but also the elective or emergency index admission that precedes it. The risk factors identified require no clinical testing and could be determined using a short screening questionnaire, in accord with the recommendations of previous research that:

'Efforts to reduce readmissions must look beyond the current focus on a single hospital discharge and transition period' (Black, 2014 pp e200).

8.4.2 Primary care

Measures aimed at the prevention of emergency and elective admissions are targeted towards the primary care sector, where since 2004 the Quality and Outcomes Framework (QOF), has provided GPs with financial incentives for identifying and managing common chronic diseases, discouraging smoking and implementing preventive measures, in the belief that reduced admission rates will follow. Around 25 individual criteria, or 'indicators', are enumerated by QOF with minor variations from year to year (NHS Employers, 2017). There is evidence that, against a backdrop of a 34% increase in rates of all-cause emergency admission, rates specific to incentivised conditions fell by 10% between 1998/9 and 2010/11 (Harrison *et al.*, 2014). Nevertheless, QOF single disease indicators have been criticised for inadequately representing the needs of an increasing population of older people with multiple complex problems (Roland and Guthrie, 2016).

The work described here suggests that those at risk of admission might be identified by the two risk factors that were common to all admission types: poorer self-rated health and higher number of systems medicated, neither of which is currently specified among QOF indicators. The future of QOF is unclear (Roland and Guthrie, 2016), but this work suggests that, whatever replaces it, self-rated health should be recorded in general practice. Others have argued that poor SRH should be addressed (Kennedy *et al.*, 2001; Jylha, 2009; Mavaddat *et al.*, 2014); this work supports that view and further suggests that the coexistence of other risks is important. In HCS, 13.3% of participants had fair or poor SRH; 37.3% had two or more systems medicated; but only 9.3% had both, thus the number of patients identified by the coexistence of these two risk factors would be modest, and could be further refined with reference to gender, smoking and physical function. Such patients could then be targeted for interventions to support self-management (Section 2.5.2).

8.4.3 Public health

The previous sections considered how the key findings of this thesis might be applied to the identification of those at greatest risk of admission. There is, however, an alternative approach. In the 1980s, Geoffrey Rose demonstrated that altering the risk of a whole population can have a greater effect on the incidence of disease than targeting those at highest risk: a large number of people at a small risk may give rise to more cases of disease than the small number who are at high risk (Rose, 1985). The same is true of hospital admissions: most do not involve the highest risk individuals, thus the greatest benefits might be achieved by reducing population risk (Roland *et al.*, 2005). Risk reduction via effective public health measures is therefore important, although if risk of admission is transmitted through multimorbidity, the potential for reduction among those who already have several chronic diseases may be limited (Oliver, 2017).

The real benefits of this strategy might be realised through the lifecourse perspective (Section 2.2.2) if future admissions could be reduced by the prevention and management of multimorbidity in younger generations. This is particularly relevant to the 'baby boomers' who, at age 60-64, already had multimorbidity of 39% in men and 38% in women (Section 2.2.3 (Pierce *et al.*, 2012)), and who, it has been predicted, will increase the contribution of age effects to overall admissions from 2020 (Section 2.4.4 (Wittenberg *et al.*, 2015)). The 2015 annual report of the Chief Medical Officer (CMO) was focused on the health of this demographic (Davies, 2015). It compared differing cohort effects in health of baby boomers and those born a generation earlier (amongst whom HCS participants belong) finding that baby boomers have lower rates of mortality but unchanged morbidity, and will face a longer period of ill health in later life than those studied here, with serious repercussions for hospital care. However, the report goes on to point out that three modifiable risk factors (poor diet, tobacco and high BMI) accounted for 45% of the disease burden in 50-69 year-olds in 2013, implying that a large proportion of the burden may be preventable. The report therefore finds that a window of opportunity exists to improve individuals' health now in anticipation of old age, areas for improvement being increases in physical activity alongside reductions in tobacco consumption, obesity and overweight. The research described here suggests that policies aimed at addressing tobacco consumption might have a direct impact on hospital admission. Although neither physical activity nor adiposity had convincing independent effects on admission of any type in the mutually adjusted models presented here, both have unequivocal effects on health (Sections 4.6.1.1 and 4.6.1.2); policies to address them are therefore to be welcomed.

The CMO observes a diminution of social stratification in diabetes and overweight as rates rise, but finds that otherwise inequalities in health and access to healthcare persist. The findings of this research show that although the effects of deprivation (assessed by housing tenure) on risk of admission were largely attenuated in the mutually adjusted model, there were strong associations with emergency admission and readmission in the earlier stages, particularly among women. Measures called for by the CMO to improve the health of the most deprived are therefore to be welcomed. A further implication of the research presented here relates to hospital admission among men. The CMO notes that the proportion of men aged 60-64 who live alone more than doubled from 9.6% in 1985 to 21.8% in 2009, although the proportion who had never partnered was equivalent to that in HCS. In the light of the observed *reduction* in risk of elective admission among HCS men who had never married, policy should ensure that men (particularly lone men) are encouraged to present for screening and to seek help when symptoms arise; missed opportunities to intervene at an early stage of the disease process might otherwise lead to an increase in emergency admissions among this population.

The CMO focuses on the baby boomer generation because they are the people who will impose the greatest demand on the economy and health and social services in the coming decades. However, the lifecourse approach suggests that even earlier intervention would more effectively prevent multimorbidity, thus public health initiatives right across the lifecourse are crucial to curb demand on hospitals in the longer term.

8.4.4 Use of routinely collected data in research

The Health and Social Care Act (2012) made extensive changes to the management structure of the NHS (Department of Health, 2012a) and, at the same time, provided a legal basis for research in this new architecture. The Health Research Authority (HRA) and NHS Digital were created by the legislation to facilitate this, and a duty was placed on the Secretary of State to promote research on matters relevant to the health service and apply evidence obtained to the NHS (Department of Health, 2012b). Whilst these were laudable aims, they have led to the replacement of an administrative structure in which the work described by this thesis was possible with one where it is, at the very least, frustratingly difficult.

The 2012 Act introduced a dual legal basis for data sharing, whereby researchers had to *either* have very explicit consent from patients *or* gain exemption from this requirement through Section 251 of the NHS Act (2006), which provides access to data without patient consent. NHS patients were given the opportunity to opt out of the sharing of their data through this latter channel by notifying their GP of their wishes.

In HCS, consent was obtained from clinic participants granting researchers future access to their GP records. When the HES data were obtained in 2010, this was accepted as implicit consent for access to the brief, anonymous coded summaries extracted from their hospital records for linkage to the HCS database, since all the fields it contained would be obtainable from the discharge summary stored in the GP record. However, when the data sharing contract expired, a renewal was refused by NHS Digital's Data Access Advisory Group because, according to their interpretation of the new law, the consent held did not satisfy the changed requirements. By that time a substantial proportion of the cohort had died or had lost contact, and could not be re-consented. It was therefore necessary to seek the opinion of a Research Ethics Committee (REC) on the validity of the patient consent, and to submit it with an application for Section 251 exemption to the HRA's Confidentiality Advice Group (CAG). This would allow the processing of data on the presumption of no consent, though data obtained on this legal basis would, in future, exclude individuals who had opted out of data sharing.

A very favourable response was received from the Cambridge and East of England REC (dated September 2016): *'the Committee is of the opinion to not allow linkage would undermine the consent of participants and further it would be unethical not to allow this study to continue'*. The Section 251 application, submitted immediately, was approved by CAG in October 2016 but the exemption certificate was not issued until six months later. Thus, in April 2017, a new application was submitted to NHS Digital and triaged to a 60-working-day response. As of January 2018, a decision is still awaited. These delays are unacceptable, not just for HCS but for cohort studies in general: through its interpretation of the law, NHS Digital is preventing the very research it was intended to facilitate. Without a valid data sharing agreement the papers that constitute the body of this thesis cannot legally be submitted for publication, contributing to the 'scandal' of unpublished research (Glasziou and Chalmers, 2017). Cohort studies are a rich resource accrued over many years; like administrative data they have been collected at public expense; this thesis shows that together the datasets are more valuable than either in isolation. Linkage requires not only excellent cohort data but also a single, dominant healthcare provider: the UK is one of few countries to have both, thus research using linked data has worldwide applicability.

The Digital Economy Act, currently progressing through Parliament, will provide *'new powers to share personal information across organisational boundaries in order to improve public services'* (GOV.UK, 2017). It is to be hoped that a fresh policy perspective on the use of hospital data in research will be enshrined.

8.5 Strengths and limitations

The primary strength of the work described is in integrating Hospital Episode Statistics with the cohort database; thus allowing exploration of individual level, as opposed to population level, determinants of admission. HCS is among few cohorts in England to achieve such linkage and is the only one to use the combined dataset to study hospital admissions of different types. Strengths and limitations of the work described stem from three sources: the linked dataset; the study design; and the comparison of the three papers. These elements are discussed in turn below.

8.5.1 The linked dataset

The papers that comprise Chapters 5-7 of this thesis share a common linked dataset; strengths and limitations that stem from the data thus apply equally to them all.

Strengths

The advantages of HES (Section 2.4.1, Section 4.2.1) as a source of follow-up data in an ageing cohort cannot be overstated. Whilst failing health and moves into care settings threaten serious attrition, the use of routinely collected data captures diagnostic and other information without input from the participant and regardless of where in England they are treated. In addition, linkage produces individual rather than ecological level data, and personal histories summarise individual experiences rather than, as is usually the case with administrative data, a single admission. Despite recent sharp increases in charges, HES data remain relatively inexpensive when compared with bespoke data collected for research purposes.

The strengths of the Hertfordshire Cohort Study have been well rehearsed (Syddall *et al.*, 2005a). In brief, participants have been particularly well characterised and were community-dwelling at baseline. Predictor panel data were prospectively collected and the follow-up period was long, thus avoiding confounding by acute ill-health at the time of admission. To have demonstrated credible relationships over a lengthy period of follow-up is a particular strength of the study; the findings relating to baseline SRH and NSM are striking, particularly given the lead-time to admission during which disease might be expected to develop or worsen differentially.

Limitations

There are also a number of limitations to the use of HES which have been addressed in more detail elsewhere ((Simmonds *et al.*, 2014b) Appendix A). First, although the validity of the data is now largely accepted (Burns *et al.*, 2012), some doubts remain about the accuracy of diagnostic and specialty coding (Brennan *et al.*, 2012). Since only fact and method of admission variables have been used here, any effect of sub-optimal accuracy on this research should be minimised. Secondly, although HES data are collected from all patients admitted to NHS hospitals whether they are funded by the NHS or privately, and from NHS funded patients admitted to private hospitals; privately funded patients in private hospitals are excluded. Around 13% of elective surgery was on these excluded patients in 2011 (Commission on the Future of Health and Social Care in England, 2014), possibly biased towards procedures that have restricted availability on the NHS (eg varicose vein removal or cosmetic surgery), and for the most part, funded by health insurance among working-aged people. The proportion of privately funded hospital care is likely to be lower among older people and for other admission types; however, if there is loss to follow-up, it may differ by admission type and by socioeconomic group. A more serious problem of HES data is that externally imposed limitations on data-sharing (see Section 8.4.4) make it unlikely that this work could be either repeated or replicated at present.

Limitations also stem from the cohort data. A healthy responder bias has been demonstrated in HCS between those targeted to attend clinic and those who did so (Section 4.9.1 (Syddall *et al.*, 2005a)), suggesting that cohort participants may not be representative of Hertfordshire. In addition, the county is in the relatively affluent south-east of England where rates of hospital admission, particularly emergency admission, are low (Blunt *et al.*, 2010). Thus the experience of hospital admission among HCS participants (the majority of whom remain in the county and would appear among local data) may not match the national picture, though internal comparisons relating risk factors to admission remain valid.

Cohort effects, whereby the unique lifetime experiences of each generation are associated with particular health outcomes in old age (Section 2.4.4), must also be considered. Generational differences in predictor variables, such as those described for SRH (Section 8.3.3.1), may alter the relationship between risk factors and outcomes from one generation to the next, so that the variables found to predict admission in HCS become more or less relevant in later generations.

Although frailty is an important limitation in later life (Section 2.2.3), it was not assessed at baseline in HCS. During clinical follow-up, frailty was characterised by Fried criteria (Fried *et al.*, 2001), but to have included these data in the predictor panel would have compromised its wholly prospective nature. The prevalence of frailty was low: 4.1% among 320 men and 8.5% among 318 women for whom data were available (Syddall *et al.*, 2010). The prevalence of multimorbidity, however measured, was higher (37.3% of the cohort had two or more systems medicated; 13.3% had fair or poor SRH; 9.3% had both). Since frailty is believed to lie on the causal path between multimorbidity and disability (Fried *et al.*, 2001) our finding that multimorbidity underlies hospital admissions of every type may imply that we have identified a predictor that can be detected earlier in the lifecourse than frailty.

8.5.2 Design and methods

A consistent study design runs through the three papers, each of which adopts the same predictor panel (Section 4.6) and modelling strategy (Section 4.8.2). Methodological differences are introduced with the definition of the three admission outcome variables (Section 4.7) and the statistical technique chosen to derive estimates of association (Sections 4.8.2.1 – 3).

Strengths

The study design is responsible for a number of strengths which are common to all three papers. First, the four-stage modelling process provided a robust, mutually adjusted assessment of the interaction between risk factors from different domains (Section 4.8.2). For each outcome, the pseudo R^2 statistic estimates the percentage of variation explained at each stage of the modelling process. Secondly, the use of SD scores for continuous variables allowed within-paper comparisons of the size of effect of different predictor variables. Thirdly, outcome measures were adopted that broadly categorised the cohort into admission history groups for analysis and so simplified the complex data. Death was also accounted for; this was considered particularly important, since people who are nearest to death make the heaviest demands on hospital services (Himsworth and Goldacre, 1999).

Of the techniques used to produce estimates of association; the PWP-TT method applied to the emergency admission/death outcome was a particular strength of Chapter 6. PWP-TT uses information from each defined failure event, in this case emergency admission, which a participant experiences during the follow-up period. It was chosen to explore emergency admissions after extensive research (Westbury *et al.*, 2016), but was less suitable for the other outcomes for reasons that are discussed in Sections 4.8.2 and 8.5.3.

Limitations

There are also limitations inherent in the study design. Although the three papers demonstrate influences on admission arising from different risk-factor domains, they do not test the extent to which the domains act through morbidity (or multimorbidity) as the conceptual framework suggests they might. Since all the predictor variables were measured at the same time, no causal pathway can be inferred (Babitsch *et al.*, 2012); neither can changes in predictor variables or their relationship to hospitalisation during the follow-up period be studied.

Given the hypothesised relationships between domains, some co linearity between predictor variables is to be expected. Tables 27 and 28 examined associations of SRH and NSM with the remainder of the predictor panel. Other correlations were explored using a polychoric correlation matrix. The associations that this showed were unsurprising: increased age was correlated with hypertension; increased adiposity with low physical function and hypertension; history of smoking with bronchitis; and increased deprivation with low physical function and history of smoking.

The advantages of the combined admission/death outcome strategy set out in Section 4.8.2 were twofold: individuals whose outcome was worse than admission were assigned to an appropriate comparator group; and any reduction in admissions due to mortality was accounted for. The papers presented in Chapters 5-7 cite the inclusion of mortality data as a particular strength of the study, and defend the combined outcomes on the grounds that few people were positive for an outcome only because they died; most were also admitted to hospital at least once in their last few years of life. However, the strategy also had disadvantages, in particular that risk factors for admission and death could be indistinguishable.

In order to investigate the impact of death on the findings, analyses were repeated from which all individuals who died were excluded (Appendix G). In these sensitivity analyses, smoking and slow walking speed were no longer significant predictors of readmission among men (Appendix Gi), suggesting that associations in the original models may have been driven, in part, by those who died. For emergency admission, the same loss of effect of smoking was seen in men and women; low SF36PF also lost its effect in women (Appendix Gii). Risk factors for the elective only group in the multinomial model were unchanged (Appendix Giii).

Interestingly, for emergency admission, some new associations were apparent in these analyses: with housing tenure in men and with activity score and NSM in women. This suggests that other risk factors for emergency admission may be detectable in people who are further from death. However, it should be noted that these analyses omit substantial groups of people who were admitted to hospital *and* died (154 for readmission and 218 for emergency admission). These late-life admissions are important, since admission rates are known to rise in the last few years of life (Himsworth and Goldacre, 1999). Whilst acknowledging potential limitations of the chosen strategy, this thesis adopted the view that to model admission without death runs the risk of failing to identify the most important predictors of admission.

In contrast to the PWP-TT models cited above as a strength of the emergencies paper (Chapter 6), the techniques applied to the other admission outcomes, whilst pragmatic, were somewhat wasteful of information. Neither the binary 'readmitted or died' outcome variable used in Chapter 5 nor the ordinal 'only ever elective' outcome variable in Chapter 7 accounted for repeated admissions; however, the PWP model could not be used for these outcomes for reasons that are discussed in Sections 4.8.2 and 8.5.3.

Although, for each outcome, the difference in the pseudo R^2 statistic between models estimates an increase in the variation explained across the stages of the modelling process, its values are always under 0.1 (ie the models explain less than 10% of the variation). This is in part due to the methodology adopted: unlike the R^2 measure used in linear regression, McFadden's pseudo R-squared does not directly measure the proportion of variance explained, and investigators are warned that values are likely to be considerably lower, so that values from 0.2-0.4 are considered to indicate excellent model fit (McFadden, 1974). There is no preferable alternative to the R^2 statistic for models that are estimated for binary and categorical outcomes.

The aim of the three papers was to investigate which of the variables in the predictor panel were most closely associated with admissions of different types, rather than to produce a validated predictive model. Although the coexistence of two measures of multimorbidity identified a relatively small 'at risk' group in HCS (13.3% had fair or poor SRH; 37.3% had two or more systems medicated; 9.3% had both), estimates of the prevalence of multimorbidity among older people range from 55-98% (Marengoni *et al.*, 2011); thus whilst multimorbidity (ascertained by these two variables) is a strong predictor of admission its positive predictive value in older age groups than HCS may be low. A pragmatic limitation of this finding is therefore how to apply it: perhaps it is best interpreted as an indicator of the need to lower the population distribution of multimorbidity as described in Section 8.4.3.

8.5.3 Cross-paper comparison

The comparison of the three papers (Tables 25 and 26) is a source of both strengths and limitations.

Strengths

The major strength of this research is that it uses the same dataset and the same modelling strategy to examine three admission outcomes, allowing them to be compared. This has rarely been done other than with ecological level data, and never for the three admission types considered here. However, the complex data dictated different approaches to the definition of the outcome variables; these required different methods of analysis and in turn produced different measures of association. There are therefore several caveats to the cross-paper comparison.

Limitations

The first of these is the potentially differential effect of death between the admission outcomes summarised in Tables 25 and 26. The papers on readmission and emergency admission examined the admission type *or* death as their outcome. In both, therefore a number of cohort members who died were positive for the outcome although they had not experienced the admission type in question. This excess accounted for 17.6% of those considered positive for the readmission/death outcome and 4.3% of those positive for the emergency admission/death outcome. In contrast, the multinomial paper, from which the summary on elective admission is taken, allocated those who died to the highest of three ordered outcome groups, alongside emergency admissions. Twenty-six people who died after experiencing only elective admissions were therefore excluded from the elective only group. This deficit was small, accounting for 2.3% of those who only ever had elective admissions or died. Overall therefore, the readmissions summary perhaps over represents the effect of mortality in comparison to the other two papers; the summary for emergency admissions includes a small excess due to death and the summary for electives a small deficit.

In addition to those who died without experiencing a readmission or emergency admission, 19.3% of those who were positive for the readmission outcome and 21.0% who were positive for the emergency outcome died *and* experienced the admission type in question. Thus, in total, just over a third of the readmission group and a quarter of the emergency admission group died.

The second limitation to the cross-paper comparison is that the different estimates of association do not allow a quantification of the risk associated with each predictor variable relative to its risk in other admission types, other than by comparing the strength of the statistical associations. Moreover, converting model outputs to risk estimates in relation to risk factor scores (Figures 17 and 18) required different approaches; in the readmissions paper, a probability was derived from the Poisson regression model and in the emergency admissions paper a hazard ratio was derived from the PWP model. Risk factor scores were not applicable to the multinomial model; instead, a regression model was used to estimate the impact of each additional risk factor (Section 8.3.5).

To explore the impact of statistical analysis technique on the final model, Table 30 compares the PWP model for emergency admissions, as summarised in Table 25, with the 'ever emergency or died' group from the multinomial model. Significant associations from the PWP model are shown by filled grey diamonds (for consistency with Table 25), and from the multinomial model by open diamonds. The essential difference between the techniques is that the former captured information from every emergency admission a cohort member had, whilst the latter categorised individuals on the basis of ever having had an emergency admission. Death was included in each of the outcomes, thus the techniques consider the same people positive for the same outcome. The final models differ in just 4 particulars: history of IHD, which predicted admission in men in the PWP model, was not significant in the multinomial regression model; conversely, not owning one's home, history of bronchitis and number of systems medicated achieved significance in women in the multinomial regression that was lacking from the PWP model. Finding few discrepancies between the modelling techniques is reassuring. It confirms the PWP model as the technique of choice in view of its fourfold advantages, namely that it: captures information from every emergency admission a cohort member experiences rather than just the first; reflects increasing risk with accumulated admissions for an individual; excludes time spent in hospital from time at risk of admission; and recognises that times to admission are correlated within an individual's admission history (Westbury *et al.*, 2016)

Table 30 Comparison of methods used to model emergency and elective admission; findings from final (Stage 4) models

Predictor variables	**Emergency**		**Elective**	
	Men	**Women**	**Men**	**Women**
Anthropometric				
Age				□
Height				
Weight				
Weight for height residual				
BMI				
Lifestyle				
Smoking history	◆ ◇	◆ ◇	□	□
High alcohol intake				
Activity score				
Social circumstances				
Social class				
Relationship status			■	
Housing tenure		◇	□	
Physical function				
Grip strength				
Low physical function	◆ ◇	◆ ◇		■
Walking speed				
Fall history				
Morbidity				
Ischaemic heart disease	◆		□	
Stroke				
Hypertension				
Diabetes				
Fracture history				
Osteoarthritis (hand)				
Self-rated health	◆ ◇	◆ ◇	□	■ □
Depression				
Anxiety				
Bronchitis		◇		
Medication	◆ ◇	◇	■ □	■ □

Emergencies:

◆ PWP model

◇ ever emergency group in multinomial model

Electives:

■ only elective group in multinomial model

□ PWP model

Table 30 also compares the ‘only elective’ group in the multinomial model, as summarised in Table 25, with an additional analysis considering elective admission or death as the outcome in a PWP model (Appendix H). Significant associations from the multinomial model are shown by filled grey squares (so that they are again consistent with Table 25), and in the PWP model by open squares. In this case, there is a substantial difference in the information captured: from those who had only elective admissions and did not die on the one hand; and on the other, from every elective admission a cohort member had, irrespective of whether they also had emergency admissions, and from every cohort member who died. Not surprisingly, there are more differences in the final models in this comparison: never having married among men and low physical function among women were significantly associated with elective admission in the multinomial model but not in the PWP model. Conversely, more variables were associated with increased risk of elective admission in the PWP model: history of IHD and low SRH in men; older age in women and smoking in both sexes. Renting one’s home was associated with reduced risk of elective admission among men, suggesting that those who are economically deprived are less likely to seek elective care. Thus the PWP model captures more admissions, among more people, but many of those people also experience emergency admissions. Indeed, the predictors in the final PWP model for elective admission are the same as the final PWP model for emergency admission, but fewer are significant once they are mutually adjusted. This model, although more sophisticated, limits the conclusions that can be drawn about the predictors of elective admission. The use of the multinomial model is therefore justified.

One final limitation inherent in the use of differing techniques is that the PWP model used to summarise risks for emergency admission or death in Table 25 accounts for time at risk of admission or death, whilst the models used for the other outcomes do not. To examine any effect on the results, the readmission and multinomial analyses were repeated, controlling for length of follow-up (not shown). The only apparent difference in these models was that among risk factors for readmission in men, increased age was of borderline significance.

Overall therefore, the limitations in the individual papers and the differences that check their comparability are outweighed by the novelty of the linked dataset and by a design which divides cohort members into contrasting groups according to their admission histories.

8.6 Future research

The methodology and findings of the research described in this thesis have potential for development in several ways.

8.6.1 Data-sharing agenda

A resolution to the access problems currently faced by researchers (Sections 4.10.3 and 8.4.4) is fundamental to *any* future UK work using data linkage. The Digital Economy Act presents an opportunity to address the following issues:

First, to ensure that wherever possible patient consent is the legal basis for data sharing, the validity of consent collected in a manner approved by a Research Ethics Committee in the past needs to be upheld, even if that consent does not meet the more exacting standards of today. Many longitudinal studies are affected by this problem; to deny access to data goes against the spirit of the participants' agreement and the researchers' goodwill. Moreover, it prevents the full exploitation of both cohort and routinely collected data by research organisations that are well regulated and conform to very strict standards of data security and confidentiality. The number and range of outcomes studied in HES data from the Million Women study show how valuable linkage can be (Section 3.2.2). We recognise that some participants may change their mind over issues of consent and we make every effort to retain channels of communication with them (Section 4.10.4); however, this is not always possible, and the current policy adopted by NHS Digital, to err on the side of rejection, seems overly stringent and needs to be discussed.

Secondly, to ensure that data supplied under Section 251 (where patient consent cannot be demonstrated) is a viable source of follow-up, patient opt-outs need to be re-evaluated. The exclusion from such datasets of records for individuals who have opted out of data sharing limits their value, especially if the outcome of interest is rare. Whilst public unease over data sharing is recognised and needs to be addressed, the validity of opt-outs is questionable. Although little publicity has been given to the scheme, there are some GP practices where 100% of patients are opted out, suggesting that the practice is exercising the right on behalf of its patients. Even where the proportion is smaller, it is not clear how much information patients are given in making their decision. This is another issue that needs to be discussed.

Finally, the capacity of organisations tasked with evaluating applications for data needs to match the volume of applications generated by the legislation, be that the existing Health and Social Care Act or the new Digital Economy Act. Five years have passed since the implementation of the 2012 Act; these are not teething troubles.

Data sharing causes concern across the research community (Van Staa *et al.*, 2016), and has been a particularly challenging part of this PhD. The candidate is contributing to the data sharing agenda by representing HCS on the CLOSER (Cohort and LOngitudinal Studies Enrichment Resources) collaboration, and is involved in CLOSER's consultations with NHS Digital about data sharing and with government over the Digital Economy Act. The purpose of CLOSER is to share knowledge between studies: with Children of the 90s (University of Bristol), HCS is leading a work package on linkage with HES data, the primary publication from which is in press (Boyd *et al.*, 2018). If the problems encountered can be resolved, the work described in this thesis could be developed in HCS as suggested below.

8.6.2 Follow-up into advanced old age

The principal advantage of HES as a source of follow-up data in an ageing cohort is that they are almost attrition-proof: neither failing health nor moving to a care setting prevents the accumulation of information if no contact is required between researcher and participant. The data on which this thesis draws relate to the period between HCS baseline and March 2010, at which point the participants were aged 71-79. No further data have been acquired during the intervening years, though HES will have been accruing on participants who are now aged 79-87. At least 500 cohort members are known to have died since 2010 and the likelihood is that rates of hospitalisation have risen substantially; linkage of these additional data with HCS would provide an immediate source of information about service use and diagnoses at advancing ages. With a clear regulatory framework in place, further data could be acquired annually to examine the patterns and predictors of hospital use among the oldest-old.

8.6.3 Patterns of hospitalisation in later life

A history of recent hospitalisation was identified by the literature review as a predictor of readmission and emergency admission but has not been investigated in this thesis. However, the complex dataset could be used, especially if expanded into older age, to study patterns of hospitalisation in later life. Previous research has demonstrated that hospital use is concentrated in the few years before death, irrespective of the age at which death occurs (Werblow *et al.*, 2007), leading to claims that population ageing will not increase healthcare costs. However, the expansion of morbidity, combined with the crisis in social care may undermine this argument. It seems possible that periods of intense hospital use may precede changes other than death, for example a move from community to care home. Admission source and discharge destination could be used to investigate this in an expanded dataset.

Such a dataset could also be used to explore how admissions of different sorts are related in an individual. Section 2.2.2 outlined the existence of disability thresholds in the lifecourse model; it is possible that hospitalisation thresholds exist in parallel, perhaps ranging from a predominantly elective admission threshold to a predominantly emergency admission threshold, with readmissions characterising the last years of life. Such a model might allow a pattern of admissions to be identified that marks the beginning of a period of intense hospital use and signals the need for intervention. The extent of alterations in the relationship between morbidity and hospitalisation when an acute condition develops could also be explored in the light of other predictors; it may be, for example, that those living in rented accommodation are less likely to be cared for at home.

8.6.4 Other cohorts

One of the weaknesses identified above was that whilst mutually adjusted analyses identified which of the predictor panel variables were associated with admission, they did not allow a causal sequence to be identified among them. A path through morbidity was initially hypothesised (Figure 6) and, in the light of the findings, was adapted to recognise the importance of multimorbidity (Figure 19). However, since all the predictor variables were measured simultaneously, this was purely pragmatic. A beneficial development of the work might therefore be to carry out structured mediation analyses formally to test the relationships observed. This would require frequent, cohort-wide longitudinal follow-up of predictor variables, data which are unavailable in HCS. Other longitudinal data would therefore be required, such as those collected by the English Longitudinal Study of Ageing.

Extending the work to other cohorts would allow differential risk factors to be investigated. For example, baby boomers have higher and less socially stratified levels of obesity than previous generations (Davies, 2015); this might alter the balance of risk factors for hospitalisation among them.

Linkage in other cohorts might also be used to confirm the sex differences in predictive potential of SRH and NSM. Whilst the magnitude of difference is equivocal, these are interesting findings for which plausible explanations have been advanced. Due to these doubts and to their novelty, they require replication.

8.7 Conclusions

The National Health Service is struggling to cope with the current demand for hospital care, especially from older people (Iacobucci, 2017b); wider understanding of the causes of hospitalisation is required. The research presented in this thesis successfully linked data from the Hertfordshire Cohort Study with routinely collected Hospital Episode Statistics to create an individual level dataset in which to explore the antecedents of hospital admission. This is a major contribution of the research.

The three papers presented in this thesis each compared a common panel of participant characteristics as potential predictors of a primary admission outcome: readmission within 30 days; emergency admission; or elective admission. Two characteristics, poor self-rated health and increased number of systems medicated, were key common drivers of all admission types; in addition, poor SF-36 physical function and history of smoking were common drivers of two admission types each. Some sex differences were observed; self-rated health was a better predictor of admission risk in women whilst number of systems medicated was more important in men. With reference to admission type, self-rated health was the best predictor of emergency admission and number of systems medicated the best predictor of elective admission; both variables were associated with readmission.

The policy implications of this work are that older people at highest risk of admission could be identified prospectively in a primary care setting; screening for poor SRH and a high number of systems medicated is suggested as an area of focus in revising the Quality and Outcomes Framework (Marshall and Roland, 2017). This would enable the finite resources available for healthcare to be targeted efficiently. Meanwhile, Public Health departments should seek to decrease risk profiles in younger generations and thus increase healthy life expectancy (Government Office for Science, 2016). In addition, Government need to use the Digital Economy Act to address the access problems that beset research of this nature; through its interpretation of the law, NHS Digital is preventing the very research it was intended to facilitate. Cohort studies are a rich resource accrued over many years; like administrative data they have been collected at public expense; this thesis has shown that together the datasets are more valuable than either in isolation. A fresh policy perspective on data sharing is urgently required in England.

Appendices

Appendix A Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study

The paper reproduced in this appendix has been written and published whilst a candidate for the degree of MPhil/PhD at the University of Southampton:

Simmonds SJ, Syddall HE, Walsh B, Evandrou M, Dennison EM, Cooper C, Aihie Sayer A. (2014) Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study. Age Ageing, 43, 653-660

Although it broadly summarises Sections 4.1 - 4.5 of this thesis, please note that the start of the follow-up period is defined in the paper by the date of the baseline home interview. This contrasts with the thesis, which takes the date of the baseline clinic as the start of follow-up. This explains apparent discrepancies in the numbers of admissions between Figure 1 of the paper and Figure 9 of the thesis, and in rates of admissions between Figure 2(a) of the paper and Figure 10 of the thesis.

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Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study

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Appendix A

Abstract

Background

Concern over the sustainability of the National Health Service is often focussed on rising numbers of hospital admissions, particularly among older people. Hospital admissions are enumerated routinely by the Hospital Episode Statistics (HES) Service, but published data do not allow individual level service use to be explored. This study linked information on Hertfordshire Cohort Study (HCS) participants with HES inpatient data. with the objective of describing patterns and predictors of admissions among individuals.

Methods

2997 community-dwelling men and women aged 59-73 years completed a baseline HCS assessment between 1998 and 2004; HES and mortality data to 31/03/2010 were linked with the HCS database. This paper describes patterns of hospital use among the cohort at both the admission and individual person level.

Results

The cohort experienced 8741 admissions; rates were 391 per 1000 person-years among men (95%CI 380, 402) and 327 among women (95%CI 316,338), p<0.0001 for gender difference. 1187 men (75%) and 981 women (69%) were admitted to hospital at least once; among these, median numbers of admissions were 3 in men (IQR 1,6) and 2 in women (IQR 1,5). 48% of those ever admitted had experienced an emergency admission and 70% had been admitted overnight.

Discussion

It is possible to link routinely collected HES data with detailed information from a cohort study. Hospital admission is common among community dwelling ‘young-old’ men and women. These linked datasets will facilitate research into lifecourse determinants of hospital admission and inform strategies to manage demand on the National Health Service.

Keywords: hospital admissions, older people, hospital episode statistics, data linkage, healthcare burden

Key points:

- Concern over the sustainability of the National Health Service is focussed on rising numbers of hospital admissions, particularly among older people.
- We have shown that it is possible to link routinely collected HES data with detailed information collected as part of a cohort study
- Hospital admission is common among community dwelling ‘young-old’ men and women.
- These linked datasets will facilitate research into lifecourse determinants of hospital admission and inform strategies to manage demand on the National Health Service.

Appendix A

Introduction

The House of Lords' recently published 'Ready for Ageing?' report [1] follows a succession of publications emotive in their concern about the effect of rising hospital admissions on the National Health Service (NHS). It has been suggested that hospitals are *'on the edge'* [2] and that admissions are *'out of control'* [3]. The 'Ready for Ageing?' report suggested that the burden from long term conditions associated with an ageing population may underlie these trends in hospital admissions. Furthermore it proposed that intervention by improved community services earlier in the disease process could circumvent unnecessary admissions and prevent *'older people drifting into hospital avoidably'*, and concluded that the NHS needs to transform to cope with increasing demand and at the same time improve quality of care. However the emphasis was on managing long-term conditions rather than preventive strategies: it did not consider the lifecourse determinants of hospital admission [1].

Clinical and administrative details of inpatient admissions and outpatient appointments at NHS hospitals in England are collected routinely by the Hospital Episode Statistics (HES) service [4]. They are used in a wide range of healthcare analyses and are important in informing policy on health and social care. They show a rise in the number of inpatient admissions between 2000/01 and 2010/11 focused in the oldest age groups, for example by 33% at 65-74, 45% at 75-84 and 48% at 85+ [5]. A projected increase in the proportion of older people aged 65+ from 17% of UK population in 2010 to 23% in 2035 [6] will increase the number of admissions further.

However these routine data cannot be used to identify patterns and determinants of admissions in individuals. Linkage of HES data with a well-characterised birth cohort study would enable investigation of lifecourse determinants of hospital admission. Only one UK cohort study (the Paisley Renfrew Study [7]) has previously been linked with HES data, but follow-up with regard to hospital admissions ceased in 1995. In the context of recent rises in hospital admissions and a growing awareness of the implications of an ageing population, an update of this research is long overdue.

Between 1998 and 2004, 2997 community-dwelling men and women aged 59-73 years participated in the baseline phase of the Hertfordshire Cohort Study during which their health, lifestyle and socioeconomic characteristics were assessed [8]. We have linked the HCS database with HES records for the study participants to the end of March 2010, thereby yielding a novel and important resource for research into the lifecourse determinants of hospital admission. This paper outlines the process of data linkage and describes patterns of hospital use among the cohort at both the admission and individual person level.

Materials and methods

The Hertfordshire Cohort Study

The Hertfordshire Cohort Study comprises a group of men and women born in that county between 1931 and 39 whose birth, infancy and early childhood were documented by Health Visitors. 1579 men and 1418 women who still lived in Hertfordshire between the end of 1998 and 2004 were interviewed at home and subsequently attended clinics for detailed physiological investigations. These included anthropometry, spirometry, ECGs and blood tests for assessment of cardiovascular and genetic risk. Subsamples underwent a battery of tests of physical performance, DXA scans and knee x-rays. Combining details from the health visitors' records, information from the interview and measurements made in clinic produced a social and biological lifecourse overview for each individual at baseline. Methods have been described in more detail elsewhere, and the representativeness of the cohort to older people in England has been assessed [8].

Linkage with HES data

The Hertfordshire Cohort Study fulfils the two important prerequisites for linkage with HES data. First, NHS number is recorded and cross-referenced with the internal serial number. It is used purely for tracking participants, who are flagged for continuous notification of death on the Central Register at the NHS Information Centre, and is never included in analysis files.

Secondly, participants gave signed consent for the investigations they underwent in clinic and (on the same form) for researchers to access their medical records in the future. Permission to obtain a HES extract for HCS participants covering the period 01/04/98-31/03/10 was granted by the Ethics and Confidentiality Committee of the National Information Governance Board

HES Records

A hospital episode is a period of care under one consultant, several of which may be recorded during the period between admission and discharge. The HES data obtained for linkage with HCS comprised 15 variables for each episode experienced by a member of the cohort (HES ID and NHS numbers; gender; date, method and source of admission; date and destination at discharge; main specialty; primary and other diagnoses coded to ICD-10 [9]; and primary and other procedures coded to OPCS-4 [10]).

Data were prepared for analysis in two stages and as illustrated in figure 1. First, admission and discharge dates were checked for chronological consistency within and between episode records for the same individual. Common discrepancies included discharge dates that were missing, that preceded the admission date of the same episode, or that succeeded the admission date of a subsequent one. Second, validated consecutive or concurrent episodes were collapsed into one completed admission record, all contributing diagnosis and procedure codes being retained. A total of 8741 admissions was identified among 2168 HCS participants after their date of HCS baseline but before 31/3/10; 829 had no admissions. Mortality data from the NHS Central Register were dovetailed with the combined HCS and HES admissions databases; 275 members of the cohort died during the follow-up period, 19 without admission, 127 during an admission and 129 after being discharged alive. Records relating to the same individual were brought together to create a personal admissions history alongside details of death where appropriate.

Statistical methods

Data were described at both the admissions and individual levels using means and standard deviations (SD), medians and inter-quartile ranges (IQR) and frequency and percentage distributions. Admission rates were calculated per 1000 person/years according to gender and age groups. All analyses were carried out using Stata 12.1 [11].

Results

Characteristics of admissions

Of 8741 admissions accrued by members of the cohort, 5183 (59%) involved a male patient, 6504 (74%) were elective and 5057 (58%) were day cases. Only 13% lasted more than one week. The median length of stay amongst all admissions was 1 day (IQR 1-4); among overnight admissions it was 5 days for both genders, (IQR 2-9 in men and 3-9 in women). In 98% of admissions patients came from and/or returned to their usual residence. General surgery (n=1257) and general medicine (n=1119) accounted for larger proportions of admissions than any other specialty (14 and 13% respectively). At least one surgical procedure was carried out during 6622 (75.8%) of the admissions; the most common being endoscopy of the bladder, endoscopy of upper GI tract, cataract surgery, angiography, knee replacement and hip replacement in 468, 454, 385, 350, 176 and 174 admissions respectively.

Rates of admission

Overall rates of admission per 1000 person-years across the follow-up period were 391 among men [95%CI 380,402] and 327 among women [95%CI 316,338], $p<0.0001$ for gender difference. Figure 2 shows rates of admission by year, gender and age group; rates of admission increased significantly over time irrespective of adjustment for gender and age ($p<0.001$ for all).

Patterns of admission at the individual person level

75% (1187) men and 69% (981) women were admitted to hospital at least once during the follow-up period. Figure 3(a) shows the percentage distribution of number of admissions experienced, by gender. Among those who were admitted at least once, the median number of admissions was 3 (IQR 1-6) among men, and 2 (IQR 1-5) among women, with maxima of 34 in men and 56 in women. Nearly half (48%) of those ever admitted had experienced an emergency admission (figure 3b), and over two-thirds (70%) had been admitted overnight at least once (figure 3c). Overall, ever admitted men spent a median of 8 days (IQR 3-22) in hospital during the follow-up period and ever admitted women a median of 6 days (IQR 2-16). High total days' stay resulted from both frequent day case admissions (eg for procedures such as haemodialysis or blood transfusions) and fewer long ones (eg for diagnoses such as mental illness).

Figure 3(d) shows the proportion of the overall cohort experiencing an admission by ICD chapter of primary diagnosis. Men most commonly experienced admissions coded to chapter R (signs and symptoms), chapter K (digestive disease) and chapter I (cardiovascular disease). Among women, the equivalent ranking for frequency of occurrence of admissions involving specific ICD-10 chapters was first, chapter K (digestive disease); followed by chapter M (musculoskeletal disease), and chapter R (signs and symptoms).

1992 (91.9%) of ever-admitted cohort members had at least one surgical procedure carried out during an admission, the most common being endoscopy of the upper GI tract, angiography, cataract surgery, endoscopy of the bladder, knee replacement and hip replacement in 345, 303, 262, 225, 148 and 136 people respectively.

Deaths among cohort members

275 members of the cohort died during the follow-up period; 189 (12%) men and 86 (6.1%) women. 19 deaths (11 men and 8 women) occurred among people who had no admissions, 127 (89 men and 38 women) during an admission and 129 (89 men and 40 women) after being discharged.

Discussion

We have shown that it is possible to link routinely collected HES data with detailed information collected as part of a cohort study. Hospital admission is common among community-dwelling men and women in early old age; 75% of men and 69% of women were admitted to hospital at least once during the 10-year follow-up period. Presence of co-morbidity is common in early old age [12], and this paper suggests that the burden of ill-health translates into substantial NHS service use. A healthy responder bias was apparent in HCS [8], a study based in the relatively affluent South East of England: for these reasons the healthcare burden of the ageing national population is likely to be even greater than these data suggest.

HCS is the first English cohort study to use record linkage to identify individual-level longitudinal patterns of service use among a group of well-characterised individuals. The facility to link individual-level admissions episodes within HES data has been used infrequently; linkage with outside sources (eg the National Joint Registry [13], a cancer registry [14;15], or the General Practice Research Database [16]) is rarer still. The Oxford Record Linkage Study (ORLS) is an example of a study which has linked births, deaths and hospital admissions at the individual level [17-20]; however, the ORLS was not able to consider individual level characteristics other than those recorded routinely.

In Scotland record linkage is routine [21]. Maternity records and births, cancer registrations, hospital discharges and deaths are permanently linked. This fact has been exploited by a group of cohorts collectively known as MIDSPAN studies [7]; three samples originally screened in middle age in the 1960s and 70s, along with a fourth comprising their offspring. The Paisley Renfrew study is one of them, and comprises over 15 000 men and women sampled from the population of two industrial towns in central Scotland whose health profile was characterised at age 45-64. Follow-up of hospital admissions was reported to 1995 [22;23], by which time 79% of the cohort had experienced at least one, and an average of 4.6 admissions over a 23 year period. The study concluded that a high proportion of hospital days accrued near the time of death and that the absolute demand for hospital services was 'strikingly large and increasing over time'. This study demonstrated that baseline lung function, BMI and deprivation were important predictors of subsequent admission. Patterns and predictors of hospital admissions have not been reported since 1995.

Our study had some limitations: first, doubts have been expressed over both case ascertainment and coding accuracy in Hospital Episode Statistics and errors have been shown to exist, including adults apparently treated in paediatrics, children in geriatrics and men in obstetrics and gynaecology [24]. Given that 17.5 million finished consultant episodes were recorded during 2011-12 [4], some mistakes are hardly surprising. Furthermore, case ascertainment has been compared with a number of source registers, for example the 'yellow-card' system for reporting adverse drug reactions [25], police statistics on road traffic accidents [26] and cancer registry data [27] and in general, HES have been found to be the more complete. In addition, discharge coding accuracy was assessed in a systematic review published in 2011, which reported an improvement since payment by results was introduced in 2002 and found the accuracy of the primary diagnostic code to be 96.0% (IQR 89.3-96.3). The authors concluded that routinely collected data are sufficiently robust for research and managerial decision making [28].

Secondly, a healthy responder bias has been described in HCS and the study was conducted in the relatively affluent southeast of England [8]. However the demographic, social and medical characteristics among HCS participants have been shown to be broadly comparable with those in the nationally representative Health Survey for England [8].

Our study also had many strengths. First, the data used were collected routinely by the Hospital Episode Statistics service for England. They cover all patients treated in NHS hospitals however funded, and NHS patients treated in private hospitals. Only privately funded patients attending private hospitals and those treated outside England are excluded. Secondly, HES data have the advantage that they are not subject to the effects of attrition of the sickest members of the cohort. Response bias, which is introduced if the least healthy individuals are selectively lost to follow-up, is a particular problem among ageing cohorts [29]. HES data accrue for all members of the cohort, whether they live independently or not, and irrespective of cognitive ability. Thirdly, continued follow-up through hospital admissions into advanced old-age is possible; a new data linkage service [30] launched by the NHS Information Centre in September 2012 should streamline the process. Finally, older people differ in the use they make of hospital services, and whilst some experience many admissions, others need none at all. It is possible to link records within HES to produce individual histories that differentiate those with many admissions from those with few, but people with no admissions clearly generate no records and would thus be omitted from such linked data. Linkage with the Hertfordshire Cohort Study enables individuals who experienced hospital admission to be contrasted with those who did not.

In summary, we have shown that it is possible, with appropriate consents, to link routinely collected HES data with the detailed information collected as part of a cohort study. Moreover, we have shown that hospital admission is common among community-dwelling young-old men and women. Given the current level of concern about the sustainability of the NHS in the face of an ageing population, the linked HCS/HES database represents an important resource for research into lifecourse determinants of hospital admission. The potential of the linked dataset extends beyond the descriptive results presented in this paper and offers the opportunity to identify social, biological and medical predictors of admission. This research will inform strategies called for by the House of Lords to manage demand on the NHS.

Appendix A

References

1. House of Lords Select Committee on Public Service and Demographic Change. Ready for Ageing. HL Paper 140. 2013. Stationery Office.

2. Royal College of Physicians. Hospitals on the edge? The time for action. 2012. London, Royal College of Physicians.

3. Robinson P. Are hospital admissions out of control? 2010. Alcester, CHKS.

4. HESonline. Headline Figures, 2010-11. 2012. NHS Information Centre for Health and Social Care. http://www.hscic.gov.uk/hes accessed 29/08/13

5. NHS Information Centre. Elderly people account for bigger proportion of NHS hospital activity every year, report shows. accessed 10/05/12 - content no longer available.

6. Office for National Statistics. Population ageing in the United Kingdom its constituent countries and the European Union. 2012. London, Office for National Statistics.

7. Hart CL, MacKinnon PL, Watt GCM et al. The Midspan studies. Int J Epidemiol 2005;34:28-34.

8. Syddall HE, Aihie Sayer A, Dennison EM, Martin HJ, Barker DJP, Cooper C. Cohort Profile: The Hertfordshire Cohort Study. Int J Epidemiol 2005;34:1234-1242.

9. World Health Organisation. International Classification of Diseases (ICD). 2011.

10. Health and Social Care Information Centre. OPCS-4 classification. 2013.

11. Statacorp. Stata Statistical Software Release 10. College Station TX: Statacorp LP; 2007.

12. Pierce MB, Silverwood RJ, Nitsch D *et al*. Clinical disorders in a post war British cohort reaching retirement: evidence from the first national birth cohort study. PLoS one 2012;7:e44857.

13. Stafford G, Charman S, Borroff M, Newell C, Tucker J. Total hip replacement for the treatment of acute femoral neck fractures: results from the National Joint Registry of England and Wales at 3-5 years after surgery. Ann R Coll Surg Engl 2012;94:193-198.

14. Maddams J, Utley M, Moller H. A person-time analysis of hospital activity among cancer survivors in England. Br J Cancer 2011;105:S38-S45.

15. Downing A, Wilson R. Older people's use of accident and emergency services. Age Ageing 2005;34:24-30.

16. van Staa T, Patel D, Gallagher A, de Bruin M. Glucose-lowering agents and the patterns of risk for cancer: a study with the General Practice Research Database and secondary care data. Diabetologia 2012;55:654-665.

17. Acheson ED, Evans JG. The Oxford Record Linkage Study: A review of the method with some preliminary results. Proc R Soc Med 1964;57:269-274.

18. Goldacre MJ, Ferguson JA. In-patient workload in medical specialties: 1. Demographic profiles and time trends from linked statistics. QJM 1995;88:649-659.

19. Ashton CM, Ferguson JA, Goldacre MJ. In-patient workload in medical specialties: 2. Profiles of individual diagnoses from linked statistics. QJM 1995;88:661-672.

20. Goldacre MJ, Ferguson JA, Welch A, Kettlewell MGW. Profiles of workload in general surgery from linked hospital statistics. Br J Surg 1993;80:1073-1077.

21. Kendrick S. The Scottish Record Linkage System. 2012. Information Services Division (ISD) NHS Scotland.

22. Hanlon P, Walsh D, Whyte BW, Scott S, Lightbody P, Gilhooly MLM. Hospital use by an ageing cohort: an investigation into the association between biological, behavioural and social risk markers and subsequent hospital utilization. J Public Health Med 20, 467-476. 1998.

23. Hanlon P, Walsh D, Whyte BW, Scott SN, Lightbody P, Gilhooly MLM. The link between major risk factors and important categories of admission in an ageing cohort. J Public Health Med 2000;22:81-89.

24. Brennan L, Watson M, Klaber R, Charles T. The importance of knowing context of hospital episode statistics when reconfiguring the NHS. BMJ 2012;344:2432.

25. Barrow P, Waller P, Wise L. Comparison of hospital episodes with 'drug-induced' disorders and spontaneously reported adverse drug reactions. Br J Clin Pharmacol 2006; 61:233-237.

26. Gill M, Goldacre MJ, Yeates DG. Changes in safety on England's roads: analysis of hospital statistics. BMJ 2006;333:73-75.

27. Moller H, Richards S, Hanchett N *et al*. Completeness of case ascertainment and survival time error in English cancer registries: impact on 1-year survival estimates. Br J Cancer 2011;105:170-176.

28. Burns EM, Rigby E, Mamidanna R *et al*. Systematic review of discharge coding accuracy. J Public Health 2011;34:138-148.

29. Howe LD, Tilling K, Galobardes B, Lawlor DA. Loss to follow-up in cohort studies. Bias in estimates of socioeconomic inequalities. Epidemiol 2013;24:1-9.

30. Data Linkage Service. Health and Social Care Information Centre http://www.hscic.gov.uk/dles accessed 29/08/13.

Appendix A

Figure 1: Study Structure

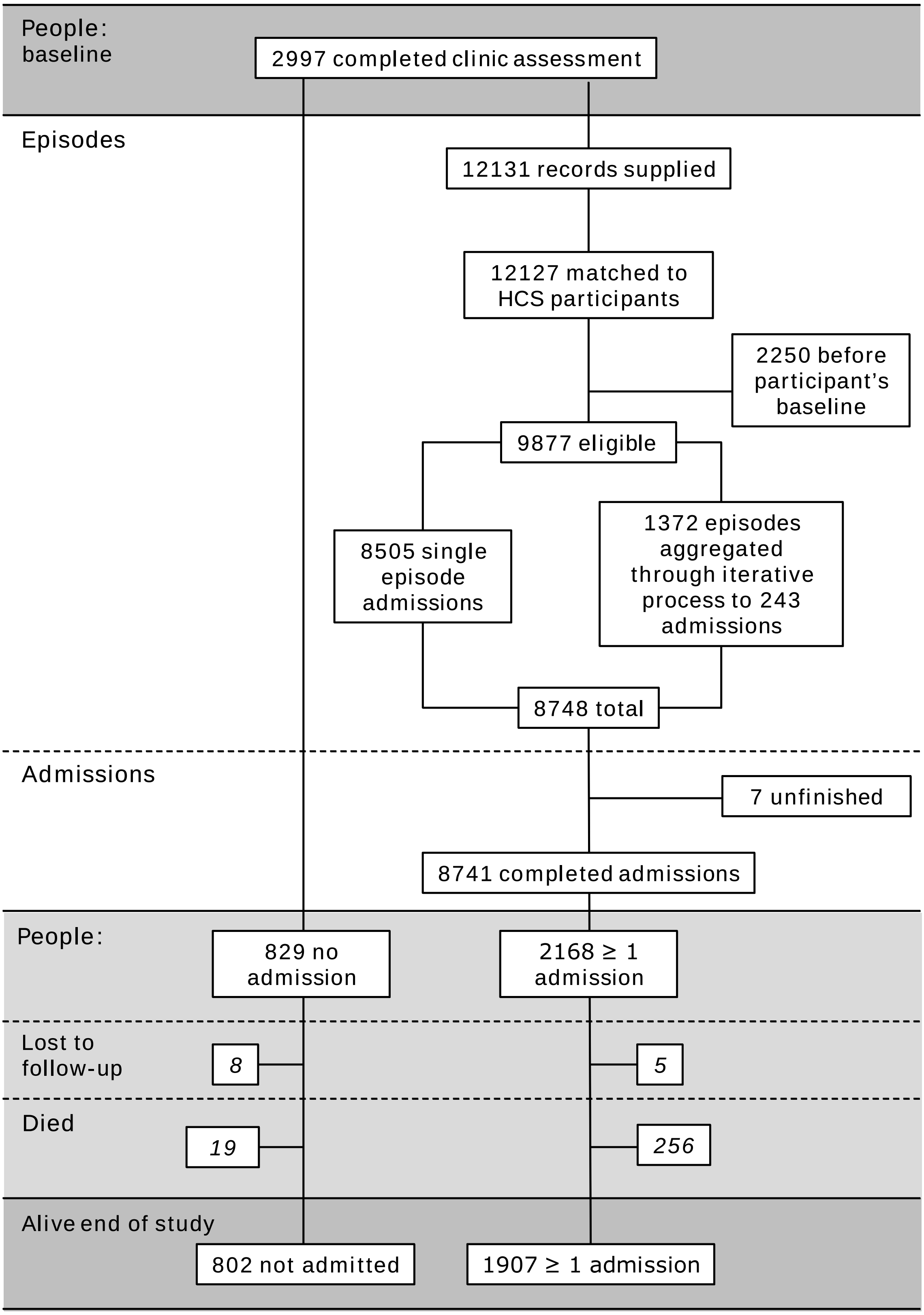
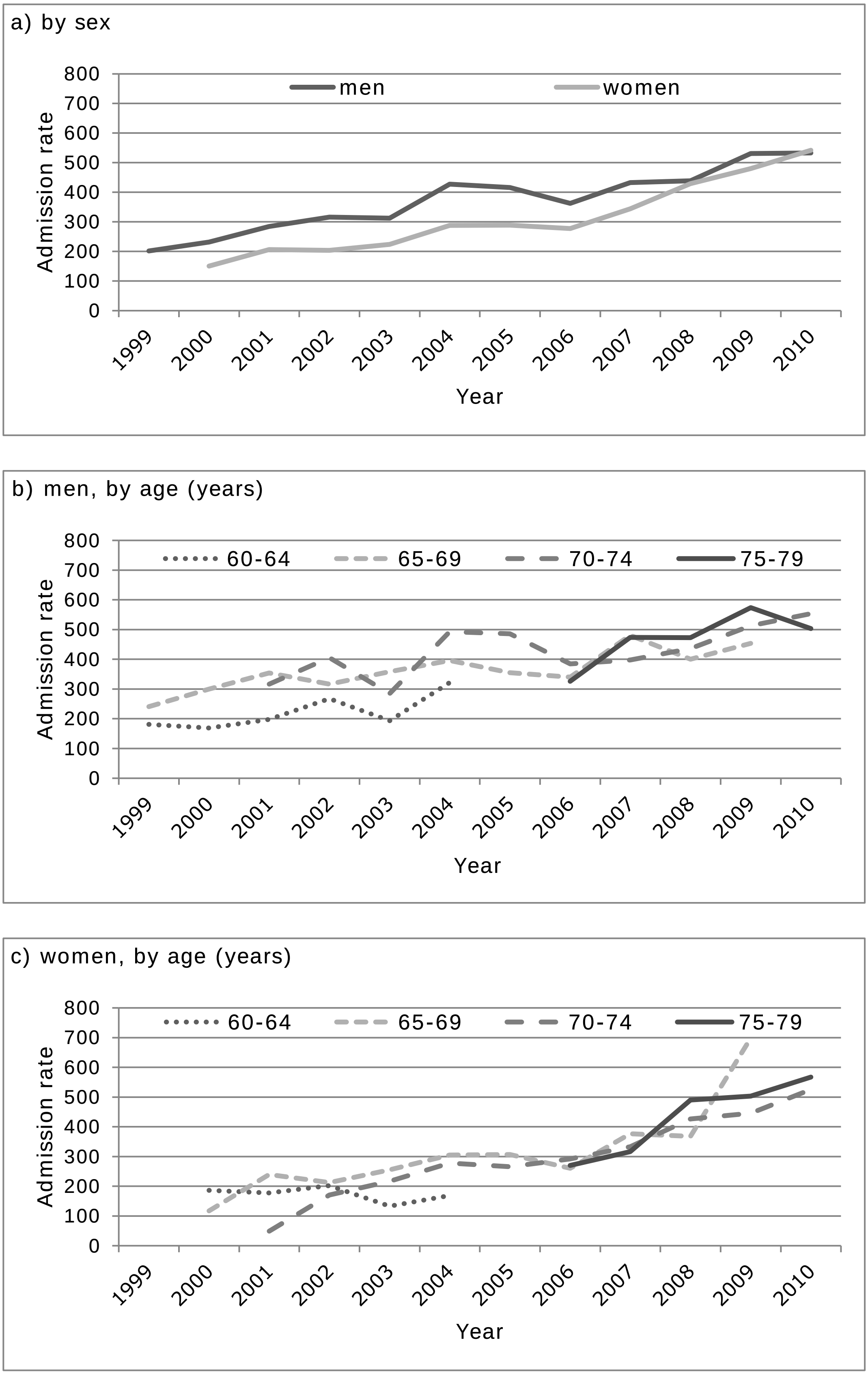
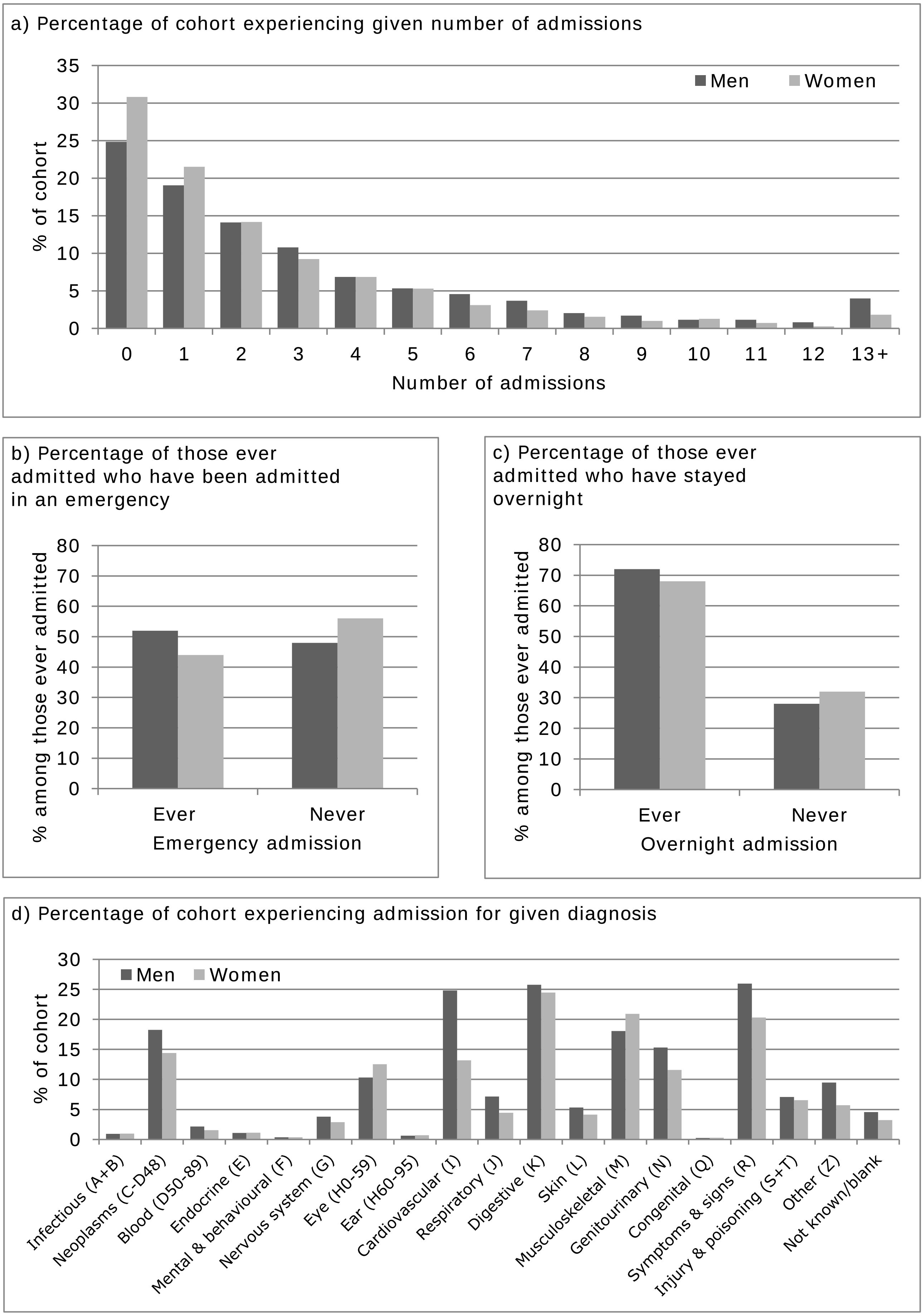


Figure 2: Rates of admission per 1000 person years, 1999-2010



Appendix A

Figure 3: Individual level admissions characteristics



Appendix B File preparation: technical information

This appendix contains information to supplement Section 4.3. It describes how episode level data were cleaned and combined to produce admissions level data (Section B1); how admissions of different types were identified (Section B2); and how the data were brought together to produce admission histories in two formats and so to facilitate a variety of analyses (Section B3).

B1. Data cleaning

The HES extract obtained for the purposes of this research contained a total of 12,131 episodes, of which 12,127 were successfully matched to HCS participants by NHS number. 2,250 episodes were identified that preceded individuals' baseline home interviews and were excluded from the analysis. The remaining 9,877 episodes were combined into admissions level data by first, carrying forward 8,505 single-episode admissions that required no further cleaning, and then by attending to inconsistencies among the 1,372 episodes that contributed to multi-episode admissions. Two problems were particularly common:

i) Overlapping dates of two or more episodes (1,005 episodes)
ii) Absent discharge destination (905 episodes)

In 538 episodes these problems coexisted. Concurrent or consecutive episodes were combined using a computer algorithm where less than four episodes were involved, and by a manual two-person review of those that remained. This process yielded a further 243 admissions which, with the 8,505 single-episode admissions, totalled 8,748. Seven admissions were ongoing at the end of the study and were excluded, along with 54 admissions that occurred between participants' home interview and clinic dates. Thus 8,687 eligible admissions were identified between participants' dates of clinic attendance and the end of March 2010, and were organised into a coherent, chronologically correct list of admissions for each cohort member (See also Figure 9).

Individual histories in the file were completed by the addition of dummy records for 836 people who had no admissions during the follow-up period. Date and cause of 275 deaths that occurred between baseline and study end were coded from certificates supplied by NHSCR and appended to the relevant histories. Twenty-one deaths occurred among people who had no admissions, the remainder of those who died had been admitted at least once.

Checks were carried out at all stages to ensure the logical consistency of the data file, for example that admission preceded discharge; that fields reported by both HES and HCS matched; and that no HES events occurred after a date of death. Further checks were made on the validity of the data, for example that ICD-10 and OPCS-4 codes reported mapped to the coding manual and that ranges of values were credible and without outliers. Minor alterations were made to the file as a result. No names were ever stored in conjunction with HES data. The final analysis file contained 9,523 records relating to 2,997 people. 8,687 admissions arose from 2,161 people, whilst 836 had none.

B2. Classification of admissions by type

Fields from the HES record (Table 6) were used to classify each admission to type. Elective and emergency admissions were defined by the admission method of their first episode; readmissions were flagged according to the lag between one date of discharge and the next date of admission in an individual's history. Start and end dates were drawn from the beginning of the first episode and the end of the last for multiple episode admissions.

B3. File formats

To prepare for analysis in STATA (StataCorp, 2013), dates were formatted to elapsed days since 01/01/60 and variables were given suitable labels. Each admission occupied one row in the file, and was brought together with other rows for the same individual to form an admissions history. Figure B1(a) provides an example using 7 records for 5 individuals, identified by the unique 'abserno' in the first column. One of them (abserno 335023) had three admissions, two (055313 and 105015) had one each, and the others had none. Date of death (contracted to d~h on the printout) was merged from separate mortality records. It may be associated with an admission, as in the case of 105015, occur without admission (135999), or follow some time after the last discharge (335023). Note also the blank row for 445032: an individual who had no admissions and did not die, but whose baseline data have been incorporated into the file.

(a)

abserno	admidate	disdate	dateofd~h	admimeth	diag1	opertn1
55313	06apr2006	09apr2006	.	Planned	N811	P231
105015	08jan2006	22jan2006	22jan2006	Emergency	N19X	X339
135999	.	.	23jul2007	.		
335023	08may2003	27may2003	27mar2004	Emergency	C712	
335023	24jun2003	05jul2003	27mar2004	Emergency	L270	
335023	28feb2004	15mar2004	27mar2004	Emergency	C712	L634
445032	.	.	.	.		

(b)

abserno	hcsdoi	start	end	admiss~n	admimeth	death	dateofd~h	status	lossdate
55313	23mar2001	23mar2001	06apr2006	1	Planned	0	.	Alive	31 Mar 10
55313	23mar2001	09apr2006	31mar2010	0	.	0	.	Alive	31 Mar 10
105015	15dec2000	15dec2000	08jan2006	1	Emergency	1	22jan2006	Dead	22 Jan 06
135999	24jan2000	24jan2000	23jul2007	0	.	1	23jul2007	Dead	23 Jul 07
335023	20jun2001	20jun2001	08may2003	1	Emergency	0	27mar2004	Dead	27 Mar 04
335023	20jun2001	27may2003	24jun2003	1	Emergency	0	27mar2004	Dead	27 Mar 04
335023	20jun2001	05jul2003	28feb2004	1	Emergency	0	27mar2004	Dead	27 Mar 04
335023	20jun2001	15mar2004	27mar2004	0	.	1	27mar2004	Dead	27 Mar 04
445032	17oct2000	17oct2000	31mar2010	0	.	0	.	Alive	31 Mar 10

Figure B1 (a) Admissions file, showing 7 records generated by 5 admissions among 5 individuals. (b) Survival file, showing 9 periods at risk resulting from 7 records for 5 admissions among the same 5 individuals.

Admissions histories were converted to survival format data to enable calculation of standardised admission rates and PWP modelling. The first record in the survival formatted history began on the baseline interview date (hcsdoi) and ended with admission, death or the end of study (31/03/10). In the case of an admission, a second interval followed from the date the patient was discharged from hospital, and therefore once again at risk of admission, with the same possible endpoints. Figure B1(b) shows survival time data derived from the same exemplar records. Seven records among 5 people generated 9 intervals at risk: in the whole cohort, 9,523 records among 2,997 people generated 11,555 intervals.

Appendix C Admissions for common diagnoses and procedures, by admission type

This two-part appendix contains cohort-level information to supplement Section 4.4.1. Table C(i) shows, for the diagnoses that occurred most frequently across all admissions, the number of elective and emergency admissions accrued by the cohort. Table C(ii) shows the same information for the procedures that were carried out most frequently across all admissions.

Table C(i) Number of admissions for common diagnoses, by admission type

Condition	ICD 10	Admission type								
		Elective			Emergency			All		
		Men	Women	Total	Men	Women	Total	Men	Women	Total
Ischaemic heart diseases	I20-I25	216	76	292	127	44	171	347	120	467
Disorders of lens	H25-H28	170	225	395	-	-	-	170	225	395
Symptoms and signs of the circulatory and respiratory systems	R00-R09	58	50	108	136	143	279	196	193	389
Other diseases of intestines	K55-K63	168	154	322	26	40	66	194	194	388
Arthrosis	M15-M19	186	200	386	-	1	1	186	201	387
Persons attending for examination and investigation	Z00-Z13	254	72	326	5	7	12	259	79	338
Diseases of oesophagus, stomach and duodenum	K20-K31	145	138	283	24	7	31	169	145	314
Malignant neoplasms of digestive organs	C15-C26	185	80	265	22	7	29	207	87	294
General symptoms and signs	R50-R69	74	61	135	93	60	153	170	122	292
Other diseases of urinary system	N30-N39	171	85	256	21	11	32	192	96	288
Other forms of heart disease	I30-I52	97	47	144	95	36	131	192	83	275
Symptoms and signs involving the digestive system and abdomen	R10-R19	47	60	107	60	47	107	10	107	214
Hernia	K40-K46	147	49	196	6	10	16	153	59	212
Symptoms and signs involving the urinary system	R30-R39	102	41	143	42	8	50	145	49	194
Malignant neoplasms of lymphoid and related tissue	C81-C96	35	120	155	5	14	19	40	134	174
Other soft tissue disorders	M70-M79	47	33	80	34	31	65	81	64	145
Complications of surgical and medical care	T80-T88	42	31	73	27	30	57	70	61	131
Chronic lower respiratory diseases	J40-J47	3	1	4	57	17	74	60	18	78
All cancers	C00-C97	592	385	977	93	52	145	687	438	1125

Table C(ii) Number of admissions for common procedures, by admission type

Procedure	OPCS 4	Admission type								
		Elective			Emergency			All		
		Men	Women	Total	Men	Women	Total	Men	Women	Total
Endoscopy of bladder	M45	387	70	457	6	1	7	393	7	464
Endoscopy of upper GI tract	G45	201	223	424	15	8	23	216	231	447
Cataract surgery	C71 C72 C74 C75	164	221	385	-	-	-	164	221	385
Angiography	K63 K65 U102 U105	204	109	313	28	7	35	234	116	350
Knee replacement	W40 W41 W42	80	94	174	1	-	1	81	94	175
Hip replacement	W37 W38 W39 W93 W94 W95	86	68	154	8	2	20	94	80	174
Hernia repair	T19 T20 T21	113	9	122	1	1	2	114	10	124
Angioplasty	K49 K50 K75	44	15	59	24	5	29	69	20	89
Bypass surgery	K40 K41 K42 K43 K44 K45 K46	42	6	48	5	1	6	47	7	54
Varicose surgery	L84 L85 L86 L87 L88	16	14	30				16	14	30
All other procedures		2124	1638	3762	399	240	516	3867	2711	6578

Appendix D Ethical consents

This appendix provides documentary evidence of ethical consents mentioned in Section 4.10. It comprises nine parts:

D(i) CR28/2014 (permission to trace cohort and obtain mortality data)

NHS
Health Research Authority

Mrs Shirley J Simmonds,
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Email: HRA.CAG@nhs.net

17 August 2015

Dear Mrs Simmonds

Study title:	**STUDY OF BIRTH COHORT FROM HERTFORDSHIRE - 21/71/61 - MR278**
CAG reference:	**CR28/2014**

Thank you for your research application, submitted for approval under Regulation 5 of the Health Service (Control of Patient Information) Regulations 2002 to process patient identifiable information without consent. Approved applications enable the data controller to provide specified information to the applicant for the purposes of the relevant activity, without being in breach of the common law duty of confidentiality, although other relevant legislative provisions will still be applicable.

The role of the Confidentiality Advisory Group (CAG) is to review applications submitted under these Regulations and to provide advice to the Health Research Authority on whether an application should be approved, and if so, any relevant conditions. This application was considered via the proportionate review process under *criteria 15: Access to mortality, cancer or GP registration data from the Health and Social Care Information Centre – class support study*

Health Research Authority Approval Decision

The Health Research Authority, having considered the advice from the Confidentiality Advisory Team as set out below, has determined the following:

1. The application is approved, subject to compliance with the standard and specific conditions of approval.

This letter should be read in conjunction with the outcome letter dated 9th April 2015.

Context

This application from MRC Epidemiology Resource Centre, Southampton General Hospital, requested support in order to access mortality data from the Data Access Request Service (DARS) at the Health and Social Care Information Centre (HSCIC).

The Hertfordshire Birth Cohort (MR278) comprises 35000 people born between 1911 and 1939 who were overseen in early childhood by health visitors in the county. Records are being used to explore the relationship between health in infancy and eventual cause of death and also to investigate lifecourse influences on ageing as well as mortality among these men and women. A cohort of 35000 patients was flagged at the DARS.

Confidential Patient Information Requested

Access was requested to:

Data from the Central Register which are currently retained by the applicant, old and new NHS number, name at birth, date of birth, gender.

Mortality data which includes date of birth, date of death, place of birth and place of death, name at birth and death, gender, address, occupation and cause of death.

Confidentiality Advisory Team advice conclusion

The CAT agreed that the minimum criteria under the Regulations appeared to have been met, and therefore advised recommending support to the Health Research Authority, subject to compliance with the specific and standard conditions of support as set out below.

Specific conditions of support

1. Favourable opinion from REC. **Confirmed 15th July 2015.**
2. Confirmation of suitable security arrangements via IG Toolkit submission. **Confirmed 20th April 2015.**
3. Provide confirmation of how you are intending to proceed with IGT/REC approval to the Confidentiality Advice Team by 1st May 2015. **Confirmed as per specific condition 1 and 2.**

As the above conditions have been met, this letter provides confirmation of final approval. I will arrange for the register of approved applications on the HRA website to be updated with this information.

Annual review

Please note that your approval is subject to submission of an annual review report to show how you have met the conditions or report plans, and action towards meeting them. It is also your responsibility to submit this report on the anniversary of your final approval and to report any changes such as to the purpose or design of the proposed activity, or to security and confidentiality arrangements. An annual review should be provided no later than 17 August 2016 and preferably 4 weeks before this date.

Please do not hesitate to contact me if you have any queries following this letter, I would be grateful if you could quote the above reference number in all future correspondence.

Reviewed documents

The documents reviewed by the Confidentiality Advice Team were:

Document	*Version*	*Date*
Central Register Application		19th February 2014
REC Favourable Opinion		

Yours sincerely

Amy Ford
Senior Confidentiality Advisor
Deputy Confidentiality Advice Manager

Email: HRA.CAG@nhs.net
Enclosures: Standard conditions of approval

NHS
Health Research Authority

Standard conditions of approval

The approval provided by the Health Research Authority is subject to the following standard conditions.

The applicant will ensure that:

1. The specified patient identifiable information is only used for the purpose(s) set out in the application.
2. Confidentiality is preserved and there are no disclosures of information in aggregate or patient level form that may inferentially identify a person, nor will any attempt be made to identify individuals, households or organisations in the data.
3. Requirements of the Statistics and Registration Services Act 2007 are adhered to regarding publication when relevant.
4. All staff with access to patient identifiable information have contractual obligations of confidentiality, enforceable through disciplinary procedures.
5. All staff with access to patient identifiable information have received appropriate ongoing training to ensure they are aware of their responsibilities.
6. Activities are consistent with the Data Protection Act 1998.
7. Audit of data processing by a designated agent is facilitated and supported.
8. The wishes of patients who have withheld or withdrawn their consent are respected.
9. The Confidentiality Advice Team is notified of any significant changes (purpose, data flows, data items, security arrangements) prior to the change occurring.
10. An annual report is provided no later than 12 months from the date of your final confirmation letter.
11. Any breaches of confidentiality / security around this particular flow of data should be reported to CAG within 10 working days, along with remedial actions taken / to be taken.

D(ii) EC98248 (permission for baseline investigations in East and North Herts)

East & North HERTFORDSHIRE
HEALTH AUTHORITY

Dr E M Dennison
MRC Environmental Epidemiology Unit
Southampton General Hospital
Tremona Road
Southampton
SO16 6YD

29 January 1998

Dear Dr Dennison

Re: THE ASSOCIATION BETWEEN FETAL AND INFANT GROWTH AND DISEASE IN LATER LIFE STUDY: A STUDY OF CANDIDATE GENES AND ESTABLISHMENT OF A NATIONAL DNA BANK

The East and North Hertfordshire Health Authority Local Research Ethics Committee met on 14 January 1998 and considered the above study.

The Committee agreed that approval should be given for the study, but would like clarification on how you would follow up the people who participated.

I look forward to hearing from you.

Yours sincerely

Bridget Vickers

Bridget Vickers (Mrs)
Chair, East and North Hertfordshire Local Ethics Committee

EC248

Charter House, Parkway, Welwyn Garden City, Hertfordshire AL8 6JL Telephone: 01707 390855 Fax: 01707 390864
Safe Haven Fax: 01707 390234 Email: hertsha@compuserve.com.uk

D(iii) EC98248a (amendment to baseline investigations in East and North Herts)

East & North HERTFORDSHIRE
HEALTH AUTHORITY

Ref: let248a

16 November 1998

Dr Elaine Dennison
MRC Environmental Epidemiology Unit
(University of Southampton)
Southampton General Hospital
Southampton
SO16 6YD

Dear Dr Dennison,

Re: **The association between fetal and infant growth and disease in later life study (EC248)**

Further to your letter of 30 September 1998.

This is to confirm that the requests submitted in connection with the above study were discussed at the meeting of the East and North Hertfordshire Health Authority Local Research Ethics Committee held on 11 November 1998.

Approval was given to both requests made. i.e.:

1. Information on clinical events within the cohort may be abstracted from their records in the future.
2. The use of the test by a portable ultrasound machine to study bone structure and fracture risk.

Would you please note that this study has the approval reference of EC248 and this should be quoted in all correspondence.

The Committee look forward to receiving updates on progress as and when available.

Yours sincerely,

Bridget Vickers (Mrs)
Chair, East and North Hertfordshire Local Research Ethics Committee

Charter House, Parkway, Welwyn Garden City, Hertfordshire AL8 6JL. Telephone: 01707 390855 Fax: 01707 390864
Safe Haven Fax: 01707 390234 Email: hertsha@compuserve.com.uk

D(iv) WH02/98 (permission for baseline investigations in West Herts)

ADDRESS FOR CORRESPONDENCE
99 WAVERLEY ROAD, ST. ALBANS
HERTFORDSHIRE, AL3 5TL

Telephone: 01727 811888
Direct Line: 01727 897811
Fax: 01727 897788

West Hertfordshire
Health Authority
LOCAL RESEARCH
ETHICS COMMITTEE
(incorporating West Herts Community Health NHS Trust and Horizon NHS Trust)

2 February 1998

Our ref: WH02/98

Dr E Dennison
MRC Environmental Epidemiology Unit
SOUTHAMPTON
S016 6YD

Dear Dr Dennison

The association between foetal and infant growth and disease in adult life: a study of candidate genes and establishment of a national DNA bank

Thank you for attending the LREC meeting on 28 January 1998. I write to confirm LREC approval and draw your attention to the following:

(i) It is the responsibility of the investigator to notify the LREC immediately of any information received or of which you become aware which would cast doubt upon, or alter, any information contained in the original application, or a later amendment application, submitted to the LREC and/or which would raise questions about the safety and/or continued conduct of the research.

(ii) The need to comply with the Data Protection Act 1984.

(iii) The need to comply, throughout the conduct of the study, with good clinical research practice standards.

(iv) The need to refer proposed amendments to the protocol to the LREC for further review and to obtain LREC approval thereto prior to implementation (except only in cases of emergency where the welfare of the subject is paramount).

(v) The requirement to inform the LREC should the research be discontinued or any subject withdrawn.

I would be grateful if you could inform the Committee of the progress of the research project (eg annually) and also the conclusion and outcome of the study. Enclosed for your information is a list of LREC members.

Yours sincerely

Pauline Southworth

Pauline Southworth (Mrs)
Chairman
West Hertfordshire Health Authority LREC

D(v) NIC-59859-2DT25 (data reuse agreement for Hospital Episode Statistics)

AHES Data Re-Use Agreement (Extracts)

IC Ref: NIC-59859-2DT25
IG Ref: RU417

1.0 Organisations

This **Data Re-Use Agreement** (the Agreement) is drawn up between:

The Health & Social Care Information Centre (The NHS IC)
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

And:

MRC Epidemiology Resource Centre (the "Licencee")
Mailpoint 95
Southampton General Hospital
Southampton
SO16 6YD

This Agreement grants to the Licensee a time limited licence to re-use the data defined in Section 3 of this agreement. The data must only be used in accordance with the terms set out in this agreement and as additionally contained in the Standard Terms and Conditions for the Use and Re-Use of Public Sector Information, (Version 2.2 attached) and as may be additionally specified in Section 5 below.

This licence is limited to granting the Licensee rights to utilise the data in products or services supplied by you for,

Research Study herein-after the **"Field" in,**

England herein-after the "Territory".

Together the term Field and Territory represent the permissible **"Market"** for your products and services in accordance with our "Re-Use of Information, Re-Use License Fees Policy" (Version 1.2 attached). Should you require a license or licenses for additional markets, please contact **The NHS IC** to discuss the terms and conditions on which such additional licenses might be granted.

In case of doubt, the Terms and Conditions set out in this Re-Use Agreement shall take precedence over any corresponding Terms and Conditions contained in subsidiary documents referenced herein.

2.0 Period of agreement

This agreement commences on ***1st November 2010*** and will be subject to formal review on an annual basis and will terminate or be extended prior to ***31st October 2011***.

3.0 Data required

Pseudonymised Hospital Episode Statistics (HES) data containing all records extracted from the following HES databases:

- Admitted Patient Care – data years are 1998/99 to 2008/09 and 2009/10 provisional data
- Outpatient Attendances – data years are 2003/04 to 2008/09 and 2009/10 provisional data
- Accident & Emergency – data years are 2007/08 to 2008/09 and 2009/10 provisional data

3.1 Specification

See Appendix B

3.2 Permissions

Confirmation received from Ethics & Confidentiality Committee secretariat that appropriate consent is in place for the use of identifiable data fields for this project.

4.0 Purpose for which data is to be used

Re-Use Application Statement

> *"HES data will be added to the comprehensive characterisation we have built up of the lifecourse of 3000 men and women born in Hertfordshire who were still resident there and took part in an MRC baseline study around the turn of the millennium. Many of them have been seen again since. The dataset currently includes items as diverse as birthweight and method of feeding in infancy; work and reproductive histories; diet, smoking and alcohol consumption; medical history up to date of clinic attendance and a wide range of clinical measurements. Posterity samples of blood and urine have been stored and DNA extracted. The cohort are flagged for continuous notification of death, thus ultimately date and cause of death will be included too.*
> *Adding HES data will give us the potential to identify precursors to disease and track its course and outcome without the need to trouble individuals, some of whom may be increasingly frail. Conversely, now that they are aged 71-79 the cohort provide an opportunity to identify factors which underlie healthy ageing, which is crucial in an ageing society. We have self-reported inpatient data on a sub-set and will use HES data to validate this.*
> *Over 100 publications have resulted from this study to date, the most recent of which can be accessed via this link:*
> *http://www.mrc.soton.ac.uk/index.asp?page=3.*
> *An overview of the cohort was published in 2005:*
> *Syddall HE, Sayer AA, Dennison EM, Martin HJ, Barker DJ, Cooper C. Cohort Profile: The Hertfordshire Cohort Study. Int J Epidemiol 2005;34:1234-42*
> *Future publications will be submitted to high impact-factor journals appropriate to their subject matter, and no individuals will be identifiable"*

Based on your HES Extract Application statement(above), the NHS IC grants to the Licensee a non-exclusive licence to use or re-use the data specified in section 3 above for the following purposes:

- Use only within the Field and Territory as specified in this Agreement.
- Publishing the material in any medium, including featuring the information asset on websites which can be accessed via the Internet or via an internal electronic network or on an Intranet.
- ~~Authorising users and subscribers who use the Licensee's electronic or digital products to access the material.~~
- Translating the information asset into another language or converting to Braille or other formats for people who are visually impaired.

5.0 Specific Conditions

5.1 The Licensee warrants that it and named users of this dataset agree to comply with the principles of the **NHS IC HES Protocol**, and the **NHS Care Record Guarantee** before using this data.

5.2 Any data or information provided which is designated "Pre-Publication" or "Pre-Release" is subject to the additional terms and conditions contained in our ***Special Terms and Conditions for Pre-Release Access to Official Statistics***.

5.3 The National Statistician will set standards for protecting confidentiality, including a guarantee that no statistics will be produced that are likely to identify an individual unless specifically agreed with them, where the guarantee is judged against the standard that 'it would take a disproportionate amount of time, effort and expertise for an intruder to identify a statistical unit to others, or to reveal information about that unit which is not already in the public domain. Consequently any publication[1] derived from this data by any party are subject to ONS confidentiality guidance on the release of Health Statistics.

5.4 This guidance is provided in the Confidentiality Guidance document and associated working papers to be found at:

http://www.statistics.gov.uk/about/data/disclosure/health-statistics.asp

5.5 Specifically, the Licensee undertakes to ensure that appropriate controls are in place, to ensure compliance with the NHS ICs, ***Small Numbers Special Terms and Conditions***. Such controls will, as a minimum, meet the requirements of condition 3.3 of the Small Numbers Special Terms and Conditions and more generally satisfy Section 5 of the ONS confidentiality guidance.

5.6 Before undertaking publication activity, the Licensee or ***any other party*** using this dataset or any derived information will undertake an organisational Risk Assessment Exercise to ensure compliance with the above guidelines.

5.7 The NHS IC retains copyright of this information and this must be cited correctly as follows:

"Copyright © 2010, Re-used with the permission of The Health and Social Care Information Centre. All rights reserved."

[1] In the context of this Agreement the term "Publication" or "Publications" has the same definition as in the Re-Use of Public Sector Information Regulations 2005

5.8 Extension of the period of agreement will be subject to formal review by The NHS IC.

6.0 Specific Exclusions

No part of this dataset may be shared with any third party in the format in which it is provided to you by The NHS IC.

Other than specified in this Agreement, no part, derivative, or analysis produced using the data specified in section 3 may be sold, traded or otherwise used in any commercial or economic activity without the express authorisation of the NHS Information Centre, such agreement not to be unreasonably withheld subject to payment of the appropriate licence fees.

7.0 Charges

7.1 This request has been categorised as **Market 2, Type B** in accordance with our Standard Terms and Conditions for the Use and Re-Use of Public Sector Information Typology Annex 1. In accordance with this policy the following charges are deemed to apply based on the anticipated sales by period of 12 months:

(i) Re- Use Licence Fee –

a. Admitted Patient Care Annual Licence £ZERO
b. Outpatient Attendances Annual Licence £ZERO
c. Accident & Emergency Annual Licence £ZERO

(ii) Service Production Fee – **£1,351.00**; which for the avoidance of doubt is made up of **£1,351.00** cost and £ZERO Return on Investment elements.

7.2 The charges set out above are payable in accordance with condition 9 of our Standard Terms and Conditions for the Re-Use of Public Sector Information, on the following Due Date – **30 days of the receipt of the HES data extract.**

7.3 All charges are subject to the prevailing rate of VAT at the point of invoicing other than those customers who are part of the NHS VAT group.

8.0 Data sharing

No individual other than those named in this agreement can access the dataset and the dataset must only be used for the explicit purpose set out above. In case of staff changes, the Licensee will inform The NHS IC of these changes prior to new staff members gaining access to the dataset listed in this agreement.

Named individual to have access	Job title
Shirley Simmonds (Mrs)	As per application
Prof Avan Aihie Sayer	As per application
Dr Bronagh Walsh (University of Southampton)	As per application

9.0 User Obligations

9.1 The NHS IC formally wishes to acknowledge its explicit commitment to maintaining the confidentiality, safety, security and integrity of all confidential and sensitive Data to which the organisation is privy and which may be held under its guardianship.

The NHS IC continues to legitimately enter into formal agreement and/or implicit undertaking with all its clients, staff, visitors, suppliers and others, in recognition of the fact that the Data is held under the guardianship of the NHS IC and which is pertinent to the individual client, staff member, visitor, supplier and/or other, will only be used for the explicit agreed purpose or purposes for which it has been provided, and that there will be no unlawful disclosure or loss of the same.

Users of the Data supplied are obliged to fully comply with The Data Protection Act 1998, together with all other related and relevant legislation and Department of Health directives covering issues of Data sharing and including:

- British (International) Standard ISO 27001;
- The Caldicott Report 1997;
- The Freedom of Information Act 2000;
- Section 251 of the Health and Social Care Act 2006;
- Confidentiality: NHS Code of Practice 2003;
- NHS Records Management Code of Practice (Part 1, 2006 & Part 2, 2009);
- The NHS Information Security Management Code of Practice 2007;
- The Computer Misuse Act 1990;
- The Electronic Communications Act 2000;
- The Regulation of Investigatory Powers Act 2000;
- The Copyright, Designs and Patents Act 1988;

- The Re-Use of Public Sector Information Regulations 2005;
- The Human Rights Act 1998
- The NHS Care Record Guarantee 2007

9.2 Your extract may contain small numbers, by signing this document you are confirming that you understand and agree to the guidelines set out by the HES protocol. The HES protocol strictly prohibits the release of small numbers meeting certain criteria, no persons other than those named in this DRA have permission to view such small numbers and the data should be suppressed accordingly before it is shared with any other parties. ADHERENCE TO THE HES PROTOCOL IS MANDATORY, IT CAN BE VIEWED AT: http://www.hesonline.nhs.uk/Ease/servlet/ContentServer?siteID=1937&categoryID=331

10.0 Audit

During the period of this agreement The NHS IC reserves the right to undertake an audit of Licensee to ensure that all terms of this agreement are being abided by.

11.0 Transfer of data from NHS IC to The LICENSEE

- The data is categorised as **Identifiable/Sensitive** and will be treated by The NHS IC in accordance with NHS IC protocols for the transfer and use of NHS **Identifiable-Sensitive** Data.
- Unless otherwise agreed the form of data transfer will be by encrypted disk.
- Before transfer The NHS IC will encrypt the disk using WINZIP '256-bit AES encryption' with a password length of 12 which MUST include numbers, letters and symbols, and should be a mix of UPPER and lower case characters.
- The data WILL be sent via secure courier to **MRC Epidemiology Resource Centre, Mailpoint 95, Southampton General Hospital, Southampton, SO16 6YD**
- The NHS IC's sub-contractor will manage the transfer of the data and a record of the transfer will be maintained.
- The password will be provided to the named person taking responsibility within this agreement at **MRC Epidemiology Resource Centre** via telephone or e-mail. Once The NHS IC is satisfied that the password has been received safely, the information will be sent.
- The named person must NOT share the data or password with any other person at any time.

12.0 Storage of Data

Taken from the application form;

> *"Data will be stored on a secure system password protected where by access to the HES data is restricted to only those who are named within this agreement."*

13.0 Data Retention

The data will be retained by **Licensee** until the end date of the agreement or relevant review period. Extension of the retention period is subject to a formal review.

14.0 Data Destruction

Taken from the application form;

> *"Data will be securely destroyed using file shredding software. Similarly, physical media will be destroyed using a high specification shredder with the functionality to irreversibly destroy the disc. The data will also be removed from any back up tapes that contain it. Confirmation that this has occurred will be given in writing to the NHS IC"*

15.0 Breach of Conditions

Notification of breach The Licensee agrees to report immediately to The NHS IC instances of breach of any of the terms of this Agreement.

Right to terminate access The breach of any of the terms of this Agreement may result in the immediate termination of access to the data and the return of the data to The NHS IC in the manner to be advised by The NHS IC.

Sanctions The breach of any of the provisions of this Agreement may result in sanctions being sought against the Licensee.

16.0 Changes to Terms of Agreement

The NHS IC has the right to change the terms of this agreement and these will be notified to the Licencee in writing. On such occasion unless **Licensee** notifies The NHS IC in writing within 14 days of receiving notice of any changes The NHS IC will assume that the agreement will continue under the revised terms.

If the person signing for **Licensee** should leave their post or the responsibility for this agreement changes from them, then it is incumbent on that person to arrange a new signatory to this agreement and The NHS IC informed of this requirement immediately.

Agreement Signatures

By signing this document you are confirming that you understand and agree to the guidelines set out by the HES protocol. Please see User Obligations (paragraph 9.2) for further details.

For and on behalf of:

MRC Epidemiology Resource Centre

Signed:

Print name:

Post/Title:

Date:

MRC Epidemiology Resource Centre
Mailpoint 95
Southampton General Hospital
Southampton
SO16 6YD

For and on behalf of:

The NHS Information Centre

Signed:

Print name: **Dean White**

Post/Title: **Head of Commercial Management**

Date:

The NHS Information Centre
7th Floor New King's Beam House
22 Upper Ground
London
SE1 9BW

Director of Information Governance
on behalf of the NHS IC
Caldicott Guardian

Signed:

Print name: Clare Sanderson

Date:

The NHS Information Centre
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

Appendix A: DATA DISCLOSURE RISK ASSESSMENT

TO BE COMPLETED IF IDENTIFIABLE / SENSITIVE DATA REQUIRED AND APPROVED.

Appendix B: Customer Application – Data Extract Specification

EXTRACT SPECIFICATION FOR MRC Lifecourse Epidemiology Unit (ET2746)

1. Mrs Shirley Simmonds of **MRC Lifecourse Epidemiology Unit** requires an extract from the HES database for the inpatient data year(s) **1999 to 2009/10 provisional data (12** years of data), outpatient data year(s) **2003/04 to 2009/10** provisional (7 years) data and A&E data year(s) **2007/08 to 2009/10 provisional data** (3 years of data).

2. The extract will be produced in the form of ASCII files, pipe-delimited, unless otherwise stated. Depending on the size of your extract output files will be split every 5,000,000 rows. Your extract will be encrypted and password protected using Winzip v11 at 256-bit encryption levels. Please note that you will require software capable of uncompressing files using this level of encryption. If you are unsure of which version you have please contact your local IT support and if there are any problems please contact the Northgate helpdesk on 0870 7510872.

3. The following filters will be applied to the data:

   Data will be matched on NHS numbers provided by the customer.

4. The following fields will be included:

   In-Patient Extract

DOB	DIAG_02	DIAG_20	OPER_18
NEWNHSNO	DIAG_10	OPER_08	TRETSPEF
EXTRACT_HESID	DIAG_11	OPER_09	DOMPROC
HOMEADD	DIAG_12	OPER_10	GPPRAC
SEX	DIAG_13	OPER_11	EPIKEY
ADMIMETH	DIAG_14	OPER_12	
ADMIDATE	DIAG_15	OPER_13	
ADMISORC	DIAG_16	OPER_14	
DISDATE	DIAG_17	OPER_15	
DISDEST	DIAG_18	OPER_16	
DIAG_01	DIAG_19	OPER_17	
DIAG_03	OPER_01	OPER_19	
DIAG_04	OPER_02	OPER_20	
DIAG_05	OPER_03	OPER_21	
DIAG_06	OPER_04	OPER_22	
DIAG_07	OPER_05	OPER_23	
DIAG_08	OPER_06	OPER_24	
DIAG_09	OPER_07	MAINSPEF	

Outpatient Extract

DOB	DIAG_06
NEWNHSNO	DIAG_07
EXTRACT_HESID	DIAG_08
HOMEADD	DIAG_09
SEX	DIAG_10
APPTDATE	DIAG_11
ATENTYPE	DIAG_12
OUTCOME	MAINSPEF
DIAG_01	TRETSPEF
DIAG_02	ATTENDKEY
DIAG_03	
DIAG_04	
DIAG_05	

A&E Extract

DOB	DIAG_06	DIAGA_07	DIAGS_07
NEWNHSNO	DIAG_07	DIAGA_08	DIAGS_08
HOMEADD	DIAG_08	DIAGA_09	DIAGS_09
EXTRACT_HESID	DIAG_09	DIAGA_10	DIAGS_10
SEX	DIAG_10		
AEARRIVALMODE	DIAG_11	DIAGA_11	DIAGS_11
AEATTENDDISP	DIAG_12	DIAGA_12	DIAGS_12
ARRIVALDATE	DIAGA_01	DIAGS_01	GPPRAC
DIAG_01	DIAGA_02	DIAGS_02	DOMPROC
DIAG_02	DIAGA_03	DIAGS_03	AEKEY
DIAG_03	DIAGA_04	DIAGS_04	
DIAG_04	DIAGA_05	DIAGS_05	
DIAG_05	DIAGA_06	DIAGS_06	

5. **Please note that the data files supplied will be encrypted and password protected. To access these files the Data Custodian, or appointed contact, should call the HES Servicedesk on 0870 7510872 quoting the 'ET' reference number and ask to be supplied with the extract password. The Servicedesk will then check the details supplied and email the password to the data custodian.**

6. A list will be provided giving the order in which the fields are presented. Note that the data will not be identical to that received from the data providers. It has been cleaned by the HES system and in some cases, the "unknown" and "inapplicable" values have been changed to conform to the "typing" requirements of the system. The HES data dictionary explains the meaning of the fields, in particular giving the "unknown and "inapplicable"

codes for many fields. The HES data dictionary can be accessed via the HES web pages at www.hesonline.nhs.uk

7. **Copyright © 2010, The Information Centre. All rights reserved.**
This work remains the sole and exclusive property of The Information Centre and may only be reproduced where there is explicit reference to the ownership of The Information Centre.

Please sign below to confirm that you wish to continue with this data request to receive the data as specified above.

If you have any queries regarding this data specification or would like to make any amendments then please raise these issues with the NHS IC via enquiries@ic.nhs.uk before returning this document. (Please include your reference number beginning '*NIC*' in the title of any responses)

Requests to make amendments to this data specification after the data has been dispatched may result in you being required to submit a new data request application. The production costs stated in DRA section '7.0 - Charges' for dispatched data specified above will still be charged.

SPECIFICATION AGREED

_______________ (Signature) _______________ (Name) _______________ (Date)

D(vi) NIC-59859-2DT25 (data reuse amendment for Hospital Episode Statistics)

AHES Data Re-Use Agreement (Extracts)

IC Ref: NIC-59859-2DT25
IG Ref: RU417

1.0 Organisations

This **Data Re-Use Agreement** (the Agreement) is drawn up between:

The Health & Social Care Information Centre (The NHS IC)
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

And:

MRC Lifecourse Epidemiology Unit (the "Licencee")
Mailpoint 95
Southampton General Hospital
Southampton
SO16 6YD

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England herein-after the "Territory".

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2.0 Period of agreement

This agreement commences on *1st February 2011* and will be subject to formal review on an annual basis and will terminate or be extended prior to *31st January 2012.*

3.0 Data required

Pseudonymised Hospital Episode Statistics (HES) data containing all records extracted from the following HES databases:

- Admitted Patient Care – data years are 1998/99 to 2008/09 and 2009/10 provisional data
- Outpatient Attendances – data years are 2003/04 to 2008/09 and 2009/10 provisional data
- Accident & Emergency – data years are 2007/08 to 2008/09 and 2009/10 provisional data

3.1 Specification

See Appendix B

3.2 Permissions

Confirmation received from Ethics & Confidentiality Committee secretariat that appropriate consent is in place for the use of identifiable data fields for this project.

4.0 Purpose for which data is to be used

Re-Use Application Statement

> *"HES data will be added to the comprehensive characterisation we have built up of the lifecourse of 3000 men and women born in Hertfordshire who were still resident there and took part in an MRC baseline study around the turn of the millennium. Many of them have been seen again since. The dataset currently includes items as diverse as birthweight and method of feeding in infancy; work and reproductive histories; diet, smoking and alcohol consumption; medical history up to date of clinic attendance and a wide range of clinical measurements. Posterity samples of blood and urine have been stored and DNA extracted. The cohort are flagged for continuous notification of death, thus ultimately date and cause of death will be included too.*
> *Adding HES data will give us the potential to identify precursors to disease and track its course and outcome without the need to trouble individuals, some of whom may be increasingly frail. Conversely, now that they are aged 71-79 the cohort provide an opportunity to identify factors which underlie healthy ageing, which is crucial in an ageing society. We have self-reported inpatient data on a sub-set and will use HES data to validate this.*
> *Over 100 publications have resulted from this study to date, the most recent of which can be accessed via this link:*
> *http://www.mrc.soton.ac.uk/index.asp?page=3.*
> *An overview of the cohort was published in 2005:*
> *Syddall HE, Sayer AA, Dennison EM, Martin HJ, Barker DJ, Cooper C. Cohort Profile: The Hertfordshire Cohort Study. Int J Epidemiol 2005;34:1234-42*
> *Future publications will be submitted to high impact-factor journals appropriate to their subject matter, and no individuals will be identifiable"*

Based on your HES Extract Application statement(above), the NHS IC grants to the **Licensee** a non-exclusive licence to use or re-use the data specified in section 3 above for the following purposes:

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- ~~Authorising users and subscribers who use the Licensee's electronic or digital products to access the material.~~
- Translating the information asset into another language or converting to Braille or other formats for people who are visually impaired.

5.0 Specific Conditions

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5.2 Any data or information provided which is designated "Pre-Publication" or "Pre-Release" is subject to the additional terms and conditions contained in our *Special Terms and Conditions for Pre-Release Access to Official Statistics*.

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[1] In the context of this Agreement the term "Publication" or "Publications" has the same definition as in the Re-Use of Public Sector Information Regulations 2005

5.8 Extension of the period of agreement will be subject to formal review by The NHS IC.

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7.0 Charges

7.1 This request has been categorised as **Market 2, Type B** in accordance with our Standard Terms and Conditions for the Use and Re-Use of Public Sector Information Typology Annex 1. In accordance with this policy the following charges are deemed to apply based on the anticipated sales by period of 12 months:

(i) Re- Use Licence Fee –

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7.2 The charges set out above are payable in accordance with condition 9 of our Standard Terms and Conditions for the Re-Use of Public Sector Information, on the following Due Date – **30 days of the receipt of the HES data extract.**

7.3 All charges are subject to the prevailing rate of VAT at the point of invoicing other than those customers who are part of the NHS VAT group.

8.0 Data sharing

No individual other than those named in this agreement can access the dataset and the dataset must only be used for the explicit purpose set out above. In case of staff changes, the Licensee will inform The NHS IC of these changes prior to new staff members gaining access to the dataset listed in this agreement.

Named individual to have access	Job title
Shirley Simmonds (Mrs)	As per application
Prof Avan Aihie Sayer	As per application
Dr Bronagh Walsh (University of Southampton)	As per application
Mrs Holly Syddall	As per application
Ms Karen Jameson	As per application
Ms Vanessa Cox	As per application

9.0 User Obligations

9.1 The NHS IC formally wishes to acknowledge its explicit commitment to maintaining the confidentiality, safety, security and integrity of all confidential and sensitive Data to which the organisation is privy and which may be held under its guardianship.

The NHS IC continues to legitimately enter into formal agreement and/or implicit undertaking with all its clients, staff, visitors, suppliers and others, in recognition of the fact that the Data is held under the guardianship of the NHS IC and which is pertinent to the individual client, staff member, visitor, supplier and/or other, will only be used for the explicit agreed purpose or purposes for which it has been provided, and that there will be no unlawful disclosure or loss of the same.

Users of the Data supplied are obliged to fully comply with The Data Protection Act 1998, together with all other related and relevant legislation and Department of Health directives covering issues of Data sharing and including:

- British (International) Standard ISO 27001;
- The Caldicott Report 1997;
- The Freedom of Information Act 2000;
- Section 251 of the Health and Social Care Act 2006;
- Confidentiality: NHS Code of Practice 2003;
- NHS Records Management Code of Practice (Part 1, 2006 & Part 2, 2009);
- The NHS Information Security Management Code of Practice 2007;
- The Computer Misuse Act 1990;

- The Electronic Communications Act 2000;
- The Regulation of Investigatory Powers Act 2000;
- The Copyright, Designs and Patents Act 1988;
- The Re-Use of Public Sector Information Regulations 2005;
- The Human Rights Act 1998
- The NHS Care Record Guarantee 2007

9.2 Your extract may contain small numbers, by signing this document you are confirming that you understand and agree to the guidelines set out by the HES protocol. The HES protocol strictly prohibits the release of small numbers meeting certain criteria, no persons other than those named in this DRA have permission to view such small numbers and the data should be suppressed accordingly before it is shared with any other parties. ADHERENCE TO THE HES PROTOCOL IS MANDATORY, IT CAN BE VIEWED AT: http://www.hesonline.nhs.uk/Ease/servlet/ContentServer?siteID=1937&categoryID=331

10.0 Audit

During the period of this agreement The NHS IC reserves the right to undertake an audit of Licensee to ensure that all terms of this agreement are being abided by.

11.0 Transfer of data from NHS IC to The LICENSEE

- The data is categorised as **Identifiable/Sensitive** and will be treated by The NHS IC in accordance with NHS IC protocols for the transfer and use of NHS **Identifiable-Sensitive** Data.
- Unless otherwise agreed the form of data transfer will be by encrypted disk.
- Before transfer The NHS IC will encrypt the disk using WINZIP '256-bit AES encryption' with a password length of 12 which MUST include numbers, letters and symbols, and should be a mix of UPPER and lower case characters.
- The data WILL be sent via secure courier to **MRC Lifecourse Epidemiology Unit, Mailpoint 95, Southampton General Hospital, Southampton, SO16 6YD**
- The NHS IC's sub-contractor will manage the transfer of the data and a record of the transfer will be maintained.
- The password will be provided to the named person taking responsibility within this agreement at **MRC Lifecourse Epidemiology Unit** via telephone or e-mail. Once The NHS IC is satisfied that the password has been received safely, the information will be sent.
- The named person must NOT share the data or password with any other person at any time.

12.0 Storage of Data

Taken from the application form;

> *"Data will be stored on a secure system password protected where by access to the HES data is restricted to only those who are named within this agreement."*

13.0 Data Retention

The data will be retained by Licensee until the end date of the agreement or relevant review period. Extension of the retention period is subject to a formal review.

14.0 Data Destruction

Taken from the application form;

> *"Data will be securely destroyed using file shredding software. Similarly, physical media will be destroyed using a high specification shredder with the functionality to irreversibly destroy the disc. The data will also be removed from any back up tapes that contain it. Confirmation that this has occurred will be given in writing to the NHS IC"*

15.0 Breach of Conditions

Notification of breach The Licensee agrees to report immediately to The NHS IC instances of breach of any of the terms of this Agreement.

Right to terminate access The breach of any of the terms of this Agreement may result in the immediate termination of access to the data and the return of the data to The NHS IC in the manner to be advised by The NHS IC.

Sanctions The breach of any of the provisions of this Agreement may result in sanctions being sought against the Licensee.

16.0 Changes to Terms of Agreement

The NHS IC has the right to change the terms of this agreement and these will be notified to the Licencee in writing. On such occasion unless Licensee notifies The NHS

IC in writing within 14 days of receiving notice of any changes The NHS IC will assume that the agreement will continue under the revised terms.

If the person signing for **Licensee** should leave their post or the responsibility for this agreement changes from them, then it is incumbent on that person to arrange a new signatory to this agreement and The NHS IC informed of this requirement immediately.

Agreement Signatures

By signing this document you are confirming that you understand and agree to the guidelines set out by the HES protocol. Please see User Obligations (paragraph 9.2) for further details.

For and on behalf of:	For and on behalf of:
MRC Lifecourse Epidemiology Unit	**The NHS Information Centre**
Signed:	*Signed:*
Print name:	*Print name:* **Dean White**
Post/Title:	*Post/Title:* **Head of Commercial Management**
Date:	*Date:*

MRC Lifecourse Epidemiology Unit
Mailpoint 95
Southampton General Hospital
Southampton
SO16 6YD

The NHS Information Centre
7th Floor New King's Beam House
22 Upper Ground
London
SE1 9BW

Director of Information Governance
on behalf of the NHS IC
Caldicott Guardian

Signed:

Print name: Clare Sanderson

Date:

The NHS Information Centre
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

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for health and social care

Appendix A: DATA DISCLOSURE RISK ASSESSMENT

TO BE COMPLETED IF IDENTIFIABLE / SENSITIVE DATA REQUIRED AND APPROVED.

Appendix B: Customer Application – Data Extract Specification

EXTRACT SPECIFICATION FOR MRC Lifecourse Epidemiology Unit (ET2746)

1. Mrs Shirley Simmonds of **MRC Lifecourse Epidemiology Unit** requires an extract from the HES database for the inpatient data year(s) **1999 to 2009/10 provisional data (12** years of data), outpatient data year(s) **2003/04 to 2009/10** provisional (7 years) data and A&E data year(s) **2007/08 to 2009/10 provisional data** (3 years of data).

2. The extract will be produced in the form of ASCII files, pipe-delimited, unless otherwise stated. Depending on the size of your extract output files will be split every 5,000,000 rows. Your extract will be encrypted and password protected using Winzip v11 at 256-bit encryption levels. Please note that you will require software capable of uncompressing files using this level of encryption. If you are unsure of which version you have please contact your local IT support and if there are any problems please contact the Northgate helpdesk on 0870 7510872.

3. The following filters will be applied to the data:

   Data will be matched on NHS numbers provided by the customer.

4. The following fields will be included:

   In-Patient Extract

DOB	DIAG_02	DIAG_20	OPER_18
NEWNHSNO	DIAG_10	OPER_08	TRETSPEF
EXTRACT_HESID	DIAG_11	OPER_09	DOMPROC
HOMEADD	DIAG_12	OPER_10	GPPRAC
SEX	DIAG_13	OPER_11	EPIKEY
ADMIMETH	DIAG_14	OPER_12	
ADMIDATE	DIAG_15	OPER_13	
ADMISORC	DIAG_16	OPER_14	
DISDATE	DIAG_17	OPER_15	
DISDEST	DIAG_18	OPER_16	
DIAG_01	DIAG_19	OPER_17	
DIAG_03	OPER_01	OPER_19	
DIAG_04	OPER_02	OPER_20	
DIAG_05	OPER_03	OPER_21	
DIAG_06	OPER_04	OPER_22	
DIAG_07	OPER_05	OPER_23	
DIAG_08	OPER_06	OPER_24	
DIAG_09	OPER_07	MAINSPEF	

Outpatient Extract

DOB	DIAG_06
NEWNHSNO	DIAG_07
EXTRACT_HESID	DIAG_08
HOMEADD	DIAG_09
SEX	DIAG_10
APPTDATE	DIAG_11
ATENTYPE	DIAG_12
OUTCOME	MAINSPEF
DIAG_01	TRETSPEF
DIAG_02	ATTENDKEY
DIAG_03	
DIAG_04	
DIAG_05	

A&E Extract

DOB	DIAG_06	DIAGA_07	DIAGS_07
NEWNHSNO	DIAG_07	DIAGA_08	DIAGS_08
HOMEADD	DIAG_08	DIAGA_09	DIAGS_09
EXTRACT_HESID	DIAG_09	DIAGA_10	DIAGS_10
SEX	DIAG_10		
AEARRIVALMODE	DIAG_11	DIAGA_11	DIAGS_11
AEATTENDDISP	DIAG_12	DIAGA_12	DIAGS_12
ARRIVALDATE	DIAGA_01	DIAGS_01	GPPRAC
DIAG_01	DIAGA_02	DIAGS_02	DOMPROC
DIAG_02	DIAGA_03	DIAGS_03	AEKEY
DIAG_03	DIAGA_04	DIAGS_04	
DIAG_04	DIAGA_05	DIAGS_05	
DIAG_05	DIAGA_06	DIAGS_06	

5. **Please note that the data files supplied will be encrypted and password protected. To access these files the Data Custodian, or appointed contact, should call the HES Servicedesk on 0870 7510872 quoting the 'ET' reference number and ask to be supplied with the extract password. The Servicedesk will then check the details supplied and email the password to the data custodian.**

6. A list will be provided giving the order in which the fields are presented. Note that the data will not be identical to that received from the data providers. It has been cleaned by the HES system and in some cases, the "unknown" and "inapplicable" values have been changed to conform to the "typing" requirements of the system. The HES data dictionary explains the meaning of the fields, in particular giving the "unknown and "inapplicable"

codes for many fields. The HES data dictionary can be accessed via the HES web pages at www.hesonline.nhs.uk

7. **Copyright © 2010, The Information Centre. All rights reserved.**
This work remains the sole and exclusive property of The Information Centre and may only be reproduced where there is explicit reference to the ownership of The Information Centre.

Please sign below to confirm that you wish to continue with this data request to receive the data as specified above.

If you have any queries regarding this data specification or would like to make any amendments then please raise these issues with the NHS IC via enquiries@ic.nhs.uk before returning this document. (Please include your reference number beginning '*NIC*' in the title of any responses)

Requests to make amendments to this data specification after the data has been dispatched may result in you being required to submit a new data request application. The production costs stated in DRA section '7.0 - Charges' for dispatched data specified above will still be charged.

SPECIFICATION AGREED

______________ (Signature)	______________ (Name)	______________ (Date)

D(vii) NIC-59859-2DT25 (renewal agreement for Hospital Episode Statistics)

RDRAv0911.0

NHS
The Information Centre
for health and social care

Data Re-use Agreement – Renewal

Renewal IG Ref: NIC-59859-2DT25-R1
Renewal IC Ref: RU417-R1

1.0 Organisations

This **Data Re-Use Agreement** (the Renewal) is drawn up between:

The Health & Social Care Information Centre (The HSCIC)
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

And:

MRC Lifecourse Epidemiology Unit (the "Licencee")
Mailpoint 95
Southampton General Hospital
Southampton
SO16 6YD

2.0 Amendment(s)

This document sets out the following renewal to the original **Data Re-use Agreement** referenced **NIC-59859-2DT25/ RU417** dated 5th January 2011.

2.1 Renewal period of agreement

The NHS Information Centre hereby grants a 36 month extension to the **Data Re-use Agreement** number **NIC-59859-2DT25/ RU417**.

The agreement renewal takes effect from ***1st February 2012*** and will terminate on ***31st January 2015*** (**The Expiry Date**).

The **Licensee** confirms that retention of and use of the specified data remains subject to the conditions set out in the original **Data Re-use Agreement** and such additional terms and conditions as may be specified there-in.

Prior to **The Expiry Date** the Licensee shall remove / destroy all data specified in the **Data Re-use Agreement** from all systems in accordance with the Agreement and the HSCIC Standard Terms and Condition for the Use and Re-Use of Public Sector Information.

Requests to extend the **Data Re-use Agreement** or retain the specified data for an addition 12, 24 or 36 months should be made in writing by the **Licensee** to **The HSCIC** a minimum of 30 days before **The Expiry Date**.

3.0 Charges

3.1 In accordance with this Amendment to the original **Data Re-use Agreement** the following additional charges are deemed to apply.

(i) Extract Re- Use Licence Fee –

a. Admitted Patient Care Annual Licence £ZERO
b. Outpatient Attendances Annual Licence £ZERO
c. Accident & Emergency Annual Licence £ZERO

(ii) Service Production Fee – £ZERO; which for the avoidance of doubt is made up of £ZERO cost and £ZERO Return on Investment elements.

3.2 The charges set out above are payable in accordance with condition 9 of our Standard Terms and Conditions for the Re-Use of Public Sector Information, on the following Due Date – **30 days of the receipt of the HES data extract.**

3.3 All charges are subject to the prevailing rate of VAT at the point of invoicing other than those customers who are part of the NHS VAT group.

4.0 Conditions

IT IS HEREBY AGREED as follows:

The Health and Social Care Information. Published September 2011

4.1 The terms used in this Amendment shall have the same meanings as set out in the Agreement.

4.2 The parties acknowledge and agree that all terms and conditions of the Agreement shall remain unchanged except as otherwise stated in this Amendment.

4.3 Each of the parties shall execute, sign and do all such further notices, documents, acts and things as may be necessary to give full force and effect to the provisions of this Amendment.

4.4 Except in respect of fraudulent misrepresentations, the parties acknowledge and agree that the Agreement as varied by this Amendment contains the whole written agreement between the Customer and the HSCIC.

4.5 This Amendment is governed by and shall be construed in accordance with English Law and the parties submit to the exclusive jurisdiction of the Courts of England and Wales.

The Health and Social Care Information. Published September 2011

Agreement Signatures

For and on behalf of:	For and on behalf of:
MRC Lifecourse Epidemiology Unit	**The Health and Social Care Information Centre**
Signed:	*Signed:*
Print name:	*Print name:* **Dean White**
Post/Title:	*Post/Title:* **Head of Commercial Management**
Date:	*Date:*

MRC Lifecourse Epidemiology Unit
Mailpoint 95
Southampton General Hospital
Southampton
SO16 6YD

The Health and Social Care Information Centre
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

The Health and Social Care Information. Published September 2011

RDRAv0911.0

HSCIC Director of Information
Governance on behalf of HSCIC
Caldicott Guardian

Signed

Print name:

Date

The Health and Social Care Information
Centre
1 Trevelyan Square
Boar Lane
Leeds
LS1 6AE

D(viii) ERGO 13141 SSEGM ethics sub-committee application form

UNIVERSITY OF
Southampton

This version updated December 2013

SSEGM ETHICS SUB- COMMITTEE APPLICATION FORM

Please note:

- ***<u>You must not begin data collection for your study until ethical approval has been obtained</u>.***
- ***It is your responsibility to follow the University of Southampton's Ethics Policy and any relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data.***
- ***It is also your responsibility to provide <u>full and accurate information</u> in completing this form.***

1. **Name(s):** Shirley Simmonds

2. **Current Position** MPhil/PhD Student in Gerontology

3. **Contact Details:**

   Division/School Centre for Research on Ageing/ Social Sciences

   Email sjs3g10@soton.ac.uk

   Phone 023 8077 7624 ext 159 or 07949 429348

4. **Is your study being conducted as part of an education qualification?**

   Yes ☒ **No** ☐

5. **If Yes, please give the name of your supervisor**

   Maria Evandrou

6. **Title of your project:**

   Patterns and predictors of hospital admissions in an ageing cohort – using routinely collected data to enhance a cohort study (provisional title)

7. **Briefly describe the rationale, study aims and the relevant research questions of your study**

   Baseline data from the Hertfordshire Cohort Study (HCS) will be combined with Hospital Episode Statistics for the same people over the following decade to enable characterisation of admissions at the individual level. The social, biological and lifestyle factors that underpin various categories of hospital admission, individually and in combination, will be explored among this ageing cohort.

   This work has important policy implications given the current pressure on the NHS.

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8. Describe the design of your study

Baseline characterisation was conducted by the Medical Research Council between 1999-2004. (Please see appendices 2-4 for original ethical consent) NHS numbers were known, and cohort members gave written consent to the future interrogation of their medical records. Hospital Episode Statistics were obtained for the period from baseline to 31/03/2010 (Appendices 5-6 show original data sharing agreement and extension). The two data sources were then linked.

9. Who are the research participants?

Members of the Hertfordshire Cohort Study, ie 2997 people born in Hertfordshire between 1931-39 and resident there at baseline.

10. If you are going to analyse secondary data, from where are you obtaining it?

Medical Research Council Lifecourse Epidemiology Unit.

11. If you are collecting primary data, how will you identify and approach the participants to recruit them to your study?

Please upload a copy of the information sheet if you are using one – or if you are not using one please explain why.

n/a

12. Will participants be taking part in your study without their knowledge and consent at the time (e.g. covert observation of people)? If yes, please explain why this is necessary.

No

13. If you answered 'no' to question 13, how will you obtain the consent of participants?

Please upload a copy of the consent form if you are using one – or if you are not using one please explain why.

Already obtained, please see section 8.

14. Is there any reason to believe participants may not be able to give full informed consent? If yes, what steps do you propose to take to safeguard their interests?

n/a

15. If participants are under the responsibility or care of others (such as parents/carers, teachers or medical staff) what plans do you have to obtain permission to approach the participants to take part in the study?

n/a

16. **Describe what participation in your study will involve for study participants. Please attach copies of any questionnaires and/or interview schedules and/or observation topic list to be used**

No further contact with participants is required. The study will use secondary data analysis

17. **How will you make it clear to participants that they may withdraw consent to participate at any point during the research without penalty?**

n/a

18. **Detail any possible distress, discomfort, inconvenience or other adverse effects the participants may experience, including after the study, and you will deal with this.**

n/a

19. **How will you maintain participant anonymity and confidentiality in collecting, analysing and writing up your data?**

Analysis files do not contain named data. Individuals are identified only by their HCS serial number. No individual will be identifiable in either the thesis or publications. Care will be taken to anonymise reports where outcomes relate to numbers of cases so small as to be potentially identifiable.

20. **How will you store your data securely during and after the study?**

The University of Southampton has a Research Data Management Policy, including for data retention. The Policy can be consulted at http://www.calendar.soton.ac.uk/sectionIV/research-data-management.html

All data are stored electronically. Master files containing identifiable records are held on servers in the MRC Lifecourse Epidemiology Unit. Analysis files may be copied only onto encrypted memory sticks supplied by the MRC, as may work generated from them until published. The applicant is a member of staff at the Lifecourse Epidemiology Unit and breach of their strict data protection code constitutes grounds for dismissal.

21. **Describe any plans you have for feeding back the findings of the study to participants.**

Cohort members receive annual newsletters detailing the results of recent research

22. **What are the main ethical issues raised by your research and how do you intend to manage these?**

Patient confidentiality. Please see 19.

23. **Please outline any other information you feel may be relevant to this submission.**

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In addition to the individual consents (section 8), the Hertfordshire Cohort Study has ethical clearance from the ONS Central Ethics Committee for tracing of participants and Hertfordshire and Bedfordshire Local Research Ethics Committee for fieldwork.

6 files are attached relating to ethical permissions:

1. HCS Summary.pdf, a summary of ethical permissions held in relation to HCS to 2010
2. EC98248a.pdf, original permission from East & North Herts research ethics committee
3. EC98248b.pdf, a revision allowing information on clinical events to be stored
4. WH02_98.pdf, the equivalent permissions from West Herts research ethics committee
5. AHES DRA Extract_NIC-59859-2DT25.pdf, the HES data sharing agreement
6. DRA Renewal-ref- NIC-59859-2DT25-R1.pdf, renewal of the data sharing agreement

The applicant has been a member of the Hertfordshire Cohort Study team since its inception over 20 years ago. In this role she obtained the HES data and collaborated in collecting baseline data from the cohort members

D(ix) ERGO 13141 risk assessment form

UNIVERSITY OF Southampton

January 2012

Risk Assessment Form

- Please see Guidance Notes for completing the risk assessment form at the end of this document.

Researcher's name: Shirley Simmonds

Part 1 – Dissertation/project activities
What do you intend to do? (Please provide a brief description of your project and details of your proposed methods.) Secondary analysis of Cohort Study and Hospital Episode Statistics data
Will this involve collection of information from other people? (In the case of projects involving fieldwork, please provide a description of your proposed sample/case study site.) No
If relevant, what location/s is/are involved? n/a
Will you be working alone or with others? Alone
Part 2 – Potential safety issues / risk assessment.
Potential safety issues arising from proposed activity? Usual issues relating to spending long amounts of time sitting at one's desk/working with a computer
Person/s likely to be affected? Self
Likelihood of risk? Low

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Part 3 – Precautions / risk reduction
Existing precautions: Properly adjusted equipment
Proposed risk reduction strategies if existing precautions are not adequate: n/a

CONTINUED BELOW…

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Part 4 – International Travel
If you intend to travel overseas to carry out fieldwork then you must carry out a risk assessment for each trip you make and attach a copy of the International Travel form to this document Download the Risk Assessment for International Travel Form Guidelines on risk assessment for international travel at can be located at: www.southampton.ac.uk/socscinet/safety ("risk assessment" section). Before undertaking international travel and overseas visits all students must: • Ensure a risk assessment has been undertaken for all journeys including to conferences and visits to other Universities and organisations. This is University policy and is not optional. • Consult the University Finance/Insurance website for information on travel and insurance. Ensure that you take a copy of the University travel insurance information with you and know what to do if you should need medical assistance. • Obtain from Occupational Health Service advice on any medical requirements for travel to areas to be visited. • Ensure next of kin are aware of itinerary, contact person and telephone number at the University. • Where possible arrange to be met by your host on arrival. If you are unsure if you are covered by the University insurance scheme for the trip you are undertaking and for the country/countries you intend visiting, then you should contact the University's Insurance Office at insure@soton.ac.uk and check the Foreign and Commonwealth Office website.

Risk Assessment Form for International Travel attached	~~YES~~ / **NO**	**(Delete as applicable)**

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Guidance Notes for completing the risk assessment form

The purpose of assessing risks is to ensure everyone works safely. To carry out a Risk Assessment, ask yourself:

- How can the activity cause harm?
- Is it safe to carry out this activity without additional protection/support?
- If someone else is going to do the work, can they do it safely?

Activity

Give a brief outline of the activity/project including the methods to be used and the people to be involved

- Think about everything you are going to do, from start to finish.
- Ensure that you complete the assessment before you commence any work. If you are unsure if your proposed work carries any risk, go ahead and complete the form as the process could highlight some issues which otherwise may not have been aware of.

Potential Safety Issues

- Only list those hazards that you could reasonably expect to cause significant harm or injury.
- Talk to people who have experience of the activity.
- Will the activity involve lone working or potential exposure to violence? For more guidance see the Social Research Association website at www.the-sra.org.uk under Staying Safe.
- Are there any significant hazards due to where the work is to be done?

Who might be affected?

- List anyone who might be affected by the hazards.
- Remember to include yourself, co-workers, your participants and others working in or passing through the area of activity.
- Those more vulnerable or less experienced should be highlighted as they will be more at risk (e.g. children, disabled people or those with medical conditions, people unfamiliar with the area of activity).

Precautions/Risk Reduction

- List the control measures already in place for each of the significant hazards.
- Is the hazard dealt with by the School Health & Safety Policy, or a generic safety method statement?.
- Appropriate training is a control measure and should be listed.
- Is the risk a low as is reasonably practical?
- List any additional control measures/risk reduction strategies for each significant hazard (e.g. practical measures, training, improved supervision).

Risk Evaluation

- With all the existing control measures in place do any of the significant hazards still have a potential to cause significant harm? Rank as Low, Medium or High.

Remember

- Risk Assessments need to be suitable and sufficient, not perfect.
- Are the precautions reasonable?
- Is there something to show that a proper check was made?

This information is based on “An Introduction to Risk Assessment” produced by the Safety Office and the Training & Development Unit of the University of Southampton.

Appendix E Combined regression model using the most influential participant characteristics (4 levels to show day cases)

This appendix follows the same format at Table 24; the final model in the multinomial paper. In this case the ordinal variable divides the cohort into four groups: those who survived with no admissions (treated as the reference group); those who survived with only elective day case admissions; those who survived with overnight elective but no emergency admissions; and those who ever had an emergency admission or died. Thus for each predictor variable, the table presents three estimates of risk, relative to the non-admitted reference group.

Table E Combined regression model using the most influential participant characteristics (4 levels to show day cases)

Association between each characteristic and the admission history variable+ (footnotes overleaf)	**Men**		**Women**	
	RRR (95% CI)	**P-value**	**RRR (95% CI)**	**P-value**
	0.99 (0.85,1.16)	0.924	0.97 (0.83,1.13)	0.682
Age**	0.94 (0.80,1.10)	0.442	0.85 (0.72,1.00)	0.048
	0.96 (0.84,1.10)	0.580	0.98 (0.85,1.13)	0.770
	0.93 (0.80,1.09)	0.386	1.07 (0.91,1.24)	0.429
Height**	0.98 (0.83,1.15)	0.823	1.14 (0.96,1.34)	0.130
	1.02 (0.89,1.17)	0.784	1.16 (1.00,1.34)	0.048
	0.83 (0.71,0.98)	0.029	1.06 (0.89,1.25)	0.522
Weight for height residual**	0.95 (0.80,1.12)	0.532	1.15 (0.96,1.38)	0.125
	0.90 (0.78,1.03)	0.128	1.06 (0.90,1.24)	0.488
	0.92 (0.67,1.28)	0.632	1.16 (0.84,1.60)	0.371
Ever smoked*	1.15 (0.82,1.62)	0.411	1.15 (0.82,1.62)	0.421
	1.41 (1.06,1.88)	0.019	1.43 (1.06,1.93)	0.019
	0.94 (0.80,1.11)	0.449	1.03 (0.87,1.22)	0.755
Activity score**	1.01 (0.85,1.20)	0.904	0.98 (0.82,1.17)	0.802
	1.01 (0.88,1.17)	0.869	1.11 (0.94,1.30)	0.211
	1.28 (0.84,1.96)	0.243	1.19 (0.79,1.78)	0.413
Housing tenure (Not homeowner)*	0.64 (0.39,1.05)	0.079	0.98 (0.64,1.52)	0.941
	1.33 (0.93,1.91)	0.122	1.43 (0.99,2.07)	0.059
	0.85 (0.59,1.22)	0.369	0.94 (0.66,1.35)	0.752
Hypertension*	1.02 (0.71,1.48)	0.906	1.09 (0.75,1.59)	0.643
	1.09 (0.80,1.48)	0.601	1.04 (0.74,1.45)	0.826
	0.99 (0.59,1.65)	0.956	1.26 (0.75,2.12)	0.389
Low physical function SF36* ++	1.30 (0.79,2.15)	0.302	2.37 (1.43,3.91)	0.001
	1.67 (1.11,2.52)	0.014	2.48 (1.58,3.88)	<0.001
	1.15 (0.71,1.87)	0.563	1.33 (0.83,2.12)	0.234
Diabetes*	0.89 (0.54,1.47)	0.649	0.80 (0.47,1.35)	0.403
	1.01 (0.67,1.53)	0.956	1.05 (0.67,1.65)	0.817
	1.07 (0.88,1.30)	0.515	1.35 (1.10,1.65)	0.005
Self-rated health ***	1.20 (0.98,1.48)	0.083	1.43 (1.15,1.78)	0.001
	1.30 (1.09,1.54)	0.003	1.70 (1.40,2.06)	<0.001
	0.81 (0.37,1.79)	0.599	1.29 (0.52,3.21)	0.577
Bronchitis*	0.69 (0.30,1.61)	0.393	1.40 (0.57,3.47)	0.461
	1.53 (0.84,2.80)	0.167	2.31 (1.06,5.03)	0.035
Number of systems medicated	1.26 (1.05,1.51)	0.015	1.21 (1.04,1.40)	0.011
	1.33 (1.10,1.60)	0.003	1.33 (1.14,1.54)	<0.001
	1.48 (1.26,1.73)	<0.001	1.38 (1.21,1.58)	<0.001
Pseudo R2	*0.0399*		*0.0628*	

Footnotes:

[+]Estimates of associations are relative risk ratios (95% CI) from multinomial logistic regression models where the outcome was the variable representing admission history. All predictors were included simultaneously in this mutually adjusted model.

…continued

… footnotes (continued)

* Relative risk ratio for the presence vs absence of the characteristic

** Relative risk ratio per sex-specific SD increase in characteristic (estimates for activity score correspond to SD decreases). Relative risk ratio per unit increase in number of systems medicated is shown.

***Relative risk ratio per lower band of characteristic

+++Sex-specific score of ≤75M, <=60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

Admission history variable has the following categories: no admissions, alive (reference group); day electives, no overnight or emergency admissions, alive ; overnight electives, no emergencies, alive; ever emergency, dead

First relative risk ratio: relative risk of being in (day electives, no overnight or emergencies, alive) v (reference group)

Second relative risk ratio: relative risk of being in (overnight electives, no emergencies, alive) v (reference group)

Third relative risk ratio: relative risk of being in (ever emergency, dead) v (reference group)*

Appendix F Summary of relationships at each stage of the modelling process for all admission types, by sex

This appendix summarises the relationships identified by Chapters 5-7. The information presented by Tables 25 and 26 is extended, to show all four stages of the modelling process by sex using colour-coded circles. Associations with readmission (from Chapter 5) are shown by black circles; those with emergency admission (from Chapter 6) by grey diamonds; and with elective admission (from Chapter 7) by filled grey squares. In addition, associations identified by a subgroup analysis of people who only ever had elective day case admissions (Appendix E) are shown by open grey squares. For each stage of the regression modelling process, sex-specific findings are presented.

Table F Summary of significant relationships at each stage of the model for all admission types, by sex

Predictor variables	Stage 1*		Stage 2*		Stage 3*		Final model*	
	Men	Women	Men	Women	Men	Women	Men	Women
Demography/anthropometry								
Age	●	◆	◆	◆				
Height								
Weight		● ◆ ■			Adjusted for			
Weight for height residual		● ■ □		■			□	
BMI		● ◆ ■ □						
Lifestyle								
Smoking history	● ◆	● ◆	● ◆	● ◆			● ◆	◆
Alcohol intake					Adjusted for			
Activity score	● ◆	● ◆ ■	● ◆	● ◆				
Social circumstances								
Social class								
Relationship status	■		■		Adjusted for		■	
Home ownership	◆	● ◆		● ◆				●

Continued...

Table F Summary of significant relationships at each stage for all admission type, by sex (continued):

Predictor variables	**Stage 1***		**Stage 2***		**Stage 3***		**Stage 4***	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Physical function								
Grip strength					●	● ◆ ■		
Physical function	Not modelled		Not modelled		● ◆ ■	● ◆ ■ □	◆	◆ ■
Walking speed					● ◆	● ◆ ■ □	●	
Fall history								
Morbidity								
Ischaemic heart disease					● ◆	◆	◆	
Stroke						● ◆		
Hypertension					● ◆	● ◆ ■		
Diabetes					◆	□		
Fracture history					●		●	
Osteoarthritis (hand)	Not modelled		Not modelled					
Self-rated health					● ◆ ■	● ◆ ■ □	● ◆	● ◆ ■ □
Depression					●	●		
Anxiety						● ■		
Bronchitis					◆	● ◆		
Medication					● ◆ ■ □	● ◆ ■ □	● ◆ ■ □	● ■ □

● readmissions model; ◆ emergency admissions model; ◆ elective only group in mutinomial model; □ elective day case only group in mutinomial model

*Model stages: 1: Demo & anthro/Lifestyle/Social circs (univariate association); 2: Demo & anthro/Lifestyle/Social circs (adjusted for age and variables p<0.05 at stage 1); 3: Physical function/Morbidity (adjusted for age and variables p<0.05 at stage 2); 4: Final mutually adjusted model

Appendix G   Mutually adjusted models among survivors

This three-part appendix presents a reanalysis of each of the final models, limiting the study sample to those who survived the follow-up period. Where these tables differ from the final models, associations can be considered to have been driven, in part, by those who died. This possibility is discussed in Section 8.5.2, in the context of the strengths and limitations of the methods adopted by this research. The three tables presented are as follow:

G(i) Risk of 30-day readmission among cohort survivors

G(ii) Risk of emergency admission among cohort survivors

G(iii) Risk of three-category admission history outcome among cohort survivors

Table G(i) Combined regression model using the most influential participant characteristics to predict risk of 30-day readmission among cohort survivors

Association between each characteristic and the risk of readmission within 30 days[+]	**Men**		**Women**	
	Relative risk (95% CI)	P-value	Relative risk (95% CI)	P-value
Age**	1.03 (0.93,1.15)	0.539	1.02 (0.90,1.15)	0.772
Ever smoked*	1.00 (0.79,1.27)	0.971	1.07 (0.83,1.37)	0.606
Activity score**	1.01 (0.91,1.12)	0.852	1.09 (0.95,1.24)	0.201
Housing tenure (not homeowner)*	0.89 (0.68,1.17)	0.422	1.31 (1.00,1.72)	0.049
Low physical function SF36* [+++]	1.18 (0.90,1.56)	0.235	1.04 (0.75,1.46)	0.795
Walking speed (self-reported)***	1.08 (0.96,1.22)	0.212	1.05 (0.91,1.23)	0.493
Ischaemic heart disease*	1.11 (0.84,1.47)	0.468	0.85 (0.59,1.21)	0.366
Hypertension*	1.14 (0.90,1.44)	0.276	1.00 (0.77,1.31)	0.980
Fracture since 45yrs age*	1.36 (1.02,1.80)	0.034	0.93 (0.68,1.28)	0.667
Self-rated health ***	1.24 (1.09,1.42)	0.001	1.52 (1.27,1.82)	<0.001
Bronchitis*	0.99 (0.64,1.53)	0.970	1.15 (0.72,1.85)	0.565
Number of systems medicated [++]	1.11 (1.01,1.22)	0.033	1.18 (1.09,1.29)	<0.001
Pseudo R2	*0.0285*		*0.0747*	

Footnotes:

[+] Estimates of associations are relative risks (95% CI) from Poisson regression models where the outcome variable is whether or not the participant had a readmission within 30 days during the follow-up period. All predictors were included simultaneously in this mutually adjusted model.

* Relative risk for presence vs absence

[++] Relative risk per unit increase

** Relative risk per sex-specific SD increase (estimates for activity score represent SD decreases)

*** Relative risk per band decrease (ie slower walking speed and poorer self-rated health).

[+++] Sex-specific score of ≤75M, ≤60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

Table G (ii) Combined regression model using the most influential participant characteristics to predict risk of emergency admission among cohort survivors

Association between each characteristic and the risk of emergency admission[+]	**Men**		**Women**	
	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Age (yrs)*	1.07 (0.99,1.15)	0.084	1.08 (0.99,1.17)	0.067
Ever smoked	1.13 (0.94,1.35)	0.185	1.18 (0.99,1.40)	0.059
Activity score*	1.00 (0.94,1.08)	0.892	1.13 (1.03,1.24)	0.011
Housing tenure (not homeowner)	1.20 (1.02,1.41)	0.026	1.13 (0.94,1.35)	0.194
Low physical function SF36* ++	1.35 (1.13,1.63)	0.001	1.21 (0.98,1.50)	0.083
Ischaemic heart disease	1.30 (1.08,1.57)	0.006	0.98 (0.78,1.25)	0.900
Hypertension	1.16 (1.00,1.36)	0.056	1.11 (0.92,1.34)	0.281
Diabetes	1.07 (0.87,1.31)	0.528	0.91 (0.73,1.14)	0.422
Self-rated health**	1.11 (1.01,1.21)	0.028	1.29 (1.15,1.46)	0.000
Bronchitis	1.19 (0.96,1.49)	0.115	1.03 (0.75,1.40)	0.872
Number of systems medicated***	1.10 (1.03,1.18)	0.006	1.09 (1.02,1.16)	0.013
Pseudo R2	*0.01337819*		*0.01899098*	

Footnotes:

[+] Estimates of associations are hazard ratios (95% CI) from PWP-TT models where the failure event is an emergency admission. All predictors were included simultaneously in this mutually adjusted model.

* Hazard ratio per sex-specific SD increase (estimates for activity score correspond to SD decreases)

** Hazard ratio per lower band of characteristic

*** Hazard ratio per unit increase. For the remaining estimates, hazard ratios for the presence vs absence of the characteristic are given

++ Sex-specific score of ≤75M, ≤60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

Table G (iii) Combined regression model using the most influential participant characteristics to predict risk during follow-up of three outcomes among survivors

Association between each characteristic and the admission history variable	**Men**		**Women**	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Age (yrs)**	0.97 (0.84,1.11)	0.611	0.91 (0.79,1.04)	0.150
	0.94 (0.81,1.09)	0.439	0.95 (0.81,1.10)	0.476
Height (cm)**	0.95 (0.83,1.09)	0.448	1.10 (0.96,1.25)	0.174
	1.08 (0.93,1.25)	0.303	1.19 (1.02,1.39)	0.028
Weight for height residual**	0.88 (0.76,1.01)	0.074	1.10 (0.95,1.28)	0.197
	0.93 (0.80,1.08)	0.356	1.07 (0.90,1.27)	0.423
Ever smoked*	1.00 (0.76,1.33)	0.979	1.16 (0.88,1.54)	0.287
	1.15 (0.85,1.56)	0.376	1.36 (0.99,1.87)	0.056
Activity score**	0.98 (0.85,1.12)	0.733	1.01 (0.87,1.18)	0.877
	0.99 (0.85,1.15)	0.857	1.14 (0.96,1.35)	0.134
Housing tenure*	1.03 (0.70,1.50)	0.889	1.09 (0.76,1.56)	0.644
(not homeowner)	1.59 (1.08,2.33)	0.018	1.43 (0.97,2.10)	0.074
Relationship status	0.52 (0.30,0.90)	0.019	1.21 (0.66,2.21)	0.537
(never married)*	0.79 (0.46,1.35)	0.390	0.78 (0.38,1.63)	0.508
Hypertension*	0.92 (0.67,1.26)	0.595	1.01 (0.74,1.39)	0.929
	1.19 (0.85,1.64)	0.309	1.02 (0.72,1.45)	0.897
Low physical function SF36* [+++]	1.14 (0.74,1.75)	0.555	1.75 (1.12,2.73)	0.014
	1.51 (0.98,2.32)	0.063	2.29 (1.43,3.65)	0.001
Diabetes*	1.04 (0.68,1.58)	0.862	1.04 (0.68,1.58)	0.868
	1.00 (0.64,1.54)	0.984	0.99 (0.62,1.58)	0.959
Self-rated health ***	1.15 (0.97,1.37)	0.111	1.39 (1.16,1.66)	<0.001
	1.30 (1.08,1.57)	0.005	1.73 (1.41,2.13)	<0.001
Bronchitis*	0.75 (0.38,1.49)	0.417	1.34 (0.61,2.96)	0.469
	1.57 (0.83,2.97)	0.163	2.10 (0.93,4.72)	0.073
Number of systems medicated	1.28 (1.09,1.51)	0.002	1.27 (1.11,1.44)	<0.001
	1.43 (1.21,1.69)	<0.001	1.41 (1.23,1.62)	<0.001
Pseudo R2	*0.0375*		*0.0692*	

Footnotes:

[+] Estimates of associations are relative risk ratios (95% CI) from multinomial logistic regression models where the outcome was the variable representing admission history. All predictors were included simultaneously in this mutually adjusted model

* Relative risk ratio for the presence vs absence of the characteristic

** Relative risk ratio per sex-specific SD increase in characteristic (estimates for activity score correspond to SD decreases). Relative risk ratio per unit increase in number of systems medicated is shown.

***Relative risk ratio per lower band of characteristic

[+++] Sex-specific score of ≤75 (Men), ≤60 (Women) on SF-36 PF domain (lowest sex-specific fifth of distribution)

Admission history variable has the following categories: no admissions (reference group); only electives; ever emergency

First relative risk ratio: risk of being in (only electives) v (reference group)

Second relative risk ratio: risk of being in (ever emergency) v (reference group)

Appendix H Combined PWP regression model using the most influential participant characteristics to predict the risk of elective admission/death

This appendix applies the methodology of the emergency admissions paper to elective admissions experienced by cohort members, for comparison with the findings for the ‘elective only’ group in the multinomial paper. It is discussed in Section 8.5.3, in the context of the strengths and limitations of the methods adopted.

Table H Combined PWP regression model using the most influential participant characteristics to predict the risk of elective admission or death

Association between each characteristic and risk of elective admission or death	**Men**		**Women**	
	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Age (yrs)**	1.01 (1.00,1.03)	0.103	1.02 (1.00,1.04)	0.044
Ever smoked*	1.12 (1.03,1.22)	0.009	1.15 (1.05,1.26)	0.003
Activity score**	1.00 (1.00,1.00)	0.258	1.00 (1.00,1.00)	0.264
Home ownership (Not owned or mortgaged)*	0.84 (0.76,0.93)	0.001	1.06 (0.96,1.17)	0.252
Low physical function SF36* ++	1.07 (0.97,1.18)	0.160	1.08 (0.97,1.20)	0.153
Ischaemic heart disease*	1.10 (1.00,1.21)	0.055	0.93 (0.82,1.07)	0.310
Hypertension*	0.95 (0.87,1.04)	0.231	0.99 (0.90,1.09)	0.878
Diabetes	1.02 (0.92,1.12)	0.743	0.91 (0.81,1.02)	0.116
Self-rated health ***	0.93 (0.88,0.98)	0.010	0.89 (0.84,0.94)	<0.001
Bronchitis*	0.90 (0.78,1.04)	0.146	1.11 (0.93,1.34)	0.251
Number of systems medicated**	1.09 (1.05,1.13)	<0.001	1.08 (1.04,1.12)	<0.001
Pseudo R2	*0.00339965*		*0.00532961*	

Footnotes:

\+ Estimates of associations are hazard ratios (95% CI) from PWP-TT models where the failure event is an elective admission/death. All predictors were included simultaneously in this mutually adjusted model.

* Hazard ratio for the presence vs absence of the characteristic

** Hazard ratio per unit increase in characteristic

*** Hazard ratio per higher band of characteristic

++ Sex-specific score of ≤75M, <=60F on SF-36 PF domain (lowest sex-specific fifth of distribution)

References

Addicott, R. (2014) Commissioning and contracting for integrated care. The King's Fund. Available from: https://www.boa.ac.uk/wp-content/uploads/2015/01/Enc-1_Kings-Fund-Report1.pdf [Accessed 07/01/18].

ADLS Administrative Data Liaison Service (2017a) Health Survey for England. Available from: http://www.adls.ac.uk/find-administrative-data/linked-administrative-data/health-survey-for-england/ [Accessed 05/10/17].

ADLS Administrative Data Liaison Service (2017b) Linked administrative data. Available from: http://www.adls.ac.uk/find-administrative-data/linked-administrative-data/ [Accessed 05/10/17].

Aihie Sayer, A., Syddall, H., Martin, H.J., Patel, H., Baylis, D. and Cooper, C. (2008) The developmental origins of sarcopenia. J Nutr Health Aging, 12, 427-432.

Akbaraly, T., Sabia, S., Hagger-Johnson, G., Tabak, A.G., Shipley, M.J., Jokela, M., Brunner, E.J., Hamer, M., Batty, G.D., Singh-Manoux, A. and Kivimaki, M. (2013a) Does overall diet in midlife predict future aging phenotypes? A cohort study. Am J Med, 126, 411-419.e413.

Akbaraly, T.N., Hamer, M., Ferrie, J.E., Lowe, G., Batty, G.D., Hagger-Johnson, G., Singh-Manoux, A., Shipley, M.J. and Kivimaki, M. (2013b) Chronic inflammation as a determinant of future aging phenotypes. CMAJ, 185, E763-770.

Alderwick, H. and Ham, C. (2017) Sustainability and transformation plans for the NHS in England: what do they say and what happens next? BMJ, 356, 10.1136/bmj.j1541.

Altman, D.G. (1999) Practical statistics for medical research. Boca Raton: Chapman and Hall/CRC.

Andersen, R. and Newman, J.F. (1973) Societal and individual determinants of medical care utilization in the United States. Milbank Mem Fund Q Health Soc, 51 (1), 95-124.

Appleby, P.N., Allen, N.E. and Key, T.J. (2011) Diet, vegetarianism, and cataract risk. Am J Clin Nutr, 93 (5), 1128-1135.

Arber, S. and Cooper, H. (1999) Gender differences in health in later life: the new paradox? Soc Sci Med, 48 (1), 61-76.

Arber, S. and Ginn, J. (1993) Gender and inequalities in health in later life. Soc Sci Med, 36 (1), 33-46.

Arber, S. and Ginn, J. (2005) Gender dimensions of the age shift IN: Johnson, M.L. (ed.) The Cambridge Handbook of Age and Ageing. Cambridge: Cambridge University Press, 527-537.

Arnett, G. (2016) How does money flow through the health service in England? The Guardian, 10th February 2016. Available from: https://www.theguardian.com/society/datablog/2016/feb/10/how-does-money-flow-through-health-service-england-nhs [Accessed 10/01/18].

Arthritis Research UK (2015) Osteoarthritis of the hand. Available from: http://www.arthritisresearchuk.org/arthritis-information/conditions/osteoarthritis/which-joints-are-affected/hands.aspx [Accessed 16/09/2015].

References

Arthritis Research UK (2017) State of musculoskeletal health 2017. Chesterfield. Available from: https://www.arthritisresearchuk.org/arthritis-information/data-and-statistics/state-of-musculoskeletal-health.aspx [Accessed 07/01/18].

Au, S.Y., Chan, K.M., Chan, Y.H. and Pang, W.S. (2002) Early unplanned readmission of elderly in Singapore: a retrospective study. Ann Acad Med Singapore, 31 (6), 738-744.

Aylin, P., Williams, S., Bottle, A. and Jarman, B. (2004) Counting hospital activity: spells or episodes? BMJ, 329 (7476), 1207.

Babitsch, B., Gohl, D. and Von Lengerke, T. (2012) Re-revisiting Andersen's behavioral model of health services use: a systematic review of studies from 1998–2011. Psychosoc Med, 9, Doc11.

Bankart, M.J.G., Baker, R., Rashid, A., Habiba, M., Banerjee, J., Hsu, R., Conroy, S., Agarwal, S. and Wilson, A. (2011) Characteristics of general practices associated with emergency admission rates to hospital: a cross-sectional study. Emergency Med J, 28 (7), 558-563.

Barker, D.J.P. and Osmond, C. (1986) Infant mortality, childhood nutrition and ischaemic heart disease in England and Wales. Lancet, i, 1077-1081.

Barker, D.J.P., Winter, P.D., Osmond, C., Margetts, B. and Simmonds, S.J. (1989) Weight in infancy and death from ischaemic heart disease. Lancet, 11, 577-580.

Barnett, K., Mercer, S.W., Norbury, M., Watt, G., Wyke, S. and Guthrie, B. (2012) Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. Lancet, 380 (9836), 37-43.

Barros, A. and Hirakata, V. (2003) Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. BMC Med Res Methodol, 3, 21.

Bernard, S. and Smith, L.K. (1998) Emergency admissions of older people to hospital: a link with material deprivation. J Public Health Med (Oxf), 20 (1), 97-101.

Billings, J., Blunt, I., Steventon, A., Georghiou, T., Lewis, G. and Bardsley, M. (2012) Development of a predictive model to identify inpatients at risk of re-admission within 30 days of discharge (PARR-30). BMJ Open, 00, e001667.

Billings, J., Georghiou, T., Blunt, I. and Bardsley, M. (2013) Choosing a model to predict hospital admission: an observational study of new variants of predictive models for case finding. BMJ Open, 3, e003352.

Bjelland, I., Dahl, A.A., Haug, T.T. and Neckelmann, D. (2002) The validity of the Hospital Anxiety and Depression scale. An updated literature review. J Psychosom Res, 52 (2), 69-77.

Black, J.T. (2014) Learning about 30-day readmissions from patients with repeated hospitalizations. Am J Manag Care, 20 (6), E200-E207.

Blanchard, R.D., Bunker, J.B. and Wachs, M. (1977) Distinguishing aging, period and cohort effects in longitudinal studies of elderly populations. Socio-Economic Planning Sciences, 11, 137-146.

Blunt, I. (2013) Focus on preventable admissions. Trends in emergency admissions for ambulatory care sensitive conditions, 2001 to 2013. London: The Health Foundation and the Nuffield Trust. Available from:

http://www.qualitywatch.org.uk/sites/files/qualitywatch/field/field_document/131010_QualityWatch_Focus_Preventable_Admissions.pdf [Accessed 07/01/18].

Blunt, I., Bardsley, M. and Dixon, J. (2010) Trends in emergency admissions in England 2004-2009. The Nuffield Trust for Research and Policy Studies in Health Services. Available from: https://www.nuffieldtrust.org.uk/research/trends-in-emergency-admissions-in-england-2004-2009 [Accessed 10/01/18].

Blunt, I., Bardsley, M., Grove, A. and Clarke, A. (2015) Classifying emergency 30-day readmissions in England using routine hospital data 2004-2010: what is the scope for reduction? Emergency Med J, 32 (1), 44-50.

Bottle, A., Aylin, P. and Majeed, A. (2006) Identifying patients at high risk of emergency hospital admissions: a logistic regression analysis. J R Soc Med, 99, 406-414.

Bouillon, K., Sabia, S., Jokela, M., Gale, C.R., Singh-Manoux, A., Shipley, M.J., Kivimaki, M. and Batty, G.D. (2013) Validating a widely used measure of frailty: are all sub-components necessary? Evidence from the Whitehall II cohort study. Age (Dordr), 35, 1457-1465.

Bowling, A. (2005) Just one question: If one question works, why ask several? J Epidemiol Community Health, 59, 342-345.

Boyd, A., Cornish, R., Johnson, L., Simmonds, S., Syddall, H., Westbury, L., Cooper, C. and J., M. (2018) Understanding Hospital Episode Statistics (HES). Bristol: University of Bristol.

Brennan, L., Watson, M., Klaber, R. and Charles, T. (2012) The importance of knowing context of hospital episode statistics when reconfiguring the NHS. BMJ, 344, 2432.

Brunner, E.J., Shipley, M.J., Britton, A.R., Stansfeld, S.A., Heuschmann, P.U., Rudd, A.G., Wolfe, C.D., Singh-Manoux, A. and Kivimaki, M. (2014) Depressive disorder, coronary heart disease, and stroke: dose-response and reverse causation effects in the Whitehall II cohort study. *Eur J Prev Cardiol,* 21 (3), 340-346.

Brunner, R. (2006) Understanding gender factors affecting self-rated health. Gend Med, 3, 292-294.

Burns, E.M., Rigby, E., Mamidanna, R., Bottle, A., Aylin, P., Ziprin, P. and Faiz, O.D. (2012) Systematic review of discharge coding accuracy. J Public Health (Oxf), 34 (1), 138-148.

Care Quality Commission (2013) The state of health care and adult social care in England. Technical Annex 1: Avoidable admissions. London: The Stationery Office. Available from: https://www.cqc.org.uk/sites/default/files/documents/cqc_soc_report_2013_lores2.pdf [Accessed 07/01/18].

Carstairs, V. and Morris, R. (1990) Deprivation and health in Scotland. Health Bull (Edinb), 48 (4), 162-175.

Castaneda, J. and Gerritse, B. (2010) Appraisal of several methods to model time to multiple events per subject: modelling time to hospitalizations and death. Revista Colombiana De Estadistica, 33 (1), 43-61.

Cawthon, P.M., Fox, K.M., Gandra, S.R., Delmonico, M.J., Chiou, C.-F., Anthony, M.S., Sewall, A., Goodpaster, B., Satterfield, S., Cummings, S.R., Harris, T.B. and Health Aging and Body Composition Study (2009) Do muscle mass, muscle density, strength, and physical function similarly influence risk of hospitalization in older adults? J Am Geriatr Soc, 57 (8), 1411-1419.

References

Cesari, M., Kritchevsky, S.B., Newman, A.B., Simonsick, E.M., Harris, T.B., Penninx, B.W., Brach, J.S., Tylavsky, F.A., Satterfield, S., Bauer, D.C., Rubin, S.M., Visser, M. and Pahor, M. (2009) Added value of physical performance measures in predicting adverse health-related events: results from the Health, Aging and Body Composition Study. J Am Geriatr Soc, 57 (2), 251-259.

Chan, O.Y.A., Van Houwelingen, A.H., Gussekloo, J., Blom, J.W. and Den Elzen, W.P.J. (2014) Comparison of quadriceps strength and handgrip strength in their association with health outcomes in older adults in primary care. Age (Dordr), 36, 9714.

Chauhan, M., Bankart, M.J., Labeit, A. and Baker, R. (2012) Characteristics of general practices associated with numbers of elective admissions. J Public Health (Oxf), 34 (4), 584-590.

Chavez, L.J., Liu, C.F., Tefft, N., Hebert, P.L., Clark, B.J., Rubinsky, A.D., Lapham, G.T. and Bradley, K.A. (2016) Unhealthy alcohol use in older adults: Association with readmissions and emergency department use in the 30 days after hospital discharge. Drug Alcohol Depend, 158, 94-101.

Chenore, T., Gray, D.J.P., Forrer, J., Wright, C. and Evans, P.H. (2013) Emergency hospital admissions for the elderly: insights from the Devon Predictive Model. J Public Health (Oxf), 35 (4), 616-623.

Chu, L.W. and Pei, C.K. (1999) Risk factors for early emergency hospital readmission in elderly medical patients. Gerontology, 45 (4), 220-226.

Clegg, A., Bates, C., Young, J., Ryan, R., Nichols, L., Teale, E.A., Mohammed, M.A., Parry, J. and Marshall, T. (2016) Development and validation of an electronic frailty index using routine primary care electronic health record data. Age Ageing, 45 (3), 353-360.

Coggon, D., Rose, G. and Barker, D.J.P. (2003) Epidemiology for the Uninitiated, 5th ed.: BMJ Books.

Commission on the Future of Health and Social Care in England (2014) The UK private health market. The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/media/commission-appendix-uk-private-health-market.pdf [Accessed 07/01/18].

Conroy, S.P., Dowsing, T., Reid, J. and Hsu, R. (2013) Understanding readmissions: An in-depth review of 50 patients readmitted back to an acute hospital within 30 days. Eur Geriatr Med, 4 (1), 25-27.

Cooper, R., Kuh, D., Cooper, C., Gale, C.R., Lawlor, D.A., Matthews, F. and Hardy, R. (2011) Objective measures of physical capability and subsequent health: A systematic review. Age Ageing, 40 (1), 14-23.

Cornette, P., D'Hoore, W., Malhomme, B., Van Pee, D., Meert, P. and Swine, C. (2005) Differential risk factors for early and later hospital readmission of older patients. Aging Clin Exp Res, 17 (4), 322-328.

Cornwell, J., Levenson, R., Sonola, L. and Poteliakhoff, E. (2012) Continuity of care for older hospital patients. A call for action. London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/continuity-of-care-for-older-hospital-patients-mar-2012.pdf [Accessed 07/01/18].

Cox, L.S., Mason, P.A., Bagley, M.C., Steinsaltz, D., Stefanovska, A., Bernjak, A., McClintock, P.V.E., Phillips, A.C., Upton, J., Latimer, J.E. and Davis, T. (2014) Understanding ageing: biological and social perspectives IN: Walker, A. (ed.) The New Science of Ageing. Bristol: Policy Press, 25-75.

Craig, R. and Mindell, J. (2007) Health Survey for England 2005 Available from: http://digital.nhs.uk/catalogue/PUB01184 [Accessed 07/01/18].

Crossley, T.F. and Kennedy, S. (2002) The reliability of self-assessed health status. J Health Econ, 21, 643-658.

Crowe, F.L., Appleby, P.N., Allen, N.E. and Key, T.J. (2011) Diet and risk of diverticular disease in Oxford cohort of European Prospective Investigation into Cancer and Nutrition (EPIC): prospective study of British vegetarians and non-vegetarians. BMJ, 343, d4131.

Crowe, F.L., Appleby, P.N., Travis, R.C. and Key, T.J. (2013) Risk of hospitalization or death from ischemic heart disease among British vegetarians and nonvegetarians: results from the EPIC-Oxford cohort study. Am J Clin Nutr, 97 (3), 597-603.

Daiello, L.A., Gardner, R., Epstein-Lubow, G., Butterfield, K. and Gravenstein, S. (2014) Association of dementia with early rehospitalization among Medicare beneficiaries. Arch Gerontol Geriatr, 59 (1), 162-168.

Dallosso, H.M., Morgan, K., Bassey, E.J., Ebrahim, S.B.J., Fentem, P.H. and Arie, T.H.D. (1988) Levels of customary physical activity among the old and the very old living at home. J Epidemiol Community Health, 42, 121-127.

Damush, T.M., Smith, D.M., Perkins, A.J., Dexter, P.R. and Smith, F. (2004) Risk factors for nonelective hospitalization in frail and older adult, inner-city outpatients. Gerontologist, 44 (1), 68-75.

Davies, S. (2015) On the state of the public's health. Baby boomers: fit for the future. Department of Health. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/654806/CMO_baby_boomers_annual_report_2015.pdf [Accessed 07/01/18].

Davydow, D.S., Fenger-Gron, M., Ribe, A.R., Pedersen, H.S., Prior, A., Vedsted, P., Unutzer, J. and Vestergaard, M. (2015) Depression and risk of hospitalisations and rehospitalisations for ambulatory care-sensitive conditions in Denmark: a population-based cohort study. BMJ Open, 5, e009878.

Department of Health (2001) National Service Framework for older people. Available from: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4003066 [Accessed 26/07/2018].

Department of Health (2008) Emergency readmission rates. Further analysis. Available from: http://webarchive.nationalarchives.gov.uk/+/http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_090053 [Accessed 07/01/18].

Department of Health (2010) The Operating Framework for the NHS in England 2011/12. London. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216187/dh_122736.pdf [Accessed 07/01/18].

Department of Health (2011) Start active, stay active: A report on physical activity from the four home countries' Chief Medical Officers. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216370/dh_128210.pdf [Accessed 07/01/18].

Department of Health (2012a) Health and Social Care Act 2012: fact sheet A1. Available from: https://www.gov.uk/government/publications/health-and-social-care-act-2012-fact-sheets [Accessed 20/03/2017].

Department of Health (2012b) Health and Social Care Act 2012: fact sheet C8. Available from: https://www.gov.uk/government/publications/health-and-social-care-act-2012-fact-sheets.

Department of Health (2012c) Reference costs 2011-12. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213060/2011-12-reference-costs-publication.pdf [Accessed 15/10/2015].

Department of Health (2013) Emergency readmissions data. Available from: https://www.gov.uk/government/publications/emergency-readmissions-data.

Devis, T. and Rooney, C. (1999) Death certification and the epidemiologist. Health Stat Q, 01, 21-33.

Dinescu, A., Korc-Grodzicki, B., Farber, J. and Ross, J.S. (2012) Discharge disposition disagreements and re-admission risk among older adults: A retrospective cohort study. BMJ Open, 2, e001646.

Dixon, A., Le Grand, J., Henderson, J., Murray, R. and Poteliakhoff, E. (2007) Is the British National Health Service equitable? The evidence on socioeconomic differences in utilization. J Health Serv Res Policy, 12 (2), 104-109.

Dixon, T., Shaw, M., Frankel, S. and Ebrahim, S. (2004) Hospital admissions, age and death: retrospective cohort study. BMJ, 328, 1288.

Dodds, R.M., Syddall, H.E., Cooper, R., Benzeval, M., Deary, I.J., Dennison, E.M., Der, G., Gale, C.R., Inskip, H.M., Jagger, C., Kirkwood, T.B., Lawlor, D.A., Robinson, S.M., Starr, J.M., Steptoe, A., Tilling, K., Kuh, D., Cooper, C. and Sayer, A.A. (2014) Grip strength across the life course: normative data from twelve British studies. PLoS One, 9 (12), e113637.

Doll, R., Peto, R., Boreham, J. and Sutherland, I. (2004) Mortality in relation to smoking: 50 years' observations on male British doctors. BMJ, 328 (7455), 1519-1528.

Dombrowski, W., Yoos, J.L., Neufeld, R. and Tarshish, C.Y. (2012) Factors predicting rehospitalization of elderly patients in a postacute skilled nursing facility rehabilitation program. Arch Phys Med Rehabil, 93 (10), 1808-1813.

Dong, X. and Simon, M.A. (2015) Elder self-neglect is associated with an increased rate of 30-day hospital readmission: findings from the Chicago Health and Aging Project. Gerontology, 61 (1), 41-50.

Douglas, P.S. (2017) Clinical features and diagnosis of coronary heart disease in women. Available from: https://www.uptodate.com/contents/clinical-features-and-diagnosis-of-coronary-heart-disease-in-women? [Accessed 19/11/17].

Drozda Jr, J.P. (2013) Readmission rates. BMJ, 347, f7478.

Elias, P., Halstead, K. and Prandy, K. (1993) Computer assisted standard occupational coding. H.M. Stationery Office.

Espallargues, M., Philp, I., Seymour, D.G., Campbell, S.E., Primrose, W., Arino, S., Dunstan, E., Lamura, G., Lawson, P., Mestheneos, E., Politynska, B. and Raiha, I. (2008) Measuring case-mix and outcome for older people in acute hospital care across Europe: the development and potential of the ACMEplus instrument. QJM, 101 (2), 99-109.

Evandrou, M. (2005) Focus on Older People. Chapter 5: Health and wellbeing. Office for National Statistics. Available from: https://www.fareham.gov.uk/PDF/planning/local_plan/Examination/DHO13%20Focus%20on%20Older%20People%202005%20edition.pdf [Accessed 07/01/18].

Evans, J.G. and Tallis, R.C. (2001) A new beginning for care for elderly people? BMJ, 322, 807-808.

Ewbank, L., Thompson, J. and McKenna, H. (2017) NHS hospital bed numbers: past, present, future Available from: https://www.kingsfund.org.uk/publications/nhs-hospital-bed-numbers [Accessed 12/05/18].

Fayers, P.M. and Sprangers, M.A.G. (2002) Understanding self-rated health. Lancet, 359 (9302), 187-188.

Ferraro, K.F. and Schafer, M.H. (2008) Gerontology's greatest hits. J Gerontol B Psychol Sci Soc Sci, 63 (1), S3-S6.

Fisher, S.R., Graham, J.E., Krishnan, S. and Ottenbacher, K.J. (2016) Predictors of 30-day readmission following inpatient rehabilitation for patients at high risk for hospital readmission. PhysTher, 96 (1), 62-70.

Fisher, S.R., Kuo, Y.F., Sharma, G., Raji, M.A., Kumar, A., Goodwin, J.S., Ostir, G.V. and Ottenbacher, K.J. (2013) Mobility after hospital discharge as a marker for 30-day readmission. J Gerontol A Biol Sci Med Sci, 68 (7), 805-810.

Foot, C., Gilburt, H., Dunn, P., Jabbal, J., Seale, B., Goodrich, J., Buck, D. and Taylor, J. (2014) People in control of their own health and care. The state of involvement. London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/people-in-control-of-their-own-health-and-care-the-state-of-involvement-november-2014.pdf [Accessed 07/01/18].

Foundation Trust Network (2011) The impact of non-payment for acute readmissions. London: NHS Confederation, Issue 211. Available from: http://www.chks.co.uk/userfiles/files/The%20impact%20of%20non-payment%20for%20acute%20readmissions%20FINAL%20FOR%20WEB.pdf [Accessed 07/01/18].

Franco, O.H., Karnik, K., Osborne, G., Ordovas, J.M., Catt, M. and Van Der Ouderaa, F. (2009) Changing course in ageing research: the healthy ageing phenotype. Maturitas, 63 (1), 13-19.

Fried, L.P., Tangen, C.M., Walston, J., Newman, A.B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W.J., Burke, G. and McBurnie, M.A. (2001) Frailty in older adults: Evidence for a phenotype. J Gerontol A Biol Sci Med Sci, 56 (3), M146-M156.

Galdas, P.M., Cheater, F. and Marshall, P. (2005) Men and health help-seeking behaviour: literature review. J Adv Nurs, 49 (6), 616-623.

Galenkamp, H., Deeg, D.J.H., De Jongh, R.T., Kardaun, J. and Huisman, M. (2016) Trend study on the association between hospital admissions and the health of Dutch older adults (1995-2009). BMJ Open, 6, e011967.

Galobardes, B., Shaw, M., Lawlor, D.A., Lynch, J.W. and Smith, G.D. (2006) Indicators of socioeconomic position (part 1). J Epidemiol Community Health, 60 (1), 7-12.

References

Garcia-Perez, L., Linertova, R., Lorenzo-Riera, A., Vazquez-Diaz, J.R., Duque-Gonzalez, B. and Sarria-Santamera, A. (2011) Risk factors for hospital readmissions in elderly patients: a systematic review. QJM, 104 (8), 639-651.

Gilbert, R., Goldstein, H. and Hemingway, H. (2015) The market in healthcare data. BMJ, 351, h5897.

Gilhooly, M., Hanlon, P., Cullen, B., Macdonald, S. and Whyte, B. (2007a) Successful ageing in an area of deprivation: Part 2- a quantitative exploration of the role of personality and beliefs in good health in old age. Public Health, 121, 814-821.

Gilhooly, M., Hanlon, P., Mowat, H., Cullen, B., Macdonald, S. and Whyte, B. (2007b) Successful ageing in an area of deprivation: Part 1- a qualitative exploration of the role of life experiences in good health in old age. Public Health, 121, 807-813.

Gjonca, E. and Marmot, M. (2005) Patterns of illness and mortality across the adult lifespan IN: Johnson, M.L. (ed.) The Cambridge Handbook of Age and Ageing. Cambridge: Cambridge University Press, 106-120.

Glasziou, P. and Chalmers, I. (2017) Can it really be true that 50% of research is unpublished? Available from: http://blogs.bmj.com/bmj/2017/06/05/paul-glasziou-and-iain-chalmers-can-it-really-be-true-that-50-of-research-is-unpublished/ [Accessed 24/11/17].

Godden, S. and Pollock, A.M. (2001) The use of acute hospital services by elderly residents of nursing and residential care homes. Health Soc Care Community, 9, 367-374.

Gov.UK (2017) Digital Economy Act, part 5: data sharing codes and regulations Available from: https://www.gov.uk/government/consultations/digital-economy-act-part-5-data-sharing-codes-and-regulations [Accessed 20/11/17].

Government Office for Science (2016) The future of an ageing population. London. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/535187/gs-16-10-future-of-an-ageing-population.pdf.

Grundy, E.M.D. (2003) The epidemiology of aging IN: Tallis, R.C. and Fillit, H.M. (eds.) Brocklehurst's textbook of geriatric medicine and gerontology, 6th ed.: Churchill Livingstone.

Hall, J.F. and Mindell, J. (2011) Health Survey for England. Respiratory symptoms and diseases in adults. The Health and Social Care Information Centre. Available from: http://content.digital.nhs.uk/pubs/hse10report [Accessed 07/01/18].

Hallgren, J., Ernsth Bravell, M., Molstad, S., Ostgren, C.J., Midlov, P. and Dahl Aslan, A.K. (2016a) Factors associated with increased hospitalisation risk among nursing home residents in Sweden: a prospective study with a three-year follow-up. Int J Older People Nurs, 11, 130-139.

Hallgren, J., Fransson, E.I., Kareholt, I., Reynolds, C.A., Pedersen, N.L. and Aslan, A.K.D. (2016b) Factors associated with hospitalization risk among community living middle aged and older persons: Results from the Swedish Adoption/Twin Study of Aging (SATSA). Arch Gerontol Geriatr, 66, 102-108.

Ham, C., Alderwick, H., Dunn, P. and McKenna, H. (2017) Delivering sustainability and transformation plans. The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/STPs_proposals_to_plans_Kings_Fund_Feb_2017_0.pdf [Accessed 07/01/18].

Hanlon, P., Lawder, R., Elders, A., Clark, D., Walsh, D., Whyte, B. and Sutton, M. (2007) An analysis of the link between behavioural, biological and social risk factors and subsequent hospital admission in Scotland. J Public Health (Oxf), 29 (4), 405-412.

Hanlon, P., Walsh, D., Whyte, B.W., Scott, S., Lightbody, P. and Gilhooly, M.L.M. (1998) Hospital use by an ageing cohort: an investigation into the association between biological, behavioural and social risk markers and subsequent hospital utilization. J Public Health Med (Oxf), 20, 467-476.

Hanlon, P., Walsh, D., Whyte, B.W., Scott, S.N., Hole, D., Lightbody, P. and Gilhooly, M.L. (2000a) Influence of biological, behavioural, health service and social risk factors on the trend towards more frequent (sic). Health Bull (Edinb), 58 (4), 342-353.

Hanlon, P., Walsh, D., Whyte, B.W., Scott, S.N., Lightbody, P. and Gilhooly, M.L.M. (2000b) The link between major risk factors and important categories of admission in an ageing cohort. J Public Health Med (Oxf), 22 (1), 81-89.

Harrison, M., Dusheiko, M., Sutton, M., Gravelle , H., Doran, T. and Roland, M. (2014) Effect of a national primary care pay for performance scheme on emergency hospital admissions for ambulatory care sensitive conditions: controlled longitudinal study. BMJ, 349, g6423.

Hart, C.L., Hole, D.J., Lawlor, D.A. and Smith, G.D. (2007) Obesity and use of acute hospital services in participants of the Renfrew/Paisley study. J Public Health (Oxf), 29 (1), 53-56.

Hart, C.L., Hole, D.J. and Smith, G.D. (2000) Comparison of risk factors for stroke incidence and stroke mortality in 20 years of follow-up in men and women in the Renfrew/Paisley study in Scotland. Stroke, 31 (8), 1893-1896.

Hart, C.L., Mackinnon, P.L., Watt, G.C.M., Upton, M.N., McConnachie, A., Hole, D.J., Davey Smith, G., Gillis, C.R. and Hawthorne, V.M. (2005) The Midspan studies. Int J Epidemiol, 34, 28-34.

Hart, C.L., McCartney, G. and Watt, G.C.M. (2015) Occupational class differences in later life hospital use by women who survived to age 80: the Renfrew and Paisley prospective cohort study. Age and Ageing, 44, 515-519.

Hart, C.L. and Smith, G.D. (2008) Alcohol consumption and mortality and hospital admissions in men from the Midspan Collaborative cohort study. Addiction, 103 (12), 1979-1986.

Hart, C.L. and Smith, G.D. (2009) Alcohol consumption and use of acute and mental health hospital services in the West of Scotland Collaborative prospective cohort study. J Epidemiol Community Health, 63 (9), 703-707.

Harvey, N., Dennison, E. and Cooper, C. (2014) Osteoporosis: a lifecourse approach. J Bone Miner Res, 29 (9), 1917-1925.

Health and Social Care Information Centre (2011) HES on... falls. Available from: http://www.hesonline.nhs.uk/Ease/servlet/ContentServer?siteID=1937&categoryID=1071 (resource no longer available) [Accessed 2011].

Health and Social Care Information Centre (2013a) Hospital Episode Statistics, Emergency readmissions to hospital within 28 days of discharge - financial year 2011/12. Available from: https://digital.nhs.uk/catalogue/PUB12751 [Accessed 07/01/18].

Health and Social Care Information Centre (2013b) OPCS-4 classification. Available from: http://systems.hscic.gov.uk/data/clinicalcoding/codingstandards/opcs4 (resource no longer available without registration) [Accessed 24/04/15].

References

Health and Social Care Information Centre (2014a) Focus on the health and care of older people. Available from: https://digital.nhs.uk/catalogue/PUB14369 [Accessed 07/01/18].

Health and Social Care Information Centre (2014b) Statistics on smoking, England 2014. Available from: https://digital.nhs.uk/catalogue/PUB14988 [Accessed 07/01/18].

Hills, A.P., Mokhtar, N. and Byrne, N.M. (2014) Assessment of physical activity and energy expenditure: an overview of objective measures. Front Nutr, 1, 5.

Himsworth, R.L. and Goldacre, M.J. (1999) Does time spent in hospital in the final 15 years of life increase with age at death? A population based study. BMJ, 319, 1338-1339.

Hinnouho, G.M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E.J., Kivimaki, M. and Singh-Manoux, A. (2015) Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: the Whitehall II cohort study. Eur Heart J, 36, 551-559.

Hotchkiss, J.W., Davies, C.A. and Leyland, A.H. (2013) Adiposity has differing associations with incident coronary heart disease and mortality in the Scottish population: cross-sectional surveys with follow-up. Int J Obes, 37 (5), 732-739.

House of Lords Select Committee on Public Service and Demographic Change (2013) Ready for ageing. Stationery Office, HL Paper 140. Available from: http://www.publications.parliament.uk/pa/ld201213/ldselect/ldpublic/140/140.pdf [Accessed 07/01/18].

Hu, J., Gonsahn, M.D. and Nerenz, D.R. (2014) Socioeconomic status and readmissions: evidence from an urban teaching hospital. Health Aff (Millwood), 34 (5), 778-785.

Iacobucci, G. (2017a) Increase in life expectancy in England has halted, new figures show. BMJ, 358, j3473.

Iacobucci, G. (2017b) NHS in 2017: keeping pace with society. BMJ, 356, i6738.

Idler, E.L. and Benyamini, Y. (1997) Self-rated health and mortality: a review of twenty-seven community studies. J Health Soc Behav, 38, 21-37.

Iloabuchi, T.C., Mi, D., Tu, W. and Counsell, S.R. (2014) Risk factors for early hospital readmission in low-income elderly adults. J Am Geriatr Soc, 62 (3), 489-494.

Imison, C., Curry, N., Holder, H., Castle-Clarke, S., Nimmons, D., Appleby, J., Thorlby, R. and Lombardo, S. (2017) Shifting the balance of care. Great expectations. London: Nuffield Trust. Available from: https://www.nuffieldtrust.org.uk/files/2017-02/shifting-the-balance-of-care-report-web-final.pdf [Accessed 07/01/18].

Imison, C., Poteliakhoff, E. and Thompson, J.L. (2012) Older people and emergency bed use. Exploring variation. London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/field/field_publication_file/older-people-and-emergency-bed-use-aug-2012.pdf [Accessed 07/01/18].

Information Services Division (2018) Acute Hospital Activity and NHS Beds Information in Scotland. Available from: http://www.isdscotland.org/Health-Topics/Hospital-Care/Publications/2017-11-07/2017-11-07-Annual-QuarterlyAcuteActivity-Report.pdf [Accessed 26/07/2018].

Jamei, M., Nisnevich, A., Wetchler, E., Sudat, S. and Liu, E. (2017) Predicting all-cause risk of 30-day hospital readmission using artificial neural networks. PLoS One, 12 (7), e0181173.

Jones, R. (2006a) Overnight stay elective admissions in Thames Valley. Available from: http://www.hcaf.biz/Forecasting%20Demand/Benchmark_elective_admission.pdf [Accessed 07/01/18].

Jones, R. (2006b) Zero day stay 'emergency' admissions in Thames Valley. Available from: http://www.hcaf.biz/Forecasting%20Demand/benchmark_zerodaystay_emergency_admissions.pdf [Accessed 07/01/18].

Jylha, M. (2009) What is self-rated health and why does it predict mortality? Towards a unified conceptual model. Soc Sci Med, 69 (3), 307-316.

Kanis, J.A. (2007) Assessment of osteoporosis at the primary health care level. World Health Organization. Available from: https://www.sheffield.ac.uk/FRAX/pdfs/WHO_Technical_Report.pdf [Accessed 07/01/18].

Kanis, J.A. and Pitt, F.A. (1992) Epidemiology of osteoporosis. Bone, 13 (Supplement 1), S7-S15.

Kansagara, D., Englander, H., Salanitro, A., Kagen, D., Theobald, C., Freeman, M. and Kripalani, S. (2011) Risk prediction models for hospital readmission. A systematic review. JAMA, 306 (15), 1688-1698.

Kennedy, B.S., Kasl, S.V. and Vaccarino, V. (2001) Repeated hospitalisations and self-rated health among the elderly: a multivariate failure time analysis. Am J Epidemiol, 153, 232-241.

Kent, S., Green, J., Reeves, G., Beral, V., Gray, A., Jebb, S., Cairns, B., Mihaylova, B. and Million Women Study Collaborators (2017) Hospital costs in relation to body-mass index in 1·1 million women in England: a prospective cohort study. Lancet Public Health, 2: e214–22.

Kivimaki, M., Batty, G.D., Hamer, M., Ferrie, J.E., Vahtera, J., Virtanen, M., Marmot, M.G., Singh-Manoux, A. and Shipley, M.J. (2011) Using additional information on working hours to predict coronary heart disease: a cohort study. Ann Intern Med, 154, 457-463.

Kwok, T., Lau, E., Woo, J., Luk, J.K., Wong, E., Sham, A. and Lee, S.H. (1999) Hospital readmission among older medical patients in Hong Kong. J R Coll Physicians Lond, 33 (2), 153-156.

Laniece, I., Couturier, P., Drame, M., Gavazzi, G., Lehman, S., Jolly, D., Voisin, T., Lang, P.O., Jovenin, N., Gauvain, J.B., Novella, J.L., Saint-Jean, O. and Blanchard, F. (2008) Incidence and main factors associated with early unplanned hospital readmission among French medical inpatients aged 75 and over admitted through emergency units. Age Ageing, 37 (4), 416-422.

Lawlor, D.A., Hart, C.L., Hole, D.J., Gunnell, D. and Davey Smith, G. (2007) Body mass index in middle life and future risk of hospital admission for psychoses or depression: findings from the Renfrew/Paisley study. Psychol Med, 37 (8), 1151-1161.

Lawrie, M. and Battye, F. (2012) Older people's experience of emergency hospital readmission. London: Age UK. Available from: https://www.ageuk.org.uk/documents/en-gb/for-professionals/research/emergency_readmission_older_peoples_experiences.pdf [Accessed 07/01/18].

Layes, A., Asada, Y. and Kepart, G. (2012) Whiners and deniers - what does self-rated health measure? Soc Sci Med, 75 (1), 1-9.

Legrand, D., Vaes, B., Mathei, C., Adriaensen, W., Van Pottelbergh, G. and Degryse, J.-M. (2014) Muscle strength and physical performance as predictors of mortality, hospitalization, and disability in the oldest old. J Am Geriatr Soc, 62 (6), 1030-1038.

Lewis, G., Curry, N. and Bardsley, M. (2011) Choosing a predictive risk model: a guide for commissioners in England. London: Nuffield Trust. Available from: https://www.nuffieldtrust.org.uk/files/2017-01/choosing-predictive-risk-model-guide-for-commissioners-web-final.pdf [Accessed 07/01/18].

Librero, J., Peiro, S. and Ordinana, R. (1999) Chronic comorbidity and outcomes of hospital care: length of stay, mortality, and readmission at 30 and 365 days. J Clin Epidemiol, 52 (3), 171-179.

Lillard, L.A. and Panis, C.W.A. (1996) Marital status and mortality: the role of health. Demography, 33 (3), 313-327.

Loder, E. (2017) The great NHS debate. BMJ, 357, j1729.

Lotus Shyu, Y.I., Chen, M.C. and Lee, H.C. (2004) Caregiver's needs as predictors of hospital readmission for the elderly in Taiwan. Soc Sci Med, 58 (7), 1395-1403.

Luben, R., Hayat, S., Wareham, N. and Khaw, K.T. (2016) Predicting admissions and time spent in hospital over a decade in a population-based record linkage study: the EPIC-Norfolk cohort. BMJ Open, 6, e009461.

Macintyre, S., Hiscock, R., Kearns, A. and Ellaway, A. (2001) Housing tenure and car access: further exploration of the nature of their relations with health in a UK setting. J Epidemiol Community Health, 55 (5), 330-331.

Maddams, J., Brewster, D., Gavin, A., Steward, J., Elliott, J., Utley, M. and Moller, H. (2009) Cancer prevalence in the United Kingdom: estimates for 2008. Br J Cancer, 101 (3), 541-547.

Maguire, D., Dunn, P. and McKenna, H. (2016) How hospital activity in the NHS in England has changed over time. Available from: https://www.kingsfund.org.uk/publications/hospital-activity-funding-changes [Accessed 01/08/17].

Majeed, A., Bardsley, M., Morgan, D., O'Sullivan, C. and Bindman, A.B. (2000) Cross sectional study of primary care groups in London: association of measures of socioeconomic and health status with hospital admission rates. BMJ, 321, 1057-1060.

Mallitt, K.A., Kelly, P., Plant, N., Usherwood, T., Gillespie, J., Boyages, S., Jan, S. and Leeder, S. (2015) Demographic and clinical predictors of unplanned hospital utilisation among chronically ill patients: a prospective cohort study. BMC Health Serv Res, 15, 136.

Marcantonio, E.R., McKean, S., Goldfinger, M., Kleefield, S., Yurkofsky, M. and Brennan, T.A. (1999) Factors associated with unplanned hospital readmission among patients 65 years of age and older in a Medicare managed care plan. Am J Med, 107 (1), 13-17.

Marengoni, A., Angleman, S., Melis, R., Mangialasche, F., Karp, A., Garmen, A., Meinow, B. and Fratiglioni, L. (2011) Aging with multimorbidity: A systematic review of the literature. Ageing Res Rev, 10 (4), 430-439.

Marmot, M. (2011) Fair society, healthy lives. The Marmot review. Strategic review of health inequalities in England post 2010. Available from: http://www.parliament.uk/documents/fair-society-healthy-lives-full-report.pdf [Accessed 07/01/18].

Marshall, M. and Roland, M. (2017) The future of the Quality and Outcomes Framework in England. BMJ, 359, j4681.

Martin, S. and Smith, P. (1996) Explaining variations in inpatient length of stay in the National Health Service. J Health Econ, 15, 279-304.

Masoro, E.J. (2003) Physiology of aging IN: Tallis, R.C. and Fillit, H.M. (eds.) Brocklehurst's textbook of geriatric medicine and gerontology, 6th ed.: Churchill Livingstone, 91-100.

Mavaddat, N., Valderas, J.M., Van Der Linde, R., Khaw, K.T. and Kinmonth, A.L. (2014) Association of self-rated health with multimorbidity, chronic disease and psychosocial factors in a large middle-aged and older cohort from general practice: a cross-sectional study. BMC Fam Pract, 15, 185.

Mayden (2011) NHS Spend Profile IN: Administrator (ed). Available from: https://mayden.co.uk/2011/05/nhs-spend-profile-2/ [Accessed 26/11/17].

McCartney, G., Hart, C. and Watt, G. (2013) How can socioeconomic inequalities in hospital admissions be explained? A cohort study. BMJ Open, 3 (8), e002433.

McConnell, T.J., Appleby, P.N. and Key, T.J. (2017) Vegetarian diet as a risk factor for symptomatic gallstone disease. Eur J Clin Nutr, 71 (6), 731-735.

McDonald, S.A., Hutchinson, S.J., Bird, S.M., Graham, L., Robertson, C., Mills, P.R., Hayes, P., Dillon, J.F. and Goldberg, D.J. (2009) Association of self-reported alcohol use and hospitalization for an alcohol-related cause in Scotland: a record-linkage study of 23 183 individuals. Addiction, 104 (4), 593-602.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. Frontiers in econometrics. P. Zarembka. New York, Academic Press**:** 105-142.

McIntyre, H. (2013) Admission to hospital could be considered a disease. BMJ, 346, f3242.

Medical Research Council (2014) Maximising the value of UK population cohorts. MRC strategic review of the largest UK population cohort studies. London. Available from: https://www.mrc.ac.uk/publications/browse/maximising-the-value-of-uk-population-cohorts/ [Accessed 07/01/18].

Melzer, D., Tavakoly, B., Winder, R., Richards, S., Gericke, C. and Lang, I. (2012) Health care quality for an active later life. London: Age UK and Peninsula College of Medicine and Dentistry Ageing Research Group University of Exeter. Available from: http://www.exeter.ac.uk/media/universityofexeter/medicalschool/pdfs/Health_Care_Quality_for_an_Active_Later_Life_2012.pdf [Accessed 07/01/18].

Merino Martin, S. and Cruz-Jentoft, A.J. (2012) Impact of hospital admission on functional and cognitive measures in older subjects. Eur Geriatr Med, 3 (4), 208-212.

Metcalfe, C., Davey Smith, G., Macleod, J., Heslop, P. and Hart, C. (2003) Self-reported stress and subsequent hospital admissions as a result of hypertension, varicose veins and haemorrhoids. J Public Health Med, 25 (1), 62-68.

Metcalfe, C., Davey Smith, G., Sterne, J.A., Heslop, P., Macleod, J. and Hart, C.L. (2005) Cause-specific hospital admission and mortality among working men: association with socioeconomic circumstances in childhood and adult life, and the mediating role of daily stress. Eur J Public Health, 15 (3), 238-244.

Metcalfe, C., Smith, G.D., Sterne, J.A., Heslop, P., Macleod, J. and Hart, C. (2001) Individual employment histories and subsequent cause specific hospital admissions and mortality: a prospective study of a cohort of male and female workers with 21 years follow up. J Epidemiol Community Health, 55 (7), 503-504.

Molloy, A., Martin, S., Gardner, T. and Leatherman, S. (2016) A clear road ahead. Creating a coherent quality strategy for the English NHS. London: The Health Foundation. Available from: http://www.health.org.uk/sites/health/files/AClearRoadAhead.pdf [Accessed 07/01/18].

Morgan, M. (2003) Patients' help-seeking and access to health care IN: Gulliford, M. and Morgan, M. (eds.) Access to health care. London: Routledge.

Myint, P.K., Luben, R.N., Wareham, N.J., Welch, A.A., Bingham, S.A., Day, N.E. and Khaw, K.T. (2006a) Combined work and leisure physical activity and risk of stroke in men and women in the European Prospective Investigation into Cancer - Norfolk prospective population study. Neuroepidemiology, 27 (3), 122-129.

Myint, P.K., Luben, R.N., Welch, A.A., Bingham, S.A., Wareham, N.J. and Khaw, K.T. (2008) Plasma vitamin C concentrations predict risk of incident stroke over 10 y in 20 649 participants of the European Prospective Investigation into Cancer. Norfolk prospective population study. Am J Clin Nutr, 87 (1), 64-69.

Myint, P.K., Sinha, S., Wareham, N.J., Bingham, S.A., Luben, R.N., Welch, A.A. and Khaw, K.T. (2007a) Glycated hemoglobin and risk of stroke in people without known diabetes in the European Prospective Investigation into Cancer (EPIC) - Norfolk prospective population study: a threshold relationship? Stroke, 38 (2), 271-275.

Myint, P.K., Surtees, P.G., Wainwright, N.W., Luben, R.N., Welch, A.A., Bingham, S.A., Wareham, N.J. and Khaw, K.T. (2007b) Physical health-related quality of life predicts stroke in the EPIC-Norfolk. Neurology, 69 (24), 2243-2248.

Myint, P.K., Welch, A.A., Bingham, S.A., Luben, R.N., Wareham, N.J., Day, N.E. and Khaw, K.T. (2006b) Habitual fish consumption and risk of incident stroke: the European Prospective Investigation into Cancer (EPIC) - Norfolk prospective population study. Public Health Nutr, 9 (7), 882-888.

National Audit Office (2013) Emergency admissions to hospital: managing the demand. London: The Stationery Office, HC 739. Available from: https://www.nao.org.uk/wp-content/uploads/2013/10/10288-001-Emergency-admissions.pdf [Accessed 07/01/18].

National Osteoporosis Society (2014) What is osteoporosis? Available from: https://www.nos.org.uk/about-osteoporosis [Accessed 10/12/2015].

NHS (2013) Guide to the healthcare system in England. London: Department of Health. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/194002/9421-2900878-TSO-NHS_Guide_to_Healthcare_WEB.PDF [Accessed 07/01/18].

NHS (2014) Five year forward view. Available from: https://www.england.nhs.uk/wp-content/uploads/2014/10/5yfv-web.pdf [Accessed 07/01/18].

NHS (2017) Next steps on the NHS five year forward view. Available from: https://www.england.nhs.uk/wp-content/uploads/2017/03/NEXT-STEPS-ON-THE-NHS-FIVE-YEAR-FORWARD-VIEW.pdf [Accessed 07/01/18].

NHS Benchmarking Network (2014) National Audit of Intermediate Care Report 2014 [No longer available online].

NHS Choices (2017) Osteoporosis. Available from: https://www.nhs.uk/conditions/Osteoporosis/.

NHS Confederation (2017) Key statistics on the NHS. Available from: http://www.nhsconfed.org/resources/key-statistics-on-the-nhs.

NHS Digital (2016) Quality and Outcomes Framework Available from: http://content.digital.nhs.uk/qof [Accessed 04/08/2016].

NHS Digital (2017a) Find data and publications. Available from: https://digital.nhs.uk/pubsearch [Accessed 26/11/17].

NHS Digital (2017b) HES data dictionary. Admitted patient care. Health and Social Care Information Centre. Available from: http://content.digital.nhs.uk/hesdatadictionary [Accessed 07/01/18].

NHS Digital (2017c) Hospital Episode Statistics. Available from: http://content.digital.nhs.uk/hes [Accessed 26/11/17].

NHS Digital (2017d) Hospital Episode Statistics (HES) analysis guide. Available from: http://content.digital.nhs.uk/hesdata.

NHS Digital (2017e) Hospital Episode Statistics. Admitted patient care, England 2013-14. Available from: https://digital.nhs.uk/catalogue/PUB16719.

NHS Digital (2017f) Users and uses of Hospital Episode Statistics. Available from: http://content.digital.nhs.uk/hes [Accessed 26/11/17].

NHS Digital (2017g) What HES data are available? Available from: http://content.digital.nhs.uk/hesdata [Accessed 26/11/17].

NHS Digital (2018) Health Survey for England - 2012, Trend tables Available from: http://digital.nhs.uk/catalogue/PUB22616 [Accessed 06/01/2018].

NHS Employers (2017) Quality and Outcomes Framework. Available from: http://www.nhsemployers.org/your-workforce/primary-care-contacts/general-medical-services/quality-and-outcomes-framework.

NHS England (2013) Monitor and NHS England's review of the marginal rate rule. Available from: www.monitor.gov.uk/NT [Accessed 07/01/18].

NHS England (2015) How much do clinicians support patient activation? Available from: https://www.england.nhs.uk/wp-content/uploads/2015/11/cspam-report.pdf [Accessed 07/01/18].

NHS Health Research Authority (2016) What is Section 251? Available from: http://www.hra.nhs.uk/about-the-hra/our-committees/section-251/what-is-section-251/ (resource no longer available) [Accessed 23/01/16].

O'Dowd, A. (2017) Doctors condemn need for Red Cross to step in to aid NHS in "humanitarian crisis". BMJ, 356, j127.

Office for National Statistics (2011a) 2011 Census household questionnnaire. Available from: https://www.ons.gov.uk/census/2011census/howourcensusworks/howwetookthe2011census/howwecollectedtheinformation/questionnairesdeliverycompletionandreturn [Accessed 07/01/18].

Office for National Statistics (2011b) National population projections, 2010-based projections. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/popula tionprojections/bulletins/nationalpopulationprojections/2011-10-26 [Accessed 03/05/2015].

Office for National Statistics (2013a) What does the 2011 census tell us about older people? Available from: http://www.ons.gov.uk/ons/rel/census/2011-census-analysis/what-does-the-2011-census-tell-us-about-older-people-/what-does-the-2011-census-tell-us-about-older-people--short-story.html [Accessed 07/01/18].

Office for National Statistics (2013b) What does the 2011 census tell us about the "oldest old" living in England and Wales? Available from: http://www.ons.gov.uk/ons/rel/mortality-ageing/characteristics-of-older-people/what-does-the-2011-census-tell-us-about-the-oldest-old-living-in-england-and-wales-/characteristics-of-the--oldest-old--from-the-2011-census.html [Accessed 07/01/18].

Office for National Statistics (2014a) Annual mid-year population estimates, 2013. Available from: http://webarchive.nationalarchives.gov.uk/20160105223339/http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/index.html.

Office for National Statistics (2014b) *Changes in the Older Resident Care Home Population between 2001 and 2011*. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/ageing/articles/changesintheolderresidentcarehomepopulationbetween2001and2011/2014-08-01 [Accessed 26/07/18].

Office for National Statistics (2014c) Health expectancies at birth and at age 65 in the United Kingdom, 2009–11. Available from: http://www.ons.gov.uk/ons/rel/disability-and-health-measurement/health-expectancies-at-birth-and-age-65-in-the-united-kingdom/2009-11/stb-he-2009-2011.html [Accessed 07/01/18].

Office for National Statistics (2016) Healthy life expectancy at birth and age 65 by upper tier local authority and area deprivation: England, 2012 to 2014. Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/healthylifeexpectancyatbirthandage65byuppertierlocalauthorityandareadeprivation/england2012to2014 [Accessed 07/01/18].

Office of Population Censuses and Surveys (1990) Standard occupational classification, Vol 1 structure and definition of major, minor and unit groups. London: HMSO.

Oksuzyan, A., Jeune, B., Juel, K., Vaupel, J.W. and Christensen, K. (2013) Changes in hospitalisation and surgical procedures among the oldest-old: a follow-up study of the entire Danish 1895 and 1905 cohorts from ages 85 to 99 years. Age Ageing, 42 (4), 476-481.

Oliver, D. (2015) Who is to blame for older people’s readmission? BMJ, 351, h4244.

Oliver, D. (2016a) Four riders of the NHS apocalypse. BMJ, 355, i5623.

Oliver, D. (2016b) Wishful thinking won't save the NHS. BMJ, 354, i4544.

Oliver, D. (2017) David Oliver: Reducing acute admissions - a timely reality check. BMJ, 357, j2082.

Osmond, C., Barker, D.J.P., Winter, P.D., Fall, C.H.D. and Simmonds, S.J. (1993) Early growth and death from cardiovascular disease in women. BMJ, 307, 1519-1529.

Parliamentary Office of Science and Technology (2006) Healthy life expectancy. 257. Available from: http://www.parliament.uk/documents/post/postpn257.pdf [Accessed 07/01/18].

Payne, R.A., Abel, G.A., Guthrie, B. and Mercer, S.W. (2013) The effect of physical multimorbidity, mental health conditions and socioeconomic deprivation on unplanned admissions to hospital: a retrospective cohort study. CMAJ, 185 (5), E221-E228.

Pedersen, M.K., Meyer, G. and Uhrenfeldt, L. (2014) Risk factors for acute care hospital readmission in persons aged 60 and over from western countries: a systematic review protocol. JBI Database System Rev Implement Rep, 12 (2), 91-102.

Pedersen, M.K., Meyer, G. and Uhrenfeldt, L. (2017) Risk factors for acute care hospital readmission in older persons in Western countries: a systematic review. JBI Database System Rev Implement Rep, 15 (2), 454-485.

Pell, J., Valentine, J. and Inskip, H. (2014) One in 30 people in the UK take part in cohort studies. Lancet, 383 (9922), 1015-1016.

Petticrew, M. and Roberts, H. (2003) Evidence, hierarchies, and typologies: horses for courses. J Epidemiol Community Health, 57 (7), 527-529.

Pierce, M.B., Silverwood, R.J., Nitsch, D., Adams, J.E., Stephen, A.M., Nip, W., Macfarlane, P., Wong, A., Richards, M., Hardy, R., Kuh, D. and Nshd Scientific and Data Collection Teams (2012) Clinical disorders in a post war British cohort reaching retirement: evidence from the first national birth cohort study. PLoS One, 7 (9), e44857.

Pimouguet, C., Rizzuto, D., Lagergren, M., Fratiglioni, L. and Xu, W.L. (2017) Living alone and unplanned hospitalizations among older adults: a population-based longitudinal study. Eur J Public Health, 27 (2), 251-256.

Pines, J.M., Mongelluzzo, J., Hilton, J.A., Hollander, J.E., Shofer, F.S., Souder, J., Synnestvedt, M., Weiner, M.G. and Datner, E.M. (2010) Postdischarge adverse events for 1-day hospital admissions in older adults admitted from the emergency department. Ann Emerg Med, 56 (3), 253-257.

Pinquart, M. (2001) Correlates of subjective health in older adults: a meta-analysis. Psychol Aging, 16 (3), 414-426.

Prineas, R.J., Crow, R.S. and Blackburn, H.W. (1982) The Minnesota code manual of electrocardiographic findings: standards and procedures for measurement and classification, 2nd ed. London: Springer.

Pugh, J.A., Wang, C.P., Espinoza, S.E., Noel, P.H., Bollinger, M., Amuan, M., Finley, E. and Pugh, M.J. (2014) Influence of frailty-related diagnoses, high-risk prescribing in elderly adults, and primary care use on readmissions in fewer than 30 days for veterans aged 65 and older. J Am Geriatr Soc, 62 (2), 291-298.

Purdy, S. (2010) Avoiding hospital admissions. What does the research evidence say? London: The King's Fund. Available from: https://www.kingsfund.org.uk/sites/default/files/Avoiding-Hospital-Admissions-Sarah-Purdy-December2010.pdf [Accessed 07/01/18].

Purdy, S., Paranjothy, S., Huntley, A., Thomas, R., Mann, M., Huws, D., Brindle, P. and Elwyn, G. (2012) Interventions to reduce unplanned hospital admission: a series of systematic reviews. Available from: http://www.bristol.ac.uk/media-library/sites/primaryhealthcare/migrated/documents/unplannedadmissions.pdf [Accessed 07/01/18].

Putcha, N., Puhan, M.A., Hansel, N.N., Drummond, M.B. and Boyd, C.M. (2013) Impact of co-morbidities on self-rated health in self-reported COPD: An analysis of NHANES 2001-2008. COPD, 10 (3), 324-332.

References

Reeves, G.K., Balkwill, A., Cairns, B.J., Green, J., Beral, V. and Million Women Study Collaborators (2014) Hospital admissions in relation to body mass index in UK women: a prospective cohort study. BMC Med, 12, 45.

Reid, D.A., Cook, D.G. and Majeed, A. (1999) Explaining variation in hospital admission rates between general practices: cross sectional study. BMJ, 319, 98-103.

Robards, J., Evandrou, M., Falkingham, J. and Vlachantoni, A. (2014) Mortality at older ages and moves in residential and sheltered housing: evidence from the UK. J Epidemiol Community Health, (68), 524–529.

Roberts, H.C., Denison, H.J., Martin, H.J., Patel, H.P., Syddall, H., Cooper, C. and Sayer, A.A. (2011) A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age Ageing, 40 (4), 423-429.

Robinson, P. (2010a) Are hospital admissions out of control? Alcester: CHKS. Available from: https://www.hsj.co.uk/Journals/2/Files/2010/1/21/Are_hospital_admissions_out_of_control_final_report(1).pdf [Accessed 07/01/18].

Robinson, P. (2010b) Hospital readmissions and the 30 day threshold. CHKS. Available from: http://www.chks.co.uk/userfiles/files/CHKS%20Report%20Hospital%20readmissions.pdf [Accessed 07/01/18].

Robinson, S.M., Jameson, K.A., Syddall, H.E., Dennison, E.M., Cooper, C., Sayer, A.A. and Hertfordshire Cohort Study Group (2013) Clustering of lifestyle risk factors and poor physical function in older adults: The Hertfordshire Cohort Study. J Am Geriatr Soc, 61 (10), 1684-1691.

Robinson, T. and Kerse, N. (2012) Medical readmissions amongst older New Zealanders: a descriptive analysis. N Z Med J, 125 (1367), 24-34.

Roland, M. and Abel, G. (2012) Reducing emergency admissions: are we on the right track? BMJ, 345, e6017.

Roland, M., Dusheiko, M., Gravelle, H. and Parker, S. (2005) Follow up of people aged 65 and over with a history of emergency admissions: analysis of routine admission data. BMJ, 330 (7486), 289-292.

Roland, M. and Guthrie, B. (2016) Quality and Outcomes Framework: what have we learnt? BMJ, 354, i4060.

Rose, G. (1985) Sick individuals and sick populations. Int J Epidemiol, 14 (1), 32-38.

Rose, G.A. (1965) Chest pain questionnaire. Milbank Mem Fund Q, 43 (2), 32-39.

Royal College of Physicians (2007) Report of the Acute Medicine Task Force: Acute medical care. The right person, in the right setting - first time. Available from: https://cdn.shopify.com/s/files/1/0924/4392/files/acute_medical_care_final_for_web.pdf?1709961806511712341 [Accessed 26/07/18].

Sabia, S., Dugravot, A., Dartigues, J.F., Abell, J., Elbaz, A., Kivimaki, M. and Singh-Manoux, A. (2017) Physical activity, cognitive decline, and risk of dementia: 28 year follow-up of Whitehall II cohort study. BMJ, 357, j2709.

Sanderson, C. and Dixon, J. (2000) Conditions for which onset or hospital admission is potentially preventable by timely and effective ambulatory care. J Health Serv Res Policy, 5 (4), 222-230.

Saxena, S., George, J., Barber, J., Fitzpatrick, J. and Majeed, A. (2006) Association of population and practice factors with potentially avoidable admission rates for chronic diseases in London: cross sectional analysis. J R Soc Med, 99 (2), 81-89.

Sayer, A.A. and Kirkwood, T.B.L. (2015) Grip strength and mortality: a biomarker of ageing? Lancet, 386 (9990), 226-227.

Sayer, A.A., Syddall, H.E., Martin, H.J., Dennison, E.M., Roberts, H.C. and Cooper, C. (2006) Is grip strength associated with health-related quality of life? Findings from the Hertfordshire Cohort Study. Age Ageing, 35 (4), 409-415.

Scottish Executive (2005) The Scottish Health Survey 2003. Volume 2: Adults. Available from: http://www.scotland.gov.uk/Publications/2005/11/25145024/50251. [Accessed 07/01/18].

Shain, M. and Roemer, M.I. (1959) Hospital costs relate to the supply of beds. Mod Hosp, 92 (4), 71-73.

Shaw, S.C., Dennison, E.M. and Cooper, C. (2017) Epidemiology of sarcopenia: determinants throughout the lifecourse. Calcif Tissue Int, 101 (3), 229-247.

Shu, C.C., Lin, Y.F., Hsu, N.C. and Ko, W.J. (2012) Risk factors for 30-day readmission in general medical patients admitted from the emergency department: a single centre study. Intern Med J, 42 (6), 677-682.

Simmonds, B., Fox, K., Davis, M., Ku, P.W., Gray, S., Hillsdon, M., Sharp, D., Stathi, A., Thompson, J., Coulson, J. and Trayers, T. (2014a) Objectively assessed physical activity and subsequent health service use of UK adults aged 70 and over: a four to five year follow up study. Plos One, 9, e97676.

Simmonds, S.J., Syddall, H.E., Walsh, B., Evandrou, M., Dennison, E.M., Cooper, C. and Aihie Sayer, A. (2014b) Understanding NHS hospital admissions in England: linkage of Hospital Episode Statistics to the Hertfordshire Cohort Study. Age Ageing, 43, 653-660.

Simmonds, S.J., Syddall, H.E., Westbury, L.D., Dodds, R.M., Cooper, C. and Aihie Sayer, A. (2015) Grip strength among community-dwelling older people predicts hospital admission during the following decade. Age Ageing, 44, 954-959.

Singh-Manoux, A., Martikainen, P., Ferrie, J., Zins, M., Marmot, M. and Goldberg, M. (2006) What does self rated health measure? Results from the British Whitehall II and French Gazel cohort studies. J Epidemiol Community Health, 60 (4), 364-372.

Singh, S., Lin, Y.L., Kuo, Y.F., Nattinger, A.B. and Goodwin, J.S. (2014) Variation in the risk of readmission among hospitals: the relative contribution of patient, hospital and inpatient provider characteristics. J Gen Intern Med, 29 (4), 572-578.

Sinha, S., Myint, P.K., Luben, R.N. and Khaw, K.-T. (2008) Accuracy of death certification and hospital record linkage for identification of incident stroke. BMC Med Res Methodol, 8, 74.

Smith, P., McKeon, A., Blunt, I. and Edwards, N. (2014) NHS hospitals under pressure: trends in acute activity up to 2022. London: Nuffield Trust. Available from: https://www.nuffieldtrust.org.uk/resource/nhs-hospitals-under-pressure-trends-in-acute-activity-up-to-2022 [Accessed 07/01/18].

Spector, W.D., Limcangco, R., Mutter, R.L., Pines, J.M. and Owens, P. (2015) Inpatient admissions from the ED for adults with injuries: the role of clinical and nonclinical factors. Am J Emerg Med, 33 (6), 764-769.

St-Onge, M.P. (2005) Relationship between body composition changes and changes in physical function and metabolic risk factors in aging. Curr Opin Clin Nutr Metab Care, 8 (5), 523-528.

Statacorp (2013) Stata statistical software: release 13. College Station, TX: StataCorp LP.

Stein, C. and Moritz, I. (1999) A life course perspective of maintaining independence in older age. Geneva: World Health Organization, WHO/HSC/AHE/99.2. Available from: http://www.who.int/ageing/publications/life_course/en/ report no WHO/HSC/AHE/99.2 [Accessed 11/08/14].

Syddall, H., Roberts, H.C., Evandrou, M., Cooper, C., Bergman, H. and Aihie Sayer, A. (2010) Prevalence and correlates of frailty among community-dwelling older men and women: findings from the Hertfordshire Cohort Study. Age Ageing, 39, 197-203.

Syddall, H.E., Aihie Sayer, A., Dennison, E.M., Martin, H.J., Barker, D.J. and Cooper, C. (2005a) Cohort profile: the Hertfordshire Cohort Study. Int J Epidemiol, 34 (6), 1234-1242.

Syddall, H.E., Sayer, A., A., Simmonds, S., J., Osmond, C., Cox, V., Dennison, E.M., Barker, D.J. and Cooper, C. (2005b) Birth weight, infant weight gain, and cause-specific mortality: the Hertfordshire Cohort Study. Am J Epidemiol, 161, 1074-1080.

Syddall, H.E., Westbury, L.D., Cooper, C. and Sayer, A.A. (2015) Self-reported walking speed: a useful marker of physical performance among community-dwelling older people? J Am Med Dir Assoc, 16 (4), 323-328.

Syddall, H.E., Westbury, L.D., Simmonds, S.J., Robinson, S., Cooper, C. and Sayer, A.A. (2016) Understanding poor health behaviours as predictors of different types of hospital admission in older people: findings from the Hertfordshire Cohort Study. J Epidemiol Community Health, 70 (3), 292-298.

The King's Fund (2017) The NHS in a nutshell. Available from: https://www.kingsfund.org.uk/projects/nhs-in-a-nutshell.

Townsend, N., Wickramasinghe, K., Bhatnagar, P., Smolina, K., Nichols, M., Leal, J.R., Luengo-Fernandez, R. and Rayner, M. (2012) Coronary heart disease statistics. A compendium of health statistics. London: British Heart Foundation. Available from: https://www.bhf.org.uk/publications/statistics/coronary-heart-disease-statistics-2012 [Accessed 07/01/18].

Turney, B.W., Appleby, P.N., Reynard, J.M., Noble, J.G., Key, T.J. and Allen, N.E. (2014) Diet and risk of kidney stones in the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC). Eur J Epidemiol, 29 (5), 363-369.

UK Biobank (2016) About UK Biobank. Available from: http://www.ukbiobank.ac.uk/about-biobank-uk/ [Accessed 05/10/2017].

United Nations (2013) World population ageing 2013. New York. Available from: http://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2013.pdf [Accessed 07/01/18].

University College London (2018) Whitehall II. Available from: http://www.ucl.ac.uk/iehc/research/epidemiology-public-health/research/whitehallII/background [Accessed 12/02/18].

University of Oxford (2015a) The EPIC-Oxford Study. Available from: http://www.epic-oxford.org/home/ [Accessed 10/11/2015].

University of Oxford (2015b) The Million Women Study. Available from: http://www.millionwomenstudy.org/introduction/ & http://www.millionwomenstudy.org/publications/.

Van Staa, T.P., Goldacre , B., Buchan, I. and Smeeth, L. (2016) Big health data: the need to earn public trust. BMJ, 354, i3636.

Van Walraven, C., Jennings, A. and Forster, A.J. (2012) A meta-analysis of hospital 30-day avoidable readmission rates. J Eval Clin Pract, 18 (6), 1211-1218.

Verropoulou, G. (2009) Key elements composing self-rated health in older adults: a comparative study of 11 European countries. Eur J Ageing, 6 (3), 213-226.

Vestbo, J. (2013) Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. Global Initiative for Chronic Obstructive Lung Disease. Available from: http://goldcopd.org/gold-reports-2017/ [Accessed 07/01/18].

Vlachantoni, A. (2012) Financial inequality and gender in older people. Maturitas, 72 (2), 104-107.

Von Lengerke, T., Gohl, D. and Babitsch, B. (2014) Re-revisiting the Behavioral Model of Health Care Utilization by Andersen: a review on theoretical advances and perspectives IN: Janssen, C., Swart, E. and Von Lengerke, T. (eds.) Health Care Utilization in Germany: Theory, Methodology, and Results. New York, NY: Springer New York, 11-28.

Wallace, E., Stuart, E., Vaughan, N., Bennett, K., Fahey, T. and Smith, S.M. (2014) Risk prediction models to predict emergency hospital admission in community-dwelling adults. A systematic review. Med Care, 52 (8), 751-765.

Walsh, B. (2014) Unplanned admissions and readmissions in older people: a review of recent evidence on identifying and managing high-risk individuals. Rev Clin Gerontol, 24 (3), 228-237.

Walsh, B., Roberts, H.C. and Nicholls, P.G. (2011) Features and outcomes of unplanned hospital admissions of older people due to ill-defined (R-coded) conditions: retrospective analysis of hospital admissions data in England. BMC Geriatr, 11, 62.

Ward, H., Toledano, M.B., Shaddick, G., Davies, B. and Elliott, P. (2012) Oxford Handbook of Epidemiology for Clinicians, 1st ed. Oxford: Oxford University Press.

Ware, J.E. (2000) SF-36 health survey update. Spine, 25 (24), 3130-3139.

Wauters, M., Elseviers, M., Vaes, B., Degryse, J., Vander Stichele, R., Christiaens, T. and Azermai, M. (2016) Mortality, hospitalisation, institutionalisation in community-dwelling oldest old: the impact of medication. Arch Gerontol Geriatr, 65, 9-16.

Wellcome Trust (2015) Enabling linkage to maximise the value of public health research data. London. Available from: https://wellcome.ac.uk/sites/default/files/enabling-data-linkage-to-maximise-value-of-public-health-research-data-summary-phrdf-mar15.pdf [Accessed 07/01/18].

Welsh, P., Doolin, O., McConnachie, A., Boulton, E., McNeil, G., Macdonald, H., Hardcastle, A., Hart, C., Upton, M., Watt, G. and Sattar, N. (2012) Circulating 25OHD, dietary vitamin D, PTH, and calcium associations with incident cardiovascular disease and mortality: the MIDSPAN Family Study. J Clin Endocrinol Metab, 97 (12), 4578-4587.

Werblow, A., Felder, S. and Zweifel, P. (2007) Population ageing and health care expenditure: a school of 'red herrings'? Health Econ, 16, 1109-1126.

Westbury, L., Syddall, H., Simmonds, S., Cooper, C. and Aihie Sayer, A. (2016) Identification of risk factors for hospital admission using multiple-failure survival models: a toolkit for researchers. BMC Med Res Methodol, 16, 46.

Williams, S., Bottle, A., Rogers, R. and Aylin, P. (2005) Dr Foster's case notes. 'Frequent flier' patients. BMJ, 330, 869.

Wittenberg, R., Redding, S., Nicodemo, C. and McCormick, B. (2015) Analysis of trends in emergency and elective hospital admissions and hospital bed days: 1997/8 to 2014/15. Oxford: Centre for Health Service Economics and Organisation. Available from: https://www.chseo.org.uk/downloads/report9-admission-and-bed-day-trends.pdf [Accessed 07/01/18].

Wittenberg, R., Sharpin, L., McCormick, B. and Hurst, J. (2014) Understanding emergency hospital admissions of older people. Centre for Health Service Economics & Organisation. Available from: https://www.chseo.org.uk/downloads/report6-emergencyadmissions.pdf [Accessed 07/01/18].

Wolinsky, F.D. and Johnson, R.J. (1991) The use of health-services by older adults. J Gerontol, 46 (6), S345-S357.

Wong, F.K.Y., Chan, M.F., Chow, S., Chang, K., Chung, L., Lee, W.M. and Lee, R. (2010) What accounts for hospital readmission? J Clin Nurs, 19 (23-24), 3334-3346.

World Health Organization (1999) Definition, Diagnosis and Classification of Diabetes Mellitus and its Complications: Report of a WHO Consultation. Part 1: Diagnosis and Classification of Diabetes Mellitus.Geneva.

World Health Organization (2011) International Classification of Diseases (ICD). Available from: http://www.who.int/classifications/icd/en/ [Accessed 10/01/18].

World Medical Association (2016) WMA Declaration of Helsinki - ethical principles for medical research involving human subjects. Available from: https://www.wma.net/what-we-do/campaigns/consensus-framework-for-ethical-collaboration/consensus_framework-vf/ [Accessed 07/01/18].

Zigmond, A.S. and Snaith, R.P. (1983) The hospital anxiety and depression scale. Acta Psychiatr Scand, 67 (6), 361-370.