The relationship of sensory impairments with cardiovascular disease and mortality, disability and frailty in older age: longitudinal cohort studies using the British Regional Heart Study and the English Longitudinal Study of Ageing

THESIS

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DECLARATION OF AUTHORSHIP

I, Ann Liljas, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis. I have used data from two on-going prospective cohort studies: the British Regional Heart Study and the English Longitudinal Study of Ageing.

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ABSTRACT

Background and aim: Impairments in hearing and vision (sensory impairments) are common in older age and associated with increased risks of important adverse health outcomes such as chronic diseases and poor physical functioning. However the majority of previous studies are of cross-sectional design and little research has focused on older adults. The overarching aim of this thesis is therefore to prospectively investigate the influence of sensory impairments on the subsequent risks of adverse cardiovascular disease (CVD) incidence and mortality, disability and frailty.

Methods: This thesis uses data from two population-based cohorts: the British Regional Heart Study (BRHS) (3981 men aged 63-85 years) and the English Longitudinal Study of Ageing (ELSA) (2836 men and women aged ≥ 60 years). Data from the BRHS were used to examine the prospective relationships between self-reported sensory impairments and the risk of non-fatal and fatal CVD (MI or stroke) (data obtained from medical records), all-cause mortality, and self-reported disability defined as mobility limitation, activities of daily living (ADL) and instrumental ADL (IADL). ELSA data were used to examine the prospective relationship between self-reported sensory impairments and incident frailty defined as the Fried phenotype.

Results: In the BRHS, hearing impairment was associated with greater risks of incident CVD, in particular incident stroke, and CVD mortality. Vision impairment was not associated with incident CVD outcomes but with increased risks of all-cause mortality. Hearing impairment, but not vision impairment, was associated with increased risks of incident disability in the form of IADL. In ELSA, hearing impairment was associated with increased risks of incident frailty in individuals who were pre-frail. Vision impairment was associated with greater risks of incidence of pre-frailty and frailty in non-frail participants. The findings of this thesis emphasise the potentially important contribution of sensory impairments in older age particularly to risk of stroke, disability and frailty.

FREQUENTLY USED ABBREVIATIONS

ADL	Activities of daily living
AMD	Age-related macular degeneration
BMI	Body mass index
BRHS	British Regional Heart Study
CHD	Coronary heart disease
CI	Confidence interval
CVD	Cardiovascular disease
ELSA	English Longitudinal Study of Ageing
HR	Hazard ratio
IADL	Instrumental activities of daily living
MI	Myocardial infarction
OR	Odds ratio
PTA	Pure tone audiometry
SD	Standard deviation
VA	Visual acuity
WHO	World Health Organization

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CHAPTER 1 Introduction

This Chapter provides an overview of the thesis and its contents.

1.1. Introduction to this thesis

1.1.1. Hearing and vision impairments in an ageing population

The population in the United Kingdom (UK) is ageing due to increased life expectancy.[1] In 2014 there were 15 million adults in the UK aged 60 years and over, a number which is projected to increase to 22 million by 2037.[2] During the same time period the number of adults aged 75 years and over is projected to rise even faster and double from five million in 2014 to 10 million by 2037.[2] Advanced age increases the risk of chronic diseases and disability leading to age-related decline in health and wellbeing including loss of hearing and vision.[3] In the UK, one in four (27%) of older adults aged 61-80 years have a hearing impairment.[4] Among older adults aged 65 years and over 13% have a vision impairment.[5] The prevalence of hearing impairment and vision impairment in the UK is similar to other high-income countries.[6, 7] This makes sensory impairments (hearing or vision impairment) common health problems in later life. The number of older adults affected by sensory impairments is furthermore likely to increase as the population ages.[8, 9] Both hearing impairment and vision impairment have been associated in cross-sectional studies with cardiovascular disease (CVD),[10, 11] disability[12, 13] and frailty,[14, 15] common age-related conditions well-known for reducing the chances of good health, wellbeing and independent living in later life.[16-18] However, sensory impairments are to some extent preventable. Addressing hearing and vision impairments could therefore potentially reduce the burden of other conditions such as CVD, disability and frailty in older adults (older adults are commonly referred to individuals aged ≥ 60 years[19]).

1.1.2. Hearing impairment

Hearing impairment increases with advanced age and is estimated to affect over half (55%) of English adults aged 75 years and over and more than four-fifths (83%) of individuals aged 85 years and over.[20] Hearing impairment can often be minimised in individuals already affected through use of hearing aids, the most effective method to improve hearing in later life.[21] In 2010/11 the direct costs to the National Health Service (NHS) of addressing hearing impairment was £450 million.[22] Additional financial costs of hearing impairment to society are estimated at £136 million per annum (in 2013).[23] Considering that older adults form a rapidly growing proportion of the population, hearing impairment in older age is an important health issue.

1.1.3. Vision impairment

Similar to hearing impairment, vision impairment increases with advanced age affecting about 13% of British adults aged 65 years and over.[5] It is estimated that over half of vision impairment in the UK is avoidable and this figure includes people with vision impairment wearing spectacles that are not of the optimum strength.[24] In addition to correction of spectacles, preventive strategies include early detection and treatment of eye conditions, and health promotion interventions including weight management and smoking cessation.[25-27] Further prevention of vision impairment would have a positive impact on both individuals and society as vision impairment costs the UK economy £6.4 billion a year (in 2010/11) of which over £2.1 billion are direct costs to the NHS.[22, 25]

1.2. Relationships of sensory impairments and adverse health outcomes in the ageing population

Older adults form the fastest growing segment of the population,[28] and understanding what predicts adverse health outcomes for this group is increasingly important. Although both hearing impairment and vision impairment are common in later life, little research has focused on sensory impairments in older age. Hearing impairment and vision impairment have been previously regarded as ‘normal’ part of ageing, and as a result have been overlooked.[29] However impairments in hearing and vision are often preventable and modifiable and could therefore be targeted through public health efforts.[30] Hearing impairment and vision impairment furthermore significantly reduce the individual’s ability to communicate and move freely, negatively affecting their chances of independent living, reducing their quality of life and increasing societal costs.[17] Research examining the influence of impairments in hearing and vision on other common age-related problems including cardiovascular disease (CVD) and mortality, disability and frailty is therefore important as it has the potential to demonstrate whether addressing sensory impairments could reduce adverse health outcomes.

1.2.1. Sensory impairments and cardiovascular disease

Cardiovascular disease (CVD) is a life-threatening chronic disease common in older age and refers to all diseases affecting the heart and blood vessels including coronary heart disease (CHD) (myocardial infarction (MI) and angina) and stroke. There are 5.6 million people in the UK living with CVD and CVD accounts for nearly 1.7 million inpatient episodes in NHS hospitals across the country per annum (in 2013/14).[31] However CVD is potentially preventable through promotion of healthy lifestyle behaviours.[32] Prevention is important as CVD is a major contributor to morbidity and disability.[31] CVD is furthermore one of the main causes of mortality, accounting for nearly a third of all premature deaths.[31]

Recently there has been a growing interest in the relationship between sensory impairments and CVD as impairments in hearing and vision and CVD often co-occur in later life.[33, 34] For example, sensory impairments may be associated with CVD through underlying biological mechanisms such as inflammation. Inflammation has shown to precede the onset of CVD[35, 36] and may also be associated with increased risks of sensory impairments.[26, 33, 37] However, research on the prospective relationship between sensory impairments and incident CVD is limited. Also, little is known about sensory impairments and CVD mortality risk. There is some evidence showing an association between hearing impairment and increased risks of incident CVD,[38, 39] CVD mortality[39] and all-cause mortality.[40] However such studies have been undertaken mostly in specific subgroups of individuals such as patients diagnosed with sudden hearing loss.[41, 42] In later life, age-related hearing impairment rather than sudden hearing loss is the most common type of hearing impairment.[43] Age-related hearing impairment seldom results in hospitalisation,[44] and research on age-related hearing impairment and CVD in later life should be undertaken in community-dwelling adults. Several previous studies have furthermore been carried out in middle-aged populations rather than older adults.[38, 45-47] Middle-aged adults are more likely to be affected by noise-induced hearing impairment, a type of hearing impairment that, compared to age-related hearing impairment, is less common in later life and does not necessarily affect the ability to hear normal speech conversation.[48] Research on hearing impairment undertaken in samples of community-dwelling older adults is therefore needed. Similarly, some studies have shown an association between vision impairment and increased risks of incident CHD in older adults[49] and incident stroke in middle-aged adults.[50, 51] Vision impairment has also been associated with increased risks of CVD mortality[52] and all-cause mortality.[53] However findings are inconsistent with some studies showing no such associations.[39, 54, 55] Moreover, relatively few studies on vision impairment and incident CVD and mortality have been undertaken in older adults.

1.2.2. Sensory impairments and disability

Disability refers to difficulty or dependency in undertaking activities that are vital to independent living.[56] Chronic diseases such as CVD are among the most common causes of disability among older adults.[57] Disability is strongly linked to reduced wellbeing and quality of life and increased risk of social isolation which affect not only the older individual but also their families.[58] Disability is also associated with economic costs of underlying medical conditions and dependency on health care.[59] This makes disability a fundamental societal concern.[58]

Cross-sectional studies have consistently reported an association between sensory impairments and disability.[12, 13, 60-62] However fewer studies have examined such relationships prospectively, which is necessary to imply causality and assess the directionality of such relationship. Also, few previous studies have used complete versions of validated measures of disability such as the Katz Activities of Daily Living (ADL) index and Lawton's Instrumental Activities of Daily Living (IADL) scale, making it difficult to compare the findings of existing studies. To date, the impact of sensory impairments on increased risks of future disability remains unclear. Previous studies have shown inconsistent findings between hearing impairment and increased risks of incident disability with some studies reporting an association,[63, 64] and some studies showing no association.[65-67] Similarly, inconsistent findings have also been reported in longitudinal studies on vision impairment and increased risks of incident disability.[66-69] Also, most of the studies on sensory impairments and disability have been carried out in the United States of America (USA) and little research has been undertaken in the UK. In the last few decades disability trends have been different in the UK compared to the USA with a faster growing proportion of older adults reporting disability in the UK.[58, 70] Studies on health problems influencing the risk of disability including research on the impact of sensory impairments on disability undertaken in the UK is therefore of particular interest.

1.2.3. Sensory impairments and frailty

Frailty refers to the body's inability to respond adequately to stressors due to multi-system impairments and reduced physiological reserves.[18, 71] The consequences of frailty can be vast including increased risks of adverse outcomes such as falls, hospitalisation, institutionalisation and mortality.[18, 72-75] Different stages of frailty include pre-frailty which is an intermediate stage between having no prevalent frailty and being frail.

Very few studies have investigated the relationships between sensory impairments and frailty. To my knowledge, only two prospective studies have examined the association between hearing impairment and incident frailty,[76, 77] and the prospective relationship between vision impairment and incident frailly has not been previously reported. Most of the cross-sectional studies on vision impairment and frailty have furthermore been undertaken in middle-aged adults,[74, 78, 79] and less is known about such association in older populations. Fewer still have investigated vision impairment and incidence of frailty in those who are already pre-frail.

1.3. Thesis rationale

Whilst the impact of CVD, disability and frailty on overall health and wellbeing in older adults is well-established, sensory impairments are less studied aspects of ageing. As impairments in hearing and vision are common in older adults, it is important to investigate the effects of sensory impairments on other common age-related conditions. Therefore, this thesis seeks to understand the influence of sensory impairments on chronic age-related conditions including risks of CVD and mortality, disability and frailty to establish the impact of sensory impairments in later life. This has important public health implications including the development of effective health policies, and preventative strategies and interventions that aim to reduce age-related health problems associated with sensory impairments to increase well-being and independent living in older age.[80]

1.4. Thesis objectives

The overarching aim of this thesis is therefore to investigate the relationship of impairments in hearing and vision with adverse health outcomes including incident cardiovascular disease (CVD) and mortality, disability and frailty. The specific objectives of the thesis are to:

1. Examine the relationship between sensory impairments, socio-demographic characteristics, lifestyle factors and burden of morbidity in older age.
2. Examine the association of sensory impairments with incident CVD, incident myocardial infarction (MI), incident stroke and risks of CVD mortality and all-cause mortality in older age.
3. Examine the association between sensory impairments and incidence of disability based on mobility limitations, difficulties undertaking activities of daily living (ADLs) and difficulties undertaking instrumental activities of daily living (IADLs) in older age.
4. Examine the association between sensory impairments and incident frailty in older age.

1.5. Overview of methods

To study the objectives of this thesis, data from population-based longitudinal studies from the UK were used including the British Regional Heart Study (BRHS) and the English Longitudinal Study of Ageing (ELSA). The BRHS is a prospective study of a socioeconomically and geographically representative sample of 7735 men aged 40-59 years at baseline examination in 1978-80 when the cohort was established.[81] Since recruitment, participants have been followed-up regularly by postal questionnaires and physical examinations. Data on sensory impairments were first collected in 2003 (subjects aged 63-85 years) as part of a self-reported questionnaire on lifestyle, ill-health, physical functioning and social interaction. A more detailed description of the BRHS can be found in Chapter 3.

The BRHS is well-placed for studying objectives 1-3 of this thesis as it provides detailed assessment of CVD and mortality, standard measures of disability, a range of comorbidities and lifestyle factors, and information on sensory impairments since 2003 allowing for long follow-up of an older population. The BRHS also provides regular and objective measurements on CHD events, CVD events and mortality, with very high rates of follow-up. This enables the investigation of measures of sensory impairments in relation to CVD and mortality in older age. The BRHS has furthermore regularly collected data on several types of disability using validated standard measures. This allows for the examination of sensory impairments in relation to disability in the forms of mobility limitations, ADL and IADL difficulties in older age. However, the study sample is made up predominantly of white British men and does not include women or ethnic minority groups.

This thesis has used data specifically from the BRHS questionnaire in 2003 which was completed by 3981 men, aged 63-85 years, with follow-up data on cardiovascular outcomes and mortality until 2013, and follow-up data on disability until 2005. Outcomes assessed using BRHS data were CVD events (defined as non-fatal myocardial infarction (MI) and/or non-fatal stroke) including separate outcomes on non-fatal MI and non-fatal stroke, CHD mortality, CVD mortality, all-cause mortality, and difficulties undertaking mobility limitation, ADLs and IADLs, respectively. Outcomes were defined using standardised definitions presented in Chapter 3.

The ELSA is a prospective study of a nationally representative sample of 11,391 men and women aged 50 years and over who participated in the Health Survey for England (HSE) in 1998, 1999 or 2001. The first wave of data collection (wave 1) was conducted in 2002 and since then the participants have been interviewed about their physical, psychological, cognitive, social and economic conditions every two years. Every four years the data collection has also included a physical examination. Apart from data collected upon recruitment, the first full assessment that included a physical examination was conducted in 2004 (wave 2) and repeated in 2008 (wave 4) and in 2012 (wave 6). A more detailed description of the ELSA is provided in Chapter 3.

The ELSA is a suitable cohort for studying objective 4 of this thesis as it provides assessment of frailty components (unavailable in BRHS), a range of comorbidities and lifestyle factors, and information on sensory impairments. The ELSA provides standardised objective measurements of frailty, which have been assessed repeatedly part of the nurse visits. This enables the investigation of sensory impairments in relation to frailty in older age. However, not all participants accepted to undertake the physical examinations, limiting the sample to participants with frailty measures.

This thesis has used data specifically from the interview and nurse assessment in 2004 of 2836 men and women aged 60 years and over, with follow-up data on frailty until 2008. Outcomes assessed using ELSA data were standardised definitions of frailty and pre-frailty described in Chapter 3.

1.6. Structure of the thesis

The content of each of the subsequent chapters is a follows: Chapter 2 provides the epidemiological background to sensory impairments and the associations with CVD, mortality, disability and frailty in older age. Chapter 3 describes the design and methods of the two data sets used to investigate the thesis objectives and methods used to analyse data: the British Regional Heart Study (BRHS) and the English Longitudinal Study of Ageing (ELSA). Chapter 4 is the first of four results chapters (Chapters 4 to 7) and presents the findings on the associations between sensory impairments and socio-demographic characteristics, lifestyle factors and comorbidity in older age using data from the BRHS. Chapter 5 examines the associations between sensory impairments and incident CVD events including separate data on CHD and stroke, and mortality using data on sensory impairments in 2003 and follow-up data on CVD mortality and all-cause mortality until 2013 in BRHS. Chapter 6 examines the associations between sensory impairments in 2003 and the risk of incident mobility limitations, ADLs and IADLs over 2 years until 2005 using BRHS data. Chapter 7 examines the association between sensory impairments and incident frailty using data on sensory impairments in 2004 and follow-up data on frailty until 2008 in the ELSA.

Each results chapter (Chapters 4 to 7) is presented in the same format and consists of a brief introduction and methods specific to analyses of that chapter (including subjects and methods of data collection and statistical analysis), results of analyses presented as tables and graphs, and a discussion including a summary of the main findings, comparison with previous literature and strengths and limitations. Chapter 8 is the concluding chapter, which summarises the key findings of this thesis and presents the implications for public health and future research.

1.7. Thesis publications

The findings in this thesis have been published as five papers in peer-reviewed journals. These publications are listed below and presented in Appendix VI. A list of oral and poster presentations given at conferences based on the findings in this thesis are provided in Appendix II and Appendix III.

1. Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Socio-demographic characteristics, lifestyle factors and burden of morbidity associated with self-reported hearing and vision impairments in older British community-dwelling men: a cross-sectional study. Journal of Public Health. 2016;38(2):e21-8

2. Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Sensory impairments and cardiovascular disease incidence and mortality in older British community-dwelling men: a 10-year follow-up study. Journal of the American Geriatrics Society. 2016;64(2):442-4

3. Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Hearing impairment and incident disability and all-cause mortality in older British community-dwelling men. Age & Ageing. 2016;45(5):662-7

4. Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Self-reported hearing impairment and incident frailty in English community-dwelling older adults: a 4-year follow-up study. Journal of the American Geriatrics Society. 2017;65(5):958-65

5. Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Self-reported vision impairment and incident pre-frailty and frailty in English community-dwelling older adults: a 4-year follow-up study. Journal of Epidemiology and Community Health. 2017;71(11):1053-8

CHAPTER 2 Literature review

2.1. Introduction

This Chapter presents the background to hearing impairment and vision impairment, and reviews existing studies of the relationships between impairments in hearing and vision, and cardiovascular disease (CVD) and mortality, disability and frailty in later life. Section 2.2 describes the epidemiology and pathophysiology of hearing impairment, assessment and definition of hearing impairment and the importance of hearing impairment in older age. Section 2.3 describes the epidemiology and pathophysiology of vision impairment, assessment and definition of vision impairment and the importance of vision impairment in older age. Section 2.4 then outlines the literature on impairments of hearing and vision and cardiovascular disease and section 2.5 presents literature on hearing impairment and vision impairment and disability. Section 2.6 presents the literature on impairments of hearing and vision and frailty. Finally, section 2.7 provides a summary of the literature review findings.

2.2. Overview of hearing impairment in older age

2.2.1. Epidemiology and pathophysiology of hearing impairment

The UK population is ageing due to increased longevity leading to an increase in the number of older adults.[1] The most recent national estimates of prevalence of hearing impairment in Great Britain suggest that 27% of adults aged 61-80 years have a hearing impairment.[4] These estimates were conducted by applying the number of adults in Britain from the 2011 Census to prevalence data on objectively assessed hearing from the National Study of Hearing in the 1980s.[82] However the estimates may be underestimated as objectively measured data from Health Survey for England 2014 has shown that hearing impairment affects 29% of people aged 65-74 years, 55% of those aged 75-84 years and 83% of adults aged 85 years and over.[20]

The vast majority of hearing impairment is due to sensorineural hearing loss.[29] Sensorineural hearing loss is caused by damage to any part of the inner ear (e.g. the cochlea) or the neural pathways to the brain (the auditory nerve) either through ageing or as a result of injury.[29, 83] Age-related hearing impairment, also called presbycusis, is a form of sensorineural hearing loss that typically develops gradually due to advanced age causing dysfunction in the peripheral and the central auditory pathways.[84] Presbycusis is the most common cause of hearing impairment estimated to globally affect 25-30% of adults aged 65-74 years and 40-50% of those aged 75 years and over.[43, 85, 86] Human beings perceive sounds at frequencies between 20 and 20,000

Hertz (Hz). Sensorineural hearing loss including presbycusis initially affects the ability to hear frequencies between 6000-8000 Hz, which interferes with normal speech conversations even when the loss of hearing is mild, and develops progressively to lower frequencies over time.[83] Age-related hearing impairment can be addressed by using an amplifier such as hearing aids, which is regarded as the most effective method for improving hearing in older age.[87]

The second most common type of hearing impairment is noise-induced hearing impairment estimated to account for about one-third of hearing impairment in adults aged 18 years and over.[88] Noise-induced hearing impairment is caused by exposure to loud sound initially affecting frequencies 3000-6000 Hz and then gradually develops to affect lower and higher frequencies as a result of chronic exposure to excessive sound levels.[83] Other types of hearing impairment include conductive hearing loss affecting the middle ear preventing sounds to pass from the outer to the inner ear, a condition that may be caused by blockage such as earwax, a build-up of fluid following an ear infection, a perforated ear drum or hearing bone disorder, conditions that can be medically treated.[48] Sudden hearing loss affects 5-20 people per 100,000 individuals who often are aged of 50-60 years,[89] and can be sensorineural or conductive depending on which parts of the ear are affected.[90] It can also be caused by trauma, anti-inflammatory drugs and Ménière’s disease, an uncommon condition that involves attacks of vertigo.[90] Sudden hearing loss is often associated with tinnitus, the experience of hearing sounds such as ringing or buzzing in the individual’s ears or head, and occurs instantly or over the course of a few weeks. Depending on the cause and severity of the problem, individuals can recover from sudden hearing loss.[90]

2.2.2. Assessing and defining hearing impairment

Hearing function assessed objectively refers to loudness measured in decibels (dB) and human beings can hear sounds from 15 dB.[29] The World Health Organization (WHO) has defined hearing impairment as inability to hear frequencies greater than 40 dB in the better ear.[91] However a range of definitions and assessment methods including objectively measured and self-reported hearing are used, resulting in prevalence rates that vary considerably. There is furthermore a lack of agreement whether hearing impairment should be assessed based on performance with hearing aids or while unaided.[30, 91] Measures of sensorineural hearing loss include self-reported questionnaire instruments and single-item questions on hearing function, and objectively assessed screening tests including pure tone audiometry (PTA) and whisper tests.[29] Other types of hearing loss such as problems with speech comprehension in noisy environments is measured using tests of identification of verbally presented words.[85] Although PTA is considered as the gold standard for assessment of hearing, objectively measured hearing may not reflect the individual's experience of their hearing ability, particularly in older age, as some people may be unaware of mild or moderate hearing impairment because of its insidious onset and progression.[44] Also, a problem with objectively measured sensory function is the wide range of definitions used for hearing impairment, making it difficult to compare the findings of different studies (further discussed below in sections 2.4-2.6). For example, some studies refer to hearing impairment as hearing loss with thresholds higher than 25 dB whereas other studies use hearing loss with thresholds higher than 40 dB. Furthermore, hearing function may in different studies be tested at different frequencies. Also, some studies report the outcomes for the worse ear, some for the better ear and some for both ears. Increased use of a global standard definition of objectively assessed hearing impairment such as the WHO definition is needed.

Self-reported hearing impairment is commonly used to assess hearing impairment in large population-based samples due to the size of the studies causing logistical difficulties of performing audiometric screening on a large scale.[92] Questionnaire instruments for assessing hearing ability include the Social Hearing Handicap Index aiming to capture aspects of hearing impairment in daily life,[93] Hearing Performance Inventory developed to assess communication difficulty,[94] and the Hearing Handicap Inventory for the Elderly, covering social and emotional aspects of hearing problems.[95] In addition to comprehensive questionnaires on hearing problems, there are single-item questions on hearing function including 'Is your hearing good enough to follow a television (TV) programme at a volume others find acceptable (using a hearing aid if needed)?'.[96] This question has been shown to be associated with a mean hearing loss of 35 dB in a sample of 105 English audiology patients (mean age 56 years) referred to a hearing clinic by their general practitioner for the first time.[96] Increased TV volume reported by the patient or their accompanying partner has been demonstrated to have a sensitivity of 81% and a specificity of 52% in predicting hearing loss (pure tone threshold of ≥ 25 dB). The self-reported question on viewing TV at a volume others find acceptable has been used in national health surveys across the Organisation for Economic Co-operation and Development (OECD) countries[97] and Europe[98] including the UK Disability Survey 1996-97 and the Health Survey for England (HSE) in 2005 and 2014.

Another commonly used single-item self-reported question on hearing function refers to asking participants whether they perceive their hearing as excellent, very good, good, fair or poor using a hearing aid if they normally use one. The question has been validated against the whisper voice test (shown to be appropriate to determine hearing loss of 30-40 dB[99]) in 168 community-dwelling Irish adults aged 50 years and over and provided 56% sensitivity and 95% specificity.[100] The question has also been tested against pure tone audiometry (hearing loss defined as >25 dB in the worse ear) providing 67% sensitivity and 85% specificity. However the investigation was restricted to younger and middle-aged adults (n=188 aged 30-65 years).[101]

Self-reported questions on hearing impairment could be criticised for lacking sensitivity (resulting in some individuals being incorrectly identified as not having hearing loss).[92] However, there is a problem with self-reported hearing questions being validated in small samples rather than in large population-based studies.[92] Self-reported questions on hearing function are frequently used and advantages include that it is quick and inexpensive to administer. Advantages of self-reported questions on hearing function also include that they report the experience and degree of impairment from the patient perspective.[92]

2.2.3. The importance of hearing impairment in later life

The rapidly growing number of older adults has raised concerns about hearing impairment in later life as it is strongly associated with advanced age.[102] In the UK, nearly two-thirds of all hearing impaired individuals are aged 60 years and over.[103] Hearing impairment in older age has been associated with chronic diseases[10, 16, 17, 104] and poor physical functioning[63, 64] negatively influencing quality of life and the chances of independent living.[105] This makes hearing impairment in later life an important public health issue. Investigating the prospective relationships of hearing impairment with incident morbidity, mortality and physical functioning has the potential to highlight major age-related health issues that possibly could be prevented if hearing impairment is detected and successfully addressed. Information on the impact of hearing aid use on adverse health outcomes could further demonstrate their positive effect. An increase in hearing aid use also has the potential to considerably reduce the negative impact of hearing impairment on communication. This could facilitate social interaction and plausibly improve quality of life in hearing impaired individuals.[105] Moreover, as presented in Chapter 1 (section 1.1.2.), the financial costs of hearing impairment to the NHS and society are substantial, making hearing impairment an important target to reduce further financial costs and disease burden.[23]

2.3. Overview of vision impairment in older age

2.3.1. Epidemiology and pathophysiology of vision impairment

Around 2 million (13%) people aged 65 years and over in the UK have a vision impairment that has a significant impact on their daily lives.[5] Prevalence of vision impairment increases with advanced age and is estimated to affect 20% of adults aged 75 years and over and 50% of those aged 90 years and over.[106] Vision function has multiple dimensions including central vision (distance vision, near vision), peripheral vision (seeing objects in non-central parts of the visual field), visual contrast sensitivity (perceiving contrast between objects and their background) and colour vision.[107] Vision impairment is a broad term that encompasses any loss or abnormality of vision function.[108-110]

The most prevalent eye conditions in older age are age-related macular degeneration (AMD), cataract, glaucoma and diabetic retinopathy.[27, 111] AMD is a chronic and progressive eye condition affecting about half (53%) of visually impaired British adults aged 75 years and over.[112] It is characterised as a growing blurred area in the centre of the vision field. AMD is often divided into early and late AMD to separate more advanced AMD from early AMD, as AMD sometimes develops very slowly and individuals with early AMD may notice little change in their vision.[113] The two main types of late AMD are 'dry' AMD and 'wet' AMD. Dry AMD is the more common type of AMD and develops slowly. In contrast, wet AMD can develop rapidly, causing serious changes to the individual's central vision. The risks of developing AMD can potentially be reduced by leading a healthy lifestyle including not smoking cigarettes. Early diagnosis and treatment of wet AMD are essential to prevent severe vision impairment. Nevertheless AMD is the leading cause of blindness in older age in the UK.[25, 110]

Cataract refers to gradual changes in the lens of the eye making the lens less transparent and estimated to affect 36% of visually impaired British adults aged 75 years and over.[112] Cataract is best treated by surgery which can significantly improve visual functioning.[27, 110] Glaucoma affects around 12% of visually impaired older British adults (aged ≥ 75 years) and is due to a drainage failure causing raised intraocular pressure within the eye reducing central vision.[112, 114] Apart from central vision, glaucoma can also cause visual field loss and blindness. Glaucoma can to some extent be prevented by addressing environmental and lifestyle factors.[115] However, loss of vision due to glaucoma is irreversible and early detection and medical treatment including surgery are essential to prevent further damage to the eye.[116] Further, damage to the blood vessels that supply the retina caused by chronic high levels of glucose (diabetes mellitus) can lead to the eye condition diabetic retinopathy, affecting 3% of visually impaired British adults aged 75 years and over.[112] This makes diabetes a major cause of blindness.[117] A systematic review has reported that older adults with diabetes are 1.5 times more likely to develop vision impairment compared with older adults without diabetes.[118] Diabetic retinopathy can result in sudden or gradual worsening vision, experience of shapes floating in the field of vision, or blurred or patchy vision. The condition is treatable and can be prevented through control of underlying diabetes.[119]

2.3.2. Assessing and defining vision impairment

Given that central vision is essential for everyday function, tests of loss of central visual acuity are commonly used to assess vision function. Visual acuity is objectively assessed, generally with a Snellen vision chart where a notation of two numbers presented in meters or feet indicate the distance at which the letters provided are readable to the person tested in relation to someone with no vision impairment, often defined as 6/6 (20/20).[120] WHO defines vision impairment as visual acuity that is less than 6/18 (20/60) and equal to or better than 3/60 (20/400) measured in the better eye with best correction.[121] However, a variety of definitions of vision impairment based on objectively assessed visual acuity is used including different definitions of degrees of vision impairment (low/moderate/severe). A wider use of the WHO definition of vision impairment (using measures of visual acuity) would facilitate comparison between studies based on objectively assessed vision impairment.

Because visual acuity assesses the smallest target that can be seen under maximum contrast (black letters on a white background), it captures only one aspect of vision.[122] Assessing several aspects of an individual’s eyesight is time consuming and costly and may therefore not be appropriate for larger studies. Further, registration rates of vision impaired people have the advantage of providing an exact number of individuals affected by a vision condition but tends to be incomplete and unrepresentative for the population, and may underestimate the true number of people considered to be visually impaired.[123] Objectively assessed vision and registered vision impairment do not necessarily provide information on day-to-day functions requiring vision such as reading and driving and may not reflect someone’s self-perceived vision function.[124] Such aspects are difficult to address using objectively assessed vision,[125] but can be targeted using self-reported questionnaires designed to assess how vision problems affect everyday activities and quality of life, allowing for a comprehensive picture of self-perceived eyesight.[126-128] Similarly, single-item self-reported questions on vision which can be used on their own often refer to how someone is doing in day-to-day activities. This provides important information about the difficulties visually impaired people perceive in their everyday environments, for example, ability to read the newspaper or recognise a friend across a road.[120, 129] The question “seeing good enough to recognise a friend across a road” has demonstrated 60% sensitivity and 95% specificity when compared against visual acuity defined as 6/18-6/60 in the Norfolk-European Prospective Investigation into Cancer study (Norfolk-EPIC) (n=8317, aged 48-92 years).[11] Another common self-reported question on vision impairment refers to asking people to rank their eyesight from excellent to poor.[130] This question has been assessed against data on visual acuity from the UK Medical Research Council (MRC) Elderly Trial of 33,000 community-dwelling adults aged 75 years and over showing 79% sensitivity and 75% specificity.[130] In addition to providing information on day-to-day functions that require vision, advantages of self-reported vision measures include that it can be time-efficient and cheap. This makes single-item questions on visual function important for health-related population-based studies of older adults.[123]

2.3.3. The importance of vision impairment in later life

The dramatic increase of vision impairment with advanced age means that it is one of the most prevalent health conditions in older adults.[106] Given the projected growth of the older population, vision impairment has become an important public health issue. Vision impairment has been associated with adverse outcomes including morbidity and disability affecting everyday life and survival rates.[16, 17, 68, 131] Investigating the direction of the relationship of vision impairment with other common conditions in older age has the potential to bring clarity in what health concerns could potentially be avoided or delayed by addressing vision impairment. Prevention of vision impairment has great potential as it is estimated that over 50% of vision impairment in the UK is avoidable through correction of spectacles that are not of the optimum strength, early detection and treatment of eye conditions, and health promotion interventions including weight management and smoking cessation.[24-27] Prevention of vision impairment is furthermore likely to have a positive impact on society as the costs of vision impairment to the UK economy are vast (see Chapter 1, section 1.1.3).[22, 25]

2.4. Sensory impairments and cardiovascular disease in older age

2.4.1. Epidemiology and pathophysiology of cardiovascular disease

Globally, non-communicable diseases account for about two-thirds (68%) of the number of deaths that occur every year, and of these, cardiovascular disease (CVD) is the largest single cause of death.[132] CVD is a general term for conditions affecting the heart and blood vessels and the main forms of CVD are coronary heart disease (CHD) and stroke. Death rates from CVD have been falling in the UK since the 1970s, however in 2015 CVD remained the second most common cause of death accounting for over a quarter (27%) of all deaths (cancer was the main cause of death responsible for 29% of all deaths).[31] Just under half (45%) of all CVD deaths in the UK are from CHD and a quarter (25%) are from stroke.[31] CVD strongly contributes to morbidity and disability[133, 134] and is estimated to cost the UK £15.2 billion per annum (in 2014) including health care costs (£11 billion), productivity losses (£4 billion) and informal care-related costs (£152 million).[31]

CHD includes angina, myocardial infarction (MI) and sudden ischaemic death. The most common underlying condition that causes CHD and stroke is atherosclerosis. Atherosclerosis is characterised by chronic inflammation in the artery walls, where fatty materials and cholesterol are deposited forming atherosclerotic plaques, narrowing the arteries which restricts the blood flow. The atherosclerotic plaques can rupture and, if large enough, block a coronary or cerebral blood vessel.[31, 35] Angina is characterised by chest pain due to obstructed blood supply to the heart. MI is often referred to as ‘heart attack’ characterised by chest pain and shortness of breath and is caused by blockage of a coronary artery. Stroke is a subset of cerebrovascular disease, a collective term for all diseases affecting blood vessels that supply the brain. Stroke is due to blockage of blood supply to the brain or caused by a bleeding in or around the brain.[31]

2.4.2. Hearing impairment and cardiovascular disease

2.4.2.1. Cross-sectional studies on hearing impairment and CVD

A summary of relevant cross-sectional studies that have investigated the relationship of hearing impairment and CVD in populations that include older adults is presented in Table 2.1 (page 59). Evidence from cross-sectional studies has consistently shown an association between hearing impairment and CVD.[10, 16, 17, 38, 46, 47, 104] Early work from the 1970s includes a small study by Rubinstein et al. (1977)[104] comprising 46 older adults from a care home with objectively measured hearing impairment and clinically assessed CVD. In their study, objectively assessed hearing impairment was more common in subjects with clinically assessed CVD (n=23) compared with participants of the same age without CVD (no effect size reported). However, the study did not report adjusting for possible confounding factors including sociodemographic factors such as sex and social class. Also, the study was undertaken in a small number of participants recruited from a care home and not necessarily representative of the community-dwelling older population.

Early work also includes cross-sectional analyses of data from the Framingham Heart Study of 1662 older adults undertaken in the early 1990s.[10] The findings have shown that the magnitude of the association between hearing impairment and clinically assessed stroke is greater in hearing impairment in lower frequencies, which refer to hearing impairment caused by exposure to noise, compared to hearing impairment in higher frequencies which are primarily affected by presbycusis.[10] For instance, in men, hearing impairment in lower frequencies was associated with over 3-fold increased odds of having a stroke (odds ratio (OR) 3.46, 95% CI 1.60-7.45). This can be compared to their findings on hearing impairment in higher frequencies being associated with 1.97 increased odds of having a stroke in men (OR 1.97, 95% CI 1.05-3.72). While these findings may be more strongly associated with increased risk of stroke compared to age-related hearing impairment, they were adjusted only for age. Adjustment for additional socio-demographic factors including social class is important as research has shown that individuals from manual social class have greater risks of noise-induced hearing impairment caused by harmful occupational noise.[135] Individuals from manual social class may possibly also be at greater risks of being exposed to noise during leisure activities, due to a less healthy lifestyle, compared to non-manual workers.[135]

In addition to adjustment for socio-demographic factors, few cross-sectional studies investigating the relationship of hearing impairment and CVD have adjusted for other potential confounding factors including lifestyle factors such as smoking and obesity and physical activity, and CVD-related chronic conditions including diabetes and hypertension. Of the cross-sectional studies on hearing impairment and CVD presented in Table 2.1, only one study has adjusted for obesity[47] and only one other study has adjusted for physical activity.[46] Lifestyle factors are important to adjust for as literature has reported independent relationships between hearing impairment and physical inactivity, smoking and obesity,[8, 102, 136-139] established risk factors for CVD.[31] Smoking and obesity increase the risk of atherosclerosis of the auditory artery. This can negatively affect the individual’s hearing function as atherosclerosis reduces the cochlear blood flow which is essential for adequate hearing.[140] Physical activity may furthermore act as a possible causal mechanism as hearing impairment may be related to low physical activity due to damage to the cochlea causing poor balance, making it difficult to be physically active.[141] Also, hypertension and diabetes are strongly associated with CVD.[31] Both hypertension[10, 17, 142] and diabetes[16, 143, 144] have furthermore been associated with hearing impairment. Thus, it is possible that hypertension and diabetes confounded the relationship observed and should therefore be considered for adjustment.

Besides lack of adjustment for lifestyle factors and CVD-related chronic conditions, limitations to several cross-sectional studies examining the relationship between hearing impairment and CVD include use of self-reported data on CVD (Table 2.1).[9, 16, 17, 46] Some of the studies using self-reported data on CVD have furthermore not checked the data provided by the respondents against medical records.[16, 17, 46] This raises the possibility of CVD data being misreported due to recall bias.[145] Also, all studies in Table 2.1 were of cross-sectional design which means that the direction of the relationship between hearing impairment and CVD could not be assessed. In the next section, findings from literature on prospective studies investigating the relationship between hearing impairment and risks of incident CVD are presented.

2.4.2.2. Longitudinal studies on hearing impairment and risks of incident CVD

Table 2.2 (page 61) summarises relevant longitudinal studies that have investigated the relationship of hearing impairment and the risks of incident CVD including MI, stroke and CVD mortality.

To date, few longitudinal studies have examined the relationship of hearing impairment and the risk of incident CVD events. To my knowledge, only one study has investigated the association between hearing impairment and incident MI. This study[42] was of retrospective design using data from 44,830 patients of all ages (≥ 0 years) diagnosed with sudden sensorineural hearing impairment and 44,830 age-matched patients as controls. The study provided separate findings on older adults (≥ 65 years). The findings showed a strong association between hearing impairment and increased risks of MI in older adults after 3-5 years of follow-up (hazard ratios (HR) 24.77, 95% CI 12.67-48.41 in participants aged ≥ 65 years).[42] Data on MI were obtained from medical records and the analyses were adjusted for socio-demographic factors and chronic conditions including hypertension and diabetes, however, no adjustment was made for lifestyle factors. Smoking, obesity and physical activity are important confounding factors between hearing impairment and the risk of CVD (as described above in section 2.4.2.1) that need to be adjusted for. Also, this study was a case-control study. Selecting patients rather than individuals from the general population for the comparison group may over-select individuals who have been exposed to sudden sensorineural hearing impairment. Thus there is a risk of selection bias of the subjects in the comparison group. Such risk can be reduced by undertaking a cohort study in the general population where individuals are followed forward in time which allows for investigations of whether exposure to hearing impairment will affect the incidence of disease such as MI.[145]

Longitudinal studies have also investigated associations between hearing impairment and incidence of stroke. Previous studies on hearing impairment and increased risks of stroke have shown inconsistent findings with some research demonstrating an association and some research showing no association (Table 2.2). A prospective study of 1423 patients of all ages (≥ 0 years) with diagnosed sudden sensorineural hearing impairment reported increased risks of diagnosed stroke at 5-year follow-up (HR 1.64, 95% CI 1.31-2.07).[41] The findings were compared to patients without diagnosed hearing impairment and adjusted for socio-demographic factors and chronic conditions including hypertension and diabetes. However, the study was undertaken in patients hospitalised with sudden sensorineural hearing loss and did not present specific data on older adults. The findings may therefore not apply to other types of hearing impairment including presbycusis which develops gradually and typically does not result in hospitalisation.[44] In contrast, a prospective study undertaken in a sub-sample of 1556 community-dwelling middle-aged and older adults (aged >49 years) participating in the Blue Mountains Hearing Study (BMHS) showed no association between hearing impairment and risk of incident stroke over a 5-year follow-up period (OR 1.14, 95% CI 0.59-2.23).[45] However, this could be due to the small sample of incident stroke (n=43). Another limitation to the study is that no separate findings for older adults were provided.[45]

2.4.2.3. Hearing impairment and the risk of CVD mortality

Previous studies examining the relationship between hearing impairment and CVD mortality are presented in Table 2.2 (page 61). Overall, relatively little is known about the relationship between hearing impairment and risk of CVD mortality. A prospective study of middle-aged and older adults has shown an age- and sex-adjusted association between objectively measured hearing impairment and CVD mortality (HR 1.36, 95% CI 1.00-1.84).[146] However the association disappeared after further adjustment for lifestyle factors, chronic conditions, self-reported health, cognition and disability in walking (HR 1.06, 95% CI 0.76-1.48). In contrast, in a study comprising older adults only, the relationship between objectively assessed hearing impairment and CVD mortality at 7-year follow-up remained after adjustment for lifestyle factors, comorbidities and cognitive impairment (HR 1.70, 95% CI 1.27-2.27).[39] The association was, however, not adjusted for social class, an important confounder of the relationship between hearing impairment and CVD.[135] Lack of adjustment for social class may furthermore have overestimated the association between hearing impairment and CVD mortality.

2.4.2.4. Other possible pathways linking hearing impairment to CVD

Besides the potential pathways linking hearing impairment to CVD presented above, literature has shown that hearing impairment, even when mild, reduces an individual's ability to communicate with others.[147, 148] Poor communication is furthermore associated with increased risks of depression, [105, 147, 149, 150] and can seriously affect social relationships.[151, 152] Substantial evidence has shown that depression is a risk factor for CVD morbidity and mortality,[153] potentially through a more sedentary lifestyle which in turn can lead to early development of atherosclerosis, the most common cause of CHD and stroke.[154] Sedentary lifestyle among hearing impaired older adults may furthermore be due to walking problems. Damage to the inner ear can result in poor balance, reducing the individual's physical activity levels and increasing the risk of CVD.[31, 136] However, the role of physical inactivity, depression and social isolation as mediators on the pathway between hearing impairment and incident CVD is not fully established.[150]

Further, it is possible that in hearing impaired individuals, greater cognitive resources are dedicated to processing information received in order to compensate for auditory information not perceived.[155] Lack of intellectual stimulation due to poor communication associated with hearing impairment could possibly also lead to a decline in cognitive function.[156] In a recent systematic review and meta-analysis, cognitive impairment was shown to increase the risk of future stroke including fatal stroke, possibly through shared pathophysiological mechanisms including the autoregulation of cerebral blood flow that ensures the supply of oxygen or silent brain infarcts.[157] Cognitive impairment may also increase the risk of incident stroke through shared risk factors including hypertension, diabetes, obesity and physical inactivity. However, apart from stroke, it is unclear whether cognitive impairment may increase the risk of other vascular conditions such as myocardial infarction and angina.

Hearing impairment and CVD often co-occur in later life and may therefore share common underlying mechanisms such as chronic inflammation[33] and microvascular disease.[10] Inflammation has been shown to increase the risk of CVD[35] and possibly also the risk of hearing impairment.[33, 37] For example, research has shown that circulating inflammatory molecules can negatively affect tissues of the cochlea.[158] The association between inflammatory markers and hearing impairment furthermore appear to be age dependent.[33] Inflammation may therefore explain the relationship between hearing impairment and CVD in older age.[33] Microvascular disease including arteriolosclerosis of blood vessels to the cochlea may furthermore increase the risk of both hearing impairment and CVD.[10] Possible pathways linking hearing impairment with CVD presented in this section have been visually outlined in Figure 2.1 (page 79).

2.4.2.5. Hearing impairment and the risk of all-cause mortality

Previous studies on hearing impairment and all-cause mortality are presented in Table 2.3 (page 62). The relationship between hearing impairment and all-cause mortality is unclear. Recent findings from the Health, Aging and Body Composition (Health ABC) study, which comprises 1958 community-dwelling adults aged 70 years and over followed for 8 years, have reported an association between objectively measured hearing impairment and all-cause mortality even after adjustment for socio-demographic factors, smoking, chronic conditions including hypertension and depression, gait speed, cognition and hearing aid use (HR 1.20, 95% CI 1.03-1.41).[40] However, apart from smoking, the findings were not adjusted for any lifestyle factors and were not adjusted for CVD, previously associated with both hearing impairment[10] and mortality risk.[31] Contrary to this, some studies have shown no association between hearing impairment and all-cause mortality.[146, 159, 160] Such studies include early research from the 1990s undertaken in 1408 community-dwelling older adults (aged ≥ 65 years) participating in the Study of the Wellbeing of Older People in Cleveland (SWOPC) (HR 1.18, 95% CI 0.54-2.60).[161] However, participants in SWOPC were only followed for one year. Longer follow-up is likely to be important when investigating the impact of hearing impairment on all-cause mortality in older age since presbycusis, the most common type of hearing impairment in later life, develops gradually.[84]

2.4.3. Vision impairment and cardiovascular disease

2.4.3.1. Cross-sectional studies on vision impairment and CVD

Relevant cross-sectional studies investigating the relationship between vision impairment and CVD in populations comprising older adults have been summarised in

Table 2.4 (page 63). Large cross-sectional studies including the National Health Interview Survey (NHIS) and Supplement on Aging II (SOA-II) carried out in American older adults have found that individuals who reported having trouble seeing or were blind had greater risks of heart disease and, in particular, stroke, compared to those who had no trouble seeing.[16, 17] For example, in SOA-II, participants with trouble seeing or blindness had 2-fold risks of heart disease (OR 2.00, 95% CI 1.70-2.40) and were 2.6 times more likely to report having had a stroke (2.60, 95% CI 2.10-3.20) compared to participants who had no trouble seeing. The analyses were undertaken in community-dwelling older adults (≥ 70 years), however, NHIS and SOA-II have used self-reported data on vision impairment, heart disease and stroke. The prevalence of self-reported vision impairment in the two studies (18%[17] and 9%[16]) are comparable or lower than American national estimates of vision impairment in older adults (17% in adults 65-74 years, 26% in adults ≥ 75 years),[162] and therefore may be underestimated. Further, none of the studies reported checking the data on self-reported CVD events against medical records, suggesting that there may be risks of recall bias.[145] Also, the analyses did not adjust for potential confounding factors such as socio-demographic factors and lifestyle factors including smoking, obesity and physical activity, previously associated with both vision impairment and CVD.[16, 163-168] For example, excessive calorie intake and cigarette smoke have independently been associated with oxidative stress which can damage the eye.[169] Also, the relationship between vision impairment and low physical activity could be explained by limited ability to move freely due to poor vision.[17] Additional confounders to consider include chronic conditions such as diabetes and hypertension. High levels of glucose also increase the risk of atherosclerosis, the most common underlying condition that causes CVD.[31] Hypertension has been shown to have profound effects on the eye and has been associated with increased risks and development of diabetic retinopathy, glaucoma and AMD.[170] Adjustment for lifestyle factors, diabetes and hypertension is therefore important when investigating the relationship between vision impairment and CVD outcomes.

Similar to the findings from the NHIS and SOA-II, a cross-sectional study using data from the European Prospective Investigation into Cancer-Norfolk eye study (EPIC-Norfolk) has reported associations between vision impairment (objectively assessed visual acuity <6/12, and self-reported inability to recognise a friend across a road) and increased risks of CHD (p<0.01 for both measures of vision impairment). In contrast, neither self-reported (p=0.1) nor objectively assessed vision impairment (p=0.4) was associated with greater risks of stroke. Findings from the EPIC-Norfolk were, however, undertaken in middle-aged and older adults combined (n=8317, aged 48-92 years) with no separate data on older adults. Furthermore, the studies presented in this section using data from NHIS, SOA-II and EPIC-Norfolk are cross-sectional and causality cannot be established. The next section focuses on findings from prospective studies investigating the relationship between vision impairment and risks of incident CVD.

2.4.3.2. Longitudinal studies on vision impairment and incident CVD

Table 2.5 (page 64) presents relevant longitudinal studies of prospective design that have investigated the relationship of vision impairment and the risks of incident CVD including MI, stroke and CVD mortality using data that comprise older adults. Relatively few prospective studies have examined the relationship of vision impairment and the risk of incident CVD events including separate data on MI and stroke. Also, most previous studies have defined vision impairment as having age-related macular degeneration (AMD) and little is known about the relationship of vision impairment in general with increased risks of incident CVD in later life.

In a large population-based study of nearly 1.5 million American community-dwelling adults aged 65 years and over, individuals diagnosed with AMD were associated with increased risks of incident MI at 2-year follow-up (OR 1.19, 95% CI 1.16-1.22).[49] The relationship was adjusted for socio-demographic factors, hypertension and diabetes but not for lifestyle factors. The importance of adjusting for confounders including smoking, obesity and physical activity when assessing the relationship between vision impairment and CVD risks has been discussed above (section 2.4.3.1).

Diagnosed AMD has also been associated with risks of incident CHD in the Cardiovascular Health Study (CHS) of 1786 community-dwelling adults aged 69-97 years (HR 1.57, 95% CI 1.17-2.22)[55] and in the Atherosclerosis Risk in Communities study (ARIC) (n=12,536, aged 49-73 years) (RR 3.05, 95% CI 1.14-8.17).[171] The associations were adjusted for socio-demographic factors, smoking and chronic conditions including diabetes. Data from CHS and ARIC have also been used to investigate the prospective relationship of vision impairment and incident stroke. Vision impairment defined as diagnosed AMD has been associated with increased risks of incident stroke in the CHS at 9-year follow-up (HR 1.89, 95% CI 1.19-3.01)[51] and in the ARIC at 13-year follow-up (HR 1.51, 95% CI 1.11-2.06).[50] However, both studies relied on self-reported data on CHD, albeit checked against medical records. Furthermore, the findings from the ARIC were based on data on middle-aged and older adults combined and data on findings in older adults only were not provided.

2.4.3.3. Vision impairment and the risk of CVD mortality

Previous literature has shown inconsistent findings between vision impairment and the risk of CVD mortality (Table 2.5, page 64). A recent study undertaken in 3280 community-dwellers aged 40-80 years in Singapore has reported an association between objectively assessed vision impairment and CVD mortality risks (HR 1.49, 95% CI 1.02-1.88).[52] The findings were adjusted for socio-demographic factors, smoking, obesity, diabetes and hypertension. Findings on older adults only were, however, not presented. In the Blue Mountains Eye Study (BMES) (n=2335, aged >49 years), over 5-fold increased risks of CVD mortality was reported in participants aged 50-74 years with diagnosed AMD (risk ratios (RR) 5.57, 95% CI 1.35-22.99).[54] However, separate findings on older participants (aged ≥ 75 years) showed no association between AMD and CVD mortality (RR 1.43, 95% CI 0.76-2.67).[54] It was speculated that the lack of association between AMD and CVD mortality in those aged 75 years and over could be due to other age-related conditions dominating the mortality risk in later life.

To my knowledge, only one study on vision impairment and CVD mortality has been undertaken in the UK. Such study consisted of 13,569 adults aged 75 years and over and showed no association between diagnosed cataract or AMD and CVD mortality at 6-year follow-up (cataract: RR 0.98, 95% CI 0.65-1.48; AMD: RR 1.03, 95% CI 0.72-1.45).[168] Similarly, a recent prospective study of 4926 Icelandic adults aged 67 years and over using objectively assessed vision impairment has shown no increased risks of CVD mortality (HR 1.10, 95% CI 0.74-1.65).[39]

2.4.3.4. Other possible pathways linking vision impairment to CVD

Possible pathways between vision impairment and CVD are presented in Figure 2.1. Increasing evidence suggests that the association between vision impairment and incident CVD may be explained by mediating factors on the pathway such as social isolation and depression. Vision impairment has consistently been associated with difficulties communicating.[13, 130, 172] Poor communication due to vision impairment has been shown to reduce the individual’s capacity to develop and maintain social networks and may result in withdrawal from social activities.[148, 172] Absence of stimulating social activities can negatively affect the individual’s psychosocial health and extensively increase the risk of depression.[173] Vision impairment can also directly cause depression.[174] Depression is one of the most prevalent conditions in vision impaired older adults,[174] and an established risk factor for CVD.[154] Therefore, depression and social isolation may mediate the relationship between vision impairment and incident CVD.

Extensive evidence over the past few decades has shown that chronic inflammation in the artery walls increases the risks of CVD.[35, 36] There is also accumulating evidence of a relationship between inflammation and increased risks of vision impairment in later life.[34, 175, 176] It has been speculated that inflammatory markers during acute phase reactions over a lifetime can result in tissue damage to the eye, increasing the risk of vision impairment in older age.[34] Inflammation may therefore be a mechanism underlying the relationship of vision impairment and incident CVD. The relationship between vision impairment and CVD could furthermore be explained by microvascular disease as the eyes are vulnerable to microvascular complications.[177]

2.4.3.5. Vision impairment and the risk of all-cause mortality

Relevant previous studies investigating the relationship of vision impairment and all-cause mortality in samples comprising older adults are presented in Table 2.6 (page 66). Previous studies have reported inconsistent findings of the association of vision impairment and increased risks of all-cause mortality. Research carried out in older adults include analyses of two large sex-specific Australian cohorts comprising community-dwelling men (n=2340) and women (n=3014) aged 76-81 years. The analyses showed an association between vision impairment and increased risks of all-cause mortality in both men (HR 1.44, 95% CI 1.17-1.77) and women (HR 1.50, 95% CI 1.24-1.82).[53] Evidence for a relationship between objectively assessed vision impairment and all-cause mortality in later life has furthermore been reported in the Salisbury Eye Study (SES).[178] In SES, moderate but not mild vision impairment was associated with increased mortality risks in older adults aged 65-84 years (moderate vision impairment: HR 2.26, 95% CI 1.45-3.52; mild vision impairment: HR 0.91, 95% CI 0.61-1.36). Although the findings were adjusted for socio-demographic factors, smoking, obesity and diabetes, no adjustment was made for other possible confounders such as physical activity, hypertension and CVD. Lack of adjustment for such confounders may explain the relationship shown between moderate vision impairment and all-cause mortality. The study furthermore obtained data on mortality from family members and newspapers rather than death records, possibly resulting in some deaths not being recorded. However, any unreported deaths would have underestimated rather than overestimated the associations observed.

In addition to studies of older adults only, there is also some evidence of a relationship between vision impairment and risks of all-cause mortality from studies undertaken in cohorts of middle-aged and older adults combined.[52, 179] Such evidence include findings from the BMES (n=3654) which has shown that prevalent cataract in adults aged over 49 years and prevalent AMD in adults aged 50-74 years was associated with increased risks of all-cause mortality (HR 1.26, 95% CI 1.04-1.53; HR 1.59, 95% CI 1.04-2.43).[179] However the study did not observe increased risks of all-cause mortality in adults aged 75 years and over with AMD (HR 0.90, 95% CI 0.65-1.26) and in adults aged over 49 years with objectively assessed vision impairment (HR 1.18, 95% CI 0.86-1.61). The association observed between cataract and all-cause mortality could be due to poorer lifestyle. The association between cataract and all-cause mortality could also be explained by lack of adjustment for potential confounders such as physical activity.[179]

In contrast, no relationship between objectively assessed vision impairment and all-cause mortality was shown in a study of 4926 Icelandic community-dwelling adults aged 67 years and over (HR 0.93, 95% CI 0.72-1.20).[39] Lack of an association between vision impairment and all-cause mortality in later life has also been reported in English older adults (n=469, aged ≥ 75 years) (RR 1.62, 95% CI 0.87-3.01).[180] However, studies on vision impairment and all-cause mortality undertaken in the UK are limited.

2.5. Sensory impairments and disability in older age

2.5.1. Epidemiology and pathophysiology of disability and physical functioning

Disability is often caused by chronic diseases such as CVD and refers to difficulty or dependency in undertaking activities that are vital to independent living.[56] Due to increased life expectancy, people are living longer with disability.[133, 134, 181, 182] Prevalence of disability increases with advanced age,[70, 183] affecting quality of life and increases the demand for care.[133, 134] However, prevalence of disability varies between countries and over time. Analyses of four population-based surveys from the USA have reported that prevalence of disability in later life declined in the 1990s.[70] The report also showed that the prevalence of disability has remained the same since 2000 in individuals aged 65-84 years and decreased in those aged 85 years and over.[58] In contrast, the prevalence of disability is steadily increasing in the UK.[184] In 2010, nearly 2.4 million (18%) of British adults aged 65 years and over lived with a disability and this number is projected to increase to 3.3 million by 2022.[185]

Disability in later life often occurs first as mobility limitation which involves problems walking and taking the stairs.[186, 187] Mobility limitation is the most common form of disability affecting more than one third (36%) of adults aged 70-103 years.[69] From the age of 65 years, the risk of developing mobility limitation increases 2-fold with each 10-year increase in age.[188] Adequate mobility function is vital in completing activities of daily living (ADL) in later life.[189] Disability in the form of ADL difficulty refers to basic tasks essential to caring for oneself and includes bathing, getting dressed, eating, getting in or out of bed or chair, toileting, and walking across a room.[190] Disability in undertaking more complex tasks refers to having difficulty performing instrumental activities of daily living (IADL). IADLs include shopping, cooking, using public transport, managing money and telephoning.[191] Performance in IADLs reflects the ability to live independently in the community. In the UK, the number of adults aged 65 years and over with difficulties performing one or more ADLs or one or more IADLs is predicted to rise from 2.4 million in 2010 to around 4.1 million by 2030, increasing the demand for prevention and management of chronic diseases.[192] However the number of older adults with disability may be underestimated as older adults tend to underreport disability[193] and not report concerns about their physical function until the situation becomes unbearable.[194]

2.5.2. Hearing impairment and disability in older age

Although disability is highly prevalent in older age, its relationship with hearing impairment remains unclear. Cross-sectional studies have consistently reported an association between hearing impairment and increased risks of disability variously defined.[12, 60, 61, 195-197] Such studies have, however, often defined disability as having difficulty undertaking various activities that require some physical capacity such as vacuuming or moving a table,[196] and, standing for long periods or ability to undertake work at a job.[60] Fewer studies have investigated the prospective relationship of hearing impairment and incidence of different types of disability using validated measures of disability such as the Katz index of Activities of Daily Living (ADL)[190] and Lawton's Instrumental Activities of Daily Living (IADL).[191] Also, little such research has been undertaken in older adults. This section (section 2.5.2) focuses on findings from longitudinal studies on the relationship between hearing impairment and incidence of mobility limitation, ADL difficulty and IADL difficulty in populations that comprise older adults. Table 2.7 (page 68) provides a summary of relevant prospective studies on the relationship of hearing impairment and increased risk of incident disability defined as mobility limitation, ADL difficulty, IADL difficulty or a mix of these disabilities in populations comprising older adults.

2.5.2.1. Longitudinal studies on hearing impairment and incident mobility limitation

Although mobility limitation (problems walking and/or taking the stairs) is the most prevalent form of disability in older age,[69] little is known about the relationship between hearing impairment and mobility limitation. To my knowledge, no cross-sectional study has investigated the relationship between hearing impairment and the risks of mobility limitation and only one study has investigated the prospective relationship between hearing impairment and incident mobility limitation. Such prospective study was undertaken in 2442 community-dwelling middle-aged and older American adults (≥ 50 years) participating in the Alameda County Study. The findings showed no association between hearing impairment and incident mobility limitation (OR 1.21, 95% CI 0.88-1.66).[148] The findings were adjusted for several important confounders including CVD, diabetes and hypertension. Chronic conditions such as CVD, diabetes and hypertension have previously been associated with both hearing impairment[10, 144, 198] and disability.[133, 199, 200] However, no separate findings on older adults were presented.

Some longitudinal studies have furthermore defined disability as having mobility limitation and/or one or more ADL deficits.[68, 150] Research based on such definition of disability has shown an association between objectively assessed hearing impairment and increased risks of disability in older (70-79 years) community-dwelling women (HR 1.31, 95% CI 1.08-1.60) but not in men (HR 1.21, 95% CI 0.99-1.46).[150] The findings were adjusted for socio-demographic factors, smoking, hypertension, diabetes and stroke. The authors furthermore speculated whether the association may be explained by low social engagement and cognitive impairment. Indeed, another study using the same definition of disability (mobility limitation and/or one or more ADL deficits) taking low social engagement and poor cognition into account did not show an increased risk of incident disability in hearing impaired community-dwelling older women compared to older women without hearing impairment (aged ≥ 69 years) (OR 1.10, 95% CI 0.71-1.73).[68] However, few studies have defined disability as mobility limitation and/or one or more ADL, making it difficult to compare the findings with other studies.

There is also some evidence of an association between hearing impairment and incident disability defined according to the Rosow-Brelau scale[201] (mobility limitation and difficulties performing activities such as heavy housework combined). The findings of such study showed that both objectively measured and self-reported hearing impairment were associated with increased risks of disability defined as Rosow-Brelau (RR 1.66, 95% CI 1.20-2.30; RR 1.76, 95% CI 1.11-2.77).[66] However, the Rosow-

Brelau definition of disability is less often used and the results may not be comparable with findings of studies based on mobility limitation alone due to its definition combining mobility limitation and domestic activities.

2.5.2.2. Longitudinal studies on hearing impairment and incident ADL difficulty

Longitudinal studies have furthermore investigated the prospective relationship between hearing impairment and incidence of ADL difficulty (Table 2.7, page 68). Early work by Keller et al. (1999)[64] carried out in 576 patients (aged 56-102 years) recruited from a geriatric clinic has reported an association between hearing impairment and incident ADL difficulty (no effect size provided). However, the study was undertaken in combined middle-aged and older adults. There is also some evidence from the Alameda County Study (n=2442, aged 50-102 years) of an association of self-reported mild hearing impairment, but not moderate/severe hearing impairment, with incident ADL difficulty (OR 1.61, 95% CI 1.14-2.28; OR 1.45, 95% CI).[148] The findings were adjusted for socio-demographic factors and chronic conditions including CVD. However, no separate data on older adults only were presented.

Contrary, several previous prospective studies undertaken in healthy community-dwelling older adults have shown no association between hearing impairment (objectively measured and self-reported) and incident ADL difficulty.[66, 67, 161, 202] For example, no association was shown between self-reported hearing impairment (any troubles hearing) an incident ADL difficulty at 3 year follow-up in the Women's Health Initiative Observational Study (WHI) of 29,544 community-dwelling women (≥ 65 years) (RR 1.24, 95% CI 0.98-1.57).[67] However the ADL components 'toileting' and 'walking across a room', tasks that require sufficient balance and therefore possibly affected by a hearing impairment, were not included in the analyses. Nevertheless, no association between self-reported hearing impairment and incident ADL, using the complete ADL index, was reported in the Longitudinal Study of Aging (LSOA) of 4452 community-dwelling adults aged 70 years and over (RR 1.04, 95% CI 0.90-1.20).[202] The findings from WHI and LSOA were adjusted for socio-demographic factors and chronic conditions including CVD. Also, the results of an analysis of data from 5444 community-dwelling adults aged 55-74 years in the National Health and Nutrition Examination Survey (NHANES) showed no association between neither self-reported nor objectively assessed hearing impairment and incident ADL difficulty on adjustment for socio-demographic factors, CVD, diabetes and hypertension (self-reported hearing impairment RR 1.31 95% CI 0.67-2.56; objectively assessed hearing impairment RR 1.69, 95% CI 0.88-3.26).[66]

2.5.2.3. Longitudinal studies on hearing impairment and incident IADL difficulty

Longitudinal studies have also investigated associations between hearing impairment and incidence of IADL difficulty. Evidence from prospective studies has shown inconsistent findings between hearing impairment and incident IADL difficulty. Keller et al. (1999)[64] (n=576 patients aged 56-102 years) showed an association between hearing impairment and increased risks of IADL difficulty at 6 year follow-up (no effect size reported). However the study was undertaken in a relatively small sample of middle-aged and older patients and may therefore not be representative of community-dwelling older adults. Further, some studies reporting an association between hearing impairment and incident IADL difficulty have used an incomplete IADL score.[63, 203] For example, the IADL component 'cooking' was not included in the analyses of 2143 Brazilian community-dwelling men and women aged 60 years and over showing an association between self-reported hearing impairment and incident IADL difficulty (men: incidence rate ratio (IRR) 1.99, 95% CI 1.10-3.59; women: IRR 1.68, 95% CI 1.09-2.58).[203] Similarly, the IADL component 'telephoning' was removed from the analyses of 1254 Japanese community-dwelling adults aged 65-98 years. The findings showed an association between self-reported hearing impairment and incident IADL difficulty (OR 1.79, 95% CI 1.12-2.87).[63] Given that adequate hearing is important for telephoning, the IADL component 'telephoning' is of particular interest when investigating the relationship of hearing impairment and incident IADL difficulty. It would be interesting to explore the role of the component 'telephoning' when investigating the relationship of hearing impairment and incident IADL difficulty. In contrast, some longitudinal studies have reported no association between hearing impairment and incident IADL difficulty.[65, 66, 148] For example, in the NHANES (n=5444, aged 55-74 years) neither objectively measured hearing impairment nor self-reported hearing impairment was associated with incident risks of IADL difficulty at 10-year follow-up (objectively measured hearing impairment (HI): RR 1.49, 95% CI 0.88-2.54); self-reported HI: RR 1.24, 95% CI 0.73-2.10).[66] The majority of previous studies on hearing impairment and incident disability have been undertaken in the USA and little is known about hearing impairment and incident disability in the UK. Therefore population-based studies investigating the relationship between hearing impairment and disability in older adults in the UK are needed. Furthermore, as discussed above and presented in Table 2.7, several studies have excluded one or more of the original IADL deficits.[63, 65, 66, 148] Therefore, the relationship between hearing impairment and incident IADL difficulty including all its components needs to be assessed. The role of the component 'telephoning' also needs to be explored when investigating the relationship between hearing impairment and incident IADL difficulty.

2.5.2.4. Other possible pathways linking hearing impairment with disability

An overview of possible pathways between hearing impairment and disability is presented in Figure 2.2 (page 80). There are several possible confounders that may explain the relationship between hearing impairment and incident disability including socio-demographic factors, lifestyle factors and comorbidity. However, some possible confounders have not been addressed in previous studies including social class and lifestyle factors. In terms of social class, several previous longitudinal studies on hearing impairment and incident disability presented in Table 2.7 have adjusted for education,[63, 66, 68, 148, 150, 202] a marker of early life socioeconomic position.[204] However, only one of the studies has adjusted for social class,[203] which refers to previous long-term or current position in the labour market and shown to influence the risks of disability in later life.[205] Therefore, adjustment for social class should be considered when investigating the relationship between hearing impairment and incident disability in older adults.

Few previous studies on hearing impairment and incident disability have furthermore adjusted for lifestyle factors in the analyses. Whilst some studies have adjusted for smoking[63, 68, 150] and obesity,[68, 202] none of the previous studies on hearing impairment and incident disability presented in Table 2.7 has adjusted for physical activity. Older adults who are physically inactive are more likely to report disability.[206] Hearing impairment has been associated with increased risks of physical inactivity, possibly due to damage to the cochlea causing balance problems restricting physical activity.[141] Therefore, physical activity may be a possible mediator on the causal pathway linking hearing impairment with incident disability.

The relationship between hearing impairment and incident disability may furthermore be mediated by depression and social isolation.[63, 207] Depression in older age has been associated with reduced engagement and motivation in leading a healthy lifestyle including exercising and healthy eating habits, increasing the risk of becoming dependent.[208] Alternatively, the relationship of hearing impairment and disability may be mediated by cognitive impairment, a major contributor to disability and dependence in older adults,[157] also shown to be associated with hearing impairment.[108, 118] Research has furthermore shown a strong association between chronic inflammation and disability in older adults.[209] Therefore, it is possible that chronic inflammation act as shared aetiological pathways linking hearing impairment to disability.

2.5.3. Vision impairment and disability in older age

Poor vision has consistently been associated with disability in cross-sectional studies.[13, 62, 210, 211] However, studies examining the prospective association of impairment in vision and increased risks of incident disability have reported inconsistent findings. A summary of relevant prospective studies of vision impairment and incident disability comprising older adults is presented in Table 2.8 (page 71).

2.5.3.1. Longitudinal studies on vision impairment and incident mobility limitation

Several large population-based longitudinal studies have investigated the relationship between vision impairment and incident mobility limitations. However the findings of these studies are inconsistent. Research reporting a strong association of vision impairment and incident mobility limitations includes findings from the InChianti study (n=622, aged 50-85 years),[212] and the Health ABC study (n=1862, aged 70-79 years).[122] The analysis of the InChianti study showed 2-fold increased risks of incident mobility limitations in vision impaired individuals compared to participants without vision impairment (OR 2.37, 95% CI 1.12-5.04). Similarly, findings from the Health ABC study showed an association between vision impairment and increased risks of both walking limitation (HR 1.50, 95% CI 1.20-1.80) and stair climbing (HR 1.60, 95% CI 1.30-2.00) at 5-year follow-up. In both studies vision impairment was defined as poor visual contrast sensitivity. As described above (section 2.3.1), visual contrast sensitivity refers to reduced ability to distinguish between objects and their background.[213] Such vision problems include decreased ability to detect edges when walking. Individuals with poor visual contrast sensitivity may therefore be less likely to walk compared to people with normal vision.[212] Poor contrast sensitivity has furthermore been associated with the need to use handrails while climbing stairs.[214] Loss of contrast sensitivity is believed to be more prominent and disturbing to the individual than the loss of visual acuity.[213] However, in the Established Studies of the Elderly (ESE) (n=3133, aged 70-103 years), severe vision impairment based on visual acuity was associated with 3-fold increased risks of incident mobility limitations (RR 3.50, 95% CI 1.70-7.20).[69] However, no associations were shown between mild and moderate vision impairment and incident mobility limitations (RR 1.40, 95% CI 0.97-2.10; RR 1.20, 95% CI 0.80-1.80). The lack of associations between mild and moderate vision impairment and incident mobility limitations suggest that mobility may not necessarily require perfect vision. Severe vision problems are, however, likely to have major consequences on walking ability and stair climbing.[215] The analyses in the ESE were adjusted for socio-demographic factors, diabetes and stroke. The analyses were, however, not adjusted for additional potential confounders including lifestyle factors and important chronic conditions such as hypertension, commonly associated with CVD.[133] CVD risk factors including lifestyle factors and hypertension associated with vision impairment[16, 170] and disability[200, 206, 216, 217] are therefore important confounders to consider when investigating the relationship between vision impairment and disability.

Further, findings from the NHANES (n=5444, aged 55-74 years) have shown an association of self-reported (RR 1.95, 95% CI 1.52-2.50) but not measured (RR 1.29, 95% CI 0.92-1.82) vision impairment with incident disability.[66] However the definition of disability in NHANES referred to mobility limitations and difficulty undertaking heavy housework combined, making it difficult to compare the findings with other studies on vision impairment and incident mobility limitations. Similarly, the Study of Osteoporotic Fractures (SOF) of 6112 women (aged ≥ 69 years) reported an association between vision impairment and incident disability defined as difficulty walking, taking stairs, undertaking housework, cooking and/or shopping (OR 1.79, 95% CI 1.15-2.79).[68] However, 'cooking' and 'shopping' relate to IADL rather than mobility limitations and should be separated from research based on mobility limitation (defined as problems walking and taking the stairs)[186, 187] to allow for comparison of findings across studies.

2.5.3.2. Longitudinal studies on vision impairment and incident ADL

Longitudinal studies have furthermore investigated the prospective relationship of vision impairment and incident ADL difficulty. The majority of such studies have reported an association between vision impairment and increased risks of incident ADL difficulty in older adults. For example, an association between self-reported vision impairment and increased risk of incident ADL difficulty has been observed in LSOA (n=4452, aged ≥ 70 years) (RR 1.39, 95% CI 1.20-1.61)[202] and in the Alameda County Study (n=2442, aged 50-102 years) (mild vision impairment: OR 1.50, 95% CI 1.07-2.10; moderate/severe vision impairment: OR 2.29, 95% CI 1.49-3.52).[148] The findings on self-reported vision impairment and incident ADL difficulty in these studies have been confirmed in other studies using objectively assessed vision impairment. For example, 2-fold increased risks of incident ADL difficulty have been shown in both self-reported and objectively assessed vision impairment in NHANES (n=5444, aged 55-74 years) (RR 2.21, 95% CI 1.59-3.06; RR 2.01, 95% CI 1.29-3.13).[66] The findings from the LSOA, Alameda County Study and NHANES have been adjusted for confounders including socio-economic factors and chronic conditions. However, none of these studies has explored the potential role of, for example, depression and poor social engagement, common consequences of vision impairment,[148, 172, 174] also associated with increased risks of disability.[207] Depression and poor social engagement may act as mediators linking vision impairment to incident ADL difficulty and other domains of disabilities. Thus, exploring the role of depression and poor social engagement of the relationship between vision impairment and incident disability should be considered.

2.5.3.3. Longitudinal studies on vision impairment and incident IADL

Both self-reported and objectively assessed vision impairment have been found to be strongly associated with increased risks of developing IADL difficulty after adjustment for demographic factors and comorbidities.[64-66, 148, 218] For example, compared to individuals with normal vision, over 2-fold increased risks of incident IADL difficulty in vision impaired individuals were shown in both the BMES (n=761, aged >60 years) (OR 2.06, 95% CI 1.11-3.83),[218] and NHANES (n=5444, aged 55-74 years) (RR 2.44, 95% CI 1.87-3.17).[66] However, different definitions of IADL have been used. Several previous studies have excluded one or more of the IADL components,[65, 66, 148] making it difficult to compare the findings. For instance, in the SWOPC (n=1315, aged ≥ 65 years), IADL difficulty included only ‘shopping’ and ‘using public transportation’. In the Alameda County Study[148] and NHANES,[66] the IADL components ‘telephoning’ and ‘using public transportation’ were excluded. Given that vision impairment reduces the ability to move freely,[17] the IADL component ‘using public transport’ may strongly influence the association of vision impairment and IADL difficulty. Exploring the relationship between vision impairment and individual IADLs would therefore be useful.

To date, the vast majority of previous studies investigating the relationship of vision impairment and incident ADL and IADL difficulty have been undertaken in the USA. To my knowledge, no prospective study on vision impairment and incident risks of ADL and IADL difficulty in older age has been conducted in the UK. Prospective population-based studies on vision impairment and subsequent disability in later life in the UK are therefore needed. Such research should furthermore be undertaken in community-dwelling older adults using standard definitions of ADL and IADL.

2.5.3.4. Other possible pathways linking vision impairment to disability

Besides possible mediators such as poor balance, falls, depression and social isolation presented above, the relationship between vision impairment and incident disability could potentially be explained by cognitive impairment. Vision impairment has been associated with cognitive decline in later life.[219] This may be due to optimal cognitive function being dependent on the ability to process and retrieval information acquired through the visual sensory system.[220] The relationship between vision impairment and incident cognitive dysfunction may also be explained by age-related decline in the function of the optic nerve and the retina.[221] Severe cognitive impairment is furthermore often accompanied by physical decline, increasing the risk of disability in later life.[157, 222] Thus, cognitive impairment may act as a mediator linking vision impairment to incident disability. There is also growing evidence suggesting that inflammation may contribute to incident vision impairment in later life.[175] Inflammation is furthermore strongly associated with increased risks of disability.[209] Inflammation may therefore be an underlying mechanism of the relationship of vision impairment and incident disability. Possible pathways linking vision impairment to disability are outlined in Figure 2.2.

2.6. Sensory impairments and frailty in older age

2.6.1. Epidemiology and pathophysiology of frailty

Whilst disability is constant and indicates loss of function, frailty refers to instability and risk of loss, or further loss, of function.[223] Frailty is characterised by an ageing-associated decline in multiple systems reducing the body's physiological reserve and functional capacity, increasing the vulnerability to adverse health outcomes including falls, hospitalisation, institutionalisation and mortality.[18, 72, 74, 75] Frailty is furthermore often regarded as a dynamic state along a continuum ranging from normal ageing to death,[71] and transition between frailty states is common.[224] Due to lack of a standardised and operationalised definition of frailty, several definitions and measures are used. Many definitions include a pre-frailty state, a position in between being non-frail and frail, acknowledging the dynamic nature of frailty over time.[225] The most commonly used instrument to measure frailty is the Fried phenotype. The Fried phenotype incorporates 5 components of physical health: unintentional weight loss, weak handgrip, slow walking speed, self-reported exhaustion and low levels of physical activity.[18, 226] A score of 0 out of these 5 components refers to no frailty, 1-2 refers to pre-frailty and 3 or more is defined as being frail. Another popular definition of frailty is the Frailty Index, a deficit accumulation model consisting of physical, social and psychological health deficits that are measured and enumerated as a ratio.[72]

A recent systematic review has reported that about 11% of community-dwelling adults aged 65 years and over are frail and about 42% are pre-frail.[225] The risk of frailty increases dramatically with advanced age and a quarter to half of adults aged 85 years and over are estimated to be frail.[227] The prevalence of frailty has been reported to be higher in older care home residents than in community-dwelling older adults,[225] potentially explained by institutionalisation being a consequence of frailty.[228]

2.6.2. Hearing impairment and frailty in older age

Despite frailty being highly prevalent in later life, there has been little focus on its relationship with hearing impairment in older adults. Hearing impairment in older age has been associated with characteristics of frailty such as increased risks of reduced functional capacity (e.g. carrying heavy items, performing chair stands).[147] However, few studies have investigated the relationship of hearing impairment and frailty, and, particularly, incident frailty.

2.6.2.1. Cross-sectional studies on hearing impairment and frailty

Table 2.9 (page 75) presents relevant cross-sectional studies on hearing impairment and frailty. Previous cross-sectional studies have consistently reported a relationship between both self-reported and objectively assessed hearing impairment and frailty defined as the Fried phenotype.[14, 74] For example, in NHANES (n=2109, aged ≥ 70 years), hearing impairment was associated with increased risks of frailty in women but not men (OR 3.79, 95% CI 1.69-8.51; OR 0.85, 95% CI 0.44-1.66).[14] Hearing impairment has also been associated with greater risks of frailty in the Singapore Longitudinal Ageing Studies (n=1685, aged ≥ 55 years) (p=0.012).[216] Both of these studies used the Fried phenotype to assess frailty. However, the studies were cross-sectional and causality could not be established.

2.6.2.2. Longitudinal studies on hearing impairment and incident frailty

Longitudinal studies on the prospective relationship between hearing impairment and risk of incident frailty are presented in Table 2.10 (page 76). To my knowledge, only two previous studies have investigated the relationship between hearing impairment and risks of incident frailty.[76, 77] One of these studies include an analysis of 407 community-dwellers aged over 70 years showing that hearing impaired older adults had 2-fold higher odds of incident frailty compared to older adults with no hearing impairment (OR 2.19, 95% CI 1.20-4.00).[76] However, the analysis was carried out in a relatively small sample (n=407). The other study undertaken in the Health ABC study of 2000 community-dwelling adults aged 70-79 years, showed an association between hearing impairment and increased risks of incident frailty (HR 1.63, 95% CI 1.26-2.12).[77] The finding was adjusted for socio-demographic factors, smoking and chronic conditions including stroke, hypertension and diabetes. However, the study did not explore possible mediators that may link hearing impairment to frailty such as depression, low social engagement, poor balance, falls and cognitive impairment,[147, 229-235] and possible underlying mechanisms including inflammation.[33, 227] Furthermore, frailty was defined as slow gait speed and/or inability to do rise from a chair without using arms. Restricting the definition of frailty to only two measures to characterise frailty may have resulted in the relationship observed being overestimated. Therefore, to assess the prospective relationship between hearing impairment and frailty a comprehensive and validated measure of frailty such as the Fried phenotype should be used. In addition to adjustment for confounding factors including socio-demographic factors and comorbidities, possible mediating factors such as poor social engagement should be explored. Possible pathways linking hearing impairment to frailty are presented in Figure 2.2 (page 80).

2.6.3. Vision impairment and frailty in older age

Vision impairment has been associated with characteristics of frailty such as poor grip strength and greater risks of mortality.[53, 236] Nevertheless, few studies have examined the association between vision impairment and frailty. Previous studies investigating the relationship between vision impairment and frailty have been of cross-sectional design and are presented in the section below. To my knowledge, no prospective study has investigated the association between vision impairment and risk of incident frailty.

2.6.3.1. Cross-sectional studies on vision impairment and frailty

Studies investigating the relationship between vision impairment and frailty are presented in Table 2.11 (page 77). Several of these previous cross-sectional studies have been undertaken in the Beaver Dam Eye study of 2962 community-dwelling adults aged 53 years and over.[15, 79, 237] Findings include associations between specific eye conditions such as cataract and age-related macular degeneration (AMD), and characteristics of frailty. Such frailty characteristics have been analysed individually and combined, and include gait speed, grip strength and chair stands. Findings include, for example, an association between AMD and weak grip strength in men (OR 1.28, 95% CI 1.08-1.52) but not in women (OR 1.04, 95% CI 0.89-1.21).[79] Similarly, the findings have also shown a relationship between cataract and the frailty characteristics combined in men (OR 1.56, 95% CI 1.15-2.11) but not in women (OR 1.22, 95% CI 0.92-1.61).[15] The associations have been adjusted for socio-demographic factors, smoking and chronic conditions. However, the studies did not explore the role of possible mediators such as depression, low social engagement and poor cognitive function, previously associated with vision impairment and increased risks of frailty,[232, 238] potentially explaining the associations observed. Underlying mechanisms such as chronic inflammation predisposing individuals to both vision impairment and frailty may furthermore link vision impairment to frailty.[175, 239] An overview of possible pathways linking vision impairment to frailty is presented in Figure 2.2.

Cross-sectional studies using objectively assessed vision impairment (visual acuity) have shown mixed findings. For example, the Singapore Longitudinal Ageing Studies (n=1658, aged ≥ 55 years) has reported an association between vision impairment and frailty on adjustment for demographic factors, smoking and comorbidities (no effect size provided).[74] However, some of the Fried frailty components were modified. For example, ‘leg muscle strength’ was used instead of ‘grip strength’. Contrary to this, in a study of patients recruited from a geriatric clinic (n=1425, age not provided), no associations were shown between objectively assessed vision impairment and pre-frailty (mild/moderate vision impairment (VI): OR 0.99, 95% CI 0.58-1.67; severe VI: OR 0.32, 95% CI 0.67-3.48) and frailty (mild/moderate VI: OR 1.18, 95% CI 0.70-2.00; severe VI: OR 1.53, 95% CI 0.37-3.49).[240] The associations were adjusted for socio-demographic factors, disability and cognition. It is possible that adjustment for disability and cognition explain the lack of association. However, all covariates were entered into the model at once and the study did not provide information on which covariate(s) may have attenuated the association. Furthermore, the study did not report on how the Fried phenotype was assessed, which is important in order to replicate the findings. Also, all of the studies on vision impairment and frailty presented in this section are cross-sectional and the associations observed do not necessarily imply causality. Therefore prospective studies on vision impairment and incident frailty in community-dwelling older adults using a validated frailty measure are needed.

2.7. Summary

Hearing impairment and vision impairment are common in older adults who form a rising proportion of the population. Impairments in hearing and vision in later life have become a growing public health concern as they are associated with morbidity, poor physical functioning and poor social functioning, negatively influencing the chances of independent living. Previous cross-sectional studies have reported a relationship between hearing impairment and cardiovascular disease (CVD). However, fewer studies have investigated such relationship prospectively. There is some evidence showing an association between hearing impairment and incident CVD including incident myocardial infarction (MI), stroke and CVD mortality, but findings are inconsistent with some studies reporting no association. Several of these previous studies have furthermore been undertaken in middle-aged and older patients hospitalised with sudden hearing loss rather than in community-dwelling older adults who are more likely to have age-related hearing impairment. There is some evidence showing that vision impairment is associated with increased risks of incident MI and stroke, however, research is limited. Several studies have furthermore not adjusted for lifestyle factors known to be associated with sensory impairments and CVD. The relationships between sensory impairments and incident CVD are complex with several confounders and potential mediators possibly explaining the associations, as summarised in Figure 2.1. Some previous studies have also shown an association between sensory impairments and all-cause mortality, however, findings are inconsistent. Therefore, research investigating the prospective relationship between sensory impairments and incident CVD including MI, stroke and mortality in community-dwelling older adults is needed.

This Chapter has also described research on impairments in hearing and vision and disability showing inconsistent findings between hearing impairment and increased risks of incident mobility limitation, difficulty undertaking activities of daily living (ADL) and difficulty undertaking instrumental activities of daily living (IADL). Similarly, some but not all previous prospective studies on vision impairment and incident disability have furthermore shown an association between vision impairment and incident mobility limitation, ADL difficulty and IADL difficulty. However, several earlier prospective studies on sensory impairments and incident IADL difficulty have excluded one or more IADL components. Also, there are several possible pathways that may link sensory impairments to disability (Figure 2.2). The vast majority of studies on sensory impairments and incident disability have furthermore been undertaken in the USA and little is known about sensory impairments and incident disability in the UK. Therefore, research is needed to investigate the prospective relationship between impairments in hearing and vision and increased risks of disability in older adults in the UK, using standard definitions of ADL and IADL. Furthermore, sensory impairments have been associated with frailty in cross-sectional studies. However, there is a paucity of prospective population-based studies on sensory impairments and incident frailty in older adults. Few previous studies have furthermore used a validated measure of frailty and little is known about sensory impairments and the risk of incident pre-frailty. Research investigating the prospective relationships between impairments in hearing and vision and incident pre-frailty and frailty using a standard definition of frailty is therefore needed.

In summary, key gaps identified in the literature include: i) limited research on sensory impairments and CVD incidence and mortality in community-dwelling older adults; ii) few studies on sensory impairments and incident disability using standard definitions of ADL and IADL undertaken in the UK; and iii) lack of evidence on sensory impairments and incident pre-frailty and frailty. This thesis sets out to address these gaps by investigating the objectives listed in section 1.4.

Table 2.1 Summary of studies investigating the cross-sectional association between hearing impairment and cardiovascular disease endpoints

Author, year	Study (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Campbell, 1999[17]	National Health Interview Survey (NHIS) and Supplement on Aging II (SOA-II) (USA)	n=8767 community-dwellers aged ≥ 70y	Self-reported no trouble hearing vs trouble hearing or deafness	Self-reported heart disease, stroke (no definition provided)	HI associated with heart disease (HI 27.6%, 95%CI ±1.2 v non HI 18.6%, 95%CI ±1.6) and stroke (HI 11.8%, 95%CI ±1.3 v non HI 7.8%, 95%CI ±0.8)	None reported
Crews, 2004[16]	SOA-II (USA)	n=9447 community-dwellers aged ≥ 70y	Self-reported no trouble hearing vs trouble hearing or deafness	Self-reported heart disease, stroke (no definition provided)	HI associated with heart disease (OR 1.70, 95%CI 1.50-1.90) and stroke (OR 1.40, 95%CI 1.20-1.80)	None reported
Friedland, 2009[38]	(USA)	n=1168 patients referred for audiological assessment aged 34-98y	No HI PTA ≤ 25 dB in any ear for low frequencies (0.25 to 2kHz) vs HI >25 dB	CHD and stroke from medical records	HI associated with CHD (OR 3.70, 95%CI 2.40-5.60) and stroke (OR 4.60, 95%CI 2.50-8.50)	Age, sex, smoking, hypertension, diabetes, hyperlipidemia
Gates, 1993[10]	(USA)	n=1662 community-dwellers 'older age' (age not specified)	No HI PTA <40 dB for each ear by low (0.25, 0.5 and 1kHz) and high frequencies (4, 6, 8kHz) vs HI ≥ 40 dB	Dr-diagnosed CHD, CVD and stroke confirmed by panel of physicians	In men and women, HI in lower frequencies associated with CVD (OR 1.75, 95%CI 1.01-3.03; OR 3.06, 95%CI 1.84-5.10), CHD (OR 1.68, 95%CI 1.10-2.57; OR 1.55, 95%CI 1.10-2.19) and stroke (OR 3.46, 95%CI 1.60-7.45; OR 2.41, 95%CI 1.04-5.58). HI in higher frequencies associated with stroke (OR 1.97, 95%CI 1.05-3.72) in men, and CVD (OR 1.49, 95%CI 1.02-2.17) and stroke (OR 1.97, 95%CI 1.00-3.90) in women	Age

Table 2.1 *Continued*. Summary of studies investigating the cross-sectional association between hearing impairment and cardiovascular disease endpoints

Author, year	Study (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Gopinath, 2009[45]	Blue Mountains Hearing Study (BMHS) (Australia)	n=2802 community-dwellers aged >49y	No HI PTA ≤ 40 dB vs HI >40 dB.	Self-reported doctor-diagnosed stroke checked against medical records	HI associated with stroke (OR 2.04, 95%CI 1.20-3.49)	Age, sex, social class, smoking, diabetes and hypertension
Rubinstein, 1977[104]	(Israel)	n=46 adults from a care home (23 without CVD, 23 with CVD) aged 65-85y	PTA (details not provided)	Clinically assessed CVD	Average PTA HI was 8.47 dB greater in subjects with CVD ($p<0.05$)	None reported
Susmano, 1988[47]	(USA)	n=103 patients from cardiology practice with CHD, and 101 patients without CHD matched for age and sex (29-81y)	No self-reported HI vs self-reported inability to participate in normal conversations, need for increased volume to hear TV/radio or PTA	Clinically assessed CHD	HI associated with CHD ($p=0.001$)	Age, sex, smoking, obesity, hypertension, diabetes, family history of CHD
Torre, 2005[46]	The Epidemiology of Hearing Loss Study (EHLS) (USA)	n=1501 community-dwellers aged 43-84y	No HI defined as ≥ +9 dB signal-to-noise ratio (SNR) at 2k, 3k and 4k Hz vs <+9 dB SNR at 2k, 3k and 4k Hz	Self-reported doctor-diagnosed angina, MI and/or stroke	HI associated with MI (OR 2.21, 95%CI 1.20-4.08) but not with stroke, angina and CVD in women. HI was not associated with MI, stroke, angina and CVD in men	Age, smoking, physical activity, alcohol, diabetes, noise exposure

Definitions: BMI = body mass index; CHD = coronary heart disease; CI = confidence intervals; CVD = cardiovascular disease; dB = decibel; HI = hearing impairment; Hz = hertz; MI = myocardial infarction; OR = odds ratio; PTA = pure tone audiometry

Table 2.2 Summary of longitudinal studies investigating the association between hearing impairment and cardiovascular disease endpoints

Author, year	Study (Design) (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Fisher, 2014[39]	Age, Gene/Environment Susceptibility-Reykjavik Study (AGES-RS) (prospective) (Iceland)	n=4926 community-dwellers aged ≥ 67y	No HI PTA <35 dB vs HI ≥ 35 dB	CVD mortality from death records (5y follow-up)	HI associated with CVD mortality (HR 1.70, 95%CI 1.27-2.27)	Age, sex, smoking, BMI, hypertension, diabetes, systolic BP, self-reported health, cognition, falls, CVD, hearing aid use
Gopinath, 2009[45]	Blue Mountains Hearing Study (BMHS) (prospective) (Australia)	n=2802 community-dwellers aged >49y	No HI PTA ≤ 25 dB vs HI >25 dB. Self-reported whether HI was gradual or sudden	Self-reported doctor-diagnosed stroke checked against medical records (5y follow-up)	HI not associated with stroke (OR 1.14, 95%CI 0.59-2.23). No difference between gradual/sudden HI and increased risk of stroke	Age, sex, social class, smoking, diabetes and hypertension
Karpa, 2010[146]	Blue Mountains Hearing Study (BMHS) (prospective) (Australia)	n=2956 community-dwellers aged >49y	No HI PTA ≤ 25 dB vs HI >25 dB. Self-reported whether HI was gradual or sudden	CVD mortality from death records (12y follow-up)	HI not associated with CVD mortality (HR 1.06, 95%CI 0.76-1.48)	Age, sex, social class, smoking, alcohol, BMI, history of acute MI, stroke, angina, hypertension, cancer, diabetes, walking disability, gout, cognition, depression, self-rated health
Lin, 2008[41]	(prospective cohort) (Taiwan)	n=1423 patients with SSNHL of all ages (≥ 0y) compared with 5692 non-SSNHL patients	HI defined as diagnosed SSHL vs no SSHL	Stroke from medical records (5y follow-up)	HI associated with incident stroke (HR 1.64, 95%CI 1.31-2.07)	Age, sex, income, level of urbanization, and comorbid medical disorders
Lin, 2013[42]	The Longitudinal Health Insurance Program (retrospective cohort) (Taiwan)	n=44,830 patients with SSHL of all ages (≥ 0y including specific data on ≥ 65y) matched with 44,830 non-SSHL controls	HI defined as diagnosed SSHL vs no SSHL	MI from medical records (3-5y follow-up)	HI associated with incident MI in patients of all ages (50-64y: HR 13.80, 95%CI 7.06-26.96; ≥ 65y: HR 24.77, 95%CI 12.67-48.41)	Age, sex, income, hypertension, chronic renal disease, diabetes, hyperlipidemia, geographic region

Definitions: BMI = body mass index; CHD = coronary heart disease; CI = confidence intervals; CVD = cardiovascular disease; dB = decibel; HI = hearing impairment; Hz = hertz; HR = hazard ratio; MI = myocardial infarction; OR = odds ratio; PTA = pure tone audiometry; SSHL = sudden sensorineural hearing loss

Table 2.3 Summary of longitudinal studies investigating the association between hearing impairment and all-cause mortality

Author, year	Study (Design) (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Appollonio, 1995[159]	(prospective) (Italy)	n=1140 community-dwellers aged 70-75y	HI defined as failing the whisper voice test v passing the test (no details provided)	All-cause mortality (no details provided) (6y follow-up)	HI not associated with all-cause mortality (OR 0.77, 95%CI 0.36-1.62)	Age, sex, social class, education, global physical health index, mood, social relationships
Genther, 2015[40]	The Health, Aging and Body Composition study (prospective) (USA)	n=1958 community-dwellers aged ≥ 70y	No HI PTA <25 dB vs HI ≥ 25 dB	All-cause mortality from death records (8y follow-up)	HI associated with all-cause mortality (HR 1.20, 95%CI 1.03-1.41)	Age, sex, ethnicity, education, smoking, hypertension, diabetes, stroke, gait speed, cognition, depression, hearing aid use
Karpa, 2010[146]	Blue Mountains Hearing Study (BMHS) (prospective) (Australia)	n=2956 community-dwellers aged >49y	No HI PTA ≤ 25 dB vs HI >25 dB	All-cause mortality from death records (12y follow-up)	HI not associated with all-cause mortality (HR 1.12, 95%CI 0.88-1.44)	Age, sex, social class, smoking, alcohol, BMI, history of acute MI, stroke, angina, hypertension, cancer, diabetes, walking disability, gout, cognition, depression, self-rated health
Laforge, 1992[65]	Study of the Wellbeing of Older People in Cleveland (SWOPC) (prospective) (USA)	n=1408 community-dwellers aged ≥ 65y	HI defined as self-reported fair/poor vs good/excellent hearing	All-cause mortality (no details provided) (1y follow-up)	HI not associated with all-cause mortality (HR 1.18, 95%CI 0.54-2.60)	Age, sex, cognition
Wahl, 2013[160]	(prospective) (Germany)	n=116 HI outpatients from ear clinic, 150 controls with no HI, aged 75-94y	No HI PTA <35 dB vs HI ≥ 35 dB	All-cause mortality (no details provided) (4y follow-up)	HI not associated with all-cause mortality after adjustments (statistical findings not provided)	Age, sex, education, marital status, subjective health, out-of-home daily activities

Definitions: BMI = body mass index; CI = confidence intervals; dB = decibel; HI = hearing impairment; HR = hazard ratio; MI = myocardial infarction; OR = odds ratio; PTA = pure tone audiometry

Table 2.4 Summary of studies investigating the cross-sectional association between vision impairment and cardiovascular disease endpoints

Author, year	Study (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Campbell, 1999[17]	National Health Interview Survey (NHIS) and Supplement on Aging II (SOA-II) (USA)	n=8767 community-dwellers aged ≥ 70y	Self-reported no trouble seeing vs trouble seeing or blindness	Self-reported heart disease, stroke (no definition provided)	VI associated with heart disease (VI 30.2%, 95%CI ±2.7 v non VI 19.7%, 95%CI ±1.0) and stroke (VI 17.4%, 95%CI ±1.8 v non VI 7.3%, 95%CI ±0.7)	None reported
Crews, 2004[16]	SOA-II (USA)	n=9447 community-dwellers aged ≥ 70y	Self-reported no trouble seeing vs trouble seeing or blindness	Self-reported heart disease, stroke (no definition provided)	VI associated with heart disease (OR 2.00, 95%CI 1.70-2.40) and stroke (OR 2.60, 95%CI 2.10-3.20)	None reported
Yip, 2014[11]	European Prospective Investigation into Cancer-Norfolk eye study (EPIC-Norfolk) (UK)	n=8317 community-dwellers aged 48-92y	VA better than 6/12 vs VI defined as VA 6/12 or worse. Self-reported: able vs unable to recognise a friend across a road	Self-reported CHD and stroke	VI (VA and self-reported) associated with CHD ($p<0.01$ for both VA and self-reported) but not stroke ($p=0.4$; $p=0.1$)	None reported

Definitions: CI = confidence intervals; CHD = coronary heart disease; OR = odds ratio; VA = visual acuity; VI = vision impairment

Table 2.5 Summary of longitudinal studies investigating the association between vision impairment and cardiovascular disease endpoints

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Duan, 2007[49]	(prospective) (USA)	n=1,445,677 community-dwellers aged ≥ 65y	No medical records of AMD vs medical records of AMD	MI from medical records (2y follow-up)	AMD associated with incident MI (OR 1.19, 95%CI 1.16-1.22)	Age, sex, ethnicity, hypertension, diabetes
Fisher, 2014[39]	Age, Gene/Environment Susceptibility-Reykjavik Study (AGES-RS) (prospective) (Iceland)	n=4926 community-dwellers aged ≥ 67y	No VI defined as VA ≥ 20/50 vs Vi defined as VA <20/50	CVD mortality from death records (5y follow-up)	VI not associated with CVD mortality (HR 1.10, 95%CI 0.74-1.65)	Age, sex, smoking, BMI, hypertension, diabetes, systolic BP, self-reported health status, cognitive status, falls, angina, record of cardiovascular event
Ikram, 2012[50]	Atherosclerosis Risk in Communities study (ARIC) (prospective) (USA)	n=12,216 community-dwellers aged 51-70y	No diagnosed AMD vs diagnosed AMD using retinal photographs	Self-reported doctor-diagnosed stroke checked against medical records (13y follow-up)	AMD associated with increased risk of incident stroke (HR 1.51, 95%CI 1.11-2.06)	Age, sex, ethnicity, education, study site, smoking, alcohol, BMI, BPs, diabetes, cholesterol, triglyceride, glucose
Siantar, 2015[52]	Singapore Malay Eye Study (SiMES) (prospective) (Singapore)	n=3280 urban Malay community-dwellers living in Singapore aged 40-80y	No VI defined as VA ≥20/40 vs Vi defined as VA <20/40	CVD mortality from death records (7y follow-up)	VI associated with CVD mortality (HR 1.49, 95% CI 1.02-1.88)	Age, sex, socio-economic status, smoking, BMI, diabetes, hypertension
Sun, 2009[55]	Cardiovascular Health Study (CHS) (prospective) (USA)	n=1786 community-dwellers aged 69-97y	No diagnosed AMD vs diagnosed AMD divided into early and late AMD using retinal photographs	Self-reported doctor-diagnosed CHD and stroke checked against medical records (7y follow-up)	Early but not late AMD associated with incident CHD (HR 1.57, 95%CI 1.17-2.22; HR 0.78, 95%CI 0.25-2.48). Early/late AMD was not associated with incident stroke (HR 1.05, 95%CI 0.69-1.58; HR 1.43, 95%CI 0.45-4.54)	Age, sex, ethnicity, smoking, hypertension, fasting glucose, diabetes, triglyceride, cholesterol, inflammation

Table 2.5 *Continued*. Summary of longitudinal studies investigating the association between vision impairment and cardiovascular disease endpoints

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Tan, 2008[54]	Blue Mountains Eye Study (BMES) (prospective) (Australia)	n=2335 community-dwellers aged >49y	No diagnosed AMD vs diagnosed AMD using retinal photographs	CVD mortality and fatal strokes (11y follow-up)	AMD associated with fatal stroke and CVD mortality in subjects aged <75y (RR 10.21, 95%CI 2.39-43.60; RR 5.57, 95%CI 1.35-22.99) but not in those aged ≥75y (RR 0.35, 95%CI 0.08-1.45; RR 1.43, 95%CI 0.76-2.67)	Age, sex, smoking, BMI, hypertension, diabetes
Thiagarajan, 2005[168]	(prospective) (UK)	n=13,569 community-dwellers aged ≥ 75y	No diagnosed cataract or AMD vs clinically diagnosed cataract or AMD	CVD mortality from death records (6y follow-up)	AMD and cataract not associated with CVD mortality (RR 1.03, 95%CI 0.72-1.45; RR 0.98, 95%CI 0.65-1.48)	Age, sex, BMI, PA, smoking, alcohol, diabetes, hypertension, ADL deficits, fractured hip, Parkinson disease, cancer, depression, urinary incontinence, falls, hearing loss, self-rated health, social isolation
Wong, 2006[51]	CHS (prospective) (USA)	n=10,405 community-dwellers aged 51-70y	No diagnosed AMD vs diagnosed AMD divided into early and late AMD using retinal photographs	Self-reported doctor-diagnosed stroke checked against medical records (9y follow-up)	AMD associated with increased risk of incident stroke (HR 1.89, 95%CI 1.19-3.01)	Age, sex, ethnicity, study site, diabetes, systolic BP, antihypertensive medications, and smoking
Wong, 2007[171]	ARIC (prospective)(USA)	n=12,536 community-dwellers aged 49-73y	No diagnosed AMD vs diagnosed AMD divided into early and late AMD using retinal photographs	Self-reported doctor-diagnosed CHD checked against medical records (10y follow-up)	Late but not early AMD associated with incident CHD (RR 3.05, 95%CI 1.14-8.17; RR 1.08, 95%CI 0.82-1.42)	Age, sex, ethnicity, study site education, smoking, alcohol, BMI, BPs, diabetes, cholesterol, triglyceride, glucose

Definitions: ADL = activities of daily living; AMD = age-related macular degeneration; BMI = body mass index; BP = blood pressure; CHD = coronary heart disease; CI = confidence intervals; CVD = cardiovascular disease; HR = hazard ratio; OR = odds ratio; PA = physical activity; RR = relative risk; VA = visual acuity; VI = vision impairment

Table 2.6 Summary of longitudinal studies investigating the association between vision impairment and all-cause mortality

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Cugati, 2008[179]	Blue Mountains Eye Study (BMES) (prospective) (Australia)	n=3654 community-dwellers aged >49y	No VI defined as VA ≥ 20/40 vs Vi defined as VA <20/40, no clinically assessed cataract or AMD vs clinically assessed cataract or AMD	All-cause mortality from death records (11y follow-up)	Cataract associated with all-cause mortality (HR 1.26, 95%CI 1.04-1.53). VA not associated with all-cause mortality (HR 1.18, 95%CI 0.86-1.61). AMD associated with all-cause mortality in subjects <75y (HR 1.59, 95%CI 1.04-2.43) but not in subjects ≥ 75y (HR 0.90, 95%CI 0.65-1.26).	Age, sex, smoking, BMI, hypertension, diabetes, history of CVD
Fisher, 2014[39]	Age, Gene/Environment Susceptibility-Reykjavik Study (AGES-RS) (prospective) (Iceland)	n=4926 community-dwellers aged ≥ 67y	No VI defined as VA ≥ 20/50 vs Vi defined as VA <20/50	All-cause mortality from death records (5y follow-up)	VI not associated with all-cause mortality (HR 0.93, 95%CI 0.72-1.20)	Age, sex, smoking, BMI, hypertension, diabetes, systolic BP, self-reported health status, cognitive status, falls, angina, record of cardiovascular event
Freeman, 2005[178]	Salisbury Eye Study (prospective) (USA)	n=2520 community-dwellers aged 65-84y	No VI defined as no vision change over 2 years compared to mild VI defined as VA loss of 0.2-0.3 logMar units, and moderate VI defined as VA loss of ≥0.3 logMar units	All-cause mortality data from family members and newspapers (8y follow-up)	Moderate VI associated with all-cause mortality (HR 2.26, 95%CI 1.45-3.52). Mild VI not associated with all-cause mortality (HR 0.91, 95%CI 0.61-1.36)	Age, sex, ethnicity, smoking, BMI, diabetes
Lopez, 2011[53]	Health in Men Study and the Australian Longitudinal Study on Women's Health (prospective) (Australia)	n=2340 men and n=3014 women (community-dwellers) aged 76-81y	Self-reported no trouble seeing newspaper print vs trouble seeing newspaper print even with glasses	All-cause mortality from death records (6y follow-up)	VI associated with all-cause mortality in men (HR 1.44, 95%CI 1.17-1.77) and in women (HR 1.50, 95%CI 1.24-1.82)	Age, smoking, education, BMI, diabetes, hypertension, heart disease, stroke

Table 2.6 *Continued*. Summary of longitudinal studies investigating the association between vision impairment and all-cause mortality

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Siantar, 2015[52]	Singapore Malay Eye Study (SiMES) (prospective) (Singapore)	n=3280 urban Malay community-dwellers living in Singapore aged 40-80y	No VI defined as VA ≥ 20/40 vs Vi defined as VA <20/40	All-cause mortality from death records (7y follow-up)	VI associated with all-cause mortality (HR 1.46, 95% CI 1.14-1.88)	Age, sex, socio-economic status, smoking, BMI, diabetes, hypertension
Thompson, 1989[180]	(prospective) (England)	n=469 adults aged ≥ 75y recruited from 12 GP practices in Melton Mowbray, Leicestershire	No VI defined as VA ≥ 6/6 vs four groups of VI defined as VA 6/7.5-6/9, VA 6/12-6/18, VA 6/24-6/60, and VA ≤ 6/60	All-cause mortality (no details provided) (5y follow-up)	None of the four VI groups associated with all-cause mortality (RR 1.62, 95%CI 0.87-3.01; RR 1.83, 95%CI 0.93-3.63; RR 1.72, 95%CI 0.77-3.84; RR 0.35, 95% CI 0.08-1.57)	Age, sex

Definitions: AMD = age-related macular degeneration; BMI = body mass index; BP = blood pressure; CI = confidence intervals; CVD = cardiovascular disease; HR = hazard ratio; OR = odds ratio; RR = relative risk; VA = visual acuity; VI = vision impairment

Table 2.7 Summary of longitudinal studies investigating the association between hearing impairment and disability

Author, year	**Study (Design) (Country)**	**Population**	**Hearing measurement**	**Outcomes**	**Relevant findings**	**Adjustments**
Alexandre, 2014[203]	Health, Wellbeing and Ageing Study (SABE) (prospective) (Brazil)	n=2143 community-dwellers aged ≥ 60y	HI defined as self-reported poor vs good hearing	None vs ≥1 IADL (did not include cooking but taking medications) (6y follow-up)	HI associated with incident IADL (men: IRR 1.99, 95%CI 1.10-3.59; women: IRR 1.68, 95%CI 1.09-2.58)	Social class, hypertension, diabetes, chronic lung disease, heart disease, stroke, osteoarthritis
Chen, 2015[150]	Health, Aging and Body Composition (Health ABC) (prospective) (USA)	n=2190 community-dwellers aged 70-79y	No HI PTA ≤ 25 dB vs mild HI >25-40 dB and moderate/severe HI >40 dB	Disability defined as none vs difficulty or inability to walk 1/4 mile and/or climb 10 steps or having any difficulty performing ADL (ADL defined as getting in/out of bed or chair, bathing or dressing) (10y follow-up)	Moderate/severe HI associated with increased risks of disability in women (HR 1.31, 95%CI 1.08-1.60) but not in men (HR 1.21, 95%CI 0.99-1.46)	Age, sex, ethnicity, education, smoking, hypertension, diabetes, stroke
Keller, 1999[64]	(prospective) (USA)	n=576 patients aged 56-102y	HI defined as failure on the whisper test vs passing the test	Scores on ADL and IADL with higher scores indicating better function (6y follow-up)	HI associated with higher scores of ADL (21/23 v 20/23, p<0.001) and IADL (11/23 v 13/23, p<0.001) compared with non-HI	Sex, cognition, physical illness (no details provided)
Laforge, 1992[65]	Study of the Wellbeing of Older People in Cleveland (SWOPC) (prospective) (USA)	n=1315 community-dwellers aged ≥ 65y	HI defined as self-reported fair/poor vs good/excellent hearing	None vs ≥1 ADL (did not include toileting and walking across a room); none vs ≥1 IADL (only included shopping and using transportation) (1y follow-up)	HI not associated with incident ADL (OR 0.60, 95%CI 0.30-1.18) and incident IADL (OR 0.84, 95%CI 0.46-1.52)	Age, sex, cognition

Table 2.7 *Continued*. Summary of longitudinal studies investigating the association between hearing impairment and disability

Author, year	Study (Design) (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Lin, 2004[68]	Study of Osteoporotic Fractures (SOF) (prospective) (USA)	n=6112 community-dwelling women aged ≥ 69y	No HI PTA <40 dB vs HI ≥ 40 dB at 2kHz	Disability defined as none vs some problems, much problems or unable to do walking, climbing stairs, cooking, shopping, undertaking housework (4y follow-up)	HI not associated with increased risks of disability (OR 1.10, 95%CI 0.71-1.73)	Age, education, smoking, BMI, CVD, arthritis, diabetes, vertebral fracture, benzodiazepine use, social network, grip strength, walking speed, cognition
Reuben, 1999[66]	National Health and Nutrition Examination Survey (NHANES) (prospective) (USA)	n=5444 community-dwellers aged 55-74y	No HI PTA <40 dB vs HI ≥ 40 dB at 1- or 2kHz in both ears or at 1- and 2kHz in one ear. Self-reported hearing: no trouble hearing vs HI if trouble hearing	Modified Rosow-Brelau scale defined as problems with walking 1/4 mile, climbing up and down 2 steps or performing heavy housework; ADL; IADL (did not include telephoning and using public transport) (10y follow-up)	Objectively measured and self-reported HI associated with increased risks of Rosow-Brelau (RR 1.66, 95%CI 1.20-2.30; RR 1.76, 95%CI 1.11-2.77). No association between HI and incident ADL (RR 1.69, 95%CI 0.88-3.26; RR 1.31 95%CI 0.67-2.56) and IADL (RR 1.49, 95%CI 0.88-2.54; RR 1.24, 95%CI 0.73-2.10)	Age, sex, ethnicity, education, CVD, diabetes, hypertension
Rosso, 2013[67]	Women's Health Initiative Observational Study (WHI) (prospective) (USA)	n=29,544 community-dwelling women aged ≥ 65y	Self-reported HI defined as any troubles hearing vs no hearing problem	None vs ≥1 ADL (did not include toileting and walking across a room) (3y follow-up)	HI not associated with incident ADL (RR 1.24, 95%CI 0.98-1.57)	Age, income, smoking, chronic diseases (CVD, Alzheimer's disease, arthritis, stomach ulcers, liver disease, asthma, emphysema)

Table 2.7 *Continued*. Summary of longitudinal studies investigating the association between hearing impairment and disability

Author, year	Study (Design) (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Rudberg, 1993[202]	Longitudinal Study of Aging (LSOA) (prospective) (USA)	n=4452 community-dwellers aged ≥ 70y	Self-reported HI defined as troubles hearing, deafness or tinnitus vs none of these hearing problems	None vs ≥1 ADL (4y follow-up)	HI not associated with incident ADL (RR 1.04, 95%CI 0.90-1.20)	Age, sex, ethnicity, marital status, education, BMI, osteoporosis, arthritis, hypertension, CVD, diabetes, cancer
Wallhagen, 2001[148]	Alameda County Study (prospective) (USA)	n=2442 community-dwellers aged 50-102y	Self-reported ability hearing and understanding words in a normal conversation, hearing words clearly over the telephone, and hearing good enough to carry on a conversation in a noisy room classified as none vs mild or moderate/severe HI	Mobility disability defined as difficulties walking 1/4 mile or climbing up 10 steps without rest; ADL; IADL did not include telephoning and using public transport (1y follow-up)	Mild but not moderate/severe HI associated with incident ADL (OR 1.61, 95%CI 1.14-2.28; OR 1.45, 95%CI 0.96-2.18). No association between mild HI, moderate/severe HI and incident mobility limitation (OR 1.21, 95%CI 0.88-1.66; OR 1.07, 95%CI 0.72-1.58) or IADL (OR 1.17, 95%CI 0.91-1.51; OR 1.22, 95%CI 0.88-1.68)	Age, sex, ethnicity, education, marital status, CVD, hypertension, diabetes, cancer, bronchitis, emphysema
Yamada, 2012[63]	(prospective) (Japan)	n=1254 community-dwellers aged 65-98y	Self-reported HI defined as difficulty hearing what a person says to you in a quiet room when speaking normally vs no hearing problem	Scores on IADL deficits (did not include telephoning) (3y follow-up)	HI associated with decline in performance of IADL (OR 1.79, 95%CI 1.12-2.87)	Age, sex, education, marital status, self-reported well-being, osteoporosis, smoking, hearing aid use

Definitions: ADL = activities of daily living; BMI = body mass index; CI = confidence intervals; CVD = cardiovascular disease; dB = decibel; HI = hearing impairment; Hz = hertz; IADL = instrumental activities of daily living; OR = odds ratio; PTA = pure tone audiometry; RR = relative risk; SSHL = sudden sensorineural hearing loss

Table 2.8 Summary of longitudinal studies investigating the association between vision impairment and disability

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Deshpande, 2014[212]	InChianti study (prospective) (Italy)	n=622 community-dwellers aged 50-85y	Poor visual contrast sensitivity defined as Pelli-Robson score <1.7 vs ≥1.7 visual contrast sensitivity	Mobility limitation defined as inability to walk 1/4 mile without resting or inability to walk up a flight of stairs unsupported (3y follow-up)	Poor visual contrast sensitivity associated with increased risk of incident mobility limitation (OR 2.37, 95%CI 1.12-5.04)	Age, sex, cognition, depression
Gopinath, 2014[218]	Blue Mountains Eye Study (BMES) (prospective) (Australia)	n=761 community-dwellers aged >60y	No diagnosed AMD vs diagnosed AMD divided into early and late AMD using retinal photographs	None vs ≥ 1 ADL (did not include walking across a room); none vs ≥ 1 IADL (5y follow-up)	AMD associated with increased risk of incident ADL difficulty (OR 2.87, 95%CI 1.44-5.71) and with incident IADL (OR 2.06, 95%CI 1.11-3.83)	Age, sex, housing status, self-rated poor health, smoking, best corrected VI, hypertension, diabetes, hospital admissions in past year, mobility limitations, depression
Keller, 1999[64]	(prospective) (USA)	n=576 patients aged 56-102y	VA 20/70 or better vs VA worse than 20/70	Mean scores on ADL and IADL with higher scores indicating better function (6y follow-up)	VI associated with poorer ADL (18/23 v 21/23, p<0.001) and IADL scores (8/23 v 12/23, p<0.001) compared with non-VI	Sex, physical illness (unspecified) and cognition
Laforge, 1992[65]	Study of the Wellbeing of Older People in Cleveland (SWOPC) (prospective) (USA)	n=1315 community-dwellers aged ≥ 65y	Self-reported VI defined as fair/poor vs good/excellent vision	None vs ≥ 1 ADL (did not include toileting and walking across a room); none vs ≥ 1 IADL (only included shopping and using transportation) (1y follow-up)	VI associated with incident IADL (OR 1.78, 95%CI 1.08-2.92) but not incident ADL (OR 1.27, 95%CI 0.77-2.11)	Age, sex, cognition

Table 2.8 *Continued*. Summary of longitudinal studies investigating the association between vision impairment and disability

Author, year	**Study (Design) (Country)**	**Population**	**Vision measurement**	**Outcomes**	**Relevant findings**	**Adjustments**
Lin, 2004[68]	Study of Osteoporotic Fractures (SOF) (prospective) (USA)	n=6112 community-dwelling women aged ≥69y	VA 20/40 or better vs VI VA worse than 20/40	Disability (modified Rosow-Brelau scale) defined as none vs some problems, much problems or unable to do walking, climbing stairs, cooking, shopping, undertaking housework (4y follow-up)	VI associated with increased risk of disability (OR 1.79, 95%CI 1.15-2.79)	Age, education, smoking, BMI, CVD, arthritis, diabetes, vertebral fracture, benzodiazepine use, grip strength, walking speed, social network, cognition
Reuben, 1999[66]	National Health and Nutrition Examination Survey (NHANES) (prospective) (USA)	n=5444 community-dwellers aged 55-74y	VA better than 20/40 vs VI VA 20/40 or worse. Self-reported vision: no trouble seeing vs VI if trouble seeing	Modified Rosow-Brelau scale defined as problems with walking 1/4 mile, climbing up and down 2 steps or performing heavy housework; none vs ≥1 ADL; none vs ≥ 1 IADL (did not include telephoning and using public transport) (10y follow-up)	Self-reported and VA VI associated with incident ADL (RR 2.21, 95%CI 1.59-3.06; RR 2.01, 95%CI 1.29-3.13) and IADL (RR 2.44, 95%CI 1.87-3.17; RR 1.72, 95%CI 1.20-2.48). Self-reported but not VA VI associated with incident Rosow-Breslau (RR 1.95, 95%CI 1.52-2.50; RR 1.29, 95%CI 0.92-1.82)	Age, sex, ethnicity, education, past MI, diabetes, hypertension, heart failure
Rosso, 2013[67]	Women's Health Initiative Observational Study (WHI) (prospective) (USA)	n=29,544 community-dwelling women aged ≥ 65y	Self-reported VI defined as any troubles seeing vs no vision problem	None vs ≥ 1 ADL (did not include toileting and walking across a room) (3y follow-up)	VI associated with increased risk of incident ADL difficulty (RR 1.60, 95%CI 1.26-2.04)	Age, income, smoking, chronic diseases (CVD, Alzheimer's disease, arthritis, stomach ulcers, liver disease, asthma, emphysema)
Rudberg, 1993[202]	Longitudinal Study of Aging (LSOA) (prospective) (USA)	n=4452 community-dwellers aged ≥ 70y	Self-reported VI defined as troubles seeing, blindness, cataracts, glaucoma or reinal condition vs none of these vision problems	None vs ≥ 1 ADL (4y follow-up)	VI associated with incident ADL difficulty (RR 1.39, 95%CI 1.20-1.61)	Age, sex, ethnicity, marital status, education, BMI, CVD, diabetes, osteoporosis, arthritis, hypertension, cancer

Table 2.8 *Continued*. Summary of longitudinal studies investigating the association between vision impairment and disability

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Salive, 1994[69]	Established Studies of the Elderly (ESE) (prospective) (USA)	n=3133 community-dwellers aged 70-103y	VA 20/40 or better vs mild VI VA 20/60 or better but worse than 20/40, moderate VI VA 20/200 or better but worse than 20/60, severe VI VA worse than 20/200	Mobility limitation defined as unable to climb a flight of stairs or walk 1/2 mile without help; none vs ≥ 1 ADL (15m follow-up)	Severe but not mild or moderate VI associated with incident mobility limitation (severe: RR 3.50, 95%CI 1.70-7.20; moderate: RR 1.40, 95%CI 0.97-2.10; mild: RR 1.20, 95%CI 0.80-1.80). Severe and mild but not moderate VI associated with ADL (severe: RR 3.10, 95%CI 1.70-5.70; moderate: RR 1.30, 95%CI 0.90-2.00; mild: RR 1.90, 95%CI 1.30-2.90)	Age, sex, ethnicity, study site, income, diabetes, stroke
Swenor, 2015[122]	Health, Aging and Body Composition (Health ABC) (prospective) (USA)	n=1862 community-dwellers aged 70-79y	VI defined as VA worse than 20/40 and visual contrast sensitivity <1.55 Pelli-Robson (investigated separately)	Difficulty walking 1/4 mile and difficulty climbing up 10 steps analysed separately (1, 3 and 5y follow-up)	Poor VA associated with incident walking limitation and stair climbing limitation at 1y follow-up (HR 2.00, 95%CI 1.30-3.20; HR 2.50, 95%CI 1.50-4.20), 3y follow-up (HR 1.50, 95%CI 1.10-2.10; HR 1.50, 95%CI 1.01-2.30), 5y follow-up (HR 1.70, 95%CI 1.30-2.30; HR 1.70, 95%CI 1.20-2.30). Contrast sensitivity associated with walking limitation and stair climbing limitation at 1y follow-up (HR 1.40, 95%CI 1.03-2.00; HR 1.80, 95%CI 1.20-2.70), 3y follow-up (HR 1.70, 95%CI 1.40-2.20; HR 1.80, 95%CI 1.40-2.40), 5y follow-up (HR 1.50, 95%CI 1.20-1.80; HR 1.60, 95%CI 1.30-2.00)	Age, sex, ethnicity, study site, BMI, depression, diabetes, smoking and comorbidity (CVD, hypertension, arthritis, cancer)

Table 2.8 *Continued*. Summary of longitudinal studies investigating the association between vision impairment and disability

Author, year	Study (Design) (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Wallhagen, 2001[148]	Alameda County Study (prospective) (USA)	n=2442 community-dwellers aged 50-102y	Self-reported vision on seeing good enough to read street signs at night, recognise a friend across a street and read the newspaper classified as none vs mild and moderate/severe VI.	Mobility disability defined as difficulties walking 1/4 mile or climbing up 10 steps without rest; none vs ≥ 1 ADL; none vs ≥1 IADL did not include telephoning and using public transport (1y follow-up)	Mild but not moderate/severe VI associated with mobility limitation (OR 1.58, 95%CI 1.16-2.14; OR 1.42, 95%CI 0.93-2.18). Mild and moderate/severe VI associated with increased risk of incident ADL (OR 1.50, 95%CI 1.07-2.10; OR 2.29, 95%CI 1.49-3.52) and IADL (OR 1.45, 95%CI 1.15-1.84; OR 1.79, 95%CI 1.25-2.58).	Age, sex, ethnicity, education, marital status, CVD, hypertension, diabetes, cancer, bronchitis, emphysema
Whitson, 2007[241]	North Carolina Established Populations for the Epidemiologic Studies of the Elderly (NC EPESE) (prospective) (USA)	n=3878 community-dwellers at baseline, aged ≥ 65y	Self-reported VI defined as unable to recognise a friend across a street or not being able to read the newspaper vs no such problems	None vs ≥ 1 ADL (did not include walking across a room) (6y follow-up)	VI associated with incident ADL (OR 1.78, 95%CI 1.41-2.24)	Age, sex, ethnicity, highest educational level, self-rated health, CVD, hypertension, diabetes, cancer, depression

Definitions: AMD = age-related macular degeneration; ADL = activities of daily living; BMI = body mass index; CVD = cardiovascular disease; IADL = instrumental activities of daily living; OR = odds ratio; RR = relative risk; VA = visual acuity; VI = vision impairment

Table 2.9 Summary of studies investigating the cross-sectional association between hearing impairment and frailty

Author, year	Study (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Kamil, 2014[14]	National Health and Nutrition Examination Survey (NHANES) (USA)	n=2109 community-dwellers aged ≥ 70y	HI defined as self-reporting a lot of trouble hearing vs good/a little trouble hearing	None vs ≥3 components of Fried phenotype (frailty component weakness was self-reported)	HI associated with frailty in women (OR 3.79, 95%CI 1.69-8.51) but not men (OR 0.85, 95%CI 0.44-1.66)	Age, sex, ethnicity, education, income, health status, BMI, smoking, hypertension, stroke, diabetes, hearing aid use
Ng, 2014[74]	Singapore Longitudinal Ageing Studies (Singapore)	n=1685 community-dwellers aged ≥ 55y	HI based on self-reported and whisper test (definitions for HI not provided)	None vs ≥3 components of Fried phenotype (frailty component weakness based on leg muscle strength, physical activity was self-reported)	HI associated with frailty (p=0.012)	Age, sex, housing status, smoking, diagnosed morbidity in past year

Definitions: BMI = body mass index; CI = confidence intervals; dB = decibel; HI = hearing impairment; OR = odds ratio

Table 2.10 Summary of longitudinal studies investigating the association between hearing impairment and frailty

Author, year	Study (Design) (Country)	Population	Hearing measurement	Outcomes	Relevant findings	Adjustments
Doba, 2012[76]	(prospective) (Japan)	n=407 community-dwellers aged >70y	HI defined as self-reporting slight or obvious difficulties hearing vs no problems	Symptoms and signs of frailty determined by physicians for the Clinical Frailty Scale (none vs ≥4 out of 7 components) (5y follow-up)	HI associated with frailty (OR 2.19, 95%CI 1.20-4.00)	None reported
Kamil, 2016[77]	Health ABC (prospective) (USA)	n=2000 community-dwellers aged 70-79y	No HI PTA ≤ 25 dB vs mild HI PTA=26-40 dB, moderate/greater HI PTA >40 dB, self-reported hearing aid use	Frailty defined as gait speed <0.60 m/s and/or inability to rise from a chair without using arms (10y follow-up)	Moderate/greater but not mild HI associated with incident frailty (HR 1.63, 95%CI 1.26-2.12; HR 1.12, 95%CI 0.90-1.39). Hearing aid use not associated with decreased frailty risk (HR 0.81, 95%CI 0.54-1.21).	Age, sex, ethnicity, education, study site, smoking, hypertension, diabetes, stroke

Definitions: CI = confidence intervals; dB = decibel; HI = hearing impairment; HR = hazard ratio; OR = odds ratio; PTA = pure tone audiometry

Table 2.11 Summary of studies investigating the cross-sectional association between vision impairment and frailty

Author, year	Study (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Chen, 2010[242]	Survey of Health and Living Status of the Elderly (Taiwan)	n=2238 community-dwellers aged 65-103y	No cataract vs cataract (no information on definition)	None vs ≥ 3 components of Fried phenotype (modified 100% self-reported version)	Cataract associated with pre-frailty (40%) (p=0.004) but not with frailty (42%) (no statistical data given) (31% non-frail)	None reported
Klein, 2003[237]	Beaver Dam Eye Study (USA)	n=2962 community-dwellers aged ≥ 53y	VA 20/20 vs mild VI VA 20/25 to 20/32 and moderate/severe VI VA 20/40 and worse; Pelli-Robson contrast sensitivity good (≥1.80) vs fair (1.65-1.80) and poor (<1.65)	Frailty score of objectively measured frailty indicators (by gender) including being in the lowest quartile for gait speed, peak expiratory flow rate and grip strength, and unable to do a chair stand	Mild and moderate/severe VA VI associated with frailty score in women (p<0.001) but not men (p=0.07). Fair and poor contrast sensitivity associated with frailty score in both women (p<0.001) and men (p<0.001)	Age
Klein, 2005[79]	Beaver Dam Eye Study (USA)	n=2962 community-dwellers aged ≥ 53y	No diagnosed AMD vs diagnosed AMD divided into early and late AMD using retinal photographs	Objectively measured frailty indicators included being in the lowest quartile (by gender) for gait speed, peak expiratory flow rate and grip strength, and unable to do a chair stand	AMD associated with weak handgrip strength in men (OR 1.28, 95%CI 1.08-1.52). No association between AMD and the four indicators of frailty, individually or combined (combined: OR 1.04, 95%CI 0.89-1.21), in women. No association between AMD and combined frailty indicators in men (OR 1.09, 95%CI 0.92-1.29)	Age, smoking, BMI, PA, number of co-morbidities (diabetes, hypertension, CVD, arthritis, gout, non-skin cancer, Parkinson's disease, Alzheimer's disease, and asthma)

Table 2.11 *Continued*. Summary of studies investigating the cross-sectional association between vision impairment and frailty

Author, year	Study (Country)	Population	Vision measurement	Outcomes	Relevant findings	Adjustments
Klein, 2006[15]	Beaver Dam Eye Study (USA)	n=2962 community-dwellers aged ≥ 53y	No identified cataracts or cataract surgery vs identified cataracts based on retinal photographs	Frailty defined as being in the lowest quartile (by gender) for gait speed, peak expiratory flow rate and grip strength, and unable to do a chair stand (all objectively measured)	Cataract associated with frailty in men (OR 1.56, 95%CI 1.15-2.11) but not in women (OR 1.22, 95%CI 0.92-1.61)	Age, smoking, sedentary lifestyle, education, VA, ≥ 2 comorbidities (CVD, hypertension, Alzheimer's disease, asthma, arthritis, non-skin cancer, gout, emphysema, Parkinson's disease, diabetes)
Ng, 2014[74]	Singapore Longitudinal Ageing Studies (Singapore)	n=1685 community-dwellers aged ≥ 55y	VI defined as corrected VA worse than 20/40	None vs ≥3 components of Fried phenotype (frailty component weakness based on leg muscle strength, physical activity was self-reported)	VI associated with frailty (p=0.001)	Age, sex, housing status, smoking, diagnosed morbidity in past year
Soler, 2015[240]	(France)	n=1425 patients at geriatric clinic (age not specified)	VA 5/10 or better (20/40 or better) vs mild/moderate VI VA worse than 5/10 but equal or better than 3/10 and severe VI VA worse than 3/10	None vs 1-2 components defined as pre-frail and ≥3 defined as frail using Fried phenotype (no information on assessment of measures used)	Mild/moderate and severe VI groups not associated with pre-frailty (OR 0.99, 95%CI 0.58-1.67; OR 0.32, 95%CI 0.67-3.48) or frailty (OR 1.18, 95%CI 0.70-2.00; OR 1.53, 95%CI 0.37-3.49)	Age, sex, education, disability (activities of daily living), cognition

Definitions: AMD = age-related macular degeneration; ADL = activities of daily living; BMI = body mass index; CVD = cardiovascular disease; PA = physical activity; VA = visual acuity; VI = vision impairment

Figure 2.1. Conceptual pathways possibly explaining the relationships of impairments in hearing and vision with cardiovascular disease (CVD)

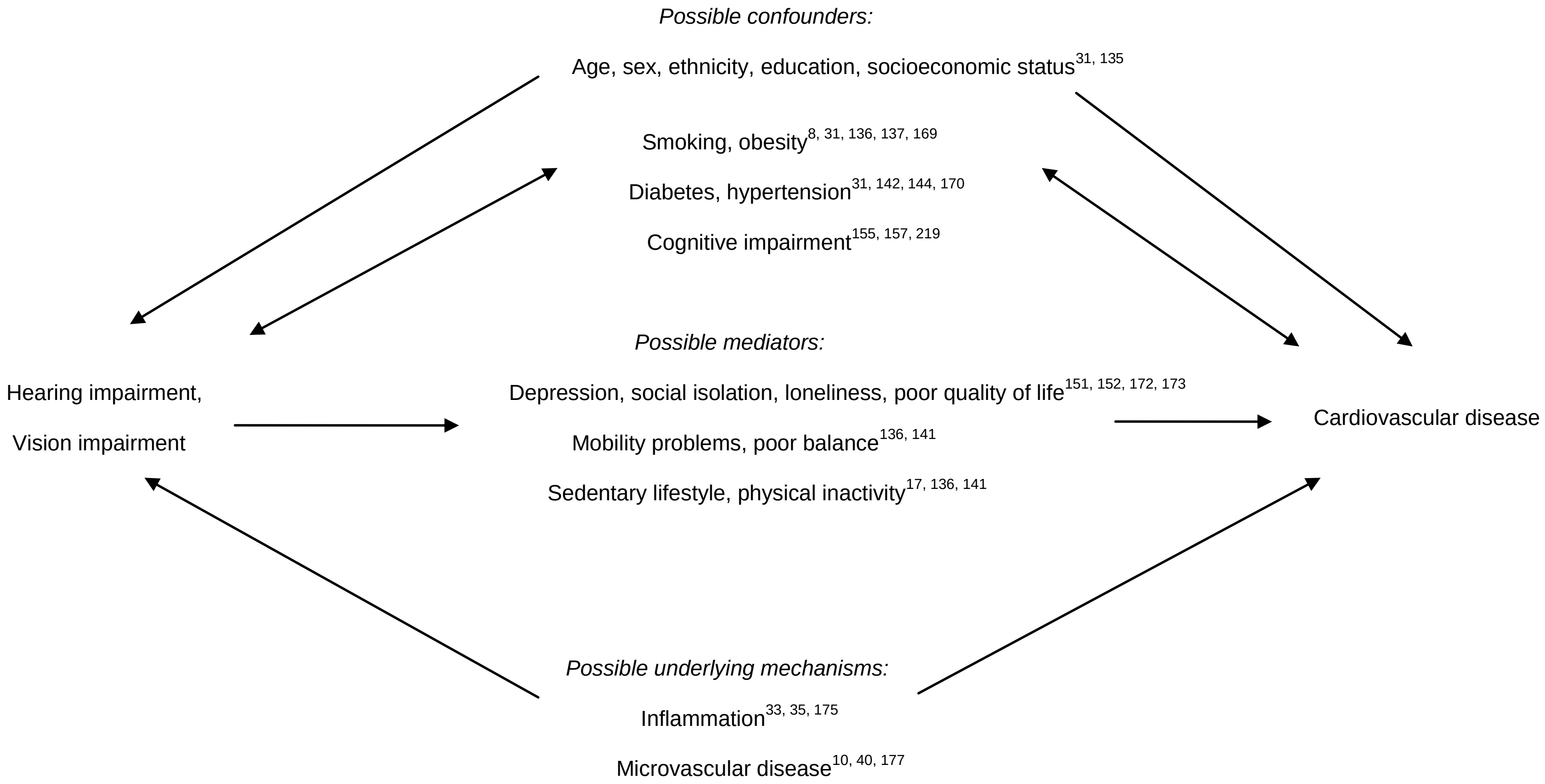
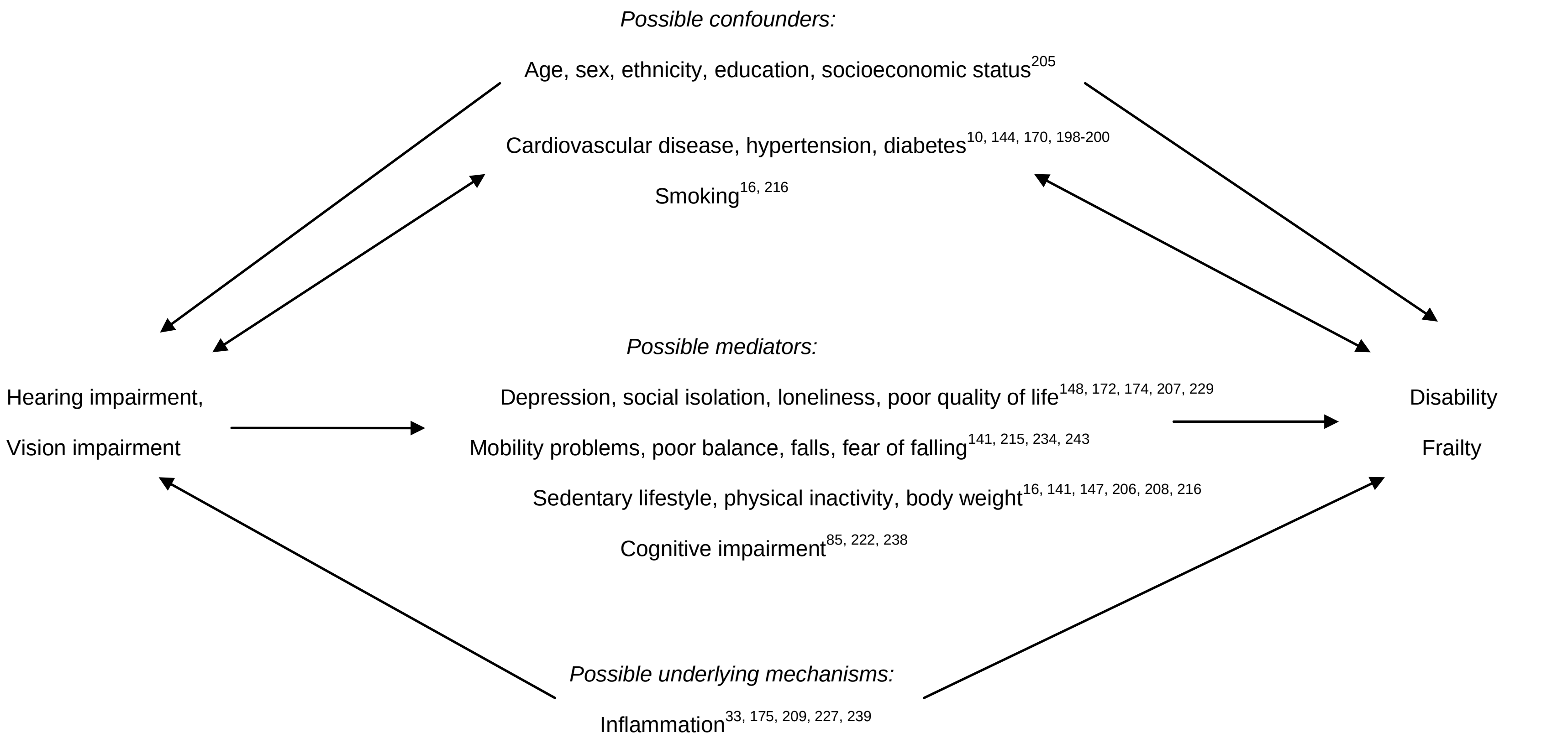


Figure 2.2. Conceptual pathways possibly explaining the relationships of impairments in hearing and vision with disability and frailty



CHAPTER 3 Methods

3.1. Introduction

This thesis consists of epidemiological analyses of data from the British Regional Heart Study (BRHS) to address objectives 1-3 and the English Longitudinal Study of Ageing (ELSA) to address objective 4. The BRHS is a prospective cohort of cardiovascular disease that was initiated in 1978-80 in 7735 men aged 40-59 years drawn from general practices in 24 towns across Britain. At recruitment, participants undertook a physical examination including measures of weight and height, and a subsequent physical examination was conducted 20 years later in 1998-2000. Data on morbidity are collected through general practice records, and for mortality through the NHS Central Register. Postal questionnaires at regular intervals are used to collect information on self-report of health and disease, lifestyle, disability, and personal and socioeconomic conditions. The ELSA is a prospective study on the health, social, wellbeing and economic circumstances of the English population aged 50 years and older. The original sample of 11,391 men and women were drawn from respondents to the Health Survey for England (HSE) in 1998, 1999 and 2001 who had given permission to be re-contacted in the future. The cohort was initiated in 2002 and is regularly replenished with new study participants from HSE to maintain the size and representativeness of the sample. Every two years of the study, data on socioeconomic conditions, lifestyle, health and disease, and cognitive function are collected through a face-to-face interview followed by a self-completed questionnaire on psychosocial health. A physical examination that includes measures of height, weight, blood pressure, gait speed and grip strength is completed every four years.

This Chapter starts with an overview of the BRHS, including the study design and methods (section 3.2). This is followed by a description of the BRHS data used in this thesis to address objectives 1-3 including measures of hearing impairment, vision impairment, cardiovascular disease, disability and other relevant risk factors and outcomes (section 3.3). Then strengths and limitations of the data source for the intended analyses are described (section 3.4).

The presentation of the BRHS data is followed by an overview of the ELSA including study design and methods (section 3.5), details of the ELSA data used in this thesis to address objective 4 including measures of hearing impairment, vision impairment and frailty (section 3.6), and strengths and limitations of the data source for the intended analysis (section 3.7). This is followed by a brief overview of statistical methods (section 3.8). Specific details of statistical analyses for the thesis objectives are described in more detail in each of the relevant chapters (Chapters 4 to 7). Finally the search strategy for relevant literature is presented (section 3.9).

3.2. The British Regional Heart Study

3.2.1. Description of data source

The British Regional Heart Study (BRHS) (https://www.ucl.ac.uk/pcph/research-groups-themes/brhs-pub) is a prospective cohort study of cardiovascular disease (CVD) in a socioeconomically and geographically representative sample of 7735 British men aged 40-59 years when randomly recruited from a general practice in each of 24 towns in Great Britain in 1978-80.[244] Since recruitment, the men have been continuously followed-up for morbidity, mortality and lifestyle behaviour. The BRHS was initiated to explain the substantial regional variations in mortality from cardiovascular disease in Great Britain, by assessing the role of environmental, socioeconomic, and behavioural risk factors.[244, 245] Over time, as the cohort has aged, there has been an increasing focus on the aetiology and prevention of cardiovascular disease in older ages.

3.2.2. Funding and ethical approval

BRHS is primarily funded by the British Heart Foundation but has also received funding from the Department of Health, the Medical Research Council (MRC), Diabetes UK and the National Institute for Health Research (NIHR). Ethical approval for the BRHS was granted by the National Research Ethics Service (NRES) Committee, London. All participants have provided written informed consent to the research study, obtained in accordance with the Declaration of Helsinki.

3.2.3. Selection procedures

The 24 towns were selected to represent all major geographic regions in Great Britain using seven criteria listed below.[244, 245]

1. All standard regions should be represented.
2. Towns should be discrete entities with populations of 50,000-100,000 at the 1971 Census. In England one larger town was included (Ipswich, 122,700). In Scotland, some towns with populations below 50,000 were considered in order to obtain a reasonable number of suitable towns.
3. The choice of towns within regions was to reflect the variations in mortality from CVD and water hardness as research in the 1960s and 1970s suggested that towns with harder water tended to have lower CVD mortality rates, potentially due to calcium

and magnesium present in hard water lowering the risk of calcium and magnesium deficiency and reducing the risk of sudden cardiac death.[245, 246]

4. Towns were to be representative of the region in socioeconomic terms.
5. Towns with noticeable population movement or with unusual population structure were not included.
6. The study included some towns that were apparent “outliers” when CVD mortality and water hardness were plotted against each other (e.g. towns with low CVD mortality rates despite lower levels of harder water) such as Hartlepool, Exeter, and Harrogate.
7. When similar towns met the above criteria, a random selection was made between those towns.

Figure 3.1 (page 108) shows a map of the 24 towns included in the BRHS. Table 3.1 (page 107) shows standardised mortality ratios (SMR) for CVD in men aged 35-64 years in 1969-73, the number of men examined and the percentage response rate for each of the 24 towns.

Participants were selected from one general practice in each town to achieve a good initial response and a good subsequent follow-up.[244] General practices were selected based on size (practice population >7500), their representativeness of socioeconomic composition and characteristics of the local population and the willingness of the practice to participate. The age and sex register of each general practice was used to randomly select and stratify 450 men aged 40-59 years into equally sized five-year age groups (40-44, 45-49, 50-54 and 55-59 years). Men with severe mental or physical disability were excluded (6-10% per practice). The remaining participants were invited to participate in the study through a letter signed by the practice doctors encouraging them to attend the cardiovascular health check at a local venue, usually the practice premises. Of nearly 10,000 men invited to participate, 7735 men aged 40-59 years were recruited into the study, generating a response rate of 78% with 18 of the 24 towns having a response rate of 75% or more (Table 3.1).[81] This resulted in a total sample of 7735 men, which equates to approximately 300 men from each town.[81, 244]

3.2.4. Baseline examination

All 7735 participants attended a physical examination carried out in each of the towns at the start of the study in 1978 and were completed by 1980. A team of three nurses were provided with training before and during the study to ensure standardisation of procedures. Measurements made by the nurses included height, weight, blood pressure, electrocardiogram and lung function. In addition, a blood sample was collected and the men also completed a nurse-administered questionnaire on lifestyle factors and health and medical history.

3.2.5. Follow-up of participants from baseline

Since the baseline examination at study entry in 1978-80, all participants have been followed-up for health and lifestyle changes through postal questionnaires, morbidity outcomes through data from local general practices and mortality by the NHS Central Register,[81, 247] as shown in Figure 3.2 (page 109). Participants have also been invited to two re-examinations undertaken after 20 years of follow-up (1998-2000), and after 30 years of follow-up (2010-2012).

3.2.5.1. Mortality

Information on mortality (fatal events) was obtained through the established procedure of “flagging” participants for follow-up in the NHS Central Register in Southport for England and Wales, and in Edinburgh for Scotland.[81] Death certificates containing identification details, date and place of death and cause of death coded using the International Classification of Diseases 9th revision (ICD-9) and subsequently the 10th edition (ICD-10) were collected quarterly. Information on death was also provided by the 24 general practices as part of a periodic review and was used to verify all fatal events (see section 3.2.5.2 below).

3.2.5.2. Morbidity

Information on non-fatal cardiac, cancer and diabetes related events was obtained through on-going reports from general practitioners and by regular reviews of the patients’ medical records.[81] Every two years a standard medical record review form was sent to each of the 24 general practices requesting confirmation of each participant’s continuing registration, current address, and information on any new cardiovascular events (including myocardial infarction, angina, stroke, transient ischaemic attack and heart failure) and new diagnoses of cancer or diabetes or cardiovascular treatments (coronary artery bypass graft, coronary angioplasty) which had occurred in the past two years. All newly reported non-fatal myocardial infarction (MI) and stroke events were followed-up with an enquiry form to the general practitioner or hospital consultant to obtain confirmatory evidence that the World Health Organization (WHO) case criteria had been met for an event to be accepted as a case of definite non-fatal myocardial infarction.[81, 248] The WHO criteria for non-fatal MI refer to the presence of any two of the following three conditions: prolonged chest pain, positive electrocardiogram findings and raised cardiac enzyme levels.[249, 250] The criteria for a non-fatal stroke are based on an acute disturbance of cerebral function of vascular origin, producing a neurological deficit lasting for more than 24 hours.[81, 251]

Participants who had re-registered with another general practice were traced to their new practice using information from the local health authority. If no information was available from the local health authority, the NHS Central Register was contacted. The study now includes over 850 general practices across the country as follow-up of participants has been maintained for 98% of survivors.

3.2.5.3. Follow-up questionnaires

Self-administered questionnaires on medical history and treatment, health, lifestyle and socioeconomic factors have been sent to participants by post at regular intervals since the initial physical examination and questionnaire in 1978-80 (see Figure 3.2). The first questionnaire was sent out five years after the start of the study in 1983-85, followed by questionnaires in 1992 and 1996. In 1998-2000 the questionnaire was nurse-administrated and completed as part of the 20-year re-examination. This was followed by postal questionnaires in 2003, 2005 and 2007. In 2010-12, a nurse-administrated questionnaire was carried out at the 30-year re-examination. Since 2014, postal questionnaires have been sent out on an annual basis.

3.3. BRHS data used in this thesis

In this thesis, data from the BRHS have been used to assess the relationships between impairments of hearing and vision and the risks of adverse health outcomes including CVD incidence and mortality, and disability. These relationships have primarily been investigated using data from the questionnaire in 2003 as this was the first time data on hearing and vision were collected. Follow-up data included data on CVD and mortality until June 2013 and data on disability from the questionnaire in 2005. In addition, some data used in this thesis were obtained at the baseline examination in 1978-80 and the 20-year re-examination in 1998-2000 including socioeconomic variables and physical measures such as height. Data collection and definition of the two exposure variables hearing impairment and vision impairment, outcome variables and potential confounding variables are presented below.

3.3.1. Measures of hearing function

Hearing was initially measured in 2003 part of the postal self-completed questionnaire and has since 2003 been repeated in all follow-up questionnaires. In the self-completed questionnaire in 2003, participants were asked the questions ‘Do you use a hearing aid?’ and ‘Using a hearing aid if needed, is your hearing good enough to follow a TV programme at a volume others find acceptable?’ followed by ‘If no, can you follow a TV programme with the volume turned up?’. All questions were provided with answer options ‘yes/no’. The self-reported question on viewing TV with an increased volume has previously been validated and used in several national health surveys[96-98] (Chapter 2, section 2.2.2).

Figure 3.3 (page 110) illustrates how the hearing score in BRHS was derived. Out of 3981 participants completing the questionnaire in 2003, 73 participants did not answer the question on hearing aid and 1555 participants did not answer the question on being able to follow a TV programme at a volume others find acceptable. In the following self-administrated questionnaire in 2005, the question on being able to follow a TV programme at a volume others find acceptable was rephrased from ‘Using a hearing aid if needed, is you hearing good enough to follow a TV programme at a volume others find acceptable?’ into ‘Is your hearing good enough to follow a TV programme at a volume others find acceptable (using a hearing aid if needed)?’. The 1555 missing responses in 2003 were compared against their answers in 2005. This showed that 1113 of the 1555 non-respondents in 2003 reported they were able to follow a TV programme at a volume acceptable to others in 2005. An assumption was made that the 1113 participants reporting being able to follow a TV programme at a volume acceptable to others in 2005 would most likely have been able to do so in 2003 too. Therefore, these 1113 participants were coded as being able to hear well enough to follow a TV programme at a volume others find acceptable in 2003. Participants who did not respond to the question on ability to follow a TV programme (n=294) and had responded either yes or no to the question ‘If no, can you follow a TV programme with the volume turned up?’ were grouped together with participants who did not hear good enough to follow a TV programme at a volume others find acceptable.

The question on being able to hear good enough to follow a TV programme was then combined with the question ‘Do you use a hearing aid?’. This allowed for four categories of hearing: 1) men who could hear good enough to follow a TV programme and did not use a hearing aid (could hear, did not use a hearing aid). This group was classified as having no hearing impairment. The following categories of hearing formed three hearing impairment groups: 2) men who could hear good enough to follow a TV programme and used a hearing aid (could hear, used a hearing aid); 3) men who could not hear good enough to follow a TV programme and did not use a hearing aid (could not hear, did not use a hearing aid); and 4) men who could not hear good enough to follow a TV programme and used a hearing aid (could not hear, used a hearing aid).

Participants not responding to the question 'Do you use a hearing aid?' (n=73) were classified as not using a hearing aid. Participants reporting not using a hearing aid and not answering the question on being able to follow a TV programme were classified as hearing good enough to follow a TV programme at a volume others find acceptable (n=92). Participants who did not provide information on any of the questions on hearing were reported as missing (n=56).

3.3.2. Measures of vision function

Vision was also measured in the questionnaire in 2003 based on the questions 'Using glasses or corrective lenses if needed, can you see good enough to recognise a friend at a distance of 12 feet/4 yards (across a road)?' and 'If no, can you see good enough to recognise a friend at a distance of one yard?'. Participants who reported not seeing good enough to recognise a friend at a distance of one yard (n=32) were combined with participants reporting not seeing good enough to recognise a friend across a road (n=83). Participants who did not report whether they could see good enough to recognise a friend across a road but provided a negative response to the question on seeing good enough to recognise a friend at a distance of one yard (n=9) were also classified as not seeing good enough to recognise a friend across a road. This resulted in two categories of vision: 1) men who could see good enough to recognise a friend across a road (could see). This category was classified as having no vision impairment; 2) men who did not see good enough to recognise a friend across a road (could not see). Participants who did not respond to any of the questions on vision were classified as missing (n=57). The question on seeing good enough to recognise a friend across a road has previously been tested against objectively measured vision[11] (Chapter 2, section 2.3.2).

3.3.3. Measures of socio-demographic and lifestyle factors

Socioeconomic position

The longest-held occupation of participants was reported at study entry when participants were aged 40-59 years. Subjects in the Armed Forces (n=231 (3%)) were grouped into a separate category and excluded from the analyses for this thesis because data on military ranks were not available making it difficult to allocate them a certain occupational social class. The Registrar Generals' Social Class Classification was used to classify participants into six occupational social class categories: I (professional occupations e.g. physicians, engineers), II (managerial occupations e.g. teachers, sales managers), III non-manual (skilled non-manual occupations e.g. clerks, shop assistants), III manual (skilled manual occupations, e.g. bricklayers, coalminers), IV (partly skilled occupations e.g. bus conductors, postmen) and V (unskilled occupations e.g. porters, general labourers).[252] The six occupational social classes were divided into two groups: non-manual (social classes I, II, III non-manual) and manual (social classes III manual, IV, V). The social class distribution of participants in BRHS (1978-80) has been compared to data from the National Census in 1981, showing that the BRHS sample is representative of the social distribution of the general population. For example, in BRHS, 39.6% were non-manual social class and 57.4% were manual social class compared to Census data reporting 39.5% non-manual social class and 58.1% manual social class. In the 1981 Census, 2.4% were in the Armed Forces (3% in BRHS).[81] This shows that the BRHS sample is representative of social distribution of the general population.

Cigarette smoking

In each questionnaire participants were asked detailed questions about the number of cigarettes smoked and changes in smoking habits. In 1992, participants were divided into four smoking categories: never smoked, long-term ex-smokers (those who were non-smokers in 1992 and ex-smokers at the initial survey in 1978-80), recent ex-smokers (non-smokers in 1992 and had given up since 1978-80), and current smokers. Participants reporting not being a current smoker in 2003 had their answers compared to their answer in 1992 allowing them to be grouped into ex-smokers (long-term or recent) and never smoked. From the information provided, participants were classified into three smoking groups in 2003: current smokers, ex-smokers (long-term and recent combined) and never smoked.[253]

Physical activity

In the self-completed questionnaire in 2003, data on physical activity were collected by asking the participants to indicate their usual patterns of three categories of activities: regular walking or cycling, recreational activity including gardening, pleasure walking and do-it-yourself jobs, and sporting activity such as running, swimming, dancing, golf, tennis, squash, jogging, bowls, cycling and hiking. A physical activity score was derived for each participant for each of the three activity categories on the basis of frequency and type (intensity) of physical activity.[254] Scores were assigned for each type of activity and duration on the basis of the intensity and energy demands of the activities reported.[255] The total score for each individual is a relative measure of how much physical activity has been undertaken. Participants were classified into six categories based on their physical activity score: inactive (score 0-2), occasional (score 3-5; regular walking or recreational activity only), light (score 6-8; more frequent recreational activities or vigorous exercise less than once a week), moderate (score 9-12; cycling or very frequent recreational activities or sporting activity once a week), moderately-vigorous (score 13-20; sporting activity at least once a week or frequent cycling, plus frequent recreational activities or walking, or frequent sporting activity only), and vigorous (score ≥ 21; very frequent sporting exercise or frequent sporting exercise plus other recreational activities). The physical activity score has been validated against heart rate in men without evidence of CHD showing that mean heart rate decreased significantly with increasing levels of physical activity after adjustment for age, social class, body mass index (BMI) and smoking ($p<0.0001$).[255]

Anthropometric measurements of obesity

The physical examinations at the initial data collection in 1978-80 and at 20-year follow-up in 1998-2000 included anthropometric measures including height and weight.[256] Height and weight were both measured while the participants were standing. Height was measured with a Harpenden stadiometer to the last complete 0.1 cm. For weight a Soehnle digital electronic scale (Critikon Service Center) was used measuring the participants in light clothing without shoes to the last complete 0.1 kg. In addition to the physical examinations, weight was self-reported in each questionnaire. A comparison between measured and self-reported weight at the 20-year follow-up showed that self-reported weight was on average (mean) 0.64 kg lower than the measured value. Data on height and weight were used to calculate body mass index (BMI) for each man as weight/(height)^2 in kg/m^2. In this thesis, BMI was based on self-reported weight in the questionnaire in 2003 and height measures at the 20-year follow-up physical examination in 1998-2000. For missing values at the 20-year follow-up (n=543), height was estimated by subtracting the mean difference between the baseline physical examination and the 20-year follow-up examination. Obesity was defined in accordance with the established WHO cut-point of having a BMI of 30 kg/m^2 and over.[257]

Self-reported health status and morbidity

In each questionnaire, participants were asked to rate their present state of health as excellent, good, fair or poor. The self-completed questionnaire in 2003 also sought information from participants on their medical history, which provided information on chronic conditions. Participants were asked if a doctor had ever told them that they have had a heart attack (coronary thrombosis or myocardial infarction), angina, stroke, diabetes, hypertension, arthritis, bronchitis and depression. They were also asked whether they ever have had any chest pain and if they ever get short of breath walking. Participants provided a ’yes/no’ response to each question.

Disability, falls and quality of life

In the self-completed questionnaire in 2003, participants were asked questions on their physical functioning in order to capture ascertaining problems with mobility. Participants were asked whether they had difficulty going up/down stairs and/or difficulty walking 400 yards on their own as a result of a long term health problem. Participants provided a ‘yes/no’ response to each of the activities listed. The questions on problems taking the stairs or walking 400 yards as a result of a long term health problem were further used to assess mobility limitation.

In addition to mobility limitation, questions on difficulties in physical functioning were asked to determine the extent of disability. The Katz Activities of Daily Living Index was incorporated in the 2003 questionnaire to ascertain problems with activities of daily living (ADL) including undertaking bathing, dressing, eating, getting in or out of bed or chair, toileting, and walking across a room.[190] The ADL scale has been used extensively as an instrument to assess functional status and repeatedly shown to be reliable and valid in older adults.[258, 259] The Lawton Instrumental Activities of Daily Living (IADL) scale was also part of the 2003 questionnaire and includes cooking, shopping, using public transport, managing money, and telephoning.[191] Similar to the ADL scale, the IADL scale has been widely used and there is considerable evidence for its validity and reliability in hospitalised and community-dwelling older adults.[191, 258, 260] Both the ADL index and the IADL scale have answer options ‘No difficulty’, ‘Some difficulty' and 'Difficulty' to each question. Participants who had skipped the questions on mobility limitation (n=34), ADL (n=84) and IADL (n=84) were reported as missing.

The 2003 questionnaire also asked participants if they have had a fall in the last 12 months with the answer options 'yes/no'. Three questions from the EuroQol-5D[261] were used to ask participants about their quality of life. Participants were asked to rate their experience of pain/discomfort, walking and anxiety/depression as none, moderate or extreme for each of the three quality of life components.

<u>Social engagement</u>

The social engagement scale developed for the Nottingham Activity and Ageing Study[262, 263] was used to ask participants whether they undertake any of the following nine activities on a weekly basis: voluntary work, go to the pub or a club, attend religious services, play cards or games, visit the cinema, restaurants or sports events, and attend a class or course of study. The participants were also asked if they sometimes go on day or overnight trips and if they have been on a holiday in the last year. Responses were reported as 'yes' or 'no' to each of the activities listed. The social engagement scale has been shown to strongly correlate with the widely used Life Satisfaction Index.[263]

3.3.4. Outcomes

The outcome variables assessed using BRHS data were:

- incident cardiovascular disease (CVD);

  including
    - incident myocardial infarction (MI)
    - incident stroke
- coronary heart disease (CHD) mortality;
- CVD mortality;
- all-cause mortality;
- incident mobility limitation;
- incident activities of daily living (ADL);
- incident instrumental activities of daily living (IADL).

Data on CVD events were obtained in 2003 and categorised as a non-fatal or fatal MI and/or non-fatal or fatal stroke event. A non-fatal MI was defined according to WHO criteria,[248] described in section 3.2.5.2. A fatal MI event was coded as ICD-9, 410-

414. A non-fatal stroke was defined as an event that produced a neurological deficit present for more than 24 hours.[264] Fatal stroke events were coded as ICD-9, 430-438. CHD mortality was defined as death from MI. CVD mortality was defined as all fatal CVD events (MI and/or stroke) (ICD-9, 390-459). All-cause mortality was defined as death from any cause. Deaths were ascertained from the NHS Central Register (as described in section 3.2.5.1). Non-fatal MIs and non-fatal strokes were ascertained from the regular review of general practice records (as described in section 3.2.5.2). Follow-up data on CVD incidence and for CVD and all-cause mortality were available to June 2013. Inclusion and exclusion criteria in the analyses of CVD events have been described in Chapter 5, section 5.4.3.

In this thesis disability refers to incident mobility limitation, incident ADL difficulty and incident IADL difficulty. Two questions asking the participants whether they had problems taking the stairs and problems walking 400 yards with answer options ‘yes/no’ were used to assess mobility limitation. Reporting problems with one or both was classified as having mobility limitations. ADL was classified as having some difficulty or in need of help undertaking one or more of the following activities: bathing, dressing, eating, getting in or out of bed or chair, toileting, and/or walking across a room. IADL was based on reporting some problem or in need of help undertaking cooking, shopping, using public transport, managing money and/or using the telephone. Participants with no mobility limitation, no ADL difficulty and no IADL difficulty, respectively, in 2003 (baseline) were followed-up for incident disability to 2005.

3.4. Strengths and limitations of the data source for the intended analyses

3.4.1. Strengths of BRHS

The BRHS is a suitable cohort for studying objectives 1-3 in this thesis for several reasons. First, detailed follow-up of objective measurements on CVD events and mortality allows for the prospective investigation of the relationship between sensory impairments and the risk of CVD and mortality. Second, data collection and recording have been maintained to a very high standard since baseline in 1978-80 and the cohort has benefited from high response rates throughout the follow-up with 82% of those still alive completing the follow-up questionnaire in 2003 (n=3981). The majority of participants provided an answer to most questions with a few participants not completing the questions on social class (n=117 (3%)), physical activity (n=238), smoking (n=33), self-reported general health (n=54) and social interaction (n=62). Therefore all 3981 participants formed the baseline data sample. Third, BRHS is a large population-based socio-economically and geographically diverse cohort of older British men. At the start of the study (1978-80), characteristics of non-respondents (those who declined or failed to reply to the invitation and one reminder) were recorded and compared to the study participants and showed that non-respondents were younger, more likely to be unmarried, and more likely to be less skilled workers compared to participants.[265] Death registration details including cause of death were obtained for both respondents and non-respondents and showed that in the first three years of follow-up, non-respondents had a higher total mortality rate, but this declined to non-significant levels over time. Also, CVD mortality rates were similar in participants and non-respondents, suggesting that the analyses on CVD mortality in this thesis should not be biased by non-respondents. Nevertheless, compared to respondents, non-respondents (n=717) of the 2003 questionnaire (baseline data for the analyses in this thesis) were more likely to be older ($p<0.01$), from manual social class ($p<0.01$) and reporting poor self-rated health ($p<0.01$) at the previous data collection point (1998-2000, n=4252). Fourth, extensive data on several types of disability have been collected. This enables prospective analyses of sensory impairments and subsequent mobility limitations, ADL difficulties and IADL difficulties. Finally, data on both hearing impairment and vision impairment, which are the exposure variables, have been collected using validated questions.

3.4.2. Limitations of BRHS

Limitations of BRHS include that the cohort sampling did not include cities and towns of known high mobility and hence has a small proportion of non-white ethnic minority groups resulting in exclusion of highly mobile people and ethnic minorities. Also, in the mid-1970s when the BRHS was initiated, the risk of CVD was lower in middle-aged women compared to middle-aged men. A very large number of women subjects would have been required to ensure an adequate number of CVD endpoints, considerably increasing the costs of the study. Therefore, funding was given to recruit men.[81] Finally, BRHS data available at the start of this PhD did not include data on frailty and cognitive function. Therefore, data from the English Longitudinal Study of Ageing were used to undertake analyses on sensory impairments and frailty.

3.5. The English Longitudinal Study of Ageing

3.5.1. Description of cohort

The English Longitudinal Study of Ageing (ELSA) (https://www.elsa-project.ac.uk/) is a longitudinal cohort study designed to be a nationally representative sample of English men and women aged 50 years and over and their partners, living in a private residential address drawn from households that participated in the Health Survey for England (HSE) between 1998 and 2012.[266] ELSA was initiated to complete the picture of growing older in the 21st century and to explain what accounts for the variety of patterns observed. Since 2002, participants have been followed-up every two years for health and wellbeing, lifestyle factors, economic circumstances and psychosocial health. Every four years starting in 2004 the data collection has been supplemented with a physical examination conducted by a nurse. The interview questionnaires have furthermore been designed to allow for comparability of results with other international longitudinal studies on ageing including the US Health and Retirement Study (HRS) and the Survey of Health, Ageing and Retirement in Europe (SHARE).[267]

3.5.2. Funding and ethical approval

ELSA is funded by the US National Institute on Aging and by a consortium of British Government departments led by the Office for National Statistics (ONS) including Department of Health, Department for Transport, Department of Work and Pensions, Department of Environment, Food and Rural Affairs, Her Majesty's Treasury, Communities and Local Government (formerly Office of the Deputy Prime Minister) and Her Majesty's Revenue and Customs. Ethical approval was granted from NHS Research Ethics Committees under the National Research and Ethics Service (NRES). All participants have provided written informed consent to the research study.

3.5.3. Sample design

The original sample of participants was based on nationally representative samples of private households responding to the annual cross-sectional Health Survey for England (HSE) in 1998, 1999 and 2001. The sample was drawn by postcode sector and stratified by proportion of households headed by someone in a non-manual occupation. Individuals in households participating in any of the three HSE surveys who were still alive, aged 50 years or older (born on or before 29th February 1952) and had given permission to be re-contacted in the future were classified as age-eligible and invited to participate. Cohabiting partners under the age of 50 years at the time of interview and partners who had joined the household since the HSE interview were also invited to the study to supplement the data collected from the age-eligible subjects in order to understand behaviour within a couple or household. More than 17,000 age-eligible individuals from HSE 1998, 1999 and 2001 (treated as ELSA wave 0) were identified and 11,391 of them (55% women) were successfully recruited into the study, providing a response rate of 67%. An additional 708 cohabiting partners (636 partners under the age of 50 years and 72 new partners) were recruited (56% response rate), generating a total number of 12,099 participants completing the first interview in 2002-03, referred to as wave 1.[268, 269] Age-eligible individuals who participated in wave 1 were defined as core participants. Figure 3.4 (page 111) shows the number of participants at each wave of the ELSA and indicates when replenishment samples have been added to the core sample.

3.5.4. Baseline interview

When ELSA was initiated in March 2002 (wave 1), all 12,099 participants were interviewed face-to-face and asked to complete a self-administrated questionnaire. A total of 277 trained interviewers conducted an average of 44 interviews each and wherever possible interviewers were assigned to the same households at follow-up interviews. The interviews undertaken at each wave generally started in February or March of the designated year and ended in January or February the following year. Respondents were interviewed individually in their homes. In households with more than one eligible respondent a concurrent interview was offered. The interview included questions on health, wellbeing, lifestyle factors, economic circumstances and psychosocial health. Objective measures of cognitive function and a gait speed test were also obtained part of the interview. The self-administrated questionnaire included questions on social participation and quality of life which was completed and returned to the interviewer on the same day or by post.

3.5.5. Follow-up of participants from baseline and replenishment of sample

Since wave 1, all participants have been followed-up for changes to their health, wellbeing, lifestyle and financial situation every two years through face-to-face interviews. In addition, a physical examination and blood sample have been taken by a nurse every four years starting at wave 2 in 2004-05. The sample has furthermore been replenished at waves 3, 4, 6 and 7 with new participants who just entered their 50s drawn from recent survey years of the HSE to ensure the study still covers the very youngest age range (those aged 50-54 years) (Figure 3.4).[267] Proxy interviews were pursued for eligible respondents who were physically or cognitively impaired, in hospital or temporarily in care for the whole of the data collection period. Any adult who knew enough about the respondent’s circumstances to be able to provided information about them could act as a proxy informant. Participants who moved into an institution (care or nursing home) after their first ELSA interview are still eligible for follow-up interviews. The same interview questionnaire is used for participants in private households and participants in institutions but with fewer questions on income, assets and housing.

3.5.5.1. Interview questionnaires

The two-yearly face-to-face interviews were based on a structured questionnaire on individual and household demographics, work and pension, income and assets, health, morbidity, disability, lifestyle behaviour, expectations of the future, effort and reward of caring and care service and psychosocial health. Data provided at previous wave(s) were fed forward to aid recall and improve consistency of responses across interviews. Tests on cognitive function and gait speed were undertaken after or between the survey modules. The interview also included a verbal reminder of the consent given and confirmation of current contact address including contact details of someone who could be contacted if they move. Participants who had moved were primarily traced through the NHS Central Register and the Department of Work and Pension state pension databases.[267]

Following the face-to-face interview, a self-administrated questionnaire was handed out. The questionnaire was used to collect information on social participation, quality of life, life satisfaction and consumption of alcohol, fruit and vegetables. Data on cognitive function, expectations, effort and reward, psychosocial health and confirmation of consent were administrated with no other household member present.

3.5.5.2. Physical examinations

Every four years (waves 2, 4 and 6) the interview has been followed by a separate nurse visit for a physical examination. The nurse visit included data collection on height, weight, blood pressure, lung function, balance and grip strength. Biological samples including blood, saliva and hair samples were also obtained for analysis. Additional consent was given by participants who underwent the nurse assessment. Participants were informed in advance about the elements of the assessment and asked not to eat, smoke, drink alcohol or do any vigorous exercise for 30 minutes before the nurse visit. In addition, those under the age of 80 years who did not have diabetes and were not malnourished and willing to provide a blood sample were asked to fast for at least 5 hours before having their blood sample taken. Blood pressure readings, blood test results and lung function readings were shared with their GP.[270]

Figure 3.5 (page 112) shows a timeline of the ELSA indicating data collection through interviews and physical examinations from wave 1 to wave 7.

3.6. ELSA data used in this thesis

Data from the ELSA have been used in this thesis to assess the relationships between hearing impairment and vision impairment, respectively, and the risk of incident frailty. This section also describes data collection and definition of the two exposure variables hearing impairment and vision impairment, the outcome variable frailty and potential confounding variables are presented below.

3.6.1. Study sample of ELSA used in this thesis

Figure 3.6 (page 113) shows how the data from ELSA used in this thesis were derived. Out of the 9432 original study subjects from wave 1 who also participated at wave 2 (2004) (baseline for my analyses), 5918 were aged 60 years and over. Only participants aged 60 years and over were asked to do a gait speed test which provides data on slow walking, one of the five Fried frailty phenotype components. Participants younger than 60 years therefore had to be excluded from the analyses part of this thesis. 4248 of the 5918 participants aged 60 years and over undertook the physical examination and gait speed test at wave 2 and wave 4, however, 1412 of them did not provide complete measures on one or more of the frailty components at wave 2 and/or wave 4 and were excluded as data on all Fried frailty components are needed to identify different stages of frailty (non-frail, pre-frail and frail) (as described in Chapter 2, section 2.6.1). The final sample therefore consisted of 2836 participants with complete data on frailty (67% of ELSA participants aged 60 years and over who underwent physical examinations at both wave 2 (baseline) and wave 4). These participants also had complete data on hearing function and vision function and complete data on age, sex, CVD, diabetes, cognitive function, mobility and falls at wave 2. One percent of participants did not provide information on wealth (n=40) and BMI (n=40), and a few participants had no information on smoking status (n=5) and depression (n=12) at baseline (wave 2) and were reported as missing.

3.6.2. Measures of hearing function

In the face-to-face interview at wave 2, hearing was based on the question ‘Is your hearing, using a hearing aid if you use one…’ with answer options ‘Excellent, very good, good, fair, or poor’. The question has been validated and shown to be appropriate to determine hearing impairment[99] (see Chapter 2, section 2.2.2). The five answer options were grouped into two categories: good hearing (excellent, very good,

good) and poor hearing (fair, poor). Those classified as having good hearing were considered having no or minimal hearing impairment. All 2836 respondents with complete data on frailty at wave 2 and wave 4 had answered the question on hearing.

3.6.3. Measures of vision function

Vision was measured in the face-to-face interview at wave 2 by asking participants ‘Is your eyesight, using glasses or corrective lens if you use them… Excellent, very good, good, fair, or poor’. The question has reported high sensitivity and specificity when tested against objectively assessed vision impairment[130] (as described in Chapter 2, section 2.3.2). Out of 2836 participants with complete data on frailty at wave 2 and wave 4, 2819 answered the question and the remaining 17 participants spontaneously reported they were registered or legally blind. Two categories were developed: participants with excellent, very good and good vision were classified as having good vision (no vision impairment). Those who reported fair or poor vision and those who reported being registered or legally blind were classified as having a vision impairment (poor vision).

3.6.4. Measures of socio-demographic factors and morbidity

<u>Age, wealth and education</u>

Information on date of birth was provided at wave 1 when entering the study. Participants aged 90 years and over were collapsed to avoid identification due to small numbers. In each face-to-face interview, participants provided detailed information on income and financial and physical assets of the household (a single adult or a couple and any dependent children) over the last 12 months. Information on income and assets was provided by one participant per household. The sum of net primary housing wealth, net physical wealth (other property wealth, business wealth and other physical assets) and net financial wealth for the household was used to estimate total non-pension wealth and presented by quintiles. Wealth is regarded as a robust measure in later life because earnings in older age are often low and older adults with poor income may still have high living standards as a result of previously accumulated savings.[271] Data on participants’ highest educational qualification was reported at wave 1 and the question was fed forward at wave 2, asking participants if they had a degree, higher education below degree level, general certificate of education (GCE), certificate of secondary education (CSE), foreign qualification or no qualification.

Morbidity, smoking and falls

Part of the interview at wave 1, participants were asked to indicate if they had been diagnosed with any of the following morbidities: hypertension, angina, heart attack (defined as myocardial infarction or coronary thrombosis), diabetes and stroke with answer options ‘yes/no’ to each of the conditions. At wave 2, participants were asked about any newly diagnosed cardiovascular conditions in the past two years since wave 1. Information provided on each of the morbidities at wave 1 and wave 2 were combined. Diagnoses of angina, heart attack and/or stroke were combined into cardiovascular disease.

Questions in the face-to-face interviews sought furthermore information from participants on their lifestyle and history of falls. Participants were asked whether they smoke cigarettes at all nowadays. Participants were also asked if they had had a fall in the last two years. To each question a ‘yes/no’ response was provided.

Cognition

A cognitive function score was derived for each of the three memory categories assessed in the interviews at wave 2 and wave 4 including tests of immediate and delayed recall of 10 words and orientation to the day and date.[272] A randomly assigned list of 10 common nouns was presented by a recorded computer voice to the participant once. The volume was adjusted prior to the test if necessary. Different lists of words were given to different members of the same household. Participants were asked to recall as many words as possible immediately after the list was read and then again after a five minute delay during which they completed other survey questions. The words could be recalled in any order and were written down by the interviewer. The number of words recalled correctly for each of the two tests was recorded. Orientation was assessed by asking participants to give the day, date, month and year. The interviewer recorded each of the correct answers given. Scores were assigned for each correct answer providing a scale ranging from 0 to 24 points (10 points for immediate recall, 10 points for delayed recall, and 4 points for orientation). The three memory categories have been assessed in two longitudinal studies (the Health and Retirement Study (HRS) and the Asset and Health Dynamics among the Oldest Old (AHEAD)). The memory tests, in particular the tests on immediate and delayed recall, have provided evidence for reliability demonstrating consistency over time between HRS and AHEAD.[273]

Depression

In the face-to-face interview at wave 2, data on depression were collected using the 8-item version of the Center for Epidemiologic Studies Depression scale (CES-D).[274] The 8-item CES-D scale is commonly used in large population-based studies including HRS,[275] AHEAD[276] and the European Social Survey.[277] The scale has also been shown to be a valid and reliable instrument for screening depression in community-dwelling older adults.[277, 278] Questions asked part of the CES-D scale relate to feelings experienced in the past week including whether the individual felt everything they did was an effort, if their sleep was restless, if they most of the time felt depressed, happy, lonely, sad, enjoyed life, and if they could not get going. Participants provided a 'yes/no' response to each question. The question on whether they felt happy and the question on whether they had enjoyed life in the past week were converted into 'not felt happy' and 'not enjoyed life' to give each of the questions the same value. The questions on whether they felt everything they did was an effort and whether they could not get going most of the time during the past week were part of the definition of the outcome variable frailty and therefore excluded. A score based on the remaining six questions was derived for each respondent ranging from 0-6. Participants were classified into two categories: not depressed (score 0-1) and depressed (score 2-6).

Social engagement

The self-administrated questionnaire completed at wave 2 included a question on how often the participant feels they lack companionship. Participants were asked to rate their lack of companionship as hardly ever or never, some of the time, and often.

3.6.5. Outcome

The outcome variable of the analysis using ELSA data was incident frailty. Data on the five components of the Fried frailty phenotype used including gait speed, grip strength, exhaustion, weight loss and physical activity were obtained at wave 2 (2004) and wave 4 (2008).[18] The Fried phenotype is the most commonly used frailty measure and was developed using data from the Cardiovascular Health Study, a prospective, observational study of community-dwelling men and women aged 65 years and older. In the original study, gait speed was based on a 15 feet walk and the slowest 20% of the participants (adjusting for sex and height) were classified as slow. Weight loss was defined as unintentional loss of 10 pounds or more, or 5% or more of body weight in the prior year. Exhaustion was self-reported and based on answering yes to any of the two questions from the Center for Epidemiologic Studies Depression scale

(CES-D) ‘Felt that everything I did was an effort in the last week’ and ‘Could not get going in the last week’. Poor grip strength was based on being in the lowest 20% after adjustment for sex and body mass index (BMI). A weighted score of kilocalories expended per week based on self-reported data was used to classify the lowest 20% (taking sex into account) as having low physical activity levels. The Fried phenotype has demonstrated validity in predicting adverse outcomes associated with frailty including falls, hospitalisation, disability and death independently of socio-demographic factors and morbidity.[18] The following paragraphs in this section (3.6.5) describe how frailty was assessed in this thesis using ELSA data.

<u>Gait speed</u>

In ELSA, all respondents aged 60 years and over able to complete the self-administrated questionnaire at wave 2 and wave 4 were eligible for the gait speed test. The test was performed as part of the face-to-face interview and measured as the time taken to walk a distance of 8 feet (2.4m) at their usual pace. Any walking aids used were allowed and recorded. If space allowed, the interviewer stood close enough to the participant to offer support should they lose balance. The criteria for an acceptable test included: i) the participant started with both feet together at the beginning of the 8 feet course; ii) the timing was started when either (whole) foot was placed down on the floor across the start line; iii) the participant did not race; iv) the participant walked all the way past the end of the tape measure; and v) the timing was stopped when either (whole) foot was placed down on the floor across the finish line. If the criteria were not met, the attempt was not recorded. Participants were asked to walk the course two times. Results were recorded as displayed on the stopwatch in hundredths of a second. The mean of the time taken to complete the walk twice was used for the Fried frailty phenotype. Gait speed was then calculated in relation to participants’ sex and height. Measurements of height were taken using a Stadiometer with the Frankfurt plane in the horizontal position while the participant was standing and obtained part of the HSE data collection in 1998, 1999 and 2001 (‘wave 0’) and in the physical examinations at wave 2 and wave 4. Height was divided at the sex-specific median in order to categorise those in the lowest sex- and height-specific quintile of the distribution as having slow gait speed. Gait speed has previously been reported to be a reliable and valid measurement for older adults’ walking performance showing an association with other objectively assessed measures of physical functioning such as standing balance and repetitive chair stands.[279]

Grip strength

All participants who undertook the physical examinations at wave 2 and wave 4 were eligible for the grip strength measurement. Participants who had swelling or inflammation, severe pain, a recent injury or surgery to the hand in the preceding 6 months were excluded. The grip strength measurement was explained and demonstrated and participants were asked for their consent to take part. The gripometer (grip strength gauge) 'Smedley's for Hand Dynamometer scale 0-100kg' (Lafayette Instruments) was used and adjusted to suit the participant's hand size and positioning. Participants were asked to squeeze the grip gauge as hard as they could for a couple of seconds. Three values were recorded for each hand, starting with the non-dominant hand and alternating between hands. The best value of the six measures recorded (maximum grip strength) was used for calculating frailty. Maximum grip strength of dominant hand using Smedley's dynamometer in older adults has been validated against IADL ($p<0.001$) and walking performance ($p<0.001$).[280]

Exhaustion

In the face-to-face interviews at wave 2 and wave 4, the 8-item version of the Center for Epidemiologic Studies Depression scale (CES-D) was assessed. Two of the eight items referred to self-reported exhaustion: 'Felt that everything I did was an effort in the last week' and 'Could not get going in the last week'. Participants provided a 'yes/no' response to each question. Exhaustion was defined as responding 'yes' to any of these two questions.

Weight loss

Data on weight measurements were obtained every 4 years including HSE in 1998, 1999 and 2001 (wave 0) and from ELSA wave 2 and wave 4. Participants were asked to wear light clothing, no shoes and to remove heavy jewellery and empty their pockets from loose change and keys. Weight was measured while the participant was standing. At wave 0 a Soehnle scale (Critikon Service Center) was used. At wave 2 and wave 4 a Tanita THD-305 Scale (Tanita Europe BV) was used. Both scales are electronic and provided the weight in metric units to the last complete 0.1 kg. No information on any weight loss being intentional or unintentional was provided. Therefore a validated modified version of the Fried frailty component weight loss was used, defining weight loss as either loss of 10% or more of body weight in the last 4 years or current body mass index (BMI) under 18.5 kg/m^2.[281]

Physical activity

The interviews at wave 2 and wave 4, included data on physical activity collected by asking participants about the frequency with which they undertook vigorous, moderate and mild sports and activities. The questions were extracted from a validated physical activity survey employed in the Health Survey for England (HSE).[282] Each question had 4 response options: more than once a week, once a week, one to three times a month, hardly ever or never. A physical activity score was derived based on intensity and frequency of activity.[283, 284] Participants who hardly ever or never engaged in vigorous, moderate and mild activity were classified as sedentary. Engaging in mild activity one to three times a month, once a week or more than once a week, or engaging in moderate activity one to three times a month was classified as low activity. Participants engaging in moderate activity once a week or more than once a week or vigorous activity one to three times a month were classified as being moderately active. Undertaking vigorous activity once a week or more than once a week was classified as high activity. This physical activity score has demonstrated validity against muscle strength[285] and depression[283, 286] in older adults.

3.7. Strengths and limitations of ELSA

3.7.1. Strengths of ELSA

There are several reasons ELSA is a suitable cohort for studying objective 4 in this thesis. First, data on the outcome variable frailty using the validated Fried Phenotype are available at wave 2 and wave 4. Second, data on the exposure variables hearing and vision have been collected using validated questions. Third, data have been collected regularly using the same questions and measurement allowing for prospective analyses of sensory impairments and incident frailty. Finally, ELSA was designed to be a nationally representative cohort of English men and women aged 50 years and over.

3.7.2. Limitations of ELSA

ELSA participants were drawn from HSE which itself is a sample of the population and 33% of eligible HSE participants chose not to participate in ELSA. The sample used for the analyses conducted part of this thesis were further restricted to participants with complete data on frailty in both 2004 and 2008. Of 5918 participants aged ≥ 60 years in 2004 (baseline for the analyses in this thesis), 1670 were lost to follow-up in 2008. Compared to respondents, non-respondents were more likely to be older ($p<0.01$), male ($p=0.01$), poorer wealth ($p<0.01$), being a current smoker

($p<0.01$) and having self-reported doctor-diagnosed CVD ($p<0.01$). Furthermore, ELSA is confined to England and includes people predominantly of white British ethnic origin, and generalisation of findings to other ethnic groups is therefore limited. Finally, a substantial proportion of the participants did not undertake the physical examination restricting analyses involving physical measures to participants who are more likely to be healthier, negatively affecting the representativeness of the cohort.

3.8. Data verification, descriptive analysis and statistical methods used for BRHS and ELSA

Data verification and descriptive analyses of BRHS and ELSA are described below in section 3.8.1. The main statistical methods used in this thesis are described in sections 3.8.2 and 3.8.3. Details of the statistical analyses undertaken are described in each of the results chapters.

3.8.1. Data verification and descriptive analysis

Each variable was summarised descriptively including tables of proportions for categorical variables and calculations of means and standard deviations for continuous variables. Continuous variables were also evaluated by graphs to assess the distribution and outlying values. Because the amount of missing data in BRHS was low, all 3981 participants who completed the questionnaire in 2003 including those with partial missing data were included in the analyses. Data cleaning of the ELSA sample used has been described above in section 3.6.1. ELSA participants with missing data on any frailty component at baseline and follow-up were dropped from the analyses. Those with partial missing data on other variables (wealth, BMI, smoking, depression) were included in the analyses as the number of participants with missing data on these variables was low.

3.8.2. Logistic regression model

Logistic regression is used to analyse the relationship between a dichotomous outcome variable and one or more exposure variables.[287] This involves generating the odds ratio of the outcome by dividing the odds in the exposed group by the odds in the unexposed group. Logistic regression does not require a linear relationship between the exposure and outcome variables (i.e. the outcome variable does not have to be normally distributed) because it applies a non-linear log transformation to the predicted odds ratios.[287] In this thesis, logistic regression has been used to assess the cross-sectional and longitudinal associations between impairment in hearing and vision and categorical measures in the BRHS and the ELSA (Chapters 4-7).

3.8.3. Survival analysis and Cox proportional hazards regression analysis

Survival analysis is used to examine the probability of having an event where the time to a binary event e.g. death, is the main outcome of interest.[287] Survival time for each participant is the time from a predetermined start point e.g. entry into the study, until the occurrence of the event of interest. The time to the event of interest is censored if the event has not occurred by the end of follow-up, the participant is lost to follow-up after a certain date or if the participant dies from a cause other than the event of interest. The Kaplan Meier method is used to calculate the survival probability and to plot survival curves.[145]

The Cox proportional hazards regression analysis examines the association between the exposure variable and the time to event outcome variable, and is the most commonly used approach to the regression analysis of survival data. It assumes the ratio of the hazards, which compares different exposure groups, is constant over time. This assumption is known as the proportional hazards assumption. A formal test such as the Schoenfeld residuals can further be performed to determine if the proportional hazards assumption is violated.[145]

Survival analysis and Cox proportional hazards regression analysis have been used to assess the prospective associations between measures of hearing impairment and vision impairment in 2003 with the risk of cardiovascular events and mortality over 10 years of follow-up (Chapter 5).

Statistical analyses using BRHS data were performed using SAS 9.3 software (SAS Institute, Inc, Cary, NC, USA). For the statistical analyses using ELSA data SPSS version 22 (IBM Corp, Armonk, NY, USA) was used. All statistical calculations undertaken were cross-checked by a statistician and the interpretations of the results were discussed with the thesis supervisors.

3.9. Search strategy for relevant literature

Searches to identify cross-sectional and longitudinal studies of impairments of hearing and vision and the outcomes of interest (cardiovascular disease and mortality, disability and frailty) were conducted by entering keyword/index terms into the database MEDLINE as Medical Subject Headings (MeSH), MeSH subheadings (where applicable), key-terms and as title and abstract word searches. Searches combined terms of older adults (population) with terms for hearing impairment and vision impairment separately (exposure) and for each of the key outcomes (CVD, mortality, disability and frailty). I restricted for studies on humans, but no restrictions were included for study design or language. Searches were conducted in 2014 and then updated in early 2017, with no date restrictions on the searches (i.e. from inception).

Searches for relevant literature also included forwards, backwards and lateral citation tracking, checking reference lists of relevant papers, using the ‘Related articles’ option on PubMed and the ‘Cited by’ option on Google Scholar. Resources about ageing and/or sensory impairments produced by the government, national and local organisations and relevant charities were also searched via web-searches. The search terms for relevant literature are outlined in Appendix I (page 219).

Table 3.1 Towns included in the British Regional Heart Study

Town	**Standardised mortality ratios (SMR) for cardiovascular disease in men aged 35-65 years in 1969-73**	**Men examined (n)**	**Response rate (%)**
Ayr	140	301	70
Bedford	80	303	73
Burnley	114	286	80
Carlisle	121	389	85
Darlington	109	382	82
Dewsbury	142	326	79
Dunfermline	118	350	80
Exeter	90	332	84
Falkirk	98	308	75
Gloucester	84	309	73
Grimsby	96	318	71
Guildford	78	335	82
Harrogate	82	280	77
Hartlepool	101	334	70
Ipswich	92	362	85
Lowestoft	85	324	83
Maidstone	99	319	72
Mansfield	95	321	80
Merthyr Tydfil	135	282	76
Newcastle-upon-Lyme	115	293	77
Scunthorpe	109	313	76
Shrewsbury	95	310	83
Southport	114	322	80
Wigan	134	337	77

Data source: Adapted from Shaper et al. 1981[244]

Figure 3.1 Map of Great Britain showing the 24 towns of the British Regional Heart Study

Figure 3.2 Timeline showing follow-up of the British Regional Heart Study cohort

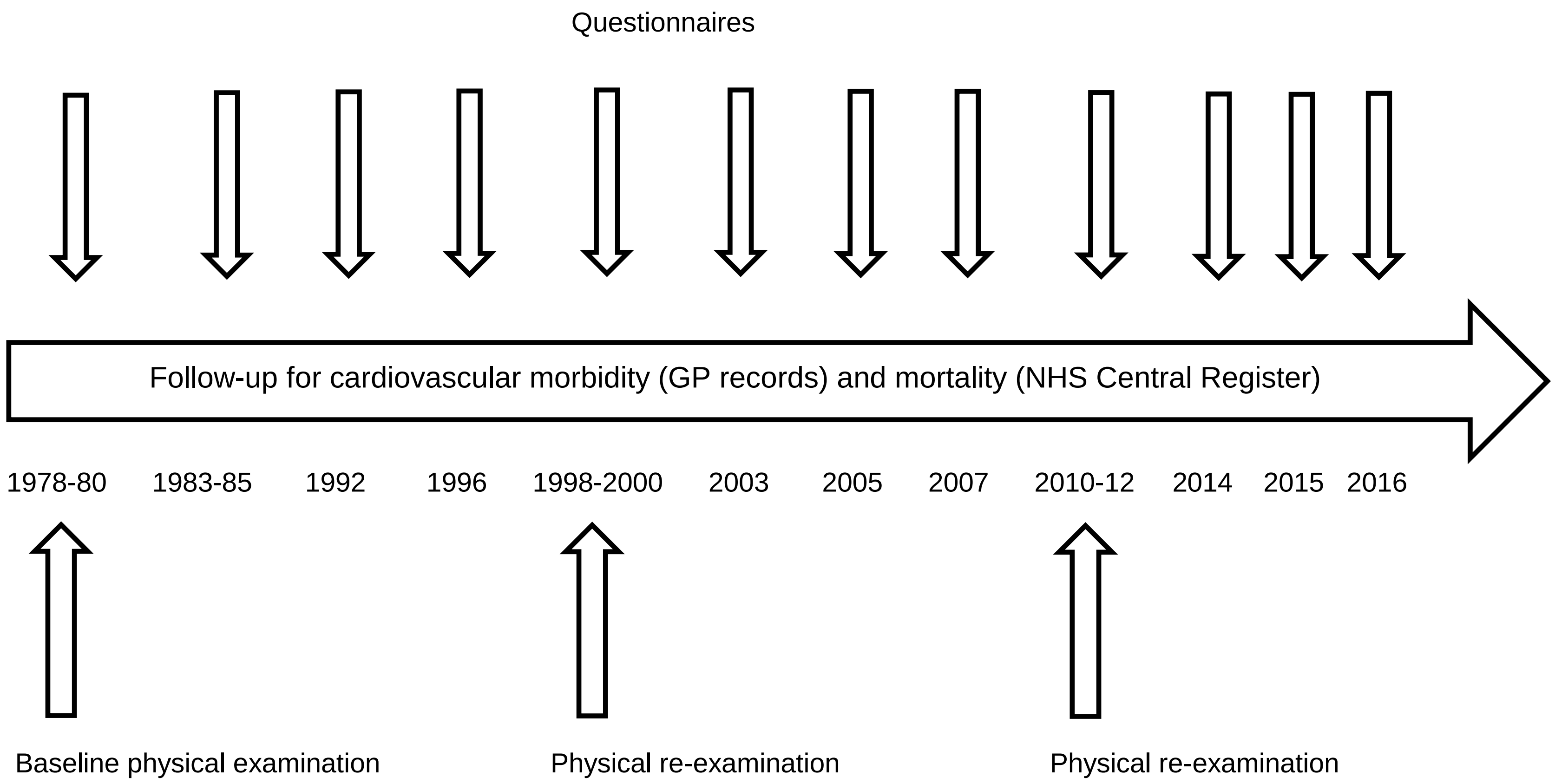


Figure 3.3 Development of hearing impairment score in the British Regional Heart Study

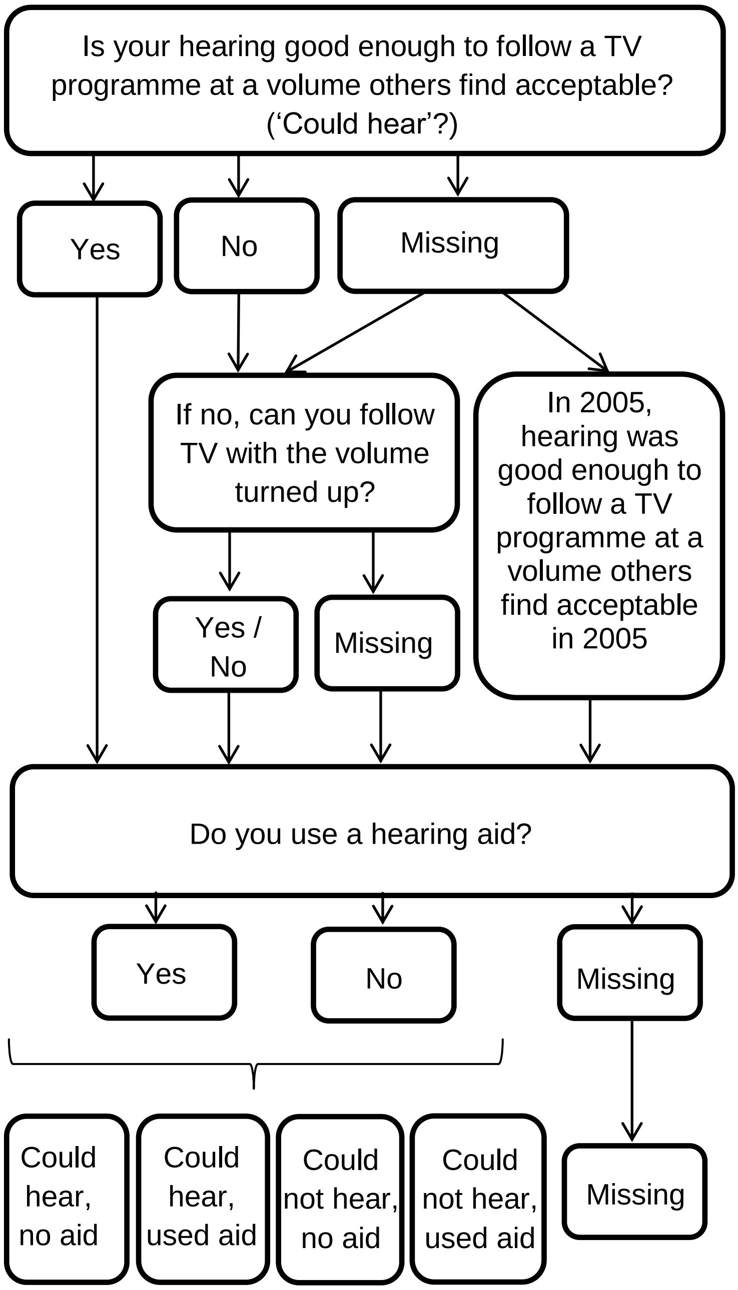
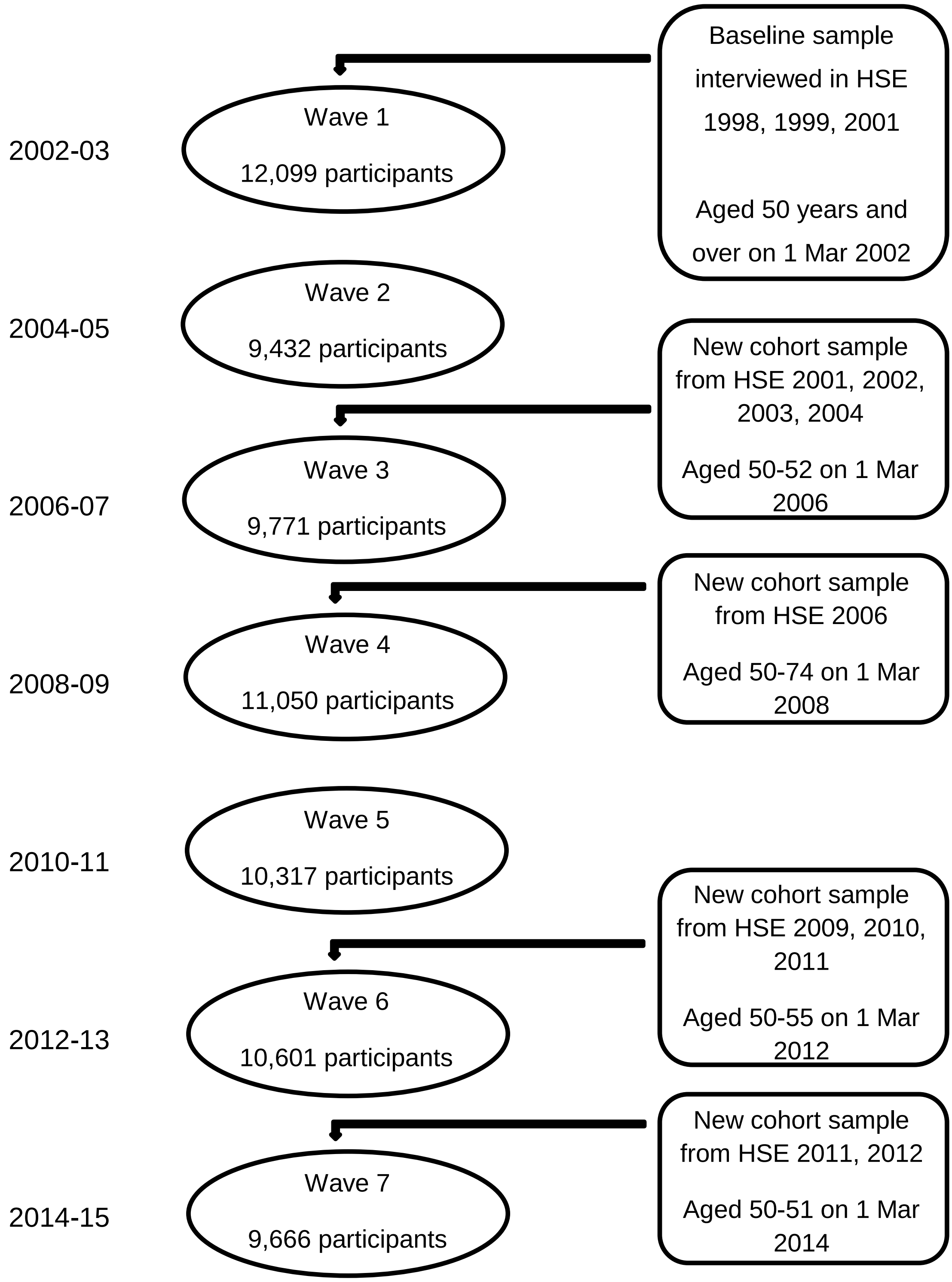


Figure 3.4 Timeline showing the number of participants for each wave in the English Longitudinal Study of Ageing



Data source: Adapted from Steptoe et al. 2013[269]

Figure 3.5 Timeline showing follow-up of the English Longitudinal Study of Ageing

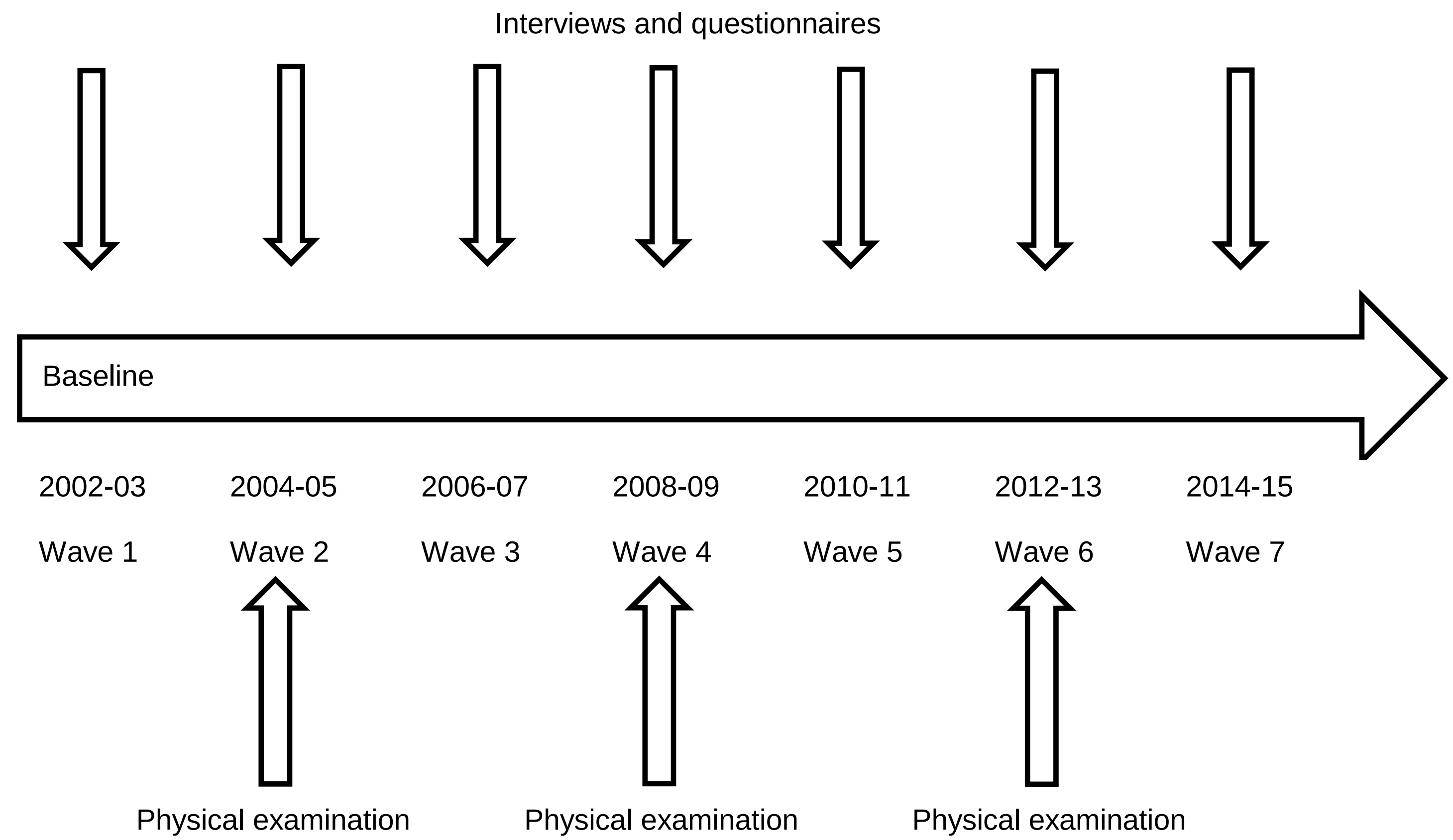
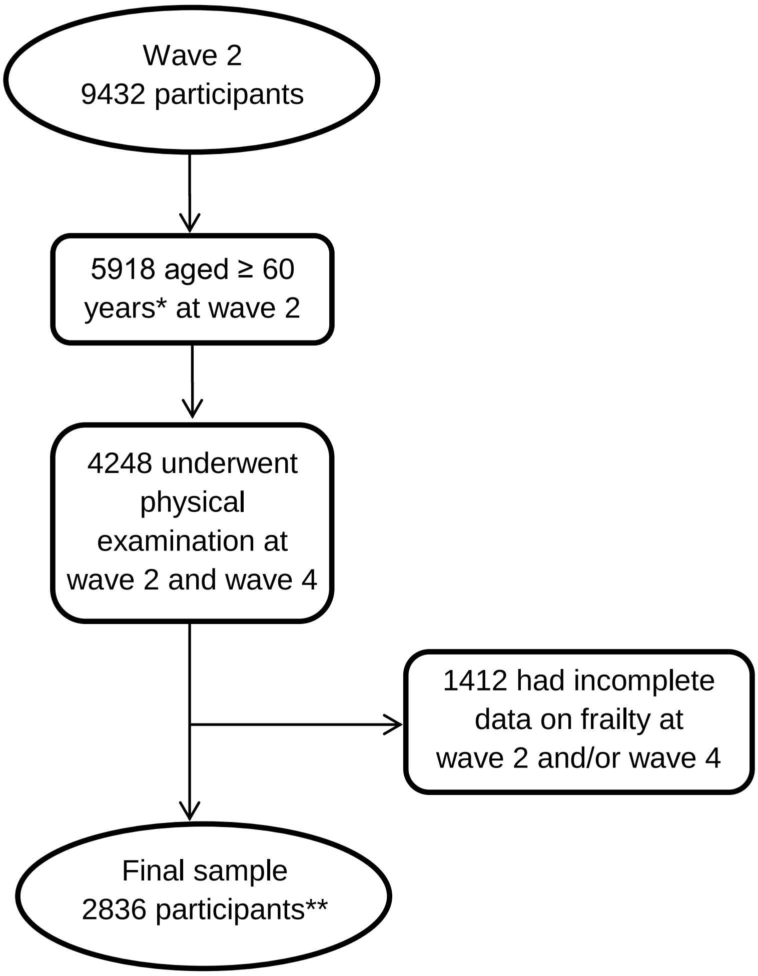


Figure 3.6 Derivation of the ELSA sample for this thesis



*Frailty component gait speed was assessed in participants aged ≥ 60 years only

**67% of those aged ≥ 60 years who underwent physical examinations at both wave 2 and wave 4

CHAPTER 4 Cross-sectional associations of sensory impairments with socio-demographic characteristics, lifestyle factors and burden of morbidity in older British men

4.1. Summary

Sensory impairments (hearing impairment and vision impairment) affect a significant proportion of older adults and have been associated with chronic conditions such as cardiovascular disease (CVD), CVD risk factors, poor physical functioning and low social engagement. In this Chapter, cross-sectional associations of sensory impairments in older adults with socio-demographic characteristics, lifestyle factors, burden of morbidity and physical and social functioning have been investigated. In the British Regional Heart Study (BRHS), 3981 men aged 63-85 years, completed a self-administrated questionnaire in 2003 on their health and lifestyle including questions on hearing and vision. A hearing score was developed based on hearing aid use and ability to hear the TV at a volume others find acceptable which allowed for four categories of hearing: could hear (no hearing impairment), could hear and used a hearing aid, could not hear and no hearing aid, and could not hear and used a hearing aid. Vision impairment was defined as not being able to recognise a friend across the street. Logistic regression was used to analyse the relationships. Overall, 27% reported hearing impairment and 3% reported vision impairment. Compared to men who could hear, men who could not hear, irrespective of use of hearing aid, were more likely to report poor quality of life, poor social interaction and poor physical functioning. Men who could not hear and used a hearing aid were also more likely to have CVD (age-adjusted odds ratios (OR) 1.93, 95% CI 1.40-2.66). Vision impairment was associated with symptoms of CVD including breathlessness (OR 2.06, 95% CI 1.38-3.06) and chest pain (OR 1.58, 95% CI 1.07-2.35). Vision impairment was also associated with poor quality of life, poor social interaction and poor physical functioning.

4.2. Introduction

Impaired hearing and vision are common chronic health problems in later life. Recently, sensory impairments have become a growing concern among older adults,[102] who form a rapidly increasing proportion of the population.[288] Earlier studies have reported a relationship between hearing impairment in older age and CVD.[10, 16, 17, 104] Some previous research has further shown a relationship between hearing impairment and low social engagement,[147] and smoking,[102] although these findings are not consistent.[63, 289] There is also evidence that hearing impairment is associated with poor physical functioning and disability including difficulty in performing activities of daily living (ADL) and instrumental ADL (IADL),[63, 64] and poor quality of life.[290] Similarly, vision impairment in later life has also been associated with CVD,[11, 17] with vision impaired older adults being twice as likely to report CVD as those not having vision problems.[16] Age-related vision impairment has also been associated with diabetes[117] and smoking.[165, 291] Previous studies have also shown associations between vision impairment and both ADL and IADL difficulties,[130, 148, 197] falls,[11, 53] poor quality of life[124] and social problems.[130, 172] However, there are relatively few population-based studies, particularly in the UK, on the associations of sensory impairments in older adults and socio-demographic characteristics, physical functioning, quality of life and the overall burden of other health conditions including cardiovascular health problems in community-dwelling older adults. Research of the impact and contribution of sensory impairments to ill-health in older adults is needed both to assess the scope of the problem and to identify modifiable lifestyle factors associated with sensory impairments as potential targets for prevention. Therefore, this Chapter aims to investigate the association of hearing impairment and vision impairment with lifestyle factors, chronic conditions, physical functioning, quality of life and social interaction in older British men using data from the British Regional Heart Study (BRHS).

4.3. Objectives

This Chapter aims to examine the relationship of sensory impairments with socio-demographic characteristics, lifestyle factors and burden of morbidity in older men (63-85 years). The specific objectives of this Chapter are:

i) To describe the prevalence of hearing impairment and vision impairment in a cohort of older British men.
ii) To examine the associations of sensory impairments with socio-demographic characteristics, chronic conditions including cardiovascular disease, cardiovascular risk factors including lifestyle factors, physical functioning, social functioning and quality of life.

4.4. Methods

Information on the British Regional Heart Study (BRHS) including selection of participants, collection of data and data verification has been described in Chapter 3 (sections 3.2 and 3.8). This section (section 4.4) focuses on the data used for the analyses of this Chapter.

4.4.1. Subjects and methods of data collection

Cross-sectional data from the BRHS self-administrated questionnaire in 2003 are used in this Chapter to investigate the objectives. Analyses are based on 3981 men (82% of survivors), aged 63-85 years in 2003, who reported on health and lifestyle factors including questions on hearing impairment and vision impairment, which have been described in detail in Chapter 3 (section 3.3).

4.4.2. Hearing and vision impairments

Data from self-completed questions on hearing aid use and ability to hear good enough to follow a TV programme at a volume others find acceptable were combined which allowed for four categories of hearing: 1) could hear good enough to follow a TV programme and did not use a hearing aid (could hear, no aid), 2) could hear good enough to follow a TV programme and used a hearing aid (could hear, used aid), 3) could not hear good enough to follow a TV programme and did not use a hearing aid (could not hear, no aid), and 4) could not hear good enough to follow a TV programme and used a hearing aid (could not hear, used aid). Participants in the group ‘could hear, no aid’ were classified as having no hearing impairment and formed the reference group.

Vision was assessed by asking participants whether they could see good enough to recognise a friend across a road. Those who reported seeing good enough to recognise a friend across a road were categorised as having no vision impairment and formed the reference group. Participants who could not recognise a friend across a road were classified as having vision impairment.

4.4.3. Age, socio-demographic and lifestyle factors

Participants’ age in years was presented as four groups: less than 70, 70-74, 75-79, 80 and over. Social class was based on the longest-held occupation at study entry in 1978-80, classifying participants into six social classes using the Registrar General’s occupational classification, as described in Chapter 3 (section 3.3.3). Participants were classified into three smoking groups: current smokers, have been a smoker in the past (ex-smokers), and never smoked. Physical activity was based on frequency and type of activity and the men were grouped into six broad categories: none, occasional, light, moderate, moderately vigorous and vigorous. Undertaking none or occasional activity was classified as being ‘inactive’. Obesity was defined as a body mass index (BMI) of 30 kg/m^2 and over.

4.4.4. Chronic conditions and physical functioning

Participants were asked to rate their present state of health as excellent, good, fair or poor where excellent or good health, and fair or poor health were combined. The self-completed questionnaire in 2003 further included questions on morbidity asking whether a doctor had ever diagnosed them with heart attack (coronary thrombosis or myocardial infarction (MI)), angina, stroke, diabetes, hypertension, arthritis, bronchitis and depression with answer options 'yes/no'. Prevalent coronary heart disease (CHD) was defined as self-reporting having been diagnosed with heart attack or angina. Prevalent cardiovascular disease (CVD) was defined as having doctor-diagnosed heart attack, angina and/or stroke. The men were also asked whether they ever had experienced breathlessness or chest pain. History of falls was based on self-reported falls in the past 12 months. Reporting one or more falls in the last 12 months was classified as having a history of falls. Mobility limitation was defined as reporting problems taking the stairs or walking 400 yards on their own as a result of a long term health problem. The Katz Activities of Daily Living (ADL) Index was used to assess difficulties undertaking bathing, dressing, eating, getting in or out of bed or chair, toileting and/or walking across a room.[190] The Lawton Instrumental ADL (IADL) scale included problems undertaking cooking, shopping, using public transport, managing money and/or using the telephone.[191] Reporting difficulty undertaking one or more activities in the ADL index and the IADL scale was defined as having ADL difficulty and IADL difficulty, respectively.

4.4.5. Quality of life and social engagement

Quality of life was assessed using three questions from the EuroQol-5D which were analysed individually: experiencing pain and/or discomfort, having walking problems, and experiencing anxiety and/or depression. Reporting moderate or extreme problems for each of these questions was classified as poor quality of life. Social engagement was based on a scale with 'yes' and 'no' responses to participation in nine activities.[263] Participants were asked if they undertake any of the following activities on a weekly basis: voluntary work, go to the pub or a club, attend religious services, play cards or games, visit the cinema, restaurants or sports events, attend a class or course of study, and, if they sometimes go on day or overnight trips and if they have been on a holiday in the last year. Doing three or fewer activities was classified as low social engagement.

4.4.6. Statistical methods

Logistic regression models were used to assess relationships of hearing impairment and vision impairment with lifestyle factors, comorbidity, falls, physical functioning, quality of life and social interaction. The regression models provided odds ratio (OR) with 95% confidence interval (CI). Models were adjusted for potential confounders related to hearing impairment and vision impairment including age, social class, obesity, smoking and physical activity. For the adjustment, BMI was entered as a categorical variable of three groups (BMI <25, 25-29, ≥ 30). Social class (six levels), cigarette smoking status (three levels) and physical activity status (six levels) were also entered as categorical variables. Age was fitted as a continuous variable. Reference categories were no hearing impairment and no vision impairment, respectively.

4.5. Results

Among 3981 men aged 63-85 years in 2003, the mean age was 72 years. The prevalence of overall hearing impairment and vision impairment was 27% (n=1074) and 3% (n=124), respectively. The prevalence of hearing impairment and vision impairment by age is presented in Table 4.1 (page 132). The prevalence of overall hearing impairment and use of hearing aid increased with advanced age. For instance, among men aged 80 years and over, 29% used a hearing aid compared to 10% of men aged less than 70 years. Similarly, among men aged 80 years and over, 7% could not hear and did not use a hearing aid, compared to 3% of participants aged less than 70 years. However, there was no difference by age in the proportion of men who could not hear and did not use a hearing aid. Vision impairment was more common in men aged 80 years and over (4%) than in men aged less than 70 years (2%).

4.5.1. Hearing impairment and social class and lifestyle factors

Table 4.2 (page 133) shows the prevalence and odds ratios (OR) with 95% CI for social class and lifestyle factors for hearing impairment. All three groups of hearing impairment were more likely to be of manual social class compared with men with no hearing impairment (‘could hear’) (age-adjusted OR 1.26, 95% CI 1.03-1.54; OR 1.90, 95% CI 1.54-2.36; OR 1.72, 95% CI 1.24-2.38). However, the association was attenuated upon further adjustment for obesity, smoking and physical activity in those who could hear and used a hearing aid. Compared with men with no hearing impairment, men who could not hear, irrespective of use of an aid, were more likely to be obese (OR 1.41, 95% CI 1.09-1.83; OR 2.12, 95% CI 1.46-3.08). These associations remained significant after further adjustment for social class, physical activity and smoking. Only men who could not hear and used a hearing aid also reported increased odds of being physically inactive compared with men without hearing problem (OR 1.83, 95% CI 1.32-2.52). Men who could hear and used a hearing aid were not more likely to be physically inactive and obese compared with men reporting no hearing impairment. Smoking was not associated with any of the hearing impairment groups.

4.5.2. Hearing impairment and chronic conditions

In Table 4.3 (page 134) the prevalence and odds ratios for overall health and chronic conditions for hearing impairment are presented. Compared with those who could hear, men who could not hear, irrespective of use of a hearing aid, were more likely to report fair/poor health with the highest odds in men who could not hear and used a hearing aid (OR 2.41, 95% CI 1.75-3.31). Self-reported doctor-diagnosed CHD and CVD were associated with men who could not hear and used a hearing aid (OR 1.89, 95% CI 1.36-2.63; OR 1.93, 95% CI 1.40-2.66) and the associations remained after further adjustment for social class, obesity, smoking and physical activity. Breathlessness and chest pain were associated with not being able to hear, irrespective of use of hearing aid. Compared with men who could hear, men who could not hear and used a hearing aid were more than twice as likely to report hypertension (OR 2.08, 95% CI 1.33-3.26), breathlessness (OR 2.51 95% CI 1.78-3.54) and chest pain (OR 2.22, 95% CI 1.60-3.10). Men who could not hear and used a hearing also had greater risks of having had a stroke (OR 2.08, 95% CI 1.33-3.26) compared with men reporting no hearing problem. All three groups of hearing impairment were further associated with arthritis and bronchitis. Diabetes was not associated with any of the hearing impairment groups.

4.5.3. Hearing impairment and physical functioning, quality of life and social interaction

Table 4.4 (page 135) presents the prevalence and odds ratios for physical functioning, quality of life and social interaction according to hearing impairment. Only the group of men who could not hear and used a hearing aid were more likely to report falls and balance difficulty than those with no hearing problem (OR 1.62, 95% CI 1.05-2.48; OR 1.95, 95% CI 1.31-2.90) however the association was attenuated after further adjustment for social class and lifestyle factors. Mobility limitation was associated with not being able to hear irrespective of use of a hearing aid. Having difficulties undertaking activities of daily living (ADL) and instrumental activities of daily living

(IADL) were associated with not being able to hear with the strongest association of IADL difficulty seen in men who used a hearing aid and could not hear (OR 4.66, 95% CI 3.33-6.53). The associations between not being able to hear and ADL and IADL difficulty remained after further adjustment for social class and lifestyle factors. Measures of quality of life show that compared to men who could hear, men who could not hear had significantly higher odds of reporting pain/discomfort, walking problems and anxiety/depression with the highest prevalence observed in men who could not hear and used a hearing aid (pain/discomfort (OR 2.68, 95% CI 1.92-3.75), walking problems (OR 2.65, 95% CI 1.93-3.64), and anxiety/depression (OR 1.79, 95% CI 1.24-2.59)). Those who could not hear, irrespective of use of hearing aid, were associated with low social engagement. However, these associations were attenuated on further adjustment for social class and lifestyle factors.

4.5.4. Vision impairment and social class and lifestyle factors

The prevalence and odds ratios for social class and lifestyle factors for vision impairment are presented in Table 4.5 (page 136). The results show that men who reported vision impairment were more likely to be from manual class (age-adjusted OR 1.89, 95% CI 1.30-2.75). However, the association did not remain after further adjustment for obesity, smoking and physical activity. Vision impairment was significantly associated with men who reported being physically inactive compared with those without vision impairment even after adjusting for social class, obesity and smoking. Smoking and obesity were not associated with poor vision.

4.5.5. Vision impairment and chronic conditions

In Table 4.6 (page 137) the prevalence and odds ratios for overall health and chronic conditions for vision impairment are presented. Vision impairment was strongly associated with fair/poor self-reported health compared with those who could see (OR 2.61, 95% CI 1.81-3.76). Poor vision was also associated with breathlessness (OR 2.06, 95% CI 1.38-3.06) and chest pain (OR 1.58, 95% CI 1.07-2.35) but the associations were attenuated on adjustment for social class and lifestyle factors. Vision impairment was not associated with CHD, CVD, stroke and hypertension.

4.5.6. Vision impairment and physical functioning, quality of life and social interaction

Table 4.7 (page 138) shows the prevalence and odds ratios for physical functioning, quality of life and social interaction for vision impairment. Indicators of low physical functioning associated with poor vision included history of falls (OR 1.82, 95% CI 1.14-2.90), mobility limitation (OR 1.93, 95% CI 1.32-2.82), difficulties with balance (OR 3.17, 95% CI 2.12-4.75), ADL (OR 1.06, 95% CI 1.04-1.07) and, particularly, IADL (OR 3.68, 95% CI 2.49-5.44) compared with reporting no vision impairment. Vision impairment was furthermore associated with the quality of life measures of 'walking problem' (OR 1.87, 95% CI 1.30-2.70) and 'anxiety/depression' (OR 1.66, 95% CI 1.09-2.53). Poor vision was further associated with 2-fold increased odds of low social engagement (OR 2.05, 95% CI 1.40-3.00) in men with vision impairment compared with men with no vision impairment. The association remained after further adjustment for social class and lifestyle factors.

4.6. Discussion

4.6.1. Summary of main findings

This Chapter has examined the relationships between sensory impairments, socio-demographic characteristics, lifestyle factors and burden of morbidity in a cross-sectional study of a cohort of British men aged 63-85 years. The prevalence of hearing impairment was 27%. The findings show that men who could not hear, irrespective of use of hearing aid, were more likely to be from manual social class and were more likely to report poor physical functioning, poor quality of life and low social engagement. Not being able to hear, irrespective of hearing aid, was further associated with greater risks of chronic conditions and obesity. Prevalence of vision impairment was 3% and men with poor vision were more likely to be from manual social class, reporting poor physical functioning, poor quality of life and poor social interaction.

4.6.2. Comparison with previous studies

4.6.2.1. Prevalence of hearing impairment

The prevalence of hearing impairment of 27% in the present study of British men aged 63-85 years is similar to one of the latest national figures of hearing impairment in older adults of similar age estimating that 26% of those aged 61-80 years old living in England, Wales and Scotland have a hearing impairment.[4] Consistent with previous research,[292] hearing impairment increased with advanced age.

4.6.2.2. Hearing impairment and lifestyle factors

Not being able to hear, irrespective of use of a hearing aid, was associated with obesity. The findings of this Chapter are similar to those of the European Population-based Multicenter Study of 4083 individuals aged 53-67 years, which has shown an association between being overweight or obese and measured hearing impairment.[137] Obesity may be associated with hearing indirectly, for example, the association observed between hearing impairment and obesity could be confounded by social class. However, in this study the association remained after further adjustment for social class. The association observed between hearing impairment and obesity could further be explained by inflammation.[37] Research has shown that obesity gradually increases the risk of inflammation[293] and previous literature has reported a relationship between inflammatory markers and hearing impairment[37] suggesting that chronic levels of inflammation due to obesity subsequently may affect the cochlea increasing the risk of hearing impairment. Obesity may also affect hearing directly through obesity-related atherosclerosis of the internal auditory artery reducing the blood flow in the cochlear, vital for hearing.[140]

The lack of an association between smoking and hearing impairment in this Chapter supports previous studies with objectively measured hearing also using three smoking groups (current smokers, ex-smokers and never smoked) showing no association between hearing impairment and current smoking.[146, 289] In contrast, other cross-sectional studies comparing non-smokers versus smokers have shown positive associations between hearing impairment and smoking.[8, 102, 139] The heterogeneity in the findings on hearing impairment and smoking could be due to difference in the types of hearing impairment such as presbycusis and hearing impairment caused by exposure to noise.[292] Exposure to second hand smoke may further contribute towards the inconsistency in previous findings as non-smoking middle-aged and older adults who live with a current smoker have been associated with greater risks of being hearing impaired after adjustment for age, sex, socio-economic factors, CVD, lifestyle factors and occupational noise exposure, compared to non-smoking participants living with non-smoking/ex-smoking partners.[292]

4.6.2.3. Hearing impairment and CVD and CVD related chronic conditions

Chronic conditions including CHD, CVD, hypertension, stroke, chest pain and breathlessness were associated with not being able to hear despite using a hearing aid. This is consistent with findings from previous studies using data of adults aged 70 years and over from the American Behavioral Risk Factor Surveillance System which showed associations between hearing impairment and CHD and stroke.[16, 17] Compared to those being able to hear, reporting not being able to hear and not using a hearing aid was associated with chest pain, a symptom of CVD (angina), but not with diagnosed major CVD itself (CHD and/or stroke). In this Chapter, hearing impairment was not associated with diabetes however men who could not hear and used a hearing aid were more than twice as likely to report hypertension compared to men who could hear. Inconsistent findings from previous studies suggest that some CVD related conditions including hypertension and diabetes may only be weakly associated with hearing impairment and their effects may be masked by stronger risk factors such as age, particularly in cohorts comprising adults of older age.[294]

4.6.2.4. Hearing impairment and other chronic conditions

All three groups of hearing impairment were associated with arthritis and bronchitis. Arthritis and bronchitis have previously been associated with self-reported hearing problems in a study based on data from 7403 individuals aged 16-95 years completing the UK Adult Psychiatric Morbidity Survey in 2007.[295] However, few studies have investigated the association between hearing impairment and arthritis and bronchitis and several of them have been based on small samples in hospital settings.[296, 297] Presence of inflammatory blood markers are strongly associated with arthritis and bronchitis and recent research has also demonstrated an association between inflammation and hearing impairment,[37] suggesting that the relationship observed between hearing impairment and arthritis and bronchitis, respectively, could be explained by inflammation.[298]

4.6.2.5. Hearing impairment and physical functioning

Consistent with the majority of cross-sectional studies on hearing impairment and physical functioning, this study showed an association between not being able to hear, irrespective of use of hearing aid, and mobility limitation, difficulties undertaking activities of daily living (ADL) such as bathing, dressing and eating, and difficulties undertaking instrumental activities of daily living (IADL) including cooking, shopping, using public transport.[12, 60, 195-197] The strongest association observed was between not being able to hear despite reporting using a hearing aid and IADL difficulty and this finding is similar to cross-sectional findings from the Epidemiology of Hearing Loss Study of 2688 American adults aged 53-97 years,[197] showing that hearing impairment was particularly associated with IADL. Several explanations could potentially account for the observed association between hearing impairment and measures of poor physical functioning. First, damage to the inner ear could plausibly contribute to poor balance causing poorer physical functioning.[299] Second, the associations observed could possibly be explained by smoking and low physical activity previously associated with hearing impairment[137, 292] and predictors of poor physical functioning.[206, 300] However, in this study the association remained after adjustment for such factors. Third, hearing impairment could also be associated with physical functioning through factors that may be on the causal pathway between hearing impairment and increased risks of disability including cognitive impairment[301] and low social engagement.[302] Furthermore, this Chapter showed an association between hearing impairment and balance but no association between hearing impairment and falls. Previous literature has suggested that reduced attentional resources of balance control critical for maintaining the control of posture, may increase the risk of having a fall.[141] The lack of an association between hearing impairment and falls in this study could potentially be explained by the relatively small number of people who had experienced a fall in the previous year.

4.6.2.6. Hearing impairment and quality of life and social engagement

Not being able to hear, irrespective of use of a hearing aid, was associated with poor quality of life. Research on 829 Australians aged 55 years and over has shown that self-perceived hearing impairment rather than objectively measured hearing impairment is associated with experiencing poor quality of life.[290] The association between hearing impairment and poor quality of life may further be caused by difficulties with communication often seriously restricted in everyday life of hearing impaired individuals.[150, 197] Social engagement has furthermore been demonstrated to be an important factor for maintaining physical functioning in later life.[303] It is possible that a large and diverse network of social relations provides support and motivation to maintain good physical functioning.[303] Hearing impairment, even when mild, reduces an individual's ability to communicate with others[147, 148] and may contribute to reduced social engagement and loneliness.[147, 207, 302] In this study, not being able to hear, irrespective of use of hearing aid, was associated with low social engagement. However, the associations did not remain after further adjustment for covariates. This finding is inconsistent with previous studies showing an association between hearing impairment and low social engagement in older adults.[60, 147, 148] Such previous studies have, however, not adjusted for lifestyle factors which may explain why no association was observed in this study.

4.6.2.7. Hearing impairment and hearing aid use

Overall the findings on hearing impairment presented in this Chapter show that compared to participants who could hear and did not use a hearing aid (the reference group), participants who could hear and used a hearing aid did not have greater risks of poor lifestyle, morbidity and poor physical and social functioning. In contrast, participants who could not hear, irrespective of use of hearing aid, were more likely to report health problems, particularly those who could not hear despite also reporting using a hearing aid. This suggests that hearing aids that successfully enable the individual to hear good enough to follow a TV programme at a volume others find acceptable may also reduce the risks of adverse health outcomes. In contrast, participants with unaddressed and unsuccessfully addressed hearing problems were associated with greater risks of poor lifestyle, morbidity and poor physical and social functioning. The findings of this Chapter further suggest that measuring hearing impairment by simply asking whether the subjects use a hearing aid ('yes/no') would not capture the difference between being able to hear and, more importantly, not being able to hear.

In this study those not using hearing aids comprised of both participants who could hear and did not use a hearing aid ('could hear' / the reference group) as they probably did not need a hearing aid, and participants who could not hear and still, for unknown reasons, did not use a hearing aid. A recent population-based study of 10,499 Norwegian adults aged 65 years and over has shown that although age-related hearing impairment affects higher frequencies of hearing first, older adults do not start using hearing aids until their hearing impairment involves the medium hearing frequencies.[304] The same study also showed that older adults who were bothered by their hearing impairment were significantly more likely to use a hearing aid compared to those with a hearing impairment who were not bothered.[304] In the present study, it is possible that some of the participants who could not hear and did not use a hearing aid do not use an aid because they do not bother about their hearing impairment. However, this hearing impairment group may also consist of hearing impaired older men whose hearing problem may not have improved by an aid, or those who are reluctant to seek help for their health needs.

4.6.2.8. Prevalence of vision impairment

The prevalence of vision impairment observed in the present study (3%) is lower than the national estimate of 13%,[5, 28] and previous studies of both objectively measured and self-reported vision impairment showing prevalence rates between 9-24%.[16, 17] The wide range of prevalence rates in previous studies may reflect variability in definition of poor vision, how vision has been measured and variability in cohort characteristics. The low prevalence of vision impairment in the present study could be because the measurement used captured only severe vision impairment.

4.6.2.9. Vision impairment, lifestyle factors and CVD related conditions

Self-reported vision impairment was associated with physical inactivity and this finding is consistent with research on middle-aged and older adults showing an association between objectively measured visual acuity and self-reported physical inactivity.[168] Several reasons may explain the association observed including anxiety and depression, which are common in vision impaired older adults,[174, 305] and may act as barriers for undertaking physical activity. Reasons unrelated to medical care including barriers in their physical environment, problems obtaining transportation, feelings of vulnerability, decreased energy levels and lack of assertiveness have also been reported by vision impaired older adults as causes for not being physically active.[306]

Contrary to previous studies,[11, 16, 165, 291] vision impairment was not associated with smoking, obesity and CVD related conditions. The lack of association in the present study is likely to be due to the definition of vision impairment resulting in an underestimation of the true prevalence of vision impairment.

4.6.2.10. Vision impairment and physical functioning

Consistent with several earlier studies, difficulties in performing instrumental activities of daily living (IADL) (e.g. cooking, shopping) was strongly associated with vision impairment.[13, 66, 148] Poor vision was also associated with difficulties undertaking activities of daily living (ADL) (e.g. bathing, dressing) which has previously been linked to both self-reported and objectively assessed vision impairment.[13, 69] It is likely that vision impairment increases the risks of ADL and IADL difficulty. However, due to its cross-sectional design the directionality of the associations observed in the present study cannot be established. It is further possible that the magnitude of the association between vision impairment and IADL difficulty may have been overestimated due to residual confounding from medical factors such as CVD and diabetes which were based on self-reported doctor-diagnosed data rather than medical records.

Vision impairment was further associated with a greater risk of balance difficulties with over 3-fold increased odds in men with poor vision. It is well-established that balance function declines with advanced age.[215, 307] This forces older adults to rely on visual input as a natural compensatory strategy to maintain stability.[307] Evidently, maintaining stability is therefore more difficult for vision impaired older adults compared to individuals without a vision problem. Poor balance is furthermore a plausible intermediary between vision impairment and falls. Several previous studies on vision impairment and history of falls have shown a strong relationship between poor vision and falls even after multiple adjustments for potential confounders including lifestyle factors and medical conditions.[11, 308, 309] However, in this study the association between vision impairment and falls was attenuated upon further adjustment for social class, obesity, smoking and physical activity, possibly due to lack of power as a consequence of the small number of vision impaired participants with a history of falls (n=23).

4.6.2.11. Vision impairment and quality of life and social functioning

In this study, vision impairment was associated with some (walking problem, anxiety/depression) but not all (pain and discomfort) EuroQol-5D components used to measure quality of life. The quality of life in older adults with vision problem can vary over time and improved visual acuity following cataract surgery has been accompanied by improved quality of life.[310, 311] Nonetheless, previous literature in older adults has shown that individuals with more severe vision impairments such as age-related macular degeneration (AMD) had a greater negative impact on their quality of life compared to individuals with mild and moderate vision impairment.[312] It is possible that the relationship between vision impairment and quality of life is influenced by social support which could potentially outweigh severity of vision impairment. Also, it has been hypothesised that changes to an individual’s eyesight may negatively/positively affect social functioning and overall well-being.[130] Consistent with several earlier studies investigating the relationship between vision impairment and social functioning,[13, 130, 148] poor vision was strongly associated with low social engagement. Poor communication due to vision impairment has been can reduce the individual’s capacity to develop and maintain social networks and may result in withdrawal from social activities.[148, 172] Absence of stimulating social activities may furthermore cause depression and poor quality of life.[173] Alternatively, poor vision may lead to poor quality of life resulting in withdrawal from social activities.

4.6.3. Strengths and limitations

4.6.3.1. Strengths

A major strength of the results of the present study is that data are from a large population-based, geographically and socioeconomically representative cohort of older British men with high follow-up rates.[81, 247] Also, data on a wide range of factors in relation to sensory impairments including demographic and lifestyle characteristics, overall burden of cardiovascular health problems, quality of life, and physical and social functioning were available allowing for investigating and providing a comprehensive picture of older British men with sensory impairments. Validated self-reported questions on hearing and vision were used to determine hearing impairment and vision impairment.[11, 96] An additional strength is that the present study has explored the impact of hearing aids, including the ability to hear with or without a hearing aid. Since there is no standard definition of hearing impairment, I explored combining the questions on hearing available in BRHS. This allowed for three groups of hearing impairment which provided aspects of hearing impairment that would not have been possible to obtain using a single question. Also, this is one of few studies examining sensory impairments in community-dwelling older adults aged over 60 years in the UK.

4.6.3.2. Possible bias and limitations

Overall limitations to the BRHS data include that the BRHS cohort comprises men, predominantly of white British ethnic origin, and the findings may not be generalisable to women and non-white ethnic groups.[313] Also, the towns selected for recruitment of male participants did not have appreciable population movement resulting in a small proportion of non-white ethnic minority groups.[81] Consequently, BRHS data used in this thesis are based on older men predominantly of white European ethnic origin.

Although the response rate to the BRHS questionnaire in 2003 was high (82%), non-respondents (n=717) were more likely to be older and have poorer health compared with respondents (section 3.4.1). This raises potential selection bias, suggesting that prevalence of impairments in hearing and vision, and outcomes of interest including CVD and disability might have been higher among non-respondents, possibly underestimating the burden of ill-health observed.

A limitation of the findings is that the analyses were cross-sectional in nature and directionality of the associations observed cannot be ascertained from these results. Findings should therefore be interpreted with caution. Measures of hearing and vision were assessed using self-reported data rather than objective measures. The question on hearing used in the present study asked the participants whether their hearing is good enough to follow a TV programme at a volume others find acceptable. This question has previously been tested in 105 patients referred to a hearing clinic by their general practitioner and showed that patients (or their accompanying partner) who reported increased TV volume in order to follow a TV programme had a 68% chance of having a hearing impairment of 25 dB or worse.[96] Increased TV volume had a sensitivity (i.e. correctly identified as having hearing impairment) of 81% and a specificity (i.e. correctly identified as not having hearing impairment) of 52% as a predictor of hearing impairment. High sensitivity is preferred for conditions that can be modified.[145] Because hearing impairment to a large extent is modifiable, a high sensitivity is of particular interest. The authors therefore concluded that self-reported TV volume is a useful screening tool for hearing impairment where audiometry is unavailable.[96]

Participants were furthermore asked whether they use a hearing aid. The question, however, did not specify whether the participants have been offered a hearing aid and chosen not to use it or whether they do not have a hearing aid at all. For the development of the four hearing groups, participants not answering all hearing questions (hearing good enough to follow TV at a volume others find acceptable, hearing good enough to follow TV with increased volume, and, use of hearing aid), assumptions on their hearing status were made based on any information provided on hearing function (e.g. their answer to one of these hearing questions). Only those not answering any of the hearing questions were classified as missing (as described in Chapter 3). Thus, classification of participants into the four hearing groups involved several assumptions that may have caused misclassification possibly resulting in participants being entered into a hearing group not matching their actual hearing status. However, the prevalence of hearing impairment in the present study cohort (27% in British men aged 63-85 years) is comparable to some population-based studies of older adults using objectively measured hearing.[314, 315] The prevalence of hearing impairment is also very similar to the latest national estimate of hearing impairment reporting that 26% in British adults aged 61-80 years have a hearing impairment,[4] and therefore unlikely to be overestimated.

The question on vision asked participants whether they can see good enough to recognise a friend across a road. In the Norfolk-EPIC study of 8317 individuals aged 48-92 years 60% sensitivity (i.e. correctly identified as having vision impairment) and 95% specificity (i.e. correctly identified as not having vision impairment) were reported when compared to objectively assessed poor visual acuity (VA) defined as 6/18-6/60.[11] The question on vision used in this study could be criticised for only providing moderate sensitivity when assessed against VA. Lack of sensitivity may explain the low prevalence of vision impairment in this study (3%). Similarly, only 1% of participants in the Norfolk-EPIC cohort reported not being able to recognise a friend across a road.[11] It is likely that the question used to assess vision impairment in the BRHS has captured a limited group of participants with more severe vision impairment. The question could also have captured problems of recognition as it asks whether the respondent's eyesight is good enough to recognise a friend across a road. Vision impairment has been associated with poor cognitive function,[316] possible due to reduced ability to process and retrieval information acquired through the visual sensory system, essential for optimal cognitive function.[220] Finally, other aspects of hearing and vision impairment such as associated symptoms e.g. tinnitus, the underlying causes of the impairments, and the chronicity of the impairments were not examined.

Limitations to the outcome measure depression include self-reported data on doctor-diagnosed depression rather than data obtained using a depression score such as CES-D which captures several symptoms of depression including mood. Also, participants may have experienced depression but have not been diagnosed with depression and potentially therefore not self-reported depression, possibly underestimating the number of participants with a history of depression. Further, the score on social engagement in BRHS referred to nine social activities including attending religious services and going to the pub. However the social engagement score did not capture, for instance, social relationships with family and friends, and feelings of loneliness, commonly reported in sensory impaired older adults.[147]

4.7. Conclusions

The results of Chapter 4 show that hearing impairment and vision impairment are common in older British men. It also shows that older men who could not hear and older men with poor vision have a statistically significantly higher risk of ill-health, poor physical functioning and poor social interaction compared to men who could hear and could see, respectively. In particular men who could not hear despite reporting using a hearing aid have the highest risks of reporting ill-health, being physically inactive and reporting poor physical functioning including increased odds of CVD and falls. However, due to the cross-sectional nature of the analyses in this Chapter the directionality of associations of impairment in hearing and vision with socio-demographic characteristics, lifestyle factors and burden of morbidity could not be established. The next Chapter, Chapter 5, will examine the prospective associations between sensory impairments and the risk of CVD, MI and stroke and CVD mortality and all-cause mortality in older age. Chapter 5 will also investigate whether these associations are independent of age, social class, lifestyle factors and comorbidity.

Table 4.1 Prevalence of hearing impairment and vision impairment n (%) by age in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Age in years <70	70-74	75-79	≥ 80	Total
	1620 (41)	1123 (28)	814 (20)	424 (11)	3981 (100)
Hearing impairment					
Could hear	1277 (80)	822 (74)	502 (63)	250 (60)	2851 (73)
Could hear, used aid	114 (7)	117 (11)	158 (20)	93 (23)	482 (12)
Could not hear, no aid	171 (11)	121 (11)	91 (11)	41 (10)	424 (11)
Could not hear, used aid	44 (3)	45 (4)	49 (6)	30 (7)	168 (4)
Overall hearing impairment	329 (21)	283 (26)	298 (37)	164 (40)	1074 (27)
Overall use of hearing aid	158 (10)	162 (14)	207 (25)	123 (29)	650 (16)
Vision impairment					
Could see	1565 (98)	1071 (97)	764 (95)	400 (96)	3800 (97)
Poor vision	38 (2)	32 (3)	39 (5)	15 (4)	124 (3)

Table 4.2 Prevalence and odds ratios (95% CI) for social class and lifestyle factors according to hearing impairment groups in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Could hear	Could hear, used aid			Could not hear, no aid			Could not hear, used aid		
			Age-adjusted	Adjusted*		Age-adjusted	Adjusted*		Age-adjusted	Adjusted*
	n (%) OR	n (%)	OR (95% CI)	OR (95% CI)	n (%)	OR (95% CI)	OR (95% CI)	n (%)	OR (95% CI)	OR (95% CI)
Social class										
Manual social class	1317 (48) 1.00	245 (53)	1.26 (1.03-1.54)	1.20 (0.97-1.48)	263 (63)	1.90 (1.54-2.36)	1.73 (1.38-2.18)	98 (60)	1.72 (1.24-2.38)	1.60 (1.14-2.26)
Lifestyle factors										
Physical inactivity	971 (36) 1.00	196 (44)	1.19 (0.97-1.47)	1.24 (0.99-1.54)	157 (41)	1.21 (0.97-1.51)	1.13 (0.90-1.42)	87 (54)	1.83 (1.32-2.52)	1.69 (1.20-2.37)
Current smoker	284 (10) 1.00	33 (7)	0.72 (0.49-1.05)	0.64 (0.42-0.98)	54 (13)	1.34 (0.98-1.83)	1.32 (0.94-1.87)	15 (9)	0.95 (0.55-1.64)	0.93 (0.53-1.65)
Ex-smoker	1681 (59) 1.00	314 (66)	1.15 (0.93-1.41)	1.16 (0.92-1.45)	244 (58)	1.24 (0.95-1.64)	1.34 (0.98-1.93)	115 (69)	0.85 (0.58-1.24)	0.94 (0.62-1.41)
Never smoked	870 (31) 1.00	131 (27)	0.97 (0.77-1.20)	1.00 (0.79-1.27)	123 (29)	0.95 (0.76-1.19)	1.13 (0.88-1.44)	37 (22)	0.71 (0.49-1.04)	0.78 (0.51-1.17)
Obese (BMI ≥ 30)	445 (16) 1.00	61 (13)	0.94 (0.70-1.26)	0.87 (0.63-1.19)	85 (21)	1.41 (1.09-1.83)	1.38 (1.04-1.83)	42 (26)	2.12 (1.46-3.08)	1.83 (1.23-2.72)

*Adjusted for age, social class, obesity, smoking and physical activity

Table 4.3 Prevalence and odds ratios (95% CI) for chronic conditions including cardiovascular disease according to hearing impairment groups in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Could hear	Could hear, used aid			Could not hear, no aid			Could not hear, used aid		
			Age-adjusted	Adjusted*		Age-adjusted	Adjusted*		Age-adjusted	Adjusted*
	n (%) OR	n (%)	OR (95% CI)	OR (95% CI)	n (%)	OR (95% CI)	OR (95% CI)	n (%)	OR (95% CI)	OR (95% CI)
Overall health										
Fair/poor health	731 (26) 1.00	132 (28)	0.99 (0.79-1.24)	0.91 (0.70-1.18)	152 (37)	1.63 (1.31-2.02)	1.56 (1.21-2.01)	80 (48)	2.41 (1.75-3.31)	1.90 (1.31-2.75)
Chronic conditions										
CHD	611 (21) 1.00	113 (23)	0.99 (0.79-1.26)	0.98 (0.76-1.26)	91 (21)	0.98 (0.76-1.26)	0.91 (0.69-1.20)	61 (36)	1.89 (1.36-2.63)	1.68 (1.18-2.39)
CVD	728 (26) 1.00	153 (32)	1.17 (0.94-1.45)	1.11 (0.88-1.40)	112 (26)	1.02 (0.81-1.29)	0.99 (0.77-1.28)	72 (43)	1.93 (1.40-2.66)	1.71 (1.21-2.41)
Hypertension	1759 (62) 1.00	286 (59)	1.58 (1.15-2.16)	1.32 (0.92-1.88)	259 (61)	1.14 (0.78-1.67)	1.17 (0.77-1.77)	90 (54)	2.08 (1.33-3.26)	1.81 (1.11-2.94)
Breathlessness	418 (15) 1.00	93 (19)	1.21 (0.93-1.55)	1.13 (0.85-1.52)	88 (21)	1.49 (1.15-1.93)	1.24 (0.92-1.69)	55 (33)	2.51 (1.78-3.54)	1.87 (1.26-2.77)
Chest pain	553 (19) 1.00	106 (22)	1.12 (0.88-1.43)	1.14 (0.88-1.47)	107 (25)	1.39 (1.10-1.77)	1.35 (1.04-1.76)	60 (36)	2.22 (1.60-3.10)	1.91 (1.34-2.73)
Stroke	196 (7) 1.00	60 (12)	1.56 (1.15-2.16)	1.32 (0.92-1.88)	34 (8)	1.14 (0.78-1.67)	1.17 (0.77-1.77)	26 (15)	2.08 (1.33-3.26)	1.81 (1.11-2.94)
Arthritis	880 (31) 1.00	200 (41)	1.47 (1.20-1.79)	1.43 (1.15-1.78)	162 (38)	1.37 (1.11-1.69)	1.41 (1.12-1.78)	74 (44)	1.64 (1.20-2.26)	1.35 (0.96-1.91)
Bronchitis	340 (12) 1.00	75 (16)	1.34 (1.02-1.77)	1.36 (1.01-1.83)	71 (17)	1.48 (1.12-1.96)	1.45 (1.07-1.97)	32 (19)	1.72 (1.15-2.57)	1.75 (1.15-2.66)
Depression	220 (8) 1.00	39 (8)	1.26 (0.87-1.81)	1.12 (0.75-1.68)	41 (10)	1.32 (0.93-1.88)	1.47 (1.01-2.13)	17 (10)	1.58 (0.93-2.67)	1.33 (0.74-2.38)
Diabetes	281 (10) 1.00	45 (9)	0.96 (0.68-1.34)	0.92 (0.64-1.34)	41 (9)	0.98 (0.70-1.39)	0.90 (0.61-1.32)	19 (11)	1.18 (0.72-1.94)	0.92 (0.53-1.59)

*Adjusted for age, social class, obesity, smoking and physical activity

Table 4.4 Prevalence and odds ratios (95% CI) for physical functioning, measures of quality of life and social engagement according to hearing impairment groups in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Could hear	Could hear, used aid			Could not hear, no aid			Could not hear, used aid		
			Age-adjusted	Adjusted*		Age-adjusted	Adjusted*		Age-adjusted	Adjusted*
	n (%) OR	n (%)	OR (95% CI)	OR (95% CI)	n (%)	OR (95% CI)	OR (95% CI)	n (%)	OR (95% CI)	OR (95% CI)
Physical functioning										
History of falls	280 (10) 1.00	68 (14)	1.31 (0.98-1.75)	1.28 (0.92-1.76)	49 (12)	1.17 (0.85-1.62)	1.15 (0.80-1.66)	28 (17)	1.62 (1.05-2.48)	1.48 (0.93-2.37)
Mobility limitations	558 (20) 1.00	122 (25)	1.20 (0.95-1.51)	1.16 (0.88-1.52)	121 (29)	1.61 (1.27-2.03)	1.61 (1.22-2.12)	62 (37)	2.12 (1.52-2.95)	1.56 (1.06-2.31)
Balance difficulty	292 (10) 1.00	73 (15)	1.23 (0.93-1.63)	1.14 (0.83-1.58)	66 (16)	1.56 (1.16-2.09)	1.33 (0.94-1.88)	36 (21)	1.95 (1.31-2.90)	1.65 (1.07-2.55)
ADL difficulty	392 (14) 1.00	84 (18)	1.16 (0.89-1.51)	1.17 (0.86-1.58)	92 (22)	1.70 (1.31-2.19)	1.56 (1.16-2.11)	52 (32)	2.48 (1.75-3.52)	1.88 (1.26-2.82)
IADL difficulty	326 (12) 1.00	77 (17)	1.25 (0.95-1.65)	1.18 (0.86-1.63)	81 (19)	1.77 (1.35-2.32)	1.71 (1.24-2.35)	68 (41)	4.66 (3.33-6.53)	4.25 (2.84-6.34)
Quality of life										
Pain/discomfort	1265 (44) 1.00	232 (48)	1.18 (0.97-1.44)	1.18 (0.95-1.47)	230 (54)	1.49 (1.21-1.83)	1.49 (1.19-1.87)	114 (68)	2.68 (1.92-3.75)	2.46 (1.71-3.55)
Mobility problem	711 (25) 1.00	145 (30)	1.14 (0.92-1.42)	1.14 (0.89-1.47)	149 (35)	1.60 (1.29-1.99)	1.53 (1.18-1.98)	83 (49)	2.65 (1.93-3.64)	2.10 (1.45-3.04)
Anxiety/depression	449 (16) 1.00	72 (15)	0.98 (0.74-1.29)	0.97 (0.72-1.30)	84 (20)	1.33 (1.03-1.73)	1.38 (1.04-1.84)	41 (24)	1.79 (1.24-2.59)	1.47 (0.98-2.21)
Social engagement										
Low engagement	663 (24) 1.00	134 (28)	1.10 (0.88-1.38)	0.94 (0.73-1.21)	122 (29)	1.31 (1.04-1.65)	1.15 (0.89-1.48)	47 (29)	1.15 (1.03-1.06)	1.03 (0.70-1.50)

*Adjusted for age, social class, obesity, smoking and physical activity

Table 4.5 Prevalence and odds ratios (95% CI) for social class and lifestyle factors according to vision impairment in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Could see		Poor vision		
				Age-adjusted	Adjusted*
	n (%)	OR	n (%)	OR (95% CI)	OR (95% CI)
Social class					
Manual social class	1840 (50)	1.00	80 (65)	1.89 (1.30-2.75)	1.49 (0.99-2.23)
Lifestyle factors					
Physical inactivity	1368 (38)	1.00	53 (50)	1.52 (1.03-2.25)	1.52 (1.01-2.28)
Current smoker	366 (10)	1.00	18 (15)	1.65 (0.99-2.75)	1.36 (0.75-2.45)
Ex-smoker	2286 (61)	1.00	72 (58)	0.85 (0.59-1.22)	0.76 (0.50-1.14)
Never smoked	1124 (30)	1.00	34 (27)	0.94 (0.63-1.40)	1.18 (0.76-1.84)
Obese (BMI ≥ 30)	619 (17)	1.00	16 (13)	0.83 (0.48-1.42)	0.79 (0.44-1.41)

*Adjusted for age, social class, obesity, smoking and physical activity

Table 4.6 Prevalence and odds ratios (95% CI) for chronic conditions including cardiovascular disease according to vision impairment in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Could see		Poor vision		
				Age-adjusted	Adjusted*
	n (%)	OR	n (%)	OR (95% CI)	OR (95% CI)
Overall health					
Fair/poor health	1038 (28)	1.00	61 (51)	2.61 (1.81-3.76)	2.09 (1.35-3.25)
Chronic conditions					
CHD	840 (22)	1.00	37 (30)	1.39 (0.93-2.07)	1.26 (0.81-1.97)
CVD	1024 (27)	1.00	44 (35)	1.40 (0.96-2.04)	1.24 (0.81-1.90)
Hypertension	2322 (61)	1.00	73 (59)	1.56 (0.91-2.68)	1.52 (0.84-2.76)
Breathlessness	620 (16)	1.00	37 (30)	2.06 (1.38-3.06)	1.53 (0.94-2.50)
Chest pain	791 (21)	1.00	37 (30)	1.58 (1.07-2.35)	1.30 (0.83-2.04)
Stroke	304 (8)	1.00	16 (13)	1.56 (0.91-2.68)	1.52 (0.84-2.76)
Arthritis	1271 (33)	1.00	47 (38)	1.17 (0.81-1.69)	0.96 (0.63-1.46)
Bronchitis	501 (13)	1.00	18 (15)	1.10 (0.66-1.84)	0.88 (0.48-1.59)
Depression	301 (8)	1.00	15 (12)	1.72 (0.99-3.00)	1.63 (0.87-3.05)
Diabetes	367 (10)	1.00	17 (14)	1.49 (0.89-2.52)	1.41 (0.77-2.57)

*Adjusted for age, social class, obesity, smoking and physical activity

Table 4.7 Prevalence and odds ratios (95% CI) for physical functioning, measures of quality of life and social engagement according to vision impairment in a cross-sectional study of 3981 British men aged 63-85 years in 2003

	Could see		Poor vision		
				Age-adjusted	Adjusted*
	n (%)	OR	n (%)	OR (95% CI)	OR (95% CI)
Physical functioning					
History of falls	401 (11)	1.00	23 (19)	1.82 (1.14-2.90)	1.47 (0.84-2.57)
Mobility limitations	827 (22)	1.00	45 (36)	1.93 (1.32-2.82)	1.40 (0.87-2.26)
Balance difficulty	436 (11)	1.00	38 (31)	3.17 (2.12-4.75)	2.52 (1.54-4.12)
ADL difficulty	592 (16)	1.00	36 (31)	1.06 (1.04-1.07)	1.80 (1.10-2.96)
IADL difficulty	518 (14)	1.00	45 (39)	3.68 (2.49-5.44)	3.63 (2.21-5.96)
Quality of life					
Pain and discomfort	1784 (47)	1.00	61 (49)	1.09 (0.76-1.56)	0.98 (0.65-1.46)
Mobility problem	1044 (27)	1.00	53 (43)	1.87 (1.30-2.70)	1.44 (0.92-2.26)
Anxiety or depression	620 (16)	1.00	30 (24)	1.66 (1.09-2.53)	1.66 (1.04-2.64)
Social engagement					
Low engagement	918 (24)	1.00	48 (41)	2.05 (1.40-3.00)	1.77 (1.15-2.73)

*Adjusted for age, social class, obesity, smoking and physical activity

CHAPTER 5 Relationships of sensory impairments with cardiovascular disease incidence and mortality in older British men

5.1. Summary

Both hearing impairment and vision impairment have been associated with increased risks of cardiovascular disease (CVD) in cross-sectional studies. However, few longitudinal studies have investigated the relationship between sensory impairments and the risk of incident CVD in community-dwelling older adults. In this Chapter, the prospective associations between impairments in hearing and vision and the risk of incident myocardial infarction (MI) events, stroke events, CVD events, coronary heart disease (CHD) mortality, CVD mortality and all-cause mortality have been examined. 3981 men from the British Regional Heart Study (BRHS) aged 63-85 years in 2003 were followed-up for a 10 year period to 2013 for cardiovascular morbidity and mortality. Hearing impairment included three groups: ‘could hear, used a hearing aid’, ‘could not hear, no hearing aid’ and ‘could not hear, used a hearing aid’. Those who ‘could hear, used no aid’ formed the reference group. Vision impairment was defined as not being able to see good enough to recognise a friend across the street and compared with those who could do so. Cox proportional hazards regression models were used to calculate the relationships. Out of the 3981 men, 812 had had a CVD event prior to 2003 and were excluded from the incidence analysis. In the 3169 men with no prevalent CVD in 2003, 422 men had an incident non-fatal or fatal CVD event, 242 men had an incident non-fatal or fatal MI event and 193 men had an incident non-fatal or fatal stroke event during the 10 year follow-up. Compared to men who could hear, men who could not hear and did not use a hearing aid had greater risks of incident CVD (age-adjusted hazard ratios (HR) 1.49, 95% CI 1.13-1.96), incident stroke (HR 1.53, 95% CI 1.02-2.28), CVD mortality (HR 1.37, 95% CI 1.02-1.85) and all-cause mortality (HR 1.19, 95% CI 1.01-1.40). No association was seen with incident MI or CHD mortality. All the associations except all-cause mortality remained after further adjustment for social class, comorbidities and lifestyle factors. Vision impairment was not associated with CVD disease outcomes but was associated with all-cause mortality (HR 1.67, 95% CI 1.31-2.13) and the association remained after further adjustment for social class, comorbidities and lifestyle factors. In conclusion, in a population-based study of older British men, hearing impairment was associated, in particular, with an increased risk of incident stroke and CVD mortality, and vision impairment was associated with all-cause mortality.

5.2. Introduction

In Chapter 4, cross-sectional relationships between hearing impairment and prevalent coronary heart disease (CHD), stroke and cardiovascular disease (CVD) were observed. It was also shown that vision impairment was associated with symptoms of CVD including breathlessness and chest pain. CVD is a major cause of death in the UK[31] and several cross-sectional studies have shown that CVD is associated with hearing impairment,[10, 38, 104] and vision impairment.[16, 17] However, relatively few longitudinal studies have investigated the prospective relationship between impairments in hearing and vision and the risk of a CVD event in community-dwelling older adults (as discussed in Chapter 2, section 2.4).

Recent studies on the relationship between hearing impairment and incident MI and stroke have mainly focused on sudden sensorineural hearing loss showing greater risks of incident MI,[42] and incident stroke,[41] but findings are inconsistent with some research showing no association with incident stroke.[45] Although age-related hearing impairment is more common than sudden sensorineural hearing loss, particularly in later life,[43] little research has focused on the relationship between age-related hearing impairment and incident MI and stroke.[45] Furthermore, several studies have been undertaken in specific subgroups such as patients with sudden sensorineural hearing loss,[41, 42] rather than community-dwelling adults. Also, studies have not distinguished between middle-aged and older adults.[41, 42] Hearing impairment has furthermore been associated with mortality from CVD in a study of older Icelandic adults[39] however little research has investigated the relationship between hearing impairment and CVD mortality and to my knowledge no study has investigated such relationship in older British adults.

Earlier studies investigating the relationship between vision impairment and incident MI and stroke have shown an association between age-related macular degeneration (AMD) and greater risks of incident MI and incident stroke.[49-51] However findings are inconsistent with some studies showing no such association.[55, 171] Moreover, several studies have been restricted to assessments of AMD in middle-aged adults,[50, 51, 171] and less is known about overall self-experienced vision loss in later life. Evidence on the association of vision impairment and CVD mortality in the community-dwelling older population is sparse although one study has shown no association.[168]

Further evidence on the influence of sensory impairments on CVD incidence and mortality, particularly from longitudinal studies of community-dwelling older adults, with separate data on incident MI events, incident stroke events and CHD mortality, is needed. Therefore this Chapter aims to examine the prospective associations between impairment in hearing and vision with the risk of incident MI events, stroke events, CVD events, CHD mortality, CVD mortality and all-cause mortality in older British men (63-85 years) over a 10 year follow-up period.

5.3. Objectives

The specific objectives of this Chapter are:

i) To examine the prospective relationships of impairments in hearing and vision with the risk of incident MI events, stroke events and CVD events over 10 years in older age.
ii) To examine the prospective relationship between impairments in hearing and vision and CHD mortality, CVD mortality and all-cause mortality over 10 years in older age.

5.4. Methods

An overview of the British Regional Heart Study (BRHS) has been presented in Chapter 3 (section 3.2). Detailed information on relevant data used for this Chapter is described below.

5.4.1. Subjects and methods of data collection

Data used in this Chapter are based on the BRHS self-administrated questionnaire in 2003 on health and lifestyle including hearing impairment and vision impairment, completed by 3981 men (82% of survivors) then aged 63-85 years. Participants with no previous CVD were followed prospectively for cardiovascular morbidity and mortality over 10 years from 2003 to 2013. Data on deaths were collected through the NHS Central Register (death certificates coded using International Classification of Diseases, ninth revision (ICD-9)). Information on non-fatal events was collected as part of on-going biennial reviews of the participants' medical records with general practitioners.[81]

5.4.2. Hearing and vision impairments

Data on hearing and vision measures in the 2003 questionnaire have been described in detail in Chapter 3 (section 3.3). Hearing was assessed using self-completed data on hearing aid use and ability to hear good enough to follow a TV programme at a volume others find acceptable. The data were combined into four groups of hearing as defined in Chapter 3, section 3.3.1.

A self-completed question on ability to see good enough to recognise a friend across a road generated two groups: participants able to recognise a friend across a road (could see) (reference group) and participants unable to recognise a friend across a road (vision impairment).

5.4.3. Incident CVD and mortality

Six outcome measures were examined: MI events (diagnosis of non-fatal myocardial infarction (MI) according to WHO criteria[248] or fatal MI (ICD-9 codes 410-414)); CVD events (diagnosis of non-fatal or fatal MI and/or non-fatal stroke (an event that produced a neurological deficit present for more than 24 hours[264]) or fatal stroke (ICD-9, 430-438)); stroke events; CHD mortality (ICD-9, 410-414); CVD mortality (ICD-9, 390-459) and all-cause mortality. Participants were censored at date of death or at the end of the study period (30th June 2013) if still alive. Prevalent CVD was defined as self-reported doctor-diagnosed heart attack, angina and/or stroke and medical records of non-fatal CVD events (MI and/or stroke). Participants with prevalent CVD were excluded from the analyses of incident CVD, incident MI and incident stroke. The analyses of all-cause mortality included all men.

5.4.4. Covariates

Covariates included social class, cigarette smoking, physical activity, obesity, hypertension and diabetes. Self-reported CVD defined as having been diagnosed with heart attack, angina and/or stroke and medical records of non-fatal MI and/or stroke were classified as prevalent CVD and included as an additional covariate in the all-cause mortality analyses only. The aforementioned covariates were obtained through a self-administrated questionnaire in 2003, as described in detail in Chapter 3 (section 3.3). Social class was measured using the baseline questionnaire in 1978-80 and based on the longest held occupation coded using the Registrar General's occupational classification and further grouped into manual and non-manual social class.[252] Participants were classified into three cigarette smoking groups (never smoked, ex-smokers and current smokers).[253] Physical activity was classified into six groups based on intensity and frequency of exercise (inactive; occasional; light; moderate; moderately vigorous and vigorous).[254] None or occasional activity was classified as 'inactive'. Obesity was defined as a body mass index (BMI) of 30 kg/m^2 and over.[257] Participants were asked whether a doctor had ever diagnosed them with hypertension and/or diabetes.

5.4.5. Statistical methods

Cox proportional hazards regression models were used to calculate age-adjusted and multivariate-adjusted hazard ratios (HRs) with 95% CIs for the risk of MI events, CVD events, stroke events, CHD mortality, CVD mortality and all-cause mortality according to hearing impairment and vision impairment respectively. Survival analysis was undertaken and Kaplan Meier curves were plotted to examine the survival probability of the cohort for MI events, CVD events, stroke events, CHD mortality, CVD mortality and all-cause mortality by hearing impairment and vision impairment. The Cox proportional hazards regression models were further tested for the proportional-hazards assumption, on the basis of Schoenfeld residuals, and not found to be violated. Men who could hear and men who could see formed the reference groups for hearing and vision respectively. Potential confounders were based on the risk factors identified as being associated with sensory impairments in this cohort (Chapter 4, section 4.5) and in previous literature (Chapter 2). All models were adjusted for age, which was entered as a continuous variable. Additional confounding variables adjusted for included social class, obesity, smoking, physical activity, hypertension and diabetes, all fitted as categorical variables. Prevalent CVD was entered as a categorical variable and adjusted for in the all-cause mortality analyses only.

5.5. Results

Analyses were based on 3981 men aged 63-85 years, who completed the questionnaire in 2003. The characteristics of the study population and relationships between sensory impairments and covariates have been presented in Chapter 4. All participants were followed from 2003 to 2013 for CVD morbidity including incident MI and incident stroke. Out of the 3981 men, a total of 812 men with prevalent CVD (MI and/or stroke) (515 from medical records and 297 self-reported events) in 2003 were excluded from the incidence analyses. In the remaining 3169 men with no prevalent CVD in 2003, there were 422 new non-fatal or fatal CVD events, 242 new non-fatal or fatal MI events and 193 new non-fatal or fatal stroke events during the follow-up. All 3981 participants were followed-up for CVD mortality and all-cause mortality to 2013. During this 10-year follow-up period, 1463 deaths occurred from all causes including 308 CHD deaths and 408 CVD deaths.

5.5.1. Hearing impairment and CVD outcomes and mortality

Figures 5.1-5.3 (pages 150-152) present crude rates of Kaplan Meier survival curves for CHD mortality, CVD mortality and all-cause mortality by hearing impairment. Table

5.1 (page 156) presents hazard ratios (HR) with 95% CIs for incident CVD, MI and stroke for hearing impairment. Compared to men who could hear (no hearing impairment), men who could not hear and did not use a hearing aid had greater risks of incident CVD (HR 1.49, 95% CI 1.13-1.96). The association remained significant after further adjustment for social class, hypertension, diabetes, obesity, smoking and physical activity (HR 1.57, 95% CI 1.17-2.11). Men who could hear and used a hearing aid and men who could not hear despite a hearing aid did not have greater risks of CVD events compared to men who could hear. Men who could not hear and did not use a hearing aid also had greater risks of incident stroke (HR 1.53, 95% CI 1.02-2.28) compared to men who could hear and the association remained significant after further adjustment for social class, hypertension, diabetes, obesity, smoking and physical activity (HR 1.70, 95% CI 1.12-2.59). No other group of hearing impairment was associated with incident stroke. None of the hearing impairment groups were associated with incident MI.

Table 5.2 (page 157) shows HR with 95% CIs for CHD mortality, CVD mortality and all-cause mortality for hearing impairment. Men who could not hear and did not use a hearing aid had a greater risk of CVD mortality compared to men who could hear (HR 1.37, 95% CI 1.02-1.85). The association remained significant after further adjustment of social class, hypertension, diabetes, obesity, smoking and physical activity. Men who could hear and used a hearing aid and men who could not hear despite reporting using a hearing aid were not associated with greater CVD mortality risk. In comparison with men who could hear, those who could not hear and did not use a hearing aid had a significantly greater risk of all-cause mortality (HR 1.19, 95% CI 1.01-1.40) but the association was attenuated on further adjustments. None of the hearing impairment groups were associated with CHD mortality.

5.5.2. Vision impairment and CVD outcomes and mortality

The crude rates of Kaplan Meier survival curves for CHD mortality, CVD mortality and all-cause mortality by vision impairment are presented in Figures 5.4-5.6 (pages 153-155). Table 5.3 (page 158) shows HR with 95% CIs for incident CVD, MI and stroke for vision impairment. No significant associations were observed between vision impairment and incident CVD, MI and stroke on adjustment for age. In Table 5.4 (page 159) HR with 95% CIs for CHD mortality, CVD mortality and all-cause mortality for vision impairment are presented. Men with poor vision had greater risks of all-cause mortality compared to men who could see (HR 1.67, 95% CI 1.31-2.13). The association remained significant after further adjustment for social class, comorbidities including CVD, hypertension and diabetes, and lifestyle factors including obesity, smoking and physical activity. Men with vision impairment did not have a greater risk of CHD mortality and CVD mortality compared to men who could see.

5.6. Discussion

5.6.1. Summary of main findings

In this Chapter the relationships between impairment in hearing and vision and the risk of MI events, stroke events, CVD events, CHD mortality, CVD mortality and all-cause mortality have been examined in a prospective population-based cohort of British men aged 63-85 years. Compared to men who could hear, men who could not hear and did not use a hearing aid had greater risks of incident CVD (age-adjusted hazard ratios (HR) 1.49, 95% CI 1.13-1.96), incident stroke (HR 1.53, 95% CI 1.02-2.28), CVD mortality (HR 1.37, 95% CI 1.02-1.85) and all-cause mortality (HR 1.19, 95% CI 1.01-1.40) but not incident MI and CHD mortality. All the associations except the association with all-cause mortality remained after further adjustment for social class, hypertension, diabetes, obesity, smoking and physical activity. Vision impairment was not associated with CVD outcomes but was associated with all-cause mortality (HR 1.67, 95% CI 1.31-2.13) and the association remained after further adjustment for social class, comorbidities and lifestyle factors.

5.6.2. Comparison with previous studies

5.6.2.1. Hearing impairment and CVD outcomes and mortality

Men who could not hear and did not use a hearing aid had significantly greater risks of incident CVD and CVD mortality compared to men who could hear and the associations remained after further adjustment for social class, comorbidities and lifestyle factors. Consistent with the present study, previous research of 4926 Icelandic adults aged 67 years and over has shown an association between objectively measured hearing impairment and increased risks of CVD mortality after adjustment for multiple confounding factors.[39] Several reasons may explain the association between hearing impairment and CVD morbidity and mortality. For example, the association could be due to potential mediators such as walking problems and depression. Substantial evidence has shown that depression is a risk factor for CVD morbidity and mortality,[153] potentially through a more sedentary lifestyle which in turn can lead to early development of atherosclerosis, the most common cause of CVD.[154] However, in this thesis, the associations remained after further adjustment for physical activity. Also, in the present study sample, depression was not associated with hearing impairment (Table 4.4 and Table 4.5), although this may be due to limitations in how depression was measured. Another possible confounding factor is cognitive impairment, previously associated with both hearing impairment[317] and CVD.[318] Indeed a previous study of 2956 Australian adults aged over 49 years observed no association between hearing impairment and CVD mortality after multivariable adjustment for age, sex, socio-economic status, comorbidities, lifestyle factors and cognitive impairment.[146] However, data on cognitive function were not available and could not be considered for this study.

Most of earlier studies on hearing impairment and incident MI and incident stroke have been carried out in populations of hospitalised middle-aged and older adults with diagnosed sudden sensorineural hearing loss (sudden damage to any part of the inner ear or the neural pathways to the brain[29]).[41, 42] Very little research has investigated the relationship between hearing impairment and incident MI and incident stroke in community-dwelling older adults who may have different forms of hearing impairment including age-related hearing impairment which develops gradually and is the most common cause of hearing impairment in later life.[233] One of few studies of community-dwelling adults (aged >49 years) examining hearing impairment and increased risks of incident stroke has been undertaken in the population-based Blue Mountains Hearing Study using objectively assessed hearing impairment. Participants with hearing impairment defined as worse than 40 dB were asked to self-report whether their hearing loss was gradual or sudden. The findings showed no association between neither gradual nor sudden loss of hearing and incident stroke at 5 years follow-up on adjustment for age, sex, diabetes, smoking and hypertension.[45] The association shown between hearing impairment and incident stroke in the present study may be due to an older population compared to the Blue Mountains Hearing Study or the grouping of hearing impairment.

Given the lack of association between hearing impairment and incident MI and CHD mortality, the association demonstrated between the hearing impairment group ‘could not hear, no aid’ and incident CVD and CVD mortality seems to largely be explained by stroke. It is possible that hearing impairment may be an early marker of an underlying vascular or arteriosclerotic process.[47] However the relationship between hearing impairment and subsequent stroke has not been well established and the mechanisms contributing to the association remain unclear.[45] Previous literature has suggested that the relationship between hearing impairment and stroke could be attributed to smoking and atherosclerosis, restricting the blood supply to the auditory system critical to cochlear function.[292, 319] However, in the present study the associations remained significant after further adjustment for smoking and CVD-related comorbidities. Furthermore, only men who could not hear and did not use a hearing aid had significantly greater risks of incident stroke (and incident CVD) compared to men who could hear. The inconsistency between the three hearing impairment groups and incident stroke (and incident CVD) suggests that hearing per se may not underlie the observed associations. For instance, different pathologies that underlie different types of hearing impairment may exist within and across the hearing impairment groups. Possible explanations of the relationship also include mediating factors associated with hearing aid use such as low social engagement due to communication problems,[151, 152] also associated with increased risk of incident CVD.[320] Inflammation, previously associated with increased risks of both hearing impairment[37] and CVD,[321] may furthermore act as a mechanism underlying the relationship observed.

Men who could not hear and did not use a hearing aid also had greater risks of all-cause mortality compared to men who could hear. However the association was attenuated after further adjustment for social class, comorbidities and lifestyle factors. This is consistent with earlier studies demonstrating no association between hearing impairment and all-cause mortality after adjustment for potential confounders including social class and poor physical functioning.[65, 160]

5.6.2.2. Vision impairment and CVD outcomes and mortality

In the present study, vision impairment did not predict the risk of incident CVD and CVD mortality including separate data on incident stroke, incident MI and CHD mortality in older age. The lack of findings is consistent with previous studies on older adults demonstrating no association between objectively assessed vision impairment[39], diagnosed AMD[54, 168] and cataract[168], respectively, and CVD mortality. Similarly, earlier studies have consistently reported no association between AMD and incident stroke in older adults.[54, 55]

In this Chapter vision impairment was associated with greater risk of all-cause mortality. This finding supports previous research showing that both objectively measured poor visual acuity[66, 131, 179, 180] and self-reported vision impairment[53] are associated with greater risks of all-cause mortality in older age. A previous study has also shown that cataract and AMD predict increased risks of all-cause mortality in adults aged 49 years and over.[179] Although the mechanisms for the relationship between vision impairment and mortality are not clear,[322] common possible explanations include that vision impairment gives rise to functional problems which may be life-threatening including falls,[109] frailty[78] and loss of independence.[64] It is also possible that the relationship is explained by factors on the causal pathway between vision impairment and mortality including depression[305] and low social engagement.[180]

5.6.3. Strengths and limitations

The major strengths of the findings presented in this Chapter are that data are from a large, geographically and socioeconomically representative population-based cohort of older British men with negligible loss to follow-up and objective ascertainment of CVD and mortality outcomes.[81, 247] Also, the cohort was followed for 10 years and the models were adjusted for several confounding variables. However, the study was in older men, predominantly of white British ethnic origin, and the findings are not generalisable to women and other ethnic groups.

Although all outcomes including incident CVD, MI and stroke, and CHD mortality, CVD mortality and all-cause mortality were based on measurements from medical records and death certificates, hearing and vision impairment were self-reported. Self-report sensory impairment could be subject to inaccurate reporting of loss because of unawareness or denial of sensory problem. Any inaccurate reporting of hearing may have underestimated the influence of hearing impairment on CVD and may also explain the inconsistent associations between the hearing impairment groups. The lack of association between vision impairment and incident CVD events and CVD mortality could be due to the definition of vision impairment used, which may have identified severe vision impairment only, possibly underestimating the true prevalence of vision impairment. However, the questions used to assess impairments of hearing and vision have been validated,[11, 96] and previous research has demonstrated comparable findings when investigating both self-reported and measured sensory impairments and 10-year all-cause mortality risks,[66] suggesting self-reported data could be used to identify those at risk. An additional limitation is that hearing impairment and vision impairment were measured at baseline only and no information on the primary cause and change in the impairments were investigated. Also, severity of CVD was not available. Data on severity of CVD would have provided more detailed information on the CVD events associated with hearing impairment.

5.7. Conclusions

The results of Chapter 5 show that older men who could not hear and did not use a hearing aid have greater risks of CVD mortality, incident CVD and, particularly, incident stroke, compared to men who could hear. This Chapter also shows that vision impairment is associated with all-cause mortality but not CVD outcomes. The meaning and implications of these findings will be discussed further in Chapter 8. Chronic conditions such as CVD further affect daily life and in the next Chapter (Chapter 6), the relationships of sensory impairments with the risk of subsequent mobility limitations and difficulty undertaking activities of daily living and instrumental activities of daily living are investigated.

Figure 5.1 Kaplan-Meier survival curves comparing CHD mortality according to hearing impairment groups in men aged 63-85 years in 2003 followed-up for 10 years

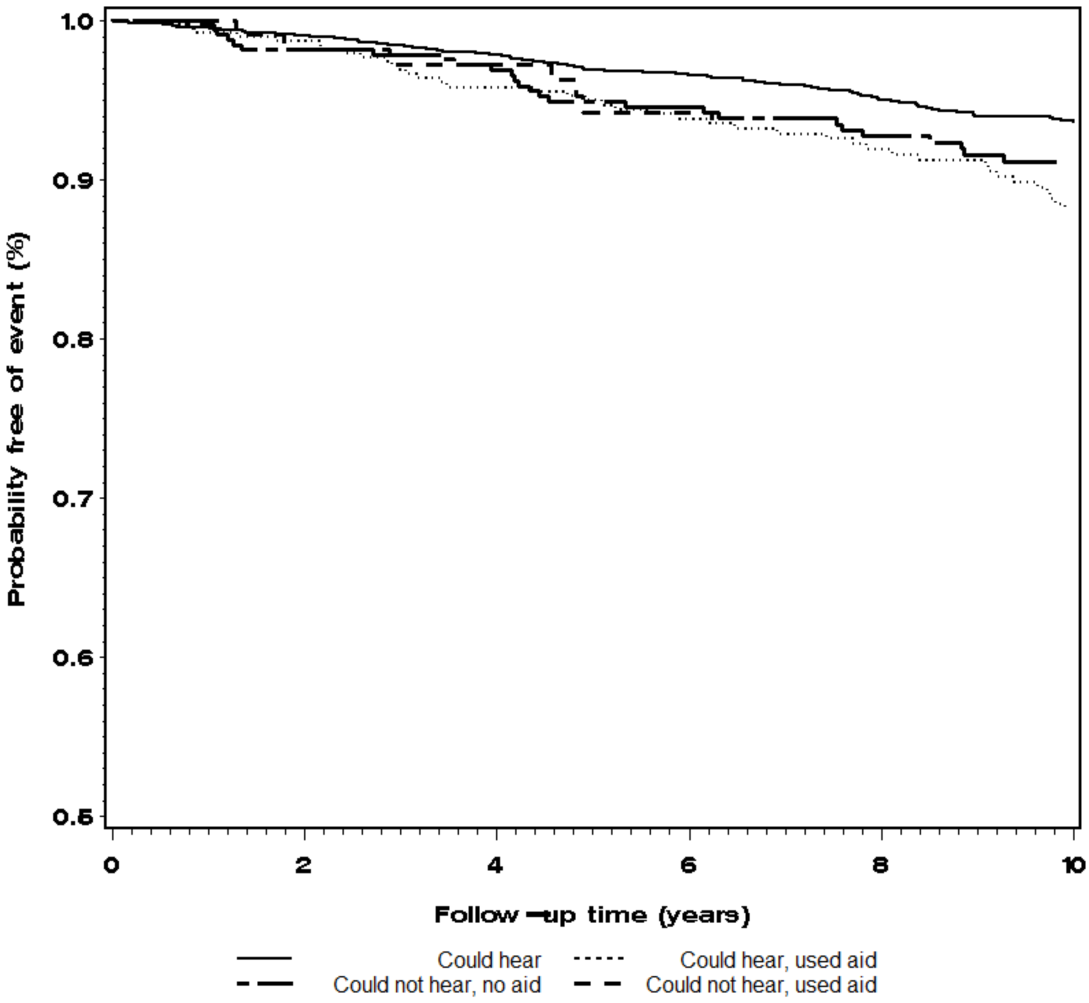


Figure 5.2 Kaplan-Meier survival curves comparing CVD mortality according to hearing impairment groups in men aged 63-85 years in 2003 followed-up for 10 years

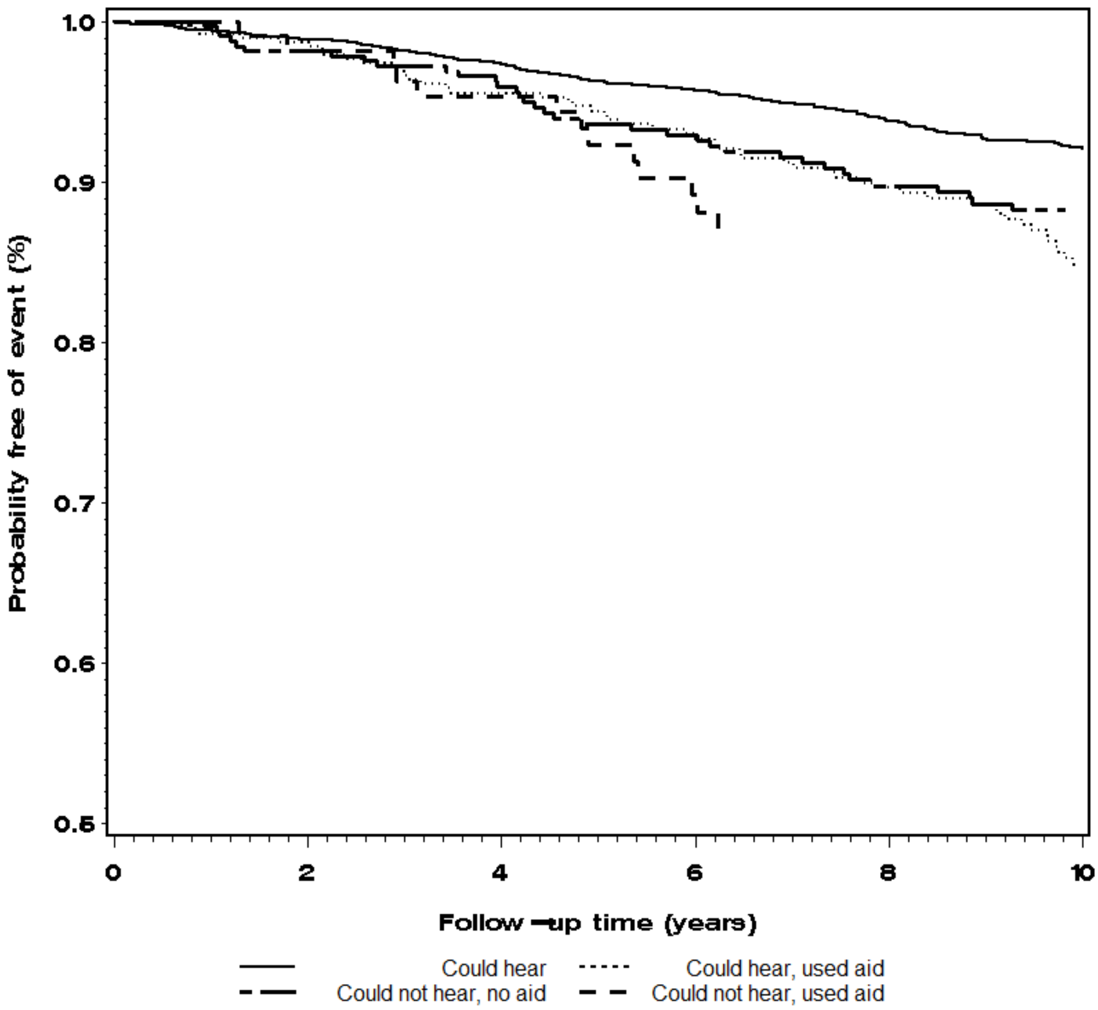


Figure 5.3 Kaplan-Meier survival curves comparing all-cause mortality according to hearing impairment groups in men aged 63-85 years in 2003 followed-up for 10 years

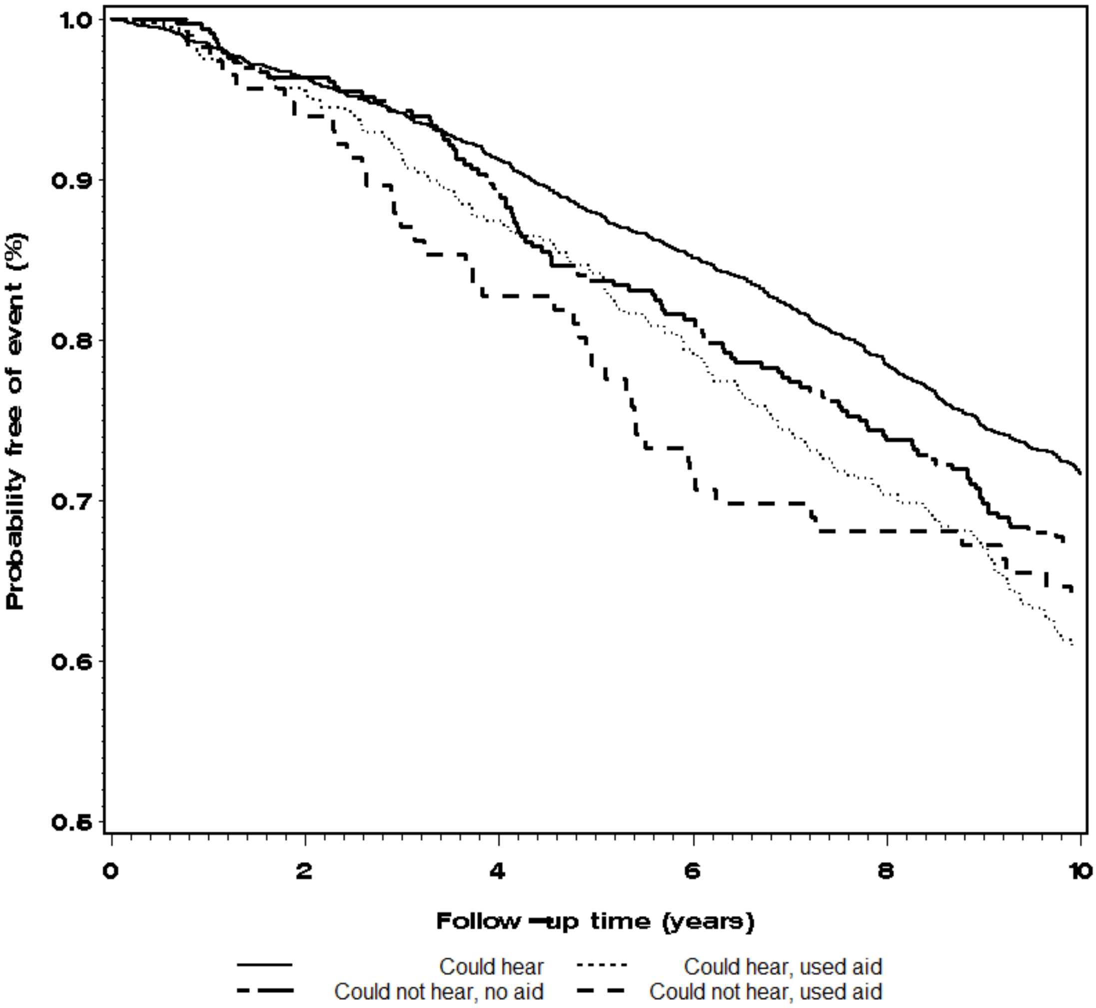


Figure 5.4 Kaplan-Meier survival curves showing CHD mortality according to vision impairment in men aged 63-85 years in 2003 followed-up for 10 years

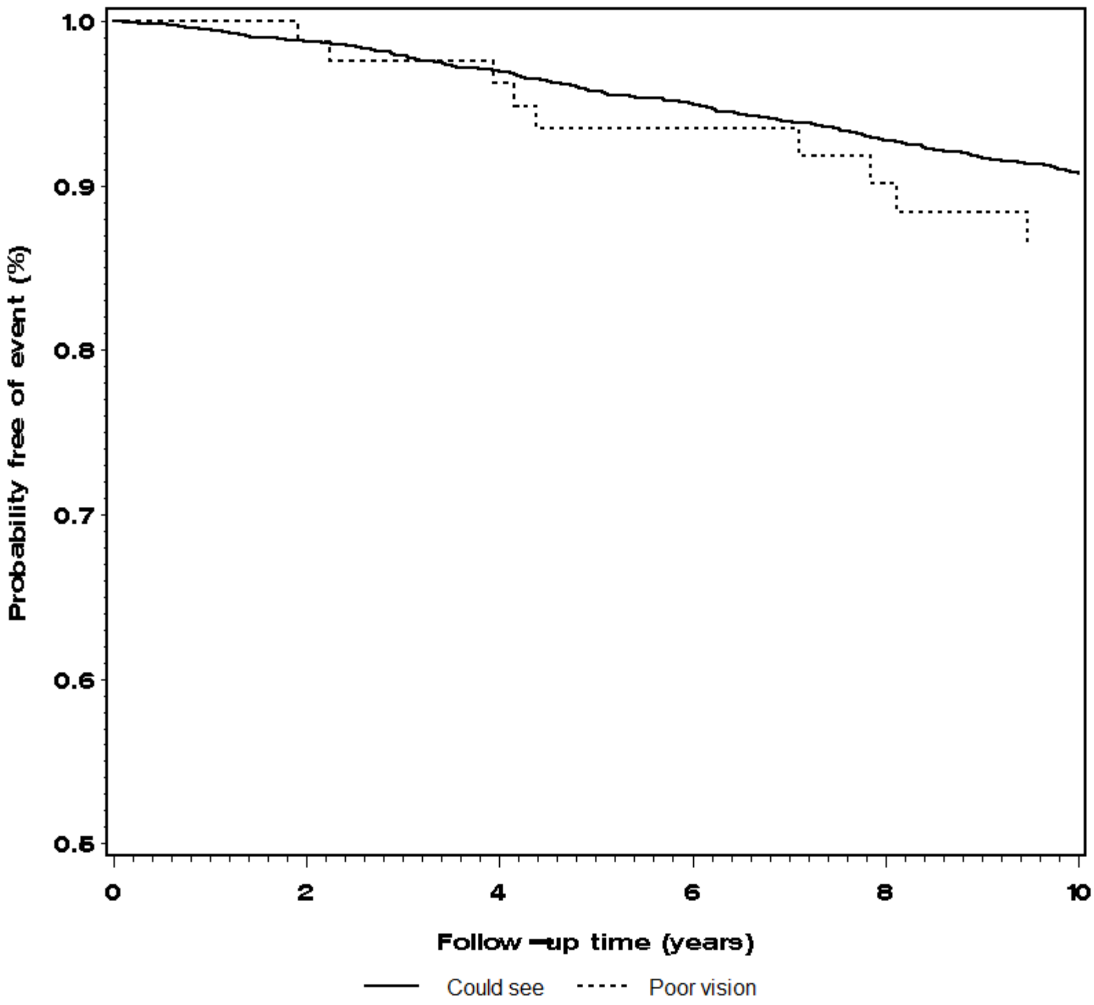


Figure 5.5 Kaplan-Meier survival curves showing CVD mortality according to vision impairment in men aged 63-85 years in 2003 followed-up for 10 years

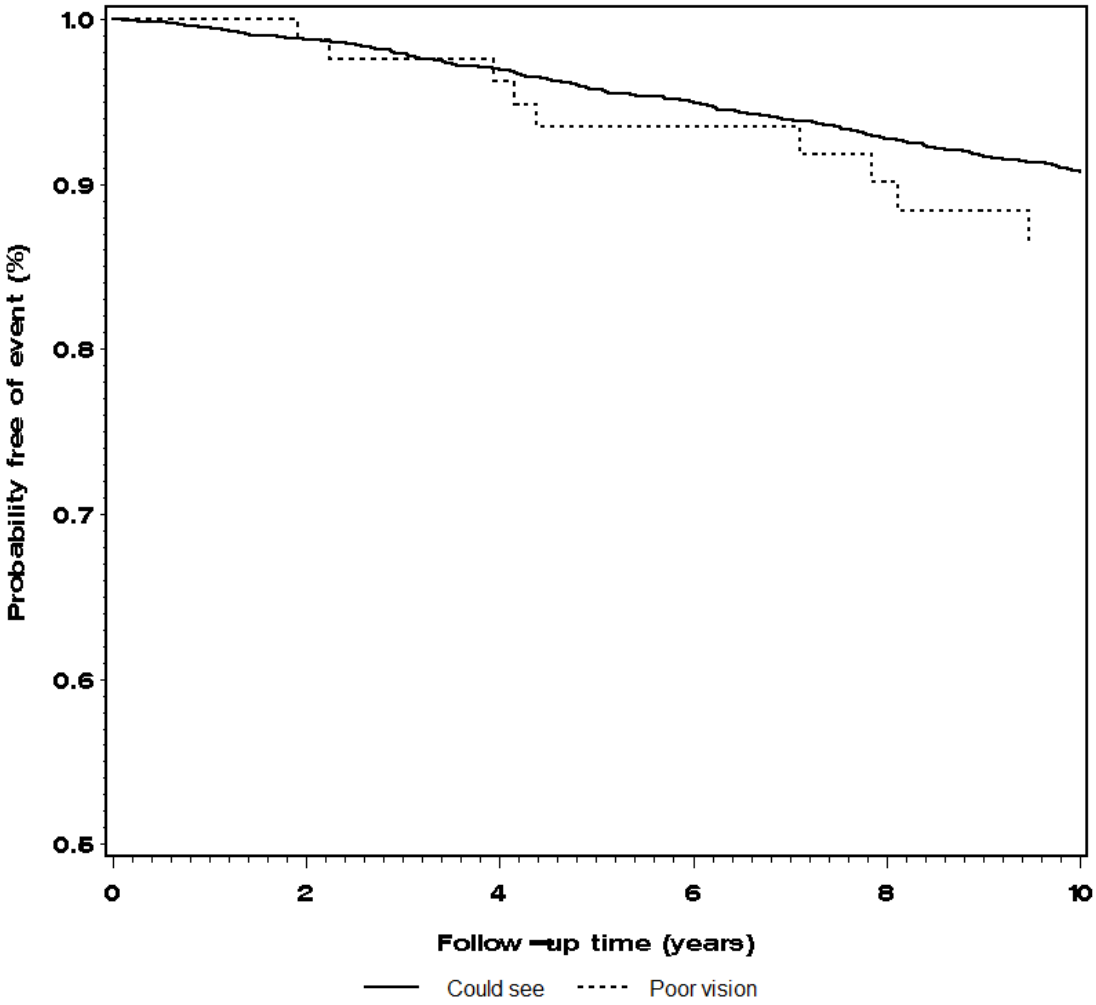


Figure 5.6 Kaplan-Meier survival curves showing all-cause mortality according to vision impairment in men aged 63-85 years in 2003 followed-up for 10 years

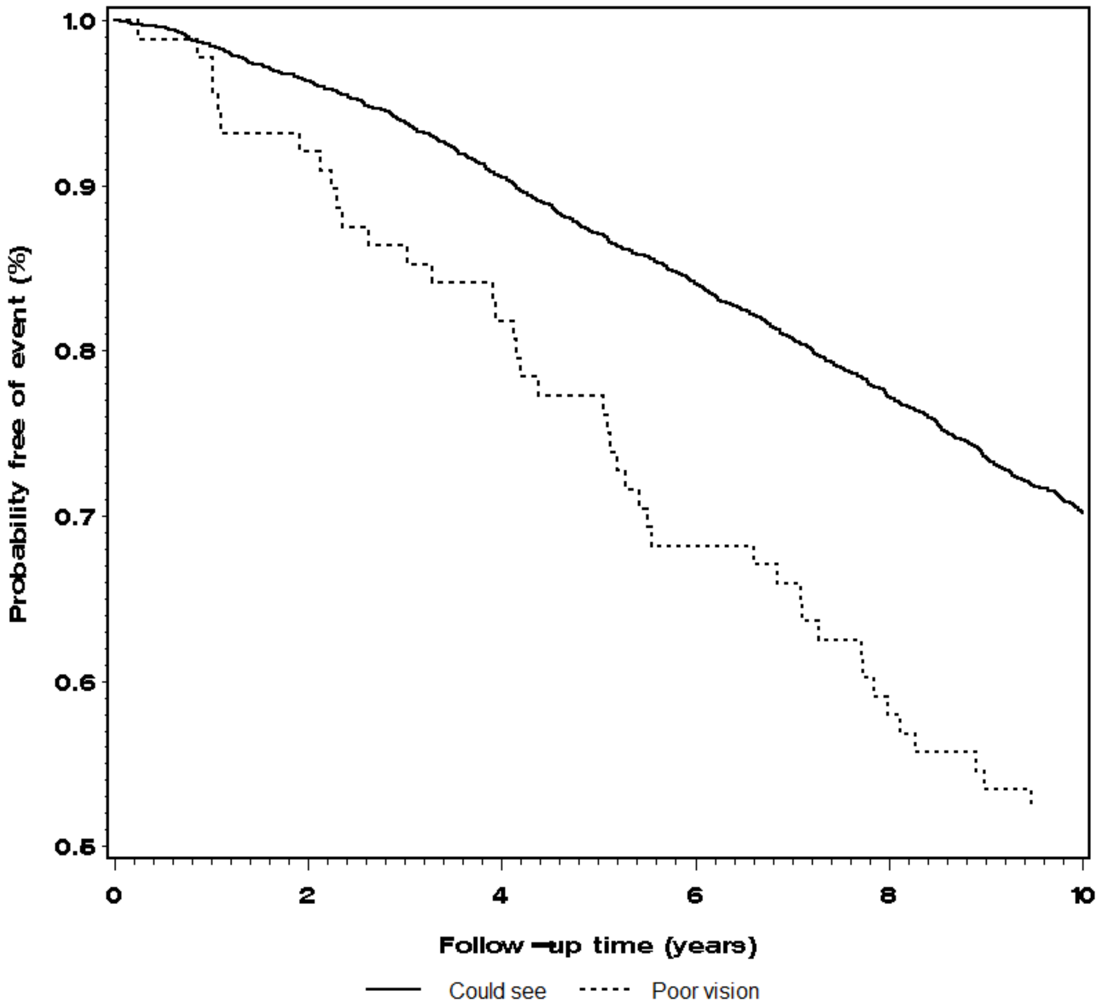


Table 5.1 Hazard ratios (HR) with 95% CIs for risk of incidence (non-fatal and fatal events) of CVD (MI and/or stroke), MI and stroke according to hearing impairment groups in British men aged 63-85 years in 2003 with no previous MI and/or stroke followed-up for 10 years to 2013

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
CVD events	Rates / 1000 (n)	16 (288)	19 (50)	24 (61)	20 (18)
Age-adjusted	HR (95% CI)	1.00	0.93 (0.69-1.26)	1.49 (1.13-1.96)	1.08 (0.67-1.75)
Adjusted*	HR (95% CI)	1.00	0.99 (0.71-1.36)	1.57 (1.17-2.11)	0.94 (0.55-1.61)
MI events	Rates / 1000 (n)	9 (163)	12 (32)	12 (33)	14 (12)
Age-adjusted	HR (95% CI)	1.00	1.09 (0.74-1.60)	1.41 (0.97-2.05)	1.33 (0.74-2.39)
Adjusted*	HR (95% CI)	1.00	1.11 (0.73-1.68)	1.41 (0.95-2.11)	1.07 (0.54-2.10)
Stroke events	Rates / 1000 (n)	7 (133)	8 (22)	11 (29)	7 (6)
Age-adjusted	HR (95% CI)	1.00	0.86 (0.54-1.36)	1.53 (1.02-2.28)	0.77 (0.34-1.74)
Adjusted*	HR (95% CI)	1.00	0.95 (0.59-1.53)	1.70 (1.12-2.59)	0.74 (0.30-1.83)

*Adjusted for age, social class, obesity, smoking, physical activity, hypertension and diabetes

Table 5.2 Hazard ratios (HR) with 95% CIs for risk of CHD mortality, CVD mortality and all-cause mortality according to hearing impairment groups in British men aged 63-85 years in 2003 followed-up for 10 years to 2013

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
CHD mortality	Rates / 1000 (n)	8 (198)	13 (53)	11 (38)	9 (12)
Age-adjusted	HR (95% CI)	1.00	1.20 (0.88-1.63)	1.30 (0.92-1.84)	1.03 (0.88-1.19)
Adjusted*	HR (95% CI)	1.00	1.09 (0.78-1.54)	1.27 (0.87-1.85)	0.88 (0.49-1.59)
CVD mortality	Rates / 1000 (n)	10 (257)	17 (68)	15 (52)	15 (20)
Age-adjusted	HR (95% CI)	1.00	1.15 (0.88-1.51)	1.37 (1.02-1.85)	1.11 (0.71-1.76)
Adjusted*	HR (95% CI)	1.00	1.07 (0.79-1.45)	1.39 (1.00-1.93)	1.09 (0.68-1.75)
All-cause mortality	Rates / 1000 (n)	39 (974)	54 (216)	48 (169)	58 (76)
Age-adjusted	HR (95% CI)	1.00	1.03 (0.88-1.19)	1.19 (1.01-1.40)	1.18 (0.93-1.49)
Adjusted**	HR (95% CI)	1.00	1.01 (0.86-1.19)	1.11 (0.93-1.34)	1.09 (0.86-1.40)

*Adjusted for age, social class, obesity, smoking, physical activity, hypertension and diabetes

**Adjusted for age, social class, obesity, smoking, physical activity, prevalent CVD, hypertension and diabetes

Table 5.3 Hazard ratios (HR) with 95% CIs for risk of incidence (non-fatal and fatal events) of CVD (MI and/or stroke), MI and stroke according to vision impairment in British men aged 63-85 years in 2003 with no previous MI and/or stroke followed-up for 10 years to 2013

		Could see	Poor vision
CVD events	Rates / 1000 (n)	17 (406)	23 (14)
Age-adjusted	HR (95% CI)	1.00	1.30 (0.76-2.21)
Adjusted*	HR (95% CI)	1.00	1.21 (0.68-2.16)
MI events	Rates / 1000 (n)	10 (232)	14 (9)
Age-adjusted	HR (95% CI)	1.00	1.45 (0.75-2.83)
Adjusted*	HR (95% CI)	1.00	1.20 (0.56-2.55)
Stroke events	Rates / 1000 (n)	8 (187)	8 (5)
Age-adjusted	HR (95% CI)	1.00	1.01 (0.42-2.47)
Adjusted*	HR (95% CI)	1.00	1.13 (0.46-2.75)

*Adjusted for age, social class, obesity, smoking, physical activity, hypertension and diabetes

Table 5.4 Hazard ratios (HR) with 95% CIs for risk of CHD mortality, CVD mortality and all-cause mortality according to vision impairment in British men aged 63-85 years in 2003 followed-up for 10 years to 2013

		Could see	Poor vision
CHD mortality	Rates / 1000 (n)	9 (289)	16 (14)
Age-adjusted	HR (95% CI)	1.00	1.56 (0.91-2.67)
Adjusted*	HR (95% CI)	1.00	1.17 (0.62-2.21)
CVD mortality	Rates / 1000 (n)	12 (383)	19 (17)
Age-adjusted	HR (95% CI)	1.00	1.42 (0.87-2.30)
Adjusted*	HR (95% CI)	1.00	1.14 (0.66-2.00)
All-cause mortality	Rates / 1000 (n)	41 (1368)	77 (69)
Age-adjusted	HR (95% CI)	1.00	1.67 (1.31-2.13)
Adjusted**	HR (95% CI)	1.00	1.32 (1.01-1.75)

*Adjusted for age, social class, obesity, smoking, physical activity, hypertension and diabetes

**Adjusted for age, social class, obesity, smoking, physical activity, prevalent CVD, hypertension and diabetes

CHAPTER 6 Relationships of sensory impairments and disability incidence in older British men

6.1. Summary

This Chapter has investigated the prospective associations of impairments in hearing and vision and the risk of incident disability. 3981 men from the British Regional Heart Study (BRHS) aged 63-85 years in 2003 were followed-up for 2 years to 2005 for incident mobility limitation (problems walking or taking stairs), difficulties undertaking activities of daily living (ADL) (e.g. bathing, dressing) and instrumental activities of daily living (IADL) (e.g. shopping, using public transport). Participants were classified as having a hearing impairment if they could hear and used a hearing aid, could not hear and no hearing aid, or could not hear and used a hearing aid. Those who did not see well enough to recognise a friend across the street were classified as visually impaired. Out of the 3981 men, 3108 men had no previous mobility limitation, 3346 men had no previous ADL difficulty and 3410 men had no previous IADL difficulty and were included in the incidence analyses. At 2-year follow-up there were 238 new cases of mobility limitation, 260 new cases of ADL difficulty and 207 new cases of IADL difficulty. Compared to men who could hear, men who could not hear and used a hearing aid had 2-fold greater risks of incident limitations in mobility (age-adjusted odds ratios (OR) 2.24, 95% CI 1.29-3.89) and incident difficulties in ADL (OR 2.01, 95% CI 1.16-3.46). However, the associations were attenuated on further adjustment for social class, lifestyle factors, co-morbidities and low social engagement. Men who could not hear and did not use a hearing aid were also associated with greater risk of incident ADL difficulty (OR 1.74, 95% CI 1.19-2.55) but the associations were attenuated on adjustments for covariates. Both men who could hear and used a hearing aid and men who could not hear and used a hearing aid had greater risks of incident IADL difficulty (OR 1.86, 95% CI 1.29-2.70; OR 2.74 95% CI 1.53-4.93) and the associations remained after further adjustment for social class, lifestyle factors, co-morbidities, low social engagement, mobility limitation, depression and poor balance. In further analyses excluding the IADL component ‘telephoning’, the magnitude of the associations were about the same in men who could hear and used a hearing aid and men who could not hear and used a hearing aid, however, the association between men who could not hear and used aid and increased risk of IADL difficulty showed only borderline significance. The inconsistent findings between the three hearing impairment groups further suggest that it may not be hearing per se underlying the observed association. Vision impairment was not associated with incident mobility limitation, ADL difficulty and IADL difficulty.

6.2. Introduction

As described in Chapter 2 (section 2.6), increased life expectancy means that people are living longer with chronic diseases such as cardiovascular disease (CVD), a major cause of disability.[181, 182] Prevalence of disability increases with advanced age,[70] affecting older adults' quality of life and need for care.[133, 134] Disability in later life often occurs first as mobility limitation (difficulties walking or climbing stairs).[186] Other forms of disability refer to disablement in tasks essential to caring for oneself (basic activities of daily living (ADL) e.g. bathing, dressing),[190] and more complex tasks that refer to domestic work and living independently in the community (instrumental activities of daily living (IADL) e.g. shopping, using public transport).[191] Numerous cross-sectional studies including the findings of Chapter 4 have shown associations between sensory impairments and mobility limitation, ADL difficulty and IADL difficulty in middle-aged and older adults combined.[12, 13, 60, 62, 195, 196, 210, 211] However, relatively few population-based studies have investigated such relationships prospectively and even fewer studies have been undertaken specifically in older adults. A recent study has shown an association between hearing impairment and increased risks of disability defined as having mobility limitation and/or ADL difficulty at 10-year follow-up in community-dwelling older adults.[150] However, a prospective study of community-dwelling adults aged 50 years and over investigating the relationship between hearing impairment and subsequent mobility limitation solely, found no association between hearing impairment and incident mobility limitation.[148] Hearing impairment has been associated with increased risks of incident ADL difficulty in hospital-based older adults,[64] but not in community-dwelling older adults.[66, 67, 161, 202] Some prospective studies on older adults have further reported an association between hearing impairment and increased risks of incident IADL difficulty,[63, 64] but findings are inconsistent with some studies showing no association.[65, 66, 148]

In terms of vision impairment and incident disability, earlier prospective studies have consistently shown an association between being visually impaired and increased risks of mobility limitation.[69, 148] The majority of earlier prospective studies on vision impairment and incident ADL difficulty have reported a positive association showing that vision impairment is associated with increased risk of incident ADL difficulty in middle-aged and older adults combined,[66, 148] and in older adults separately.[64, 67, 69, 202, 218, 241] Strong associations have furthermore been demonstrated between vision impairment and incident IADL difficulty in middle-aged and older adults.[65, 66, 148, 218]

Disability has been shown to have a negative impact on independent living in older age.[323] Consequently, it is important to understand the influence of common age-related conditions such as impairments in hearing and vision on disability including activities of daily living to establish the impact of these sensory impairments on functional independence in later life. Therefore this Chapter aims to examine the prospective associations between hearing impairment and vision impairment and the risk of incident mobility limitation, ADL difficulty and IADL difficulty in a representative sample of older British men aged 63-85 years followed-up for 2 years.

6.3. Objectives

The specific objective of this Chapter is:

i) To examine the relationships of impairments in hearing and vision with the risk of incident mobility limitation, ADL difficulty and IADL difficulty over 2 years in older age.

6.4. Methods

The British Regional Heart Study (BRHS) has been presented in Chapter 3 (section 3.2). This section (section 6.4) describes the data used in this Chapter.

6.4.1. Subjects and methods of data collection

This Chapter uses data from the BRHS self-administered questionnaire on health, lifestyle, sensory impairments and disability in 2003, completed by 3981 men (82% of survivors) aged 63-85 years. The men were followed-up prospectively for 2 years for mobility limitation, activities of daily living (ADL) difficulty and instrumental ADL (IADL) difficulty from 2003 to 2005. Data on disability at 2-year follow-up were obtained from the self-administrated health and lifestyle questionnaire in 2005.

6.4.2. Hearing and vision

Hearing and vision measures used in the 2003 questionnaire have been described in detail in Chapter 3 (section 3.3). Self-completed data on hearing aid use and ability to hear good enough to follow a TV programme at a volume others find acceptable were thus combined into the same four groups of hearing including use of a hearing aid or not (Chapter 3, section 3.3.1).

As before (Chapter 3, section 3.3.2), vision was based on a self-reported question asking about participants’ ability to recognise a friend across a road.

6.4.3. Incidence of mobility limitation, ADL and IADL difficulty

Dichotomous outcomes assessed in the present prospective study were for incident mobility limitation, incident difficulties in ADL and incident difficulties in IADL analysed as three separate endpoints. Mobility limitation was assessed using two questions asking whether the participants had problems taking the stairs (‘yes/no’) and problems walking 400 yards (‘yes/no’). Reporting problems with one or both was classified as having mobility limitation. ADL was classified as having any difficulty undertaking one or more of the following activities: bathing, dressing, eating, getting in or out of bed or chair, toileting, and/or walking across a room.[190] IADL was based on reporting any difficulty undertaking one or more of the following activities: cooking, shopping, using public transport, managing money and/or using the telephone.[191] Incidence was defined as developing mobility limitation, ADL difficulty and IADL difficulty and assessed in those having no mobility limitation, no ADL difficulty and no IADL difficulty, respectively, in 2003. Following the investigations on impairments in hearing and vision with incident mobility limitation, ADL difficulty and IADL difficulty, the relationship between hearing impairment and incidence of individual IADL components and incidence of IADL difficulty without the component ‘telephoning’ were explored.

6.4.4. Covariates

Socio-economic and lifestyle factors including social class, social engagement, cigarette smoking, obesity and physical activity were considered as covariates. The covariates were assessed in the self-administrated questionnaire in 2003, as described in detail in Chapter 3 (section 3.3). Comorbidity-related covariates included questions on doctor-diagnosed cardiovascular disease (CVD) (coronary thrombosis, myocardial infarction, angina and/or stroke), hypertension and diabetes with answer options ‘yes/no’. Participants were divided into manual and non-manual social class based on the longest-held occupation using the Registrar Generals’ Social Class Classification.[252] The men were grouped into three cigarette smoking groups: non-smokers, ex-smokers and current smokers.[253] Being obese was defined as having a body mass index (BMI) of 30 kg/m^2 and over.[257] Physical activity scores were based on exercise type and frequency categorised as none, occasional, light, moderate, moderately-vigorous and vigorous,[254] where none or occasional activity was classified as being inactive. Additional covariates included social engagement, depression and balance. Low social engagement was classified as doing three or fewer activities part of a 9-item social engagement scale on a weekly basis: voluntary work, go to the pub or a club, attend religious services, play cards or games, visit the cinema, restaurants or sports events, attend a class or course of study, and, sometimes go on day or overnight trips, and been on a holiday in the last year.[263] Doctor-diagnosed depression and self-reported poor balance were analysed dichotomously.

6.4.5. Statistical methods

Logistic regression was used to assess the associations of hearing impairment and vision impairment with incident mobility limitation, ADL and IADL difficulty separately. Odds ratios (OR) with 95% confidence intervals (CI) were obtained using no hearing impairment and no vision impairment as reference groups. All models were adjusted for potential confounders associated with sensory impairments in this cohort (see Chapter 4) and in previous literature (Chapter 2). Such confounders included age, which was entered as a continuous variable, and social class, obesity, smoking, physical activity, CVD, hypertension and diabetes, all fitted as categorical variables. In addition, possible mediators on the pathway linking impairments in hearing and vision to incident disability were explored including low social engagement, mobility limitation, depression and poor balance entered as categorical variables. Each of the three disability endpoints were analysed separately. Participants free from mobility limitation, free from difficulties in ADLs and free from difficulties in IADLs, respectively, at baseline were followed-up for each of the three disability measures.

6.5. Results

The characteristics of the study population of 3981 men and the relationships between sensory impairments and mobility limitation, difficulties undertaking activities of daily living (ADL) and instrumental activities for daily living (IADL), and covariates have been presented in Chapter 4. In this Chapter, the participants were followed-up for 2 years to 2005. Out of the 3981 men, 3108 men had no previous mobility limitation and were followed-up for incident mobility limitation, 3346 men had no previous ADL difficulty and were followed-up for ADL difficulty, and 3410 men had no previous IADL difficulty and were followed-up for IADL difficulty in the incidence analyses. At 2-year follow-up there were 238 new cases of mobility limitation, 260 new cases of ADL difficulty and 207 new cases of IADL difficulty.

6.5.1. Hearing impairment and risk of mobility limitation, ADL and IADL difficulty

Table 6.1 (page 172) presents odds ratios (OR) with 95% CIs for incident mobility limitation, ADL and IADL difficulty for hearing impairment. Compared with men who could hear, men who could not hear and used a hearing aid had over a 2-fold greater risk of mobility limitation at 2-year follow-up (age-adjusted OR 2.24, 95% CI 1.29-3.89). The association remained after further adjustment for social class, lifestyle factors and co-morbidities (OR 1.89, 95% CI 1.04-3.41) but was attenuated upon adjustment for social engagement. No association was observed between men who could not hear and did not use a hearing aid and limitations in mobility. Men who could not hear, irrespective of using hearing aid, had greater risks of developing difficulty performing ADL compared with men with no hearing impairment (‘could not hear, no aid’ OR 1.74, 95% CI 1.19-2.55; ‘could not hear, used aid’ OR 2.01, 95% CI 1.16-3.46). The association was attenuated after further adjustment for social class, lifestyle factors and comorbidities among men who used an aid but remained in those who could not hear and did not use hearing aid even after additional adjustment for social engagement (OR 1.68, 95% CI 1.11-2.55). The association was further adjusted for mobility limitation and the association was then attenuated (OR 1.49, 95% CI 0.97-2.29). Men who could hear and used an aid were not associated with increased risks of incident ADL difficulty. Compared with men with no hearing impairment, those who could hear and used a hearing aid and those who could not hear and used hearing aid were more likely to develop IADL difficulty (OR 1.86, 95% CI 1.29-2.70; OR 2.74, 95% CI 1.53-4.93). The associations remained after further adjustment for social engagement (OR 2.00, 95% CI 1.34-2.99; OR 2.61, 95% CI 1.38-4.96). The associations were further adjusted for mobility limitation, depression and poor balance and remained statistically significant (OR 2.03, 95% CI 1.35-3.07; OR 2.77, 95% CI 1.43-5.36). No association was shown between those who could not hear and did not use a hearing aid and incident IADL difficulty.

Tables 6.2, 6.3 and 6.4 (pages 173-175) show the associations between hearing impairment and individual components of IADL. In comparison with men with no hearing impairment, men who could hear and used a hearing aid and men who could not hear and used aid were both more likely to experience difficulties undertaking shopping and light housework even after further adjustment including social engagement. Men who could hear and used an aid were also more likely to have problems using public transport. Men who could hear and used a hearing aid and men who could not hear and used a hearing aid were more likely to have problems telephoning with over 4-fold increased risk in men who could not hear despite aid (OR 4.53, 95% CI 2.25-9.10). The association remained in men who could not hear and used a hearing aid after further adjustment including social engagement (OR 4.29, 95% CI 2.02-9.13) and after further adjustment for mobility limitation, depression and poor balance (OR 4.29, 95% CI 2.00-9.18). Similarly, not being able to hear and using a hearing aid was associated with difficulties managing money even after further adjustment for social engagement, mobility limitation, depression and poor balance

(OR 3.37, 95% CI 1.76-6.47). Only men who could not hear and used a hearing aid had increased risks of difficulty cooking (OR 2.03, 95% CI 1.05-3.94), but the association was attenuated after further adjustment for lifestyle factors and comorbidities. None of the hearing impairment groups were associated with difficulties taking medications.

The relationship between hearing impairment and IADL difficulty was further analysed without the component of telephoning (Table 6.5, page 176). Age-adjusted findings showed that men who could hear and used a hearing aid and men who could not hear and used an aid were more likely to develop difficulties undertaking IADLs (OR 1.75, 95% CI 1.20-2.56; OR 1.97 95% CI 1.06-3.63). The association was attenuated in men who could not hear and used a hearing aid after further adjustment for lifestyle factors and comorbidities but remained in men who could hear and used aid even after further adjustment for social engagement, mobility limitation, depression and poor balance (OR 1.84, 95% CI 1.21-2.81).

6.5.2. Vision impairment and risk of mobility limitation, ADL and IADL difficulty

Table 6.6 (page 177) presents OR with 95% CIs for incident mobility limitation, ADL and IADL difficulty for vision impairment. No significant associations were observed between vision impairment and incident mobility limitation on adjustment for age. The lack of association was still present after further adjustment for social class, obesity, smoking, physical activity, CVD, hypertension and diabetes. Similarly, vision impairment was not associated with ADL difficulty and IADL difficulty.

6.6. Discussion

6.6.1. Summary of main findings

This Chapter has examined the relationships between impairments in hearing and vision and the risk of incident mobility limitation, difficulties in ADL and difficulties in IADL in a prospective cohort of British men aged 63-85 years. The findings show that compared with men who could hear, men who could not hear and used a hearing aid had increased risks of incident limitations in mobility and ADL difficulty. Similarly, men who could not hear and did not use a hearing aid had increased risks of incident ADL difficulty. However the associations were attenuated on further adjustments for social class, lifestyle factors, co-morbidities and social engagement. Both men who could hear and used a hearing aid and men who could not hear and used a hearing aid had greater risks of incident IADL difficulty (OR 1.86, 95% CI 1.29-2.70; OR 2.74 95% CI 1.53-4.93) and the associations remained after further adjustment for covariates.

However, a similar association was not observed for men who could not hear and did not use a hearing aid. Further analyses of hearing impairment and incident IADL difficulty without the component of telephoning showed a significant positive association only in men who could hear and used a hearing aid. In this study, vision impairment was not associated with incident mobility limitation or difficulties in ADL and IADL.

6.6.2. Comparison with previous studies

6.6.2.1. Hearing impairment and incident mobility limitation, ADL difficulty and IADL difficulty

Men who could not hear and used a hearing aid had greater risk of incident limitations in mobility compared to men who could hear after adjustment for age, social class, comorbidities and lifestyle factors but was attenuated on further adjustment for social engagement. This is consistent with findings from the prospective Alameda County Study of middle-aged and older community-dwelling adults showing no association between hearing impairment and incident mobility limitation after adjustment for socio-demographic factors and comorbidities.[148] Two earlier studies on objective and self-reported hearing and subsequent mobility limitation that included additional measures of physical functioning such as chair stands[150] and housework,[66] showed a positive association between hearing impairment and mobility limitation on adjustment for demographic factors and comorbidities. However, none of the studies adjusted for lifestyle factors.[66, 150] In this study, the association between hearing impairment and mobility limitation was attenuated particularly on adjustment for social engagement. This finding supports research suggesting that low social engagement, potentially through communication problems due to lack of hearing,[150] may explain the relationship between hearing impairment and incident disability.[63, 207]

Only men who could not hear and did not use a hearing aid had greater risk of subsequent ADL difficulty after adjustment for age, social class, lifestyle factors, comorbidities and social engagement. However the association was attenuated after further adjustment for mobility limitation. This finding is consistent with previous studies of community-dwelling older adults demonstrating no association between hearing impairment and incident ADL difficulty after adjustment for potential covariates,[65-67, 202] suggesting that hearing may not be necessary to undertake basic self-care tasks including toileting and bathing.[202]

Men who could hear and used a hearing aid and men who could not hear despite reporting using a hearing aid had increased risks of subsequent IADL difficulties and the associations remained after further adjustment for social class, lifestyle factors and comorbidities. The associations also remained statistically significant after further adjustment for low social engagement, mobility limitation, depression and poor balance, possible mediators of the relationship between hearing impairment and incident disability. Literature has shown that social isolation and depression are common consequences of hearing impairment,[9, 151, 152] and may further reduce the individual's motivation to maintain good physical functioning.[303] Hearing impairment due to damage to the inner ear can furthermore cause poor balance,[141] a risk factor for mobility limitation in later life.[243] Recent research has also shown that mobility limitation is associated with increased risks of developing other domains of disability including everyday activities.[189] Therefore, associations that remained after adjustment for lifestyle factors and comorbidities were further adjusted for these possible mediators. However, the role of possible mediators on the pathway linking hearing impairment to incident disability needs further investigation, as further discussed in Chapter 8 (section 8.4.6).

Further, the findings on 'could hear, used a hearing aid' and 'could not hear, used a hearing aid' being associated with increased risks of subsequent IADL difficulty are consistent with two large studies of community-dwelling older adults in Brazil[203] and Japan.[63] Such studies have shown an association between self-reported hearing impairment and increased risks of incident IADL difficulty after adjustments for age, socio-economic factors, comorbidities and lifestyle factors. The findings on hearing impairment and incident IADL difficulty in the present study also support previous research demonstrating an association between objectively measured hearing impairment and incident IADL adjusted for age, socio-economic factors, comorbidities and lifestyle factors in a cohort of 5444 community-dwelling adults aged 55-74 years followed-up for 10 years.[66] Thus, hearing impairment seems to have a greater impact on IADLs which involve more complex tasks (such as shopping and using public transport) than basic tasks part of ADL (eating, bathing) and mobility limitation.[324] Nevertheless, these findings should be interpreted with caution as the relationship between hearing impairment and incident IADL without the component on difficulty telephoning showed an association in men who could hear and used aid but was attenuated in men who could not hear and used a hearing aid after further adjustment for social class, lifestyle factors and comorbidities. This proposes that the association between men who could not hear and used a hearing aid and incident IADL difficulty was driven by the component ‘telephoning’. However, the magnitude of association was equally as strong in both hearing impairment groups (‘could hear, used a hearing aid’, and ‘could not hear, used a hearing aid’) suggesting that the non-significant association between men who could not hear and used an aid and incident IADL difficulty without the component telephoning may be due to lack of power caused by the small number of men who could not hear and used a hearing aid (n=114) in the analysis following the removal of the component telephoning. Nevertheless, these findings are exploratory and should be interpreted with caution.

Nevertheless, the observed associations between hearing impairment and IADL difficulty could be explained by unmeasured factors such as poor cognitive functioning. Hearing impairment has been shown to increase the risk of cognitive impairment,[155, 325] a major contributor to disability and dependence in older adults.[157, 326] Deteriorating hearing in older age has been demonstrated to increase the demands on cognitive resources to understand speech and process acoustic information.[63, 203] Literature has also shown that adequate cognitive functioning is important to undertake IADLs, which include problem-solving and complex behaviour directed to a goal.[203, 326] Cognitive functioning may therefore explain the association observed between hearing impairment and incident IADL difficulty. However, data on cognitive function were not available and could not be considered in these investigations. Moreover, it has been speculated that family members may steer older relatives with hearing impairment, perceived to also have poor physical and cognitive functions, away from responsibilities and tasks such as IADLs.[63] Such behaviour could possibly result in older individuals perceiving themselves as having difficulties with IADLs. The possibility of family members steering their hearing impaired older relatives away from IADL tasks might furthermore explain the lack of consistent findings across the hearing impairment groups and incident IADL difficulty with no association observed in those unable to hear and not using a hearing aid, suggesting that this hearing impairment group receive less help and support from their relatives compared to those who use a hearing aid. The inconsistent findings on hearing impairment and incident IADL difficulty also suggests that this hearing impairment group (‘could not hear, no aid’) may consist of a combination of men with a hearing problem who do not use a hearing aid due to, for instance, lack of access to health services and audiology assessments, reluctance to wear an aid, a perception that aids are unhelpful, and men whose hearing problem is not improved by an aid. Finally, the association observed between hearing impairment and incident IADL could be explained by inflammation, which has been related to both hearing impairment and disability.[37, 327]

6.6.2.2. Vision impairment and incident mobility limitation, ADL difficulty and IADL difficulty

Vision impairment did not predict the risk of incident mobility limitation in older age. Similarly, no association was observed between vision impairment and incident ADL difficulty. This is consistent with a previous study investigating the relationship between age-related macular degeneration (AMD) and incident ADL difficulty at 5-year follow-up showing no association[218] and supports the notion that vision impairment (except for extreme cases) is unlikely to lead to the inability to perform basic tasks such as ADLs.[328] In the present study, the magnitude of association between vision impairment and incident IADL difficulty was large however the association was not statistically significant. The lack of a significant relationship between vision impairment and incident IADL difficulty is contrary to previous research showing that both self-reported[65, 148] and objectively assessed vision impairment,[66] and eye conditions such as AMD[218] increase the risk of developing difficulties undertaking IADLs. However, the definition of vision impairment in the present study may have identified those with severe vision impairment only, resulting in a small number of vision impaired participants suggesting that the lack of a statistically significant association could be due to lack of statistical power.

6.6.3. Strengths and limitations

The major strengths of this Chapter include that data are from a population-based, socioeconomically and geographically representative sample of older British men with high rates of follow-up.[81, 247] In addition, the cohort was followed-up for three types of disability and the models were adjusted for several confounding variables. However, since the study comprised predominately of white British older male participants, the findings cannot be generalised to non-white ethnic groups and women.

An additional strength of this study is that validated measures were used to assess disability including mobility limitation based on ability to walk a quarter of a mile and climbing stairs, which are among the most commonly used measures of disability in longitudinal studies of ageing.[329] Similarly, the Katz Activities of Daily Living (ADL) Index[190] and the Lawton Instrumental ADL (IADL) scale[191] are widely used and have been found to be reliable and valid.[258] Nevertheless, disability was self-reported rather than objectively measured. Objective measures may be better at capturing functional capacity but do not necessarily capture the extent of disability which may differ from an individual's actual experience.[330, 331] Finally, limitations also include that hearing impairment and vision impairment were self-reported and measured at baseline only.

6.7. Conclusions

Chapter 6 shows that older men who could hear and used a hearing aid and older men who could not hear and used a hearing aid had greater risks of incident IADL difficulty, compared to men who could hear. However the association should be interpreted with caution as the association may have been driven by the IADL component 'telephoning'. The inconsistent findings between the hearing impairment groups further suggest that it may not be hearing per se underlying the association. Potential factors explaining the findings include cognitive function, previously related to hearing impairment and essential for undertaking complex tasks such as IADL. Hearing impairment was not associated with incident ADL difficulty and mobility limitation after adjustment for covariates. In this study no association was observed between vision impairment and incident disability.

Table 6.1 Odds ratios (OR) with 95% CIs for risk of incidence of limitations in mobility, difficulties in activities of daily living (ADL) and difficulties in instrumental activities of daily living (IADL) according to hearing impairment groups in British men aged 63-85 years in 2003 followed-up for 2 years to 2005

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
Limitations in mobility		n=2293	n=360	n=303	n=106
	n (%)	150 (7)	39 (11)	23 (8)	17 (16)
Model 1	OR (95% CI)	1.00	1.40 (0.95-2.05)	1.16 (0.73-1.83)	2.24 (1.29-3.89)
Model 2		1.00	1.40 (0.92-2.12)	1.26 (0.78-2.03)	1.89 (1.04-3.41)
Model 2 + social engagement		1.00	1.41 (0.93-2.14)	1.24 (0.77-2.01)	1.79 (0.98-3.27)
ADL	n (%)	n=2408	n=383	n=324	n=113
	OR (95% CI)	161 (7)	41 (10)	37 (11)	17 (15)
Model 1		1.00	1.30 (0.90-1.88)	1.74 (1.19-2.55)	2.01 (1.16-3.46)
Model 2		1.00	1.23 (0.82-1.84)	1.76 (1.16-2.66)	1.62 (0.90-2.94)
Model 2 + social engagement		1.00	1.25 (0.83-1.87)	1.68 (1.11-2.55)	1.59 (0.87-2.88)
IADL	n (%)	n=2474	n=390	n=335	n=97
	OR (95% CI)	126 (5)	44 (11)	19 (6)	15 (15)
Model 1		1.00	1.86 (1.29-2.70)	1.09 (0.66-1.79)	2.74 (1.53-4.93)
Model 2		1.00	2.03 (1.36-3.01)	1.01 (0.59-1.75)	2.56 (1.35-4.86)
Model 2 + social engagement		1.00	2.00 (1.34-2.99)	0.95 (0.54-1.67)	2.61 (1.38-4.96)

Model 1 = adjusted for age; Model 2 = adjusted for age, social class, obesity, smoking, physical activity, CVD, hypertension and diabetes

Table 6.2 Odds ratios (OR) with 95% CIs for risk of incidence of difficulty in the IADL components of shopping, light housework and telephoning according to hearing impairment groups in British men aged 63-85 years in 2003 followed-up for 2 years to 2005

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
Shopping		n=2572	n=413	n=365	n=136
	n (%)	73 (3)	31 (7)	17 (5)	13 (9)
Model 1	OR (95% CI)	1.00	2.05 (1.32-3.20)	1.63 (0.95-2.80)	2.80 (1.50-5.23)
Model 2		1.00	1.96 (1.20-3.19)	1.56 (0.87-2.82)	2.39 (1.22-4.68)
Model 2 + social engagement		1.00	2.01 (1.23-3.28)	1.46 (0.80-2.68)	2.30 (1.15-4.60)
Light housework		n=2580	n=425	n=373	n=135
	n (%)	66 (2)	25 (6)	12 (3)	12 (8)
Model 1	OR (95% CI)	1.00	1.93 (1.19-3.12)	1.24 (0.66-2.32)	3.08 (1.61-5.88)
Model 2		1.00	1.76 (1.05-2.95)	1.05 (0.54-2.05)	2.73 (1.39-5.34)
Model 2 + social engagement		1.00	1.80 (1.07-3.04)	1.02 (0.52-2.00)	2.73 (1.39-5.38)
Telephoning		n=2706	n=434	n=387	n=129
	n (%)	43 (2)	17 (4)	7 (2)	11 (8)
Model 1	OR (95% CI)	1.00	1.85 (1.03-3.32)	1.10 (0.49-2.47)	4.53 (2.25-9.10)
Model 2		1.00	1.64 (0.88-3.04)	0.75 (0.29-1.93)	3.82 (1.80-8.09)
Model 2 + social engagement		1.00	1.74 (0.93-3.24)	0.78 (0.30-2.03)	4.29 (2.02-9.13)

Model 1 = adjusted for age; Model 2 = adjusted for age, social class, obesity, smoking, physical activity, CVD, hypertension and diabetes

Table 6.3 Odds ratios (OR) with 95% CIs for risk of incidence of difficulty in the IADL components of managing money and using public transport according to hearing impairment in British men aged 63-85 years in 2003 followed-up for 2 years to 2005

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
Managing money		n=2636	n=431	n=380	n=149
	n (%)	59 (2)	16 (4)	10 (3)	14 (9)
Model 1	OR (95% CI)	1.00	1.27 (0.71-2.25)	1.13 (0.57-2.23)	3.68 (1.99-6.82)
Model 2		1.00	1.29 (0.71-2.35)	0.97 (0.45-2.07)	3.49 (1.84-6.62)
Model 2 + social engagement		1.00	1.32 (0.72-2.41)	0.95 (0.44-2.04)	3.68 (1.94-6.98)
Using public transport		n=2456	n=395	n=345	n=118
	n (%)	75 (3)	33 (8)	13 (4)	7 (5)
Model 1	OR (95% CI)	1.00	1.98 (1.28-3.06)	1.20 (0.66-2.20)	1.42 (0.64-3.19)
Model 2		1.00	1.97 (1.23-3.16)	1.16 (0.61-2.20)	1.33 (0.58-3.05)
Model 2 + social engagement		1.00	1.93 (1.20-3.11)	1.13 (0.59-2.14)	1.36 (0.60-3.13)

Model 1 = adjusted for age; Model 2 = adjusted for age, social class, obesity, smoking, physical activity, CVD, hypertension and diabetes

Table 6.4 Odds ratios (OR) with 95% CIs for risk of incidence of difficulty in the IADL components of cooking and taking medications according to hearing impairment groups in British men aged 63-85 years in 2003 followed-up for 2 years to 2005

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
Cooking		n=2452	n=395	n=347	n=127
	n (%)	84 (3)	22 (5)	18 (5)	11 (8)
Model 1	OR (95% CI)	1.00	1.26 (0.77-2.06)	1.47 (0.87-2.49)	2.03 (1.05-3.94)
Model 2		1.00	1.30 (0.77-2.20)	1.32 (0.74-2.37)	1.78 (0.89-3.56)
Taking medications		n=2669	n=438	n=387	n=152
	n (%)	47 (2)	16 (3)	10 (2)	5 (3)
Model 1	OR (95% CI)	1.00	1.54 (0.85-2.78)	1.41 (0.71-2.83)	1.44 (0.56-3.71)

Model 1 = adjusted for age; Model 2 = adjusted for age, social class, obesity, smoking, physical activity, CVD, hypertension and diabetes

Table 6.5 Odds ratios (OR) with 95% CIs for risk of incidence of IADL difficulty without the component of telephoning according to hearing impairment groups in British men aged 63-85 years in 2003 followed-up for 2 years to 2005

		Could hear	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
IADL without 'telephoning'		n=2476	n=399	n=337	n=114
	n (%)	123 (5)	42 (10)	19 (6)	13 (11)
Model 1	OR (95% CI)	1.00	1.75 (1.20-2.56)	1.11 (0.67-1.83)	1.97 (1.06-3.63)
Model 2		1.00	1.85 (1.23-2.78)	1.05 (0.61-1.81)	1.88 (0.98-3.61)
Model 2 + social engagement		1.00	1.82 (1.20-2.75)	0.96 (0.55-1.70)	1.89 (0.99-3.74)

Model 1 = adjusted for age; Model 2 = adjusted for age, social class, obesity, smoking, physical activity, CVD, hypertension and diabetes

Table 6.6 Odds ratios (OR) with 95% CIs for risk of incidence of limitations in mobility, difficulties in activities of daily living (ADL) and difficulties in instrumental activities of daily living (IADL) according to vision impairment in British men aged 63-85 years in 2003 followed-up for 2 years to 2005

		Could see	Poor vision
Limitations in mobility		n=2973	n=79
	n (%)	224 (8)	6 (8)
Model 1	OR (95% CI)	1.00	0.91 (0.39-2.12)
Model 2		1.00	0.93 (0.39-2.23)
Model 2 + social engagement		1.00	0.80 (0.31-2.06)
ADL		n=3139	n=81
	n (%)	246 (8)	9 (10)
Model 1	OR (95% CI)	1.00	1.21 (0.60-2.47)
Model 2		1.00	1.26 (0.60-2.64)
Model 2 + social engagement		1.00	1.33 (0.63-2.81)
IADL		n=3213	n=72
	n (%)	194 (6)	9 (11)
Model 1	OR (95% CI)	1.00	1.88 (0.92-3.86)
Model 2		1.00	1.83 (0.84-3.99)
Model 2 + social engagement		1.00	1.91 (0.87-4.19)

Model 1 = adjusted for age; Model 2 = adjusted for age, social class, obesity, smoking, physical activity, CVD, hypertension and diabetes

CHAPTER 7 Relationships of sensory impairments and frailty incidence in older English men and women

7.1. Summary

Hearing impairment and vision impairment have been associated with greater risks of frailty in cross-sectional studies however few longitudinal studies have investigated the relationship between sensory impairments and the risks of incident pre-frailty and frailty. This Chapter has investigated the associations of impairments in hearing and vision and the risk of incident pre-frailty and frailty in non-frail participants and the risk of incident frailty in pre-frail participants in older adults from the English Longitudinal Study of Ageing (ELSA). Complete data on sensory impairments, covariates and frailty in 2004 and on frailty in 2008 were provided by 2836 women and men aged 60 years and over through an interview and a physical examination on their health including measures of the Fried frailty phenotype (slow walking, weak grip, self-reported exhaustion, weight loss and low physical activity where having 0 frailty components was defined as being non-frail, 1-2 pre-frail and 3 or more as frail) and self-reported hearing and vision (excellent, very good or good vs fair or poor). The relationships were analysed using logistic regression. The prevalence of hearing impairment and vision impairment was 23% (n=643) and 12% (n=339), respectively. Half of the participants (n=1396) (49%) were non-frail, 1178 (42%) were pre-frail and 262 (9%) were frail in 2004 (baseline) using the Fried phenotype. In the 1396 participants with no prevalent frailty in 2004, 343 reported pre-frailty and 24 reported frailty at 4-year follow-up in 2008. Among the 1178 participants pre-frail in 2004, 133 participants were frail at 4-year follow-up in 2008. Compared to pre-frail participants with good hearing, pre-frail participants with poor hearing had increased risks of incident frailty (age- & sex-adjusted OR 1.64, 95% CI 1.07-2.51). No association was shown between hearing impairment and incident pre-frailty and frailty in non-frail participants. Non-frail participants with poor vision had a 2-fold greater risk of incident pre-frailty and frailty combined (age- & sex-adjusted OR 2.07, 95% CI 1.32-3.24) compared to non-frail participants with good vision. Vision impairment was not associated with increased risks of frailty in those pre-frail. In conclusion, hearing impairment may be a particular problem in older adults who have started to experiencing frailty whereas vision impairment may be of particular importance in the onset of the early stages of frailty when non-frail individuals start becoming frail.

7.2. Introduction

Frailty is common in later life and refers to the body's inability to respond adequately to stressors due to multi-system impairments and reduced physiological reserves.[18, 71] Adverse health outcomes investigated in Chapters 4, 5 and 6 including cardiovascular disease (CVD) and disability are related to frailty, as described in Chapter 2. One of the most commonly used frailty measures is the Fried phenotype which has been deemed suitable for identification of community-dwelling older adults[18, 332, 333] and incorporates five frailty components: unintentional weight loss, weak grip, slow walking speed, self-reported exhaustion, and low levels of physical activity.[18] A score of 0 refers to no frailty (or 'robust'), 1-2 pre-frailty (intermediate group) and 3 or more is defined as being frail. In Chapter 4, cross-sectional analyses showed that not being able to hear, irrespectively of hearing aid use, and poor vision were associated with walking problems, a component of frailty. The findings of Chapter 4 also showed that men who could not hear and used a hearing aid, and men who could not see, were associated with low levels of physical activity, another component of the Fried phenotype. However, little is known about the relationship between impairments in hearing and vision and the risk of incident frailty. Recent cross-sectional studies have shown an association between hearing impairment and frailty defined as the Fried phenotype in older women but not in older men.[14] Hearing impairment has also been associated with incident frailty at 10-year follow-up on adjustment for socio-demographic and lifestyle factors, however, only two measures were used to define frailty (slow walking and inability to rise from a chair).[77] In terms of vision impairment, most of the previous studies have investigated the relationship between specific age-related eye conditions such as cataract and age-related macular degeneration (AMD), and separate components of frailty such as grip strength and chair stands rather than using a validated frailty measure.[15, 78, 79] Also, the studies have been of cross-sectional design, have not distinguished between middle-aged and older adults and have not adjusted for social and cognitive factors.[15, 78, 79] Cognitive function may be a possible mediator of the relationship and therefore important to consider. In a recent cross-sectional study of patients from a geriatric clinic, no association between objectively measured vision impairment and pre-frailty and frailty defined as the Fried phenotype was observed on adjustment for demographic factors and cognition.[240] Further, limited research has investigated incidence of pre-frailty and frailty separately. Therefore, this Chapter aims to examine the cross-sectional and prospective associations of hearing impairment and vision impairment with pre-frailty and frailty in a representative sample of English men and women aged 60 years and over followed for 4 years.

7.3. Objectives

The specific objectives of this Chapter are:

i) To examine the cross-sectional associations between impairments in hearing and vision and pre-frailty and frailty in a cohort of older English women and men.

ii) To examine the prospective relationship between hearing impairment and the risk of incident pre-frailty and frailty over 4 years follow-up in non-frail older adults and the risk of incident frailty over 4 years follow-up in pre-frail older adults.

iii) To examine the prospective relationship between vision impairment and the risk of incident pre-frailty and frailty over 4 years follow-up in non-frail older adults and the risk of incident frailty over 4 years follow-up in pre-frail older adults.

7.4. Methods

Information on the English Longitudinal Study of Ageing (ELSA) including data collection has been described in Chapter 3 (section 3.6). This section describes the ELSA data used in this Chapter.

7.4.1. Subjects and methods of data collection

Data in this Chapter are from the ELSA physical examination and interview on health, lifestyle, sensory impairments and frailty in 2004 and frailty in 2008, completed by 2836 men and women aged 60 years and over (67% of cohort subjects aged 60 years and over). The participants were followed-up prospectively for 4 years for pre-frailty and frailty from 2004 to 2008.

7.4.2. Hearing and vision

Measures of hearing and vision in the 2004 questionnaire have been described in detail in Chapter 3 (section 3.6). Self-rated data on hearing and vision were obtained by asking participants whether their hearing and eyesight, respectively, was excellent, very good, good, fair or poor. Reporting excellent, very good or good was classified as having no hearing impairment and vision impairment, respectively (reference groups). Fair and poor were combined and referred to as hearing impairment/vision impairment.

7.4.3. Pre-frailty and frailty

Frailty was based on the 5 components of a modified Fried phenotype: weight loss, weak grip strength, slow walking, exhaustion and low physical activity.[18] Details of data collection of the frailty components have been provided in Chapter 3 (section 3.6). In this study, weight loss was defined as either loss of 10% or more of body weight in the last 4 years or current body mass index (BMI) under 18.5 kg/m^2. However the ELSA data did not allow differentiating between intentional and unintentional weight loss. Weak grip was assessed using a grip strength gauge three times for each hand and the maximum handgrip strength measure out of a total of six attempts was used for the analysis. Weak grip was classified as being in the lowest quintile of the distribution, after taking sex and BMI into account. Slow walking speed was based on the mean of the time taken to complete an 8-feet walk at their usual pace from two measurements. The lowest sex- and height-specific quintile of the study sample distribution, and those in wheelchairs, bed bound, unable to walk due to health problems or unable to walk alone (n=34), were classified as having slow walking speed. Exhaustion was defined as giving positive responses to any of the two questions ‘Felt that everything I did was an effort in the last week’ or ‘Could not get going in the last week’. Low physical activity was based on frequency and intensity in exercise by asking participants how often they undertook vigorous, moderate and mild exercise (more than once a week, once a week, one to three times a month, hardly ever or never). Reporting exercising hardly ever or never, doing mild exercise only, or doing moderate exercise a maximum of one to three times a month was classified as low physical activity. In this study levels of physical activity were calculated without information on calorie consumption due to lack of such data in ELSA. Frailty was defined using the standard cut points as the presence of 3 or more of the 5 frailty components. Pre-frailty was defined as the presence of 1 or 2 components. No prevalent frailty was defined as having none of the frailty components. Incidence of pre-frailty and frailty was assessed in non-frail participants in 2004 (baseline), and incidence of frailty was assessed in participants who were pre-frail in 2004.

7.4.4. Covariates

Covariates included age, sex, wealth, education, cardiovascular disease (CVD), smoking, hypertension, diabetes, history of falls, cognitive function, depression and lack of companionship. The covariates were assessed in the interview in 2004, as described in detail in Chapter 3 (section 3.6). Age was grouped into 60-69 years, 70-79 years and 80 years and over. Wealth was based on total net non-pension wealth of the household presented by quintiles. Education was defined as having an intermediate or higher qualification compared to no qualification. Doctor-diagnosed CVD (myocardial infarction, angina and/or stroke), diabetes and hypertension were analysed dichotomously. History of falls was based on participants reporting falling down in the last 12 months. Cigarette smoking status was defined as reporting being a current smoker or current non-smoker. Cognitive function was assessed using a validated 24-point cognitive scale on time orientation (4 points), immediate recall (10 points) and delayed recall (10 points), where a higher score indicated better cognitive function, and analysed continuously.[272] Depression symptoms were based on the six questions on mood not part of the frailty component exhaustion from the validated 8-item version of CES-D.[275] Reporting two or more items were defined as having depression symptoms and analysed dichotomously. Feeling lack of companionship some of the time or often were combined and compared to feeling no lack of companionship.

7.4.5. Statistical methods

Logistic regression models were used to assess the cross-sectional associations of hearing impairment and vision impairment with pre-frailty and frailty, the associations of incident pre-frailty and frailty in non-frail participants and incident frailty in pre-frail participants. The regression models provided odds ratios (OR) with 95% confidence intervals (CI) using good hearing and good vision as reference groups. Confounders considered were based on the risk factors identified as being associated with sensory impairments in this cohort (Table 7.1 and Table 7.7) and in previous literature (Chapter 2). All models were adjusted for the confounding variables age and sex. The distribution of age (in years) was entered as a categorical variable of four groups: 60-69, 70-79 and 80 and over. Sex was entered as a binary variable. Statistically significantly associations were also adjusted for wealth and education, fitted as categorical variables. Additional potential confounding variables further adjusted for were CVD, diabetes, falls, cognition and depression of which all but cognition were entered as categorical variables (cognition was fitted as a continuous variable). Participants without prevalent pre-frailty and frailty were followed-up for frailty. Pre-frail participants were followed-up for frailty. A test for an interaction between hearing impairment and gender was conducted in the logistic regression models which showed no difference between men and women (p=0.25). Similarly there was no interaction between vision impairment and gender (p=0.75).

In addition to the main analyses, supplementary exploratory analyses of the cross-sectional associations between impairments in hearing and vision and individual frailty components were conducted to investigate whether the associations were driven by an individual frailty component. Also, where a positive association was demonstrated between hearing impairment/vision impairment and frailty, supplementary analyses were conducted to explore if the association might be explained by lack of companionship, a marker of social isolation which has been associated with both sensory impairments and frailty.[172, 302, 334] The analyses adjusting for lack of companionship were undertaken in a sub-sample of 2663 of the 2836 participants with data on companionship, fitted as a categorical variable.

7.5. Results

Analyses were based on 2836 men and women from the English Longitudinal Study of Ageing (ELSA) aged 60 years and over in 2004 who completed the interview and physical examination in 2004 and who also provided data on the frailty measures in 2008. Just over half of the sample were men (56%, n=1584). The prevalence of hearing impairment and vision impairment was 23% (n=643) and 12% (n=339), respectively. Half of the participants (n=1396) (49%) were non-frail, 1178 (42%) were pre-frail and 262 (9%) were frail in 2004 (baseline). In the 1396 participants with no prevalent frailty in 2004, a total of 367 reported pre-frailty (n=343) and frailty (n=24) at 4-year follow-up in 2008. Among the 1178 participants pre-frail in 2004, 133 participants were frail at 4-year follow-up in 2008.

7.5.1. Hearing impairment and risk of frailty

7.5.1.1. Baseline characteristics by hearing impairment

Table 7.1 (page 194) shows the prevalence of hearing impairment, the characteristics of all participants by hearing impairment and the prevalence of frailty at baseline (2004) by hearing impairment. The prevalence of hearing impairment increased with advanced age; in participants with poor hearing 40% were aged 60-69 years and 15% were aged 80 years and over compared to participants with good hearing of which 58% were aged 60-69 years and 9% were aged 80 years and over. Poor hearing was more common in men, participants within lower grades of wealth and those without educational qualification. Hearing impairment was further associated with doctor-diagnosed CVD, diabetes, lower cognitive function, depression symptoms and having a history of falls. Among older adults with poor hearing, 45% (n=291) were pre-frail and 14% (n=87) were frail compared to 40% (n=887) of those with good hearing being pre-frail and 8% (n=175) being frail.

7.5.1.2. Cross-sectional associations of hearing impairment and frailty

Table 7.2 (page 195) presents the odds ratios (OR) with 95% CIs for the cross-sectional associations between hearing impairment and frailty (pre-frailty and frailty combined and separately). Participants who were pre-frail or frail were more likely to have poor hearing (age- and sex-adjusted OR 1.66, 95% CI 1.37-2.01) and the association remained after further adjustment for wealth, education, CVD, cognition and depression (OR 1.41, 95% CI 1.14-1.73). The relationship was further examined in a sub-sample of 2663 participants with data on lack of companionship and the association remained after additional adjustment for lack of companionship (OR 1.44, 95% CI 1.16-1.79). Analyses of the relationships between hearing impairment and pre-frailty and frailty separately showed that both frailty (OR 1.52, 95% CI 1.25-1.86) and pre-frailty (OR 2.32, 95% CI 1.67-3.24) were significantly associated with hearing impairment.

Further exploratory analyses of cross-sectional associations between hearing impairment and individual frailty components are presented in Table 7.3 (page 196) and show that hearing impairment was associated with exhaustion (OR 1.92, 95% CI 1.58-2.35), low physical activity (OR 1.70, 95% CI 1.36-2.13) and slow gait speed (OR 1.89, 95% CI 1.53-2.34). The associations remained after further adjustment for socio-economic factors, CVD, cognition and depression. Hearing impairment was not associated with the frailty components weak grip strength (OR 1.07, 95%CI 0.81-1.41) and weight loss (OR 0.81, 95% CI 0.53-1.23).

7.5.1.3. Prospective associations of hearing impairment with the risk of incident pre-frailty and frailty

For the longitudinal analyses two cohorts were constructed, one consisting of those who were non-frail at baseline (excluding those with both pre-frailty and frailty) and one of those with pre-frailty at baseline. Table 7.4 (page 197) presents the characteristics of the participants in the first cohort who were non-frail at baseline by hearing impairment. In this cohort poor hearing was statistically significantly associated with advanced age, male, lower wealth, no educational qualification and lower cognitive function. Depression symptoms, history of falls, CVD and CVD risk factors including smoking, BMI, hypertension and diabetes were not associated poor hearing. Table 7.5 (page 198) shows the characteristics of participants in the second cohort who were pre-frail at baseline by hearing impairment. In those with pre-frailty at baseline, hearing impairment was associated with advanced age, male, CVD and lower cognitive function. No significant associations were observed with hearing impairment and wealth, education, smoking, BMI, hypertension, diabetes, depression symptoms and falls.

Table 7.6 (page 199) shows OR (95% CI) for incident pre-frailty and frailty in those who were non-frail at baseline, and incident frailty in those pre-frail at baseline. In those who were non-frail at baseline, participants with poor hearing had an increased risk of becoming pre-frail or frail at 4-year follow-up (age- & sex-adjusted OR 1.43, 95% CI 1.05-1.95) compared to those with good self-reported hearing. However the association was attenuated after further adjustment for wealth and education (OR 1.32, 95% CI 0.96-1.82).

Among participants who were pre-frail at baseline, those who reported poor hearing had an increased risk of developing frailty compared to participants with good hearing (age- & sex-adjusted OR 1.64, 95% CI 1.07-2.51). This association remained after further adjustment for wealth, education, CVD, cognition and depression. The association was further examined in a sub-sample of 1088 pre-frail participants with data on lack of companionship followed-up for incident frailty over 4 years. In the sub-analysis poor hearing remained associated with increased risk of frailty (OR 1.72, 95% CI 1.08-2.76) after further adjustment for lack of companionship.

7.5.2. Vision impairment and risk of frailty

7.5.2.1. Baseline characteristics by vision impairment

Prevalence of vision impairment, the characteristics of all participants by vision impairment and the prevalence of frailty in 2004 (baseline) by vision impairment are presented in Table 7.7 (page 200). Vision impairment was significantly more common in advanced age; in participants with poor vision 20% were aged 80 years and over compared to 9% of participants with good vision. Poor vision was associated with being male, less wealthy, no educational qualification, smoker, higher BMI, diagnosed with hypertension, CVD and diabetes, a history of falls, poorer cognitive function and depression symptoms. Half of participants with poor vision were pre-frail (50%, n=168) and 23% (n=78) were frail, in comparison 40% (n=1010) of participants with good vision being pre-frail and 7% (n=184) frail.

7.5.2.2. Cross-sectional associations of vision impairment and frailty

Table 7.8 (page 201) shows OR with 95% CIs for cross-sectional associations between vision impairment and frailty. Participants with poor vision had over 2-fold greater odds of being pre-frail or frail compared to participants with good vision (OR 2.53, 95%CI 1.95-3.30) and the association remained after further adjustment for wealth, education, CVD, diabetes, falls, cognition and depression (OR 1.72, 95% CI 1.30-2.29). The association remained after additional adjustment for lack of companionship in a sub-sample of 2,663 participants with such data (OR 1.65, 95%CI 1.22-2.22). Cross-sectional analyses of the relationships between vision impairment and pre-frailty and frailty separately showed that vision impairment was significantly associated with both groups (OR 2.10, 95% CI 1.59-2.77; OR 4.83, 95% CI 3.30-7.06). Table 7.9 (page 202) shows further exploratory analyses of associations between vision impairment and individual frailty components. Vision impairment was associated with exhaustion (OR 2.34, 95% CI 1.84-2.97), low physical activity (OR 2.90, 95% CI 2.25-3.74) and slow gait speed (OR 2.48, 95% CI 1.93-3.19) and the associations remained after further adjustment for covariates. Vision impairment was also associated with age- and sex-adjusted odds for weak grip (OR 1.51, 95% CI 1.11-2.05) but attenuated after further adjustment for wealth and education. Weight loss was not associated with vision impairment (OR 1.49, 95% CI 0.95-2.32).

7.5.1.3. Prospective associations of vision impairment with the risk of incident pre-frailty and frailty

Two cohorts were constructed for the longitudinal analyses; one consisting of non-frail participants at baseline (excluding participants with pre-frailty and frailty) and one cohort consisting of participants with pre-frailty at baseline. Table 7.10 (page 203) presents the characteristics of the first cohort consisting of participants who were non-frail at baseline by vision impairment. Non-frail participants with poor vision were associated with advanced age, lower wealth, no educational qualification, CVD and lower cognitive function. Gender, smoking, BMI, hypertension, diabetes, depression and falls were not associated with vision impairment in non-frail participants. In Table 7.11 (page 204), the characteristics of participants pre-frail at baseline (the second cohort) by vision impairment are shown. Participants pre-frail at baseline with poor vision were associated with advanced age, lower wealth, CVD, diabetes, lower cognitive function and falls. Vision impairment was not associated with gender, educational qualification, smoking, BMI, hypertension, and depression in those pre-frail at baseline.

Table 7.12 (page 205) shows OR with 95% CIs for incident pre-frailty and frailty in participants non-frail at baseline, and incident frailty in those pre-frail at baseline. Among participants non-frail at baseline, those who reported poor vision had a 2-fold increased risk of becoming pre-frail or frail at 4-year follow-up (age- & sex-adjusted OR 2.07, 95% CI 1.32-3.24) compared to participants with good vision. The association remained after further adjustment for wealth, education, CVD, diabetes, falls, cognition and depression (OR 1.86, 95% CI 1.17-2.95). Additional analysis was carried out in a sub-sample of 1338 non-frail participants with data on lack of companionship. In this analysis, vision impairment remained associated with increased risks of pre-frailty and frailty after further adjustment for lack of companionship (OR 1.98, 95% CI 1.23-3.19). Vision impairment was not associated with an increased risk of frailty in older adults pre-frail at baseline (OR 1.34, 95% CI 0.82-2.19).

7.6. Discussion

7.6.1. Summary of main findings

In this Chapter the relationships between impairments in hearing and vision and the risk of pre-frailty and frailty have been examined in a prospective cohort of English men and women aged 60 years and over. Compared to non-frail participants with good hearing, non-frail participants with poor hearing at baseline had an increased risk of becoming pre-frail or frail at 4-year follow-up (age- & sex-adjusted OR 1.43, 95% CI 1.05-1.95). However the association was attenuated after further adjustment for wealth and education. Pre-frail participants with poor hearing had greater risks of becoming frail (OR 1.64, 95% CI 1.07-2.51) compared to pre-frail participants with good hearing and the association remained after further adjustment for wealth, education, CVD, cognition and depression.

Compared to non-frail older adults with good vision, non-frail older adults with poor vision had 2-fold greater risks of becoming pre-frail or frail (age- & sex-adjusted OR 2.07, 95% CI 1.32-3.24) at 4-year follow-up and the association remained after further adjustment for wealth, education, CVD, diabetes, falls, cognition and depression. Poor vision was not significantly associated with incident frailty in older adults pre-frail at baseline (OR 1.34, 95% CI 0.82-2.19).

7.6.2. Comparison with previous studies

7.6.2.1. Prevalence of pre-frailty and frailty

In this thesis, 9% were frail and 42% were pre-frail at baseline in 2004. These figures are very similar to the findings of the original study of the Fried phenotype reporting 7% being frail and 42% being pre-frail,[18] and are also very close to findings from a recent systematic review reporting that the average prevalence for frailty and pre-frailty was 11% and 42%, respectively.[225]

7.6.2.2. Prevalence of hearing impairment and vision impairment

The prevalence of hearing impairment in this Chapter was 23% in adults aged 60 years and over. This is similar to the prevalence rate of 27% in men aged 63-85 years in the British Regional Heart Study (Chapter 4) and one of the latest national estimates of

British adults aged 61-80 years reporting 26% prevalence of hearing impairment.[4] Thus, it is unlikely that the prevalence of hearing impairment in this study has been overestimated. Similarly, the prevalence of vision impairment of 12% in individuals aged 60 years and over in the present study is comparable to a national estimate of 13% in adults aged 65 years and over living in the UK.[5] Therefore this suggests that the population in this study is broadly representative of the older British population.

7.6.2.3. Hearing impairment and frailty

The cross-sectional associations showed that hearing impairment was associated with increased risks of pre-frailty and frailty separately and combined. These findings support earlier cross-sectional studies which have consistently reported a relationship between both subjectively and objectively assessed hearing impairment and frailty.[14, 74]

The main focus of this chapter was on investigating longitudinal associations between impairments in hearing and vision and incident pre-frailty and frailty. The longitudinal findings of the relationship of hearing impairment and incident frailty showed that compared to participants with good hearing, non-frail participants with poor hearing at baseline had an increased risk of becoming pre-frail or frail at 4-year follow-up. However, the association was attenuated on further adjustment for markers of socioeconomic position including wealth and education, factors previously associated with both hearing impairment[135] and increased risks of frailty.[335-337] The longitudinal results of the present study further showed that compared to pre-frail older adults with good hearing, pre-frail older adults with poor hearing had an increased risk of becoming frail and the association remained after further adjustment for wealth, education, CVD, cognition and depression.

Objectively assessed hearing impairment has previously been associated with difficulties getting out of chair and/or reduced gait speed over 10 years after adjustment for age, demographic characteristics, CVD risk factors, cognitive status and depression in community-dwelling older adults.[77] To my knowledge this is the first study investigating hearing impairment and incident frailty in pre-frail individuals. My PhD thesis has demonstrated that poor hearing may be a particular problem in older adults who have started to experiencing frailty, suggesting that self-perceived hearing impairment potentially increases the progression of frailty. This supports earlier studies[74, 76] proposing that hearing impairment should be considered as a health deficit in multi-component ‘cumulative deficit’ models of frailty. Currently not all versions of the accumulative deficit model of frailty include hearing impairment.[333, 338-340] Nevertheless, factors that may have been inadequately adjusted for, such as self-reported doctor diagnosed CVD, and/or factors not adjusted for such as lifestyle factors, may have led to residual confounding. The relationship observed may be explained by potential mediators including low social engagement and cognitive impairment, previously associated with increased risks of becoming frail.[232, 238] However in the present study the association remained after adjustment for lack of companionship in a sub-sample of 1088 out of 1178 participants pre-frail in 2004 with data on companionship. In terms of cognitive function, the cognitive measures adjusted for in the present study (immediate and delayed recall and orientation in time) all refer to working memory.[341] However, other aspects of cognitive function available such as executive functioning were not suitable for these investigations as they required adequate sensory function.

7.6.2.4. Vision impairment and frailty

The cross-sectional findings showed that vision impairment was associated with increased risks of pre-frailty and frailty separately and combined. These findings are consistent with earlier cross-sectional research on 2962 participants (aged ≥ 53 years) from the Beaver Dam Eye Study demonstrating associations between eye conditions such as cataract and AMD and frailty indicators including weak grip strength and being unable to perform chair stands,[15, 78] particularly in men.[79] Cataract has also been associated with frailty using a modified, completely self-reported version of the Fried phenotype in older Taiwanese adults.[242]

The longitudinal results showed that non-frail older adults with vision impairment had twice the risk of becoming pre-frail and frail compared to those with good vision and the association remained after adjustment for covariates. To my knowledge, this is the first study investigating the relationship between vision impairment and incident pre-frailty and frailty in non-frail individuals and incidence of frailty in pre-frail individuals. This finding is supported by previous cross-sectional findings between objectively measured vision impairment and frailty assessed using a frailty score consisting of slow gait speed, low expiratory flow rate, poor handgrip strength and inability to perform chair stands.[237] In contrast, findings from this Chapter showed that pre-frail participants with vision impairment did not have an increased risk of developing frailty. The lack of association between vision impairment and increased risk of frailty in pre-frail participants suggest that in individuals with pre-frailty, other factors rather than poor vision influence the further development of frailty. Thus, vision impairment may be of particular importance in the onset of the early stages of frailty when individuals move from non-frail to pre-frail, rather than progression of frailty in those already pre-frail.

There are several possible confounding factors that could explain the relationship observed between vision impairment and incident pre-frailty. Vision impairment is associated with a range of comorbidities that are also known to be associated with frailty including CVD and diabetes.[342] However, the association remained after adjustment for such comorbidities. The relationship observed may also be due to unadjusted lifestyle factors such as smoking, and potential mediators on the possible causal pathway linking vision impairment with frailty, for example, social engagement. Vision impairment has been associated with increased risks of being socially isolated.[130] Literature has also shown that being socially engaged may reduce the impact of loss of physiologic reserve associated with frailty.[334] While in the present study the association between vision impairment and incident pre-frailty remained after adjustment for lack of companionship, this may have incompletely accounted for reduced social engagement of older adults with poor vision. Underlying mechanisms such as chronic inflammation predisposing individuals to both vision impairment and frailty may furthermore explain the relationship of vision impairment and incident frailty.[175, 239]

7.6.3. Strengths and limitations

The major strengths of the findings in this Chapter are that data are from a nationally representative cohort of community-dwelling English women and men aged 60 years and over.[341] A prospective study design was used, participants were followed for 4 years for pre-frailty and frailty, and the models were adjusted for several important potential confounding factors.

A limitation to the ELSA data include that participants of the original ELSA cohort were drawn from the Health Survey for England (HSE) rather than the general population of England. This raises the possibility of selection bias in ELSA as people who agree to participate in research studies and undertake physical assessments tend to be healthier[145] and from higher socioeconomic classes[343] than non-respondents, and this may be a particular problem in surveys comprising older adults.[344] Non-respondents to ELSA overall tended to be older and in poorer health,[341] which was also true for the sample used for the analyses in this thesis (section 3.7.2). The sample used in this thesis was restricted to participants with complete data on frailty at both baseline and follow-up to allow for analyses of incident pre-frailty, which means that prevalence of hearing impairment, vision impairment, pre-frailty and frailty might have been higher among non-responders. Further, households that previously had responded to the HSE in 1998, 1999 and 2001 were selected to participate. In HSE 1999, an additional number of people from ethnic minority backgrounds were recruited in order to allow for group specific analyses based on ethnicity. However, this additional sample of participants was not included in the ELSA due to considerable logistical and financial issues.[345] Therefore, ELSA data are based on older adults predominantly of white European ethnic origin.

Limitations of the findings in this Chapter include that hearing impairment and vision impairment were self-reported rather than objectively measured. The question on perceived hearing has only demonstrated moderate sensitivity (i.e. correctly identified as having hearing impairment) (56%) when tested against the whisper voice test.[100] Slightly higher sensitivity (67%) was provided when the question was tested against pure tone audiometry. However such test was restricted to individuals aged 30-65 years.[101] For modifiable conditions such as hearing impairment, a high sensitivity is preferred.[145] However, the self-reported hearing question used was assessed in small samples (n=168 and n=188, respectively) rather than in large population-based studies. Also, the prevalence rates of hearing impairment and vision impairment, respectively, are comparable to national estimates.[4] Another limitation to the ELSA data on hearing is that data on hearing aid use were not available restricting the information on any preventative action taken by participants. Sensory impairments were measured at baseline and changes in hearing impairment and vision impairment, respectively, were not investigated. Also, data on underlying causes for hearing impairment and vision impairment were not available.

A slightly modified version of the validated Fried phenotype was used due to limitations in the data available. While objectively measured data on weight loss over time was used, it was not possible to differentiate between intentional and unintentional weight loss. Also, levels of physical activity referred to frequency and intensity of exercise without information on calorie consumption. However, the data used were obtained through an interview and physical examination, and the prevalence of frailty in this study is comparable to the original Fried phenotype study.[18]

Several unmeasured and incompletely addressed factors of potential importance (e.g. anxiety and low social engagement) may have confounded or mediated the relationship between sensory impairments and frailty. As described in Chapter 2, low social engagement, depression and cognitive impairment may mediate the relationship between sensory impairments and incident frailty. However, in this study, there were insufficient data on measures of social isolation including, for example, 16% (n=457) of participants had incomplete data on quality of life, 36% had not answered the questions on loneliness and 41% had not provided complete data on the social detachment score. Analyses of these psychosocial measures would have to be undertaken in sub-samples of participants with such data, possibly resulting in lack of statistical power and not being representative of the wider population due to selection bias.[145] Therefore, social engagement was based on a single question asking about lack of companionship, a question to which most participants had responded. In terms of depression, six of eight questions from the depression score CES-D available in ELSA were part of the frailty score and the remaining two were used to assess depression. Consequently, adjustment for depression and low social engagement in this thesis may not have been fully accounted for. Similarly, measures of cognitive function available in ELSA were in this thesis restricted to immediate and delayed recall and orientation in time. Other aspects of cognitive function available including executive functioning required sensory function and were therefore not suitable. Hence, the cognitive domains adjusted for may not have fully accounted for the potential role of cognition. The observed associations between sensory impairments and frailty could potentially also be explained by underlying mechanisms such as inflammation, previously associated with both hearing impairment,[37, 346] vision impairment[175, 347] and frailty. Finally, the ELSA cohort comprised predominantly of white English population and the findings may not be generalisable to other ethnic groups.

7.7. Conclusions

The results of Chapter 7 show that pre-frail older adults with hearing impairment have greater risks of incident frailty compared to pre-frail older adults with good hearing. The findings also show that compared to non-frail older adults with good vision, non-frail older adults with vision impairment have greater risks of incident pre-frailty and frailty. Hearing impairment may be a particular problem in older adults who have started to experiencing frailty, potentially increasing the progression of frailty. In contrast, vision impairment may be of particular importance in the onset of the early stages of frailty when non-frail individuals start becoming frail. The results remained after adjustment for confounding factors and possible mediators including low social engagement. However, potential underlying factors on the pathway need to be further investigated.

The meaning and implications of the findings of this chapter will be discussed further in Chapter 8.

Table 7.1 Baseline characteristics including age, sex, socio-economic and lifestyle characteristics, comorbidities, falls and frailty status for individuals with good hearing versus hearing impairment in 2836 English men and women aged 60 years and over in 2004

	Overall	**Good hearing**	**Poor hearing**	**p-value**
Totals, n (%)	2836 (100)	2193 (77)	643 (23)	
Covariates				
Age in years, n (%)				
60-69	1526 (54)	1266 (58)	260 (40)	<0.01
70-79	1012 (36)	726 (33)	286 (45)	
80+	298 (11)	201 (9)	97 (15)	
Male gender, n (%)	1584 (56)	894 (41)	358 (56)	<0.01
Wealth, n (%)				
1 (lowest)	396 (14)	290 (13)	106 (17)	<0.01
2	541 (19)	383 (18)	158 (25)	
3	562 (20)	430 (20)	132 (21)	
4	615 (22)	499 (23)	116 (18)	
5 (highest)	690 (24)	567 (26)	123 (19)	
No education, n (%)	1086 (38)	797 (36)	289 (45)	<0.01
Smoker, n (%)	308 (11)	226 (10)	82 (13)	0.08
BMI, mean ± SD	27.8 (4.6)	27.8 (4.6)	27.8 (4.6)	0.67
Hypertension, n (%)	1302 (46)	984 (45)	318 (50)	0.40
CVD, n (%)	499 (18)	348 (16)	151 (24)	<0.01
Diabetes, n (%)	251 (9)	175 (8)	76 (12)	<0.01
Cognitive function score, mean ± SD	13.7 (3.3)	14.0 (3.2)	12.9 (3.4)	<0.01
Depression symptoms (≥ 2), n (%)	653 (23)	480 (22)	173 (27)	<0.01
History of falls, n (%)	882 (31)	657 (30)	225 (35)	0.02
Frailty prevalence, n (%)				
Non-frail, n (%)	1396 (49)	1131 (52)	265 (41)	<0.01
Pre-frail, n (%)	1178 (42)	887 (40)	291 (45)	<0.01
Frail, n (%)	262 (9)	175 (8)	87 (14)	<0.01

Table 7.2 Odds ratios (OR) with 95% CIs for cross-sectional associations of pre-frailty and frailty (combined and separately) with hearing impairment in English men and women aged 60 years and over in 2004

	Good hearing	**Poor hearing**
Participants with pre-frailty and frailty combined, n (%)	1062 (48)	378 (59)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	1.66 (1.37-2.01)
Model 2 (M2): M1 + wealth and education	1.00	1.52 (1.25-1.86)
Model 3 (M3): M2 + CVD	1.00	1.50 (1.23-1.83)
Model 4 (M4): M3 + cognition	1.00	1.46 (1.19-1.78)
Model 5 (M5): M4 + depression	1.00	1.41 (1.14-1.73)
Participants with pre-frailty, n (%)	887 (44)	291 (52)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	1.52 (1.25-1.86)
Model 2 (M2): M1 + wealth and education	1.00	1.42 (1.16-1.75)
Model 3 (M3): M2 + CVD	1.00	1.41 (1.15-1.74)
Model 4 (M4): M3 + cognition	1.00	1.38 (1.12-1.70)
Model 5 (M5): M4 + depression	1.00	1.33 (1.07-1.64)
Participants with frailty, n (%)	175 (13)	87 (25)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	2.32 (1.67-3.24)
Model 2 (M2): M1 + wealth and education	1.00	2.00 (1.40-2.84)
Model 3 (M3): M2 + CVD	1.00	1.88 (1.31-2.70)
Model 4 (M4): M3 + cognition	1.00	1.81 (1.25-2.61)
Model 5 (M5): M4 + depression	1.00	1.81 (1.22-2.67)

Table 7.3 Odds ratios (OR) with 95% CIs for cross-sectional associations between individual frailty components and hearing impairment in English men and women aged 60 years and over in 2004

Individual frailty components	**Good hearing**	**Poor hearing**
Models for adjustment	OR	OR (95% CI)
Exhaustion, n (%)	481 (22)	219 (34)
Model 1 (M1): age and sex	1.00	1.92 (1.58-2.35)
Model 2 (M2): M1 + wealth and education	1.00	1.84 (1.50-2.25)
Model 3 (M3): M2 + CVD	1.00	1.81 (1.47-2.21)
Model 4 (M4): M3 + cognition	1.00	1.76 (1.43-2.16)
Model 5 (M5): M4 + depression	1.00	1.75 (1.40-2.20)
Low physical activity, n (%)	333 (15)	151 (24)
Model 1 (M1): age and sex	1.00	1.70 (1.36-2.13)
Model 2 (M2): M1 + wealth and education	1.00	1.52 (1.21-1.92)
Model 3 (M3): M2 + CVD	1.00	1.49 (1.18-1.88)
Model 4 (M4): M3 + cognition	1.00	1.46 (1.16-1.85)
Model 5 (M5): M4 + depression	1.00	1.40 (1.11-1.78)
Slow gait speed, n (%)	383 (18)	188 (29)
Model 1 (M1): age and sex	1.00	1.89 (1.53-2.34)
Model 2 (M2): M1 + wealth and education	1.00	1.73 (1.39-2.16)
Model 3 (M3): M2 + CVD	1.00	1.68 (1.35-2.10)
Model 4 (M4): M3 + cognition	1.00	1.62 (1.30-2.03)
Model 5 (M5): M4 + depression	1.00	1.59 (1.27-2.00)
Weak grip, n (%)	397 (18)	113 (18)
Model 1 (M1): age and sex	1.00	1.07 (0.81-1.41)
Weight loss, n (%)	134 (6)	28 (6)
Model 1 (M1): age and sex	1.00	0.81 (0.53-1.23)

Table 7.4 Age, sex, socio-economic and lifestyle characteristics, comorbidities and falls according to hearing impairment in a cohort of English men and women aged 60 years and over with no frailty in 2004 (baseline)

	Overall	**Good hearing**	**Poor hearing**	**p-value**
Totals, n (%)	1396 (100)	1131 (81)	265 (19)	
Covariates				
Age in years, n (%)				
60-69	864 (62)	743 (66)	121 (46)	<0.01
70-79	459 (33)	336 (30)	123 (46)	
80+	73 (5)	52 (5)	21 (8)	
Male gender, n (%)	785 (56)	603 (53)	182 (69)	<0.01
Wealth, n (%)				
1 (lowest)	112 (8)	83 (7)	29 (11)	0.01
2	204 (15)	154 (14)	50 (19)	
3	278 (20)	218 (20)	60 (23)	
4	346 (25)	293 (26)	53 (20)	
5 (highest)	436 (31)	368 (33)	68 (26)	
No education, n (%)	420 (30)	321 (28)	99 (37)	0.04
Smoker, n (%)	103 (7)	82 (7)	21 (8)	0.69
BMI, mean ± SD	27.2 (3.9)	27.2 (3.9)	27.3 (4.1)	0.85
Hypertension, n (%)	560 (40)	450 (40)	110 (42)	0.61
CVD, n (%)	195 (14)	150 (13)	45 (17)	0.12
Diabetes, n (%)	90 (6)	70 (6)	20 (8)	0.42
Cognitive function score, mean ± SD	14.2 (3.3)	14.4 (3.1)	13.6 (3.2)	<0.01
Depression symptoms (≥ 2), n (%)	149 (11)	117 (10)	32 (12)	0.41
History of falls, n (%)	347 (25)	278 (25)	69 (26)	0.62

Table 7.5 Age, sex, socio-economic and lifestyle characteristics, comorbidities and falls according to hearing impairment in a cohort of English men and women aged 60 years and over with pre-frailty in 2004 (baseline)

	Overall	**Good hearing**	**Poor hearing**	**p-value**
Totals, n (%)	1178 (100)	887 (75)	291 (25)	
Covariates				
Age in years, n (%)				
60-69	568 (48)	458 (52)	110 (38)	<0.01
70-79	455 (39)	327 (37)	128 (44)	
80+	155 (13)	102 (12)	53 (18)	
Male gender, n (%)	413 (35)	261 (29)	152 (52)	<0.01
Wealth, n (%)				
1 (lowest)	195 (17)	144 (16)	51 (18)	0.28
2	264 (22)	189 (22)	75 (26)	
3	242 (21)	182 (21)	60 (21)	
4	236 (20)	180 (21)	56 (19)	
5 (highest)	230 (20)	184 (21)	46 (16)	
No education, n (%)	507 (43)	372 (42)	135 (46)	0.18
Smoker, n (%)	162 (14)	116 (13)	46 (16)	0.24
BMI, mean ± SD	27.9 (4.8)	28.0 (4.9)	27.8 (4.4)	0.48
Hypertension, n (%)	583 (50)	430 (49)	153 (53)	0.23
CVD, n (%)	213 (18)	144 (16)	69 (24)	<0.01
Diabetes, n (%)	121 (10)	86 (10)	35 (12)	0.26
Cognitive function score, mean ± SD	13.7 (3.4)	13.8 (3.3)	12.5 (3.4)	<0.01
Depression symptoms (≥ 2), n (%)	362 (31)	266 (30)	96 (33)	0.32
History of falls, n (%)	396 (34)	291 (33)	105 (36)	0.31

Table 7.6 Odds ratios (OR) with 95% CIs for risk of incidence of pre-frailty and frailty according to hearing impairment in English men and women aged 60 years and over in 2004 followed-up for 4 years to 2008

	Good hearing n (%)	**Poor hearing n (%)**
No prevalent frailty at baseline	n=1131	n=265
Pre-frail or frail at follow-up	280 (25)	87 (33)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	1.43 (1.05-1.95)
Model 2 (M2): M1 + wealth and education	1.00	1.32 (0.96-1.82)
Model 3 (M3): M2 + CVD	1.00	1.32 (0.96-1.82)
Model 4 (M4): M3 + cognition	1.00	1.31 (0.95-1.80)
Model 5 (M5): M4 + depression	1.00	1.32 (0.96-1.81)
Pre-frail at baseline	n=887	n=291
Frail at follow-up	91 (10)	42 (14)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	1.64 (1.07-2.51)
Model 2 (M2): M1 + wealth and education	1.00	1.63 (1.06-2.52)
Model 3 (M3): M2 + CVD	1.00	1.62 (1.05-2.51)
Model 4 (M4): M3 + cognition	1.00	1.58 (1.02-2.45)
Model 5 (M5): M4 + depression	1.00	1.57 (1.01-2.44)

Table 7.7 Baseline characteristics including age, sex, socio-economic and lifestyle characteristics, comorbidities, falls and frailty status for individuals with good vision versus vision impairment in 2836 English men and women aged 60 years and over in 2004

	Overall	**Good vision**	**Poor vision**	**p-value**
Totals, n (%)	2836 (100)	2497 (88)	339 (12)	
Covariates				
Age in years, n (%)				
60-69	1526 (54)	1400 (56)	126(37)	<0.01
70-79	1012 (36)	865 (35)	147 (43)	
80+	298 (11)	232 (9)	66 (20)	
Male gender, n (%)	1584 (56)	1121 (45)	131 (39)	0.03
Wealth, n (%)				
1 (lowest)	396 (14)	309 (13)	87 (26)	<0.01
2	541 (19)	452 (18)	89 (27)	
3	562 (20)	505 (20)	57 (17)	
4	615 (22)	563 (23)	52 (16)	
5 (highest)	690 (24)	643 (26)	47 (14)	
No education, n (%)	1086 (38)	915 (37)	171 (50)	<0.01
Smoker, n (%)	308 (11)	250 (10)	58 (17)	<0.01
BMI, mean ± SD	27.8 (4.6)	27.7 (4.5)	28.3 (4.8)	0.03
Hypertension, n (%)	1302 (46)	1123 (45)	179 (53)	<0.01
CVD, n (%)	499 (18)	400 (16)	99 (29)	<0.01
Diabetes, n (%)	251 (9)	197 (8)	54 (16)	<0.01
Cognitive function score, mean ± SD	13.7 (3.3)	13.9 (3.3)	12.8 (3.2)	<0.01
Depression symptoms (≥ 2), n (%)	653 (23)	536 (22)	117 (35)	<0.01
History of falls, n (%)	882 (31)	742 (30)	140 (41)	<0.01
Frailty prevalence, n (%)				
Non-frail, n (%)	1396 (49)	1303 (52)	93 (27)	<0.01
Pre-frail, n (%)	1178 (42)	1010 (40)	168 (50)	<0.01
Frail, n (%)	262 (9)	184 (7)	78 (23)	<0.01

Table 7.8 Odds ratios (OR) with 95% CIs for cross-sectional associations of pre-frailty and frailty (combined and separately) with vision impairment in English men and women aged 60 years and over in 2004

	Good vision	**Poor vision**
Participants with pre-frailty and frailty combined, n (%)	1194 (48)	246 (73)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	2.53 (1.95-3.30)
Model 2 (M2): M1 + wealth and education	1.00	2.08 (1.59-2.73)
Model 3 (M3): M2 + CVD and diabetes	1.00	1.96 (1.49-2.57)
Model 4 (M4): M3 + falls	1.00	1.91 (1.45-2.51)
Model 5 (M5): M4 + cognition	1.00	1.85 (1.40-2.44)
Model 6 (M6): M5 + depression	1.00	1.72 (1.30-2.29)
Participants with pre-frailty, n (%)	1010 (40)	168 (50)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	2.10 (1.59-2.77)
Model 2 (M2): M1 + wealth and education	1.00	1.80 (1.35-2.39)
Model 3 (M3): M2 + CVD and diabetes	1.00	1.72 (1.29-2.29)
Model 4 (M4): M3 + falls	1.00	1.70 (1.27-2.26)
Model 5 (M5): M4 + cognition	1.00	1.66 (1.24-2.22)
Model 6 (M6): M5 + depression	1.00	1.56 (1.16-2.10)
Participants with frailty, n (%)	184 (7)	78 (23)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	4.83 (3.30-7.06)
Model 2 (M2): M1 + wealth and education	1.00	3.91 (2.61-5.85)
Model 3 (M3): M2 + CVD and diabetes	1.00	3.30 (2.18-5.00)
Model 4 (M4): M3 + falls	1.00	3.22 (2.11-4.91)
Model 5 (M5): M4 + cognition	1.00	3.16 (2.07-4.82)
Model 6 (M6): M5 + depression	1.00	2.88 (1.83-4.54)

Table 7.9 Odds ratios (OR) with 95% CIs for cross-sectional associations between individual frailty components and vision impairment in English men and women aged 60 years and over in 2004

Individual frailty components	**Good vision**	**Poor vision**
Models for adjustment	OR	OR (95% CI)
Exhaustion, n (%)	558 (22)	142 (42)
Model 1 (M1): age and sex	1.00	2.34 (1.84-2.97)
Model 2 (M2): M1 + wealth and education	1.00	2.14 (1.67-2.73)
Model 3 (M3): M2 + CVD and diabetes	1.00	1.99 (1.56-2.56)
Model 4 (M4): M3 + falls	1.00	1.94 (1.51-2.49)
Model 5 (M5): M4 + cognition	1.00	1.90 (1.48-2.45)
Model 6 (M6): M5 + depression	1.00	1.81 (1.37-2.39)
Low physical activity, n (%)	363 (15)	121 (36)
Model 1 (M1): age and sex	1.00	2.90 (2.25-3.74)
Model 2 (M2): M1 + wealth and education	1.00	2.44 (1.88-3.18)
Model 3 (M3): M2 + CVD and diabetes	1.00	2.23 (1.71-2.92)
Model 4 (M4): M3 + falls	1.00	2.17 (1.66-2.84)
Model 5 (M5): M4 + cognition	1.00	2.15 (1.64-2.81)
Model 6 (M6): M5 + depression	1.00	2.03 (1.55-2.67)
Slow gait speed, n (%)	440 (18)	131 (39)
Model 1 (M1): age and sex	1.00	2.48 (1.93-3.19)
Model 2 (M2): M1 + wealth and education	1.00	2.06 (1.59-2.67)
Model 3 (M3): M2 + CVD and diabetes	1.00	1.89 (1.45-2.47)
Model 4 (M4): M3 + falls	1.00	1.82 (1.40-2.38)
Model 5 (M5): M4 + cognition	1.00	1.79 (1.37-2.33)
Model 6 (M6): M5 + depression	1.00	1.71 (1.31-2.24)
Weak grip, n (%)	414 (17)	96 (28)
Model 1 (M1): age and sex	1.00	1.51 (1.11-2.05)
Model 2 (M2): M1 + wealth and education	1.00	1.30 (0.95-1.79)
Weight loss, n (%)	136 (5)	26 (8)
Model 1 (M1): age and sex	1.00	1.49 (0.95-2.32)

Table 7.10 Age, sex, socio-economic and lifestyle characteristics, comorbidities and falls according to vision impairment in a cohort of English men and women aged 60 years and over with no frailty in 2004 (baseline)

	Overall	**Good vision**	**Poor vision**	**p-value**
Totals, n (%)	1396 (100)	1303 (93)	93 (7)	
Covariates				
Age in years, n (%)				
60-69	864 (62)	827 (64)	37 (40)	<0.01
70-79	459 (33)	415 (32)	44 (47)	
80+	73 (5)	61 (5)	12 (13)	
Male gender, n (%)	785 (56)	734 (56)	51 (55)	0.78
Wealth, n (%)				
1 (lowest)	112 (8)	94 (7)	18 (20)	<0.01
2	204 (15)	191 (15)	13 (14)	
3	278 (20)	262 (20)	16 (18)	
4	346 (25)	326 (25)	20 (22)	
5 (highest)	436 (31)	412 (32)	24 (26)	
No education, n (%)	420 (30)	383 (29)	37 (40)	0.04
Smoker, n (%)	103 (7)	94 (7)	9 (10)	0.38
BMI, mean ± SD	27.2 (3.9)	27.2 (3.9)	27.1 (4.4)	0.70
Hypertension, n (%)	560 (40)	517 (40)	43 (46)	0.21
CVD, n (%)	195 (14)	173 (13)	22 (24)	0.01
Diabetes, n (%)	90 (6)	80 (6)	10 (11)	0.08
Cognitive function score, mean ± SD	14.2 (3.3)	14.3 (3.1)	13.5 (3.2)	0.03
Depression symptoms (≥ 2), n (%)	149 (11)	136 (11)	13 (14)	0.29
History of falls, n (%)	347 (25)	320 (25)	27 (29)	0.34

Table 7.11 Age, sex, socio-economic and lifestyle characteristics, comorbidities and falls according to vision impairment in a cohort of English men and women aged 60 years and over with pre-frailty in 2004 (baseline)

	Overall	**Good vision**	**Poor vision**	**p-value**
Totals, n (%)	1178 (100)	1010 (86)	168 (14)	
Covariates				
Age in years, n (%)				
60-69	568 (48)	502 (50)	66 (39)	<0.01
70-79	455 (39)	388 (38)	67 (40)	
80+	155 (13)	120 (12)	35 (21)	
Male gender, n (%)	413 (35)	348 (35)	65 (39)	0.29
Wealth, n (%)				
1 (lowest)	195 (17)	158 (16)	37 (23)	<0.01
2	264 (22)	215 (21)	49 (30)	
3	242 (21)	207 (21)	35 (22)	
4	236 (20)	212 (21)	24 (15)	
5 (highest)	230 (20)	212 (21)	18 (11)	
No education, n (%)	507 (43)	426 (42)	81 (48)	0.14
Smoker, n (%)	162 (14)	133 (13)	29 (17)	0.15
BMI, mean ± SD	27.9 (4.8)	27.9 (4.8)	28.3 (4.7)	0.32
Hypertension, n (%)	583 (50)	491 (49)	92 (55)	0.14
CVD, n (%)	213 (18)	172 (17)	41 (24)	0.02
Diabetes, n (%)	121 (10)	92 (9)	29 (17)	<0.01
Cognitive function score, mean ± SD	13.7 (3.4)	13.6 (3.4)	12.8 (3.2)	<0.01
Depression symptoms (≥ 2), n (%)	362 (31)	302 (30)	60 (36)	0.11
History of falls, n (%)	396 (34)	326 (32)	70 (42)	0.02

Table 7.12 Odds ratios (OR) with 95% CIs for associations between risk of incidence of pre-frailty and frailty with hearing impairment in English men and women aged 60 years and over in 2004 followed-up for 4 years to 2008

	Good vision n (%)	**Poor vision n (%)**
No prevalent frailty at baseline	n=1303	n=93
Pre-frail or frail at follow-up	324 (25)	43 (46)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	2.07 (1.32-3.24)
Model 2 (M2): M1 + wealth and education	1.00	1.87 (1.18-2.97)
Model 3 (M3): M2 + CVD and diabetes	1.00	1.88 (1.18-2.98)
Model 4 (M4): M3 + falls	1.00	1.88 (1.18-2.98)
Model 5 (M5): M4 + cognition	1.00	1.86 (1.17-2.95)
Model 6 (M6): M5 + depression	1.00	1.86 (1.17-2.95)
Pre-frail at baseline	n=1010	n=168
Frail at follow-up	107 (11)	26 (16)
Models for adjustment	OR	OR (95% CI)
Model 1 (M1): age and sex	1.00	1.34 (0.82-2.19)
Model 2 (M2): M1 + wealth and education	1.00	1.23 (0.74-2.04)
Model 3 (M3): M2 + CVD and diabetes	1.00	1.16 (0.69-1.94)
Model 4 (M4): M3 + falls	1.00	1.14 (0.68-1.91)
Model 5 (M5): M4 + cognition	1.00	1.07 (0.63-1.80)
Model 6 (M6): M5 + depression	1.00	1.06 (0.63-1.80)

CHAPTER 8 Implications and conclusions

8.1. Summary

This chapter presents the key findings of this thesis including novelty of the findings, and the implications of the present findings for public health and for future research. This thesis has shown that hearing impairment and vision impairment in older age are major contributors towards adverse health outcomes in later life. Particular findings of potential public health importance include efforts to: i) prevent hearing impairment in older adults to potentially prevent adverse health outcomes, and ii) prevent vision impairment in older age to potentially prevent adverse health outcomes. These findings have implications for future research which include to: 1) use other large population studies comprising older women to examine sensory impairments with incident cardiovascular disease (CVD), mortality and disability; 2) use larger sample sizes of older adults from ethnic minority groups to investigate sensory impairments with incident adverse health outcomes; 3) investigate objectively assessed sensory impairments with incident CVD, mortality, disability and frailty in other large population-based studies of older adults; 4) use data on primary cause of sensory impairments and severity and changes over time in hearing impairment and vision impairment for investigations of the relationship between sensory impairments and the burden of adverse health outcomes in older adults; 5) investigate possible pathways to clarify what mediators may link sensory impairments to adverse health outcomes; 6) investigate dual sensory impairments and incident adverse health outcomes in older adults; and 7) conduct intervention studies to investigate ways to identify and address sensory impairments in older adults to possibly reduce adverse health outcomes. A concluding statement is provided at the end of this chapter.

8.2. Key findings

Findings from Chapter 4 provide a comprehensive picture of sensory impairments in older men showing that both hearing impairment and vision impairment are associated with a range of factors including socio-demographic and lifestyle characteristics, chronic conditions, and poor physical and social functioning. However, the findings of Chapter 4 were based on cross-sectional analyses and causality could not be established.

The key findings of this thesis are from the prospective analyses of sensory impairments and incidence of adverse health outcomes including cardiovascular disease (CVD), mortality, disability and frailty (Chapters 5-7). Chapter 5 examined the prospective relationships between sensory impairments and incident CVD and mortality. Such relationships are important to investigate as sensory impairments and CVD are highly prevalent in older age,[4, 5, 31] including CVD being the second most common cause of death in the UK.[31] The relationship between sensory impairments and CVD are also important to examine as these conditions are often preventable.[31, 105, 348] There is a paucity of studies investigating the prospective relationship between sensory impairments and the risk of incident CVD undertaken in community-dwelling older adults.[349] Chapter 5 specifically showed that not being able to hear and not using a hearing aid is associated with an increased risk of CVD mortality, incident CVD and, particularly, incident stroke, but not the risks of incident myocardial infarction (MI) and coronary heart disease (CHD) mortality. The findings add to the limited literature on the prospective associations between hearing impairment and the risk of incident CVD and mortality. The results also suggest that the associations between hearing impairment and incident CVD and CVD mortality may largely be explained by stroke. However, the associations observed do not necessarily imply causality.

Although the hearing impairment group ‘could not hear, no aid’ was shown to be associated with incident stroke in Chapter 5, it is unlikely that hearing impairment directly causes stroke. If hearing impairment had been directly related to incident stroke, associations between the other hearing impairment groups and incident stroke would have been expected too. Nevertheless, presence of hearing impairment has been shown to precede CVD and hearing impairment may be an early marker of an underlying vascular or arteriosclerotic process.[47] Further, a possible confounder on the pathway linking hearing impairment to incident stroke is cognitive impairment, previously associated with both hearing impairment and stroke.[325, 350, 351] Alternatively, cognitive impairment may mediate the relationship between hearing impairment and incident stroke. A recent systematic review and meta-analysis has shown that cognitive impairment is associated with increased risks of stroke, possibly through shared pathophysiological mechanisms including the autoregulation of cerebral blood flow that ensures the supply of oxygen, or silent brain infarcts.[157] Cognitive impairment may also increase the risk of incident stroke through shared risk factors including hypertension, diabetes, obesity and physical inactivity.[157] The role of cognition on the relationship of hearing impairment and stroke could however not be explored due to lack of data on cognitive function in BRHS. Additional potential mediators on the pathway linking hearing impairment with incident stroke (and incident CVD) include poor social engagement and depression, further discussed in section 8.4. Possible pathways that are likely to link hearing impairment to incident CVD and mortality need to be further explored to optimise prevention of CVD. Future research is also needed to elucidate other potential underlying mechanisms responsible for the associations observed between hearing impairment and incident stroke and incident CVD including inflammation (further discussed in section 8.4). Finally, results from Chapter 5 also provide evidence that vision impairment is associated with increased risks of all-cause mortality. These findings add to existing evidence on vision impairment and mortality, emphasizing the importance of addressing vision impairment to prevent premature death.[120]

Although there is some evidence that sensory impairments are associated with increased risks of disability, relatively few population-based studies have prospectively examined how sensory impairments in older adults relate to incident disability in those without current disability. Little research has used complete measures of disability scores including activities of daily living (ADL) and instrumental activities of daily living (IADL). Findings from Chapter 6 showed that hearing impairment is associated particularly with increased risks of difficulty undertaking IADLs. However, the findings were inconsistent across the hearing impairment groups, reducing the plausibility of hearing impairment and IADL difficulty being causally related. Chapter 6 further explored the role of the IADL component 'telephoning' on the relationship between hearing impairment and incident IADL difficulty. The findings show that the associations observed between hearing impairment and incident IADL difficulty is simply not due to telephoning. The findings on hearing impairment and incident IADL difficulty are of importance as several previous studies have based their analyses on only a few selected IADL components. Also, most of such studies have included 'telephoning' but not explored its impact despite its strong connection with hearing ability.

There is little evidence on the relationships between sensory impairments and frailty and very few studies have investigated such relationships prospectively.[77, 242] Chapter 7 showed that compared to pre-frail older adults with good hearing, pre-frail older adults with hearing impairment have an increased risk of becoming frail. To my knowledge this is the first study investigating the relationship between hearing impairment and incident frailty in pre-frail older adults and the finding is of importance as it suggests that hearing impairment may be associated with an increase in the progression of frailty from pre-frail to frail. This finding furthermore suggests that addressing hearing impairment in older adults may be an important modifiable factor to prevent further development of frailty. Findings of Chapter 7 also showed that compared to non-frail older adults with good vision, non-frail older adults with vision impairment have increased risks of becoming pre-frail or frail. However compared to pre-frail older individuals with good vision, those pre-frail with poor vision did not have an increased risk of becoming frail. These findings suggest that vision impairment may be of particular importance in the onset of the early stages of frailty rather than in the progression of frailty in older adults already pre-frail. Early prevention of vision impairment may therefore be important to reduce risks of the onset of frailty. This is to my knowledge the first study investigating the prospective relationship between vision impairment and increased risks of incident frailty. The results presented in Chapter 7 add substantially to the limited literature on the associations between impairments in hearing and vision and risks of incident frailty.

8.3. Public health implications of findings

8.3.1. Efforts to prevent hearing impairment in older adults to potentially reduce the burden of adverse health

Hearing impairment is common in later life[4] and associated with poor physical and social functioning and poor quality of life,[105] negatively influencing the chances of independent living. In this thesis, hearing impairment in older age has also been associated with increased risks of incident CVD events, particularly incident stroke, and CVD mortality (Chapter 5). This thesis has furthermore shown an association between hearing impairment and increased risks of difficulty performing instrumental activities of daily living (IADL) (Chapter 6) and increased risks of frailty (Chapter 7) in later life. Also, in this thesis, it was shown that hearing impairment is very prevalent in older age (Chapter 4, Chapter 7). Therefore, addressing hearing impairment in older adults in the general population is of importance.

The findings of this thesis suggest that hearing impairment needs to be addressed to potentially reduce the burden of adverse health outcomes in older age. In a recent framework on hearing impairment for clinical commissioning groups published by NHS England in 2016,[352] it is recommended that health professionals who deliver care to older adults should be aware of the association between hearing impairment and increased risks of adverse health outcomes including poor physical and social functioning. The report also stresses the benefits of hearing aid use, the most effective method to improve the hearing of older adults.[87] This thesis has explored the impact of hearing aid use and overall the findings show no increased risks of adverse health outcomes in subjects who ‘could hear and used a hearing aid’ compared to the reference group ‘could hear and did not use a hearing aid’ (no hearing impairment). Thus, it is likely that participants who reported that they could hear and used a hearing aid have successfully addressed their hearing problem. Having successfully addressed the hearing problem may explain why participants in this hearing impairment group did not experience worse health outcomes compared to the reference group. Use of hearing aids has been reported as the most efficient method to address hearing impairment in older age.[87] Hearing aids have previously shown to have a positive impact on physical health (based on performance in everyday activities from the SF-12 health survey)[353] and quality of life.[354] However, intervention studies are needed to further investigate the impact of hearing aid use to potentially reduce the burden of adverse health (further discussed in section 8.4).

8.3.2. Efforts to prevent vision impairment in older age to potentially reduce the burden of adverse health

Findings from ELSA presented in this thesis have shown that vision impairment is common in older age affecting 12% of adults aged 60 years and over. In this thesis, vision impairment has furthermore been associated with increased risks of incident frailty and all-cause mortality. These findings have also shown strong associations between vision impairment and low social engagement. These findings highlight the importance of vision impairment in later life. The ability to prevent and treat vision impairment depends on the cause of the eye condition.[348] Whilst some common visual conditions can be prevented (e.g. diabetic retinopathy, glaucoma) or treated (e.g. cataracts) other conditions are chronic and irreversible (e.g. dry age-related macular degeneration), making early detection crucial. The importance of vision impairment also needs to be addressed in public health policies targeting older people. For example, in the National Service Framework for older people from 2001,[355] vision impairment is only briefly mentioned as a common problem in later life. Only in the last decade has vision impairment in later life received public health attention. In 2008 the government-supported charity UK Vision Strategy (also known as Vision 2020 UK) was initiated in response to the World Health Assembly Resolution aiming to make eye health a public health priority.[356] Over the last years, the UK Vision Strategy has raised awareness of existing services and resources available from charities and the NHS. However these efforts have mainly been aimed at the general population and not been targeting older adults specifically.[357]

8.4. Implications for future research

Important research questions addressed in this thesis include the role of impairments in hearing and vision on the risk of incident CVD and mortality, disability and frailty in older adults. However this is a broad topic that needs further investigation as some unanswered questions remain and some new questions have arisen as a result of the findings. In this section the implications for future research are presented.

This thesis has the strength of using data from two population-based cohorts (as discussed in Chapter 3, section 3.4). However, study limitations presented in this section (section 8.4) show the need to extend the investigations undertaken part of this thesis to future studies in other older populations.

8.4.1. Use other large population studies comprising older women and larger sample sizes of older adults from ethnic minority groups to examine sensory impairments with incident adverse health outcomes

The BRHS cohort comprised only men.[313] To investigate whether the findings of this thesis on sensory impairments and incident CVD, mortality and disability are applicable to women, the analyses need to be replicated in other large population-based studies of older women. Future studies of older women are particularly important when investigating the relationship of sensory impairments with increased risks of CVD and mortality as research has shown that women develop CVD at an older age than men.[31, 358]

Studies investigating sensory impairments in relation to gender in older age have also reported that men have greater risks of hearing impairment compared with women.[8] There is also some evidence suggesting that, compared with men, women have greater risks of vision impairment.[13] Other large population-based studies that include older women are needed to investigate whether there is any gender difference between sensory impairments and incident CVD, mortality and disability.

Few participants in the BRHS and ELSA are from minority ethnic backgrounds. Research on sensory impairments and ethnicity in older age has reported an association between white ethnic background and increased risks of hearing impairment.[8] Research has also shown an association between black ethnic background and increased risk of vision impairment.[13] Further research is therefore needed to replicate the findings from this thesis using studies with larger sample sizes of older adults from ethnic minority groups. Such research would demonstrate whether the findings shown in this thesis apply to other ethnic groups, and if any of the sensory impairments are particularly associated with increased risks of adverse health outcomes in certain ethnic groups. Findings from such research studies would allow for more effective prevention strategies targeting those at greatest risks.

8.4.2. In other large population-based studies, investigate objectively assessed sensory impairments with incident adverse health in older adults

The analyses of this thesis are restricted to self-reported data on hearing and vision function. The self-reported questions on sensory function used in BRHS and ELSA have previously been assessed against objective measures.[11, 100, 101, 130] However, the self-reported questions used could be criticised for poor sensitivity and specificity not showing a perfect association with objectively measured sensory function (see Chapter 3). Questions on self-reported sensory function reflect the individual's experience of their ability to hear and see, respectively, often referring to everyday activities that require hearing or vision[44, 125] (as discussed in Chapter 2). Self-reported questions therefore measure different aspects of sensory function compared to objective measures of hearing and vision. However, objective measures are needed to confirm sensory impairments. Research replicating the analyses using objectively assessed sensory function is needed to evaluate whether the observed relationships of self-reported hearing and vision impairments with adverse health outcomes are consistent with objectively measured sensory function. This is of particular interest for the relationship between sensory impairments and incident disability and frailty as sensory impairments are more likely to be directly associated with disability and frailty than with CVD and mortality.

8.4.3. Data on primary cause of impairments in hearing and vision, and severity and changes over time in hearing impairment and vision impairment

No data on the primary cause and level of severity of hearing impairment and vision impairment, respectively, were available in BRHS and ELSA. Also, in this thesis sensory impairments were assessed at baseline and changes in hearing impairment and vision impairment that may have occurred between baseline and follow-up were not investigated. Therefore the findings of this thesis need to be replicated in other large population studies with information on the primary cause of the sensory impairment, data on severity of the impairment and changes over time. Such research would show if certain causes of hearing impairment and vision impairment are associated with increased risks of incident CVD and mortality, disability and frailty. Data on the primary cause, severity and changes over time in hearing impairment and vision impairment would also be useful to efficiently target the sensory problem and reduce the risk of future adverse health.

8.4.4. Investigate possible pathways that may link sensory impairments to adverse health

A key challenge in future research on sensory impairments in older age is to clarify what mediators and mechanisms may link sensory impairments with adverse health outcomes and how they influence such relationships. Hypothesised pathways discussed in this thesis include psychosocial (poor social engagement and depression), balance and biological pathways which may contribute to increased risks of adverse health outcomes in sensory impaired older adults. Future research needs to clarify the pathways responsible for the associations observed. Increased knowledge of these pathways could facilitate efforts aiming to reduce the risks of adverse health.

8.4.4.1. Role of low social engagement and depression on the pathway linking sensory impairments with adverse health outcomes

It is possible that sensory impairments could be associated with CVD, mortality, disability and frailty through low social engagement and depression. As described in Chapter 2, poor communication due to sensory impairments can lead to social isolation,[147] a common risk factor for depression.[154, 359] Low social engagement and depression have furthermore been associated with increased risks of CVD, mortality, disability and frailty.[230, 232, 303, 320] It is possible that low social engagement exerts effects on poorer health through multiple pathways that are likely to co-occur, including health behaviour (e.g. decreased adherence to medical treatment, poorer diet, increased rate of smoking), psychological pathways including depression, and physiological pathways (e.g. increased cardiovascular reactivity, immune system dysfunction).[40] Low social engagement may therefore play an essential role linking sensory impairments to adverse health outcomes.

Other health issues closely related to depression and low social engagement include anxiety and quality of life which may also have mediated the relationships of sensory impairment with adverse health outcomes. Anxiety and quality of life have been independently associated with impairments in hearing and vision.[305, 360, 361] However, anxiety and quality of life could not be considered in the analyses due to insufficient data available in BRHS and ELSA. Future research examining the relationship between sensory impairments and adverse health outcomes need to explore whether these potential mediators may be responsible for the associations shown in this thesis.

Identifying mediators linking sensory impairments to adverse health outcomes in older age is important to efficiently target these mediators, reducing the risks of subsequent adverse health outcomes.

8.4.4.2. Role of balance and mobility limitation on the pathway linking hearing impairment with IADL difficulty

In addition to low social engagement and depression, the role of mobility limitation and poor balance on the relationship between hearing impairment and incident IADL difficulty was explored (Chapter 6). Mobility limitation and poor balance, previously associated with hearing impairment,[299] have been hypothesised to mediate the relationship between hearing impairment and incident disability.[299] In this thesis, the associations observed between hearing impairment and incident IADL difficulty were not attenuated on further adjustment for poor balance and mobility limitation. However, data on balance were self-reported, rather than objectively assessed, asking if the individual experienced difficulty keeping balance as a result of a long term health problem. An additional possible mediator related to poor balance that may explain the relationship of hearing impairment with disability, not explored in this thesis, is fear of falling. Future research needs to examine to what extent balance problems and mobility limitation may explain the relationship of hearing impairment and risks of incident IADL difficulty. Such research is important to efficiently target balance problems and mobility limitations at an early stage, possibly reducing the risks of incident IADL difficulty in hearing impaired older adults.

8.4.4.3. Role of cognitive function

In this thesis it has been speculated whether cognitive impairment may act on the pathway between sensory impairments and adverse health outcomes, potentially explaining the relationships of impairments in hearing and vision with physical functioning (Chapter 4), hearing impairment and incident CVD (Chapter 5), hearing impairment and incident IADL difficulty (Chapter 6) and impairments in hearing and vision and incident frailty (Chapter 7). Cognitive decline is a major health issue in later life and the prevalence of cognitive disorders such as dementia and Alzheimer’s disease is increasing in the UK due to an ageing population and improved detection and diagnosis.[362] It is possible that hearing impairment in later life leads to cognitive decline because of degradation of inputs to the brain. For example, in people with unaddressed hearing impairment, greater cognitive resources seem to be dedicated to process auditory information to the detriment of other cognitive processes such as working memory (e.g. holding and handling information).[85, 325] However, addressing hearing problems by increased use of hearing aids could potentially free resources for other cognitive functions.[363] The relationship between vision impairment and cognitive dysfunction is believed to be explained by poor vision hindering physical functioning including performing IADLs, resulting in behavioural changes and a reduction in mentally stimulating activities causing cognitive decline.[364] It is, however, possible that addressing vision problems could prevent or delay cognitive impairment. Nevertheless, the relationship between sensory impairments and cognitive dysfunction remains unclear and needs further investigation. Future research on the relationship between sensory impairments and incident adverse health is also needed to establish the possible role of cognitive impairment as a mediator linking sensory impairments to adverse health.

8.4.4.4. Role of inflammation

Chronic inflammation is potentially associated with both impairments in hearing and vision and adverse health outcomes through shared pathological pathways.[40] Consistently high levels of inflammatory blood markers such as serum C-reactive protein and interleukin-6 have been associated with increased risks of poor sensory function.[33, 37, 85, 175] Inflammation has also been associated with the outcomes examined in this thesis including CVD, disability and frailty.[35, 239, 327] Inflammation may therefore act as a shared pathway between hearing impairment and the outcomes observed in this thesis including the risk of incident CVD (as described in Chapter 2, section 2.4.1; Chapter 5, section 5.6.2.1), and the risk of incident IADL difficulty (Chapter 6, section 6.6.2.1). It is also possible that inflammation acts as a shared pathway between impairments in hearing and vision and the risk of incident frailty (Chapter 7, section 7.6.2.4). However, it remains unclear whether chronic inflammation directly contributes to sensory impairments. Therefore it is important to investigate the role of inflammation on the associations observed in this thesis. Further prospective studies are therefore needed to investigate whether inflammation increases the risk of developing sensory impairments and whether inflammation may be an underlying mechanism of the relationship between sensory impairments and incident adverse health.

8.4.5. Investigate dual sensory impairments and adverse health outcomes in older adults

In this thesis, hearing impairment and vision impairment have been investigated separately. The two sensory impairments were not combined due to the small number of participants with both hearing impairment and vision impairment. Combined loss of hearing and vision is often referred to as dual sensory impairment and estimated to affect 7% of adults aged 65 and older in England.[365] Individuals with dual sensory impairment are believed to experience more difficulty than the sum of each impairment alone,[361, 366] as loss of both hearing and vision has an inevitable impact on communication and independent living.[30] Investigating the relationship between dual sensory impairment and risks of adverse health outcomes is therefore of importance. However, to date, research on dual sensory impairment is limited. Possible ways to investigate the prospective relationship between dual sensory impairment and the risk of adverse health outcomes include, for example, combining large population-based studies allowing for a larger sample of older adults with sensory impairments. Hearing impairment and vision impairment are often modifiable and preventable on their own, and it is believed that dual sensory impairment could be targeted using similar strategies as for single sensory impairment.[30]

8.4.6. Intervention studies to address sensory impairments to potentially reduce adverse health outcomes in older adults

The findings of this thesis are based on observational studies. Future intervention studies are therefore needed to investigate whether addressing sensory impairments in older adults eventually reduces the burden of adverse health outcomes and improves quality of life.

8.4.6.1. Intervention studies on hearing impairment to possibly reduce future adverse health outcomes

Possible ways to identify and manage hearing impairment in older age include screening and use of hearing aids. Screening for hearing impairment in British adults is regularly reviewed by the UK National Screening Committee. However, similar to previous reviews, the most recent review published in 2016,[367] does not support screening for hearing impairment in adults because of lack of evidence about the acceptability of available treatments and lack of evidence on the benefit from long-term use of hearing aids. Formal audiometric testing used to diagnose hearing impairment is furthermore not appropriate for population screening purposes due to the combination of cost, time required and need for trained staff.[48] However, considering the findings of this thesis, perceived hearing impairment could be assessed by asking a single question to identify those in greatest need of a full audiometric evaluation. Support for a single question approach was reported in the review of screening for hearing loss in British adults from 2014.[48]

Hearing aids are regarded as the most effective method to address hearing problems in older age.[87] It is important to identify and address hearing problems at an early stage as it can take a long time for the hearing impaired individual to get used to a hearing aid.[87] Research has also shown that the longer the individual has lived with an unaddressed hearing problem, the harder it is to adapt to the hearing aid.[87] Adults who experience hearing problems wait on average 10 years before they seek help for their hearing problems.[87] Consequently, it is estimated that less than one third of older British adults who may benefit from a hearing aid own one,[368] and many of these individuals do not use it.[369] However, it remains unclear whether hearing aid use reduces the burden of future adverse health outcomes. Intervention studies are therefore needed to investigate any long-term benefits of hearing aid use on reducing the burden of hearing impairment on health and wellbeing over time.

In addition to hearing aid, recent research has suggested that age-related hearing impairment may also require rehabilitative training referred to as ‘aural rehabilitation’. Aural rehabilitation comprises, for example, changes to the environment and counselling to minimise the restrictions that hearing impairment can impose on well-being and communication.[301, 370] However, little research in the UK has explored the impact of aural rehabilitation for hearing impaired older adults in the process of starting to use and adapt to hearing aids, and we do not know if it is cost-effective or feasible to deliver within the NHS with restricted resources.

Intervention studies that investigate the impact of modifying hearing impairment in order to possibly reduce the burden of CVD, disability and frailty could further include targeting communication problems related to poor hearing. A recent report on hearing impairment and chronic conditions published by the charity Action on Hearing Loss has recommended that addressing communication problems in hearing impaired older adults with for example CVD and CVD risk factors such as diabetes and hypertension should be explored.[371] The report suggests that more effective communication could facilitate access to healthcare services and diagnosis of chronic conditions in hearing impaired adults. Future intervention studies are needed to examine whether targeting communication problems in older adults with hearing impairment is effective in reducing the burden of ill-health associated with hearing impairment and potentially improve their quality of life.

8.4.6.2. Intervention studies on vision impairment to possibly reduce future adverse health outcomes

Vision impairment in older age is often modifiable (as described in Chapter 2). It has been estimated that over 50% of vision impairment in the UK is avoidable, including correction of spectacles that are not of the optimum strength.[24] Interventions are needed to investigate the impact of detecting and managing vision impairment to potentially reduce the burden of adverse health outcomes and improve quality of life. In an Australian educational programme targeted at people aged 70 years and over, traditional media (TV, radio, newspapers) was used to increase the uptake of eye tests in the elderly population. It was reported that over one quarter (27%) of the targeted audience had their vision tested as a consequence of the intervention.[372] A similar intervention aiming to generate greater awareness and access to services in order to discover mild vision impairment in older adults who may not have otherwise presented, could be carried out in the UK. Participants could then be followed for long-term outcomes such as frailty and all-cause mortality, shown to be associated with vision impairment in this thesis.

8.5. Concluding statements

The population in the UK is ageing due to increased longevity leading to an increase in the number of older adults.[1] Impairments in hearing and vision are common in older age. Findings from this thesis have shown an association of hearing impairment with greater risks of incident cardiovascular disease (CVD), in particular incident stroke, and CVD mortality. In this thesis, hearing impairment was also associated with incident disability in the form of instrumental activities of daily living (IADL) and incident frailty in individuals who were pre-frail. Vision impairment was not associated with incident CVD outcomes but with increased risks of all-cause mortality. No statistically significant association was observed between vision impairment and incident disability. However, vision impairment was associated with greater risks of incidence of pre-frailty and frailty in non-frail participants. Findings from this thesis establish the importance of sensory impairments in later life and their potential influence on adverse health outcomes. These results emphasise the possibility for public health efforts to target sensory impairments in order to potentially reduce the burden of adverse health outcomes in older age. Further research needs to determine if modifying impairments in hearing and vision also improves these outcomes.

APPENDIX I. Search terms for relevant literature

Population:

Old* adult*
Old* people
Old* age
Ageing/aging
Aged
Elder*
Geriatric*

Exposure:

Sensory loss
Sensory impairment*
Hearing loss
Hearing impairment
Hearing aid

Vision loss
Vision impairment
Visual loss
Visual impairment
Eyesight
Macular degeneration
Cataract
Glaucoma
Diabetic retinopathy
Diabetic eye

Outcomes:

Cardiovascular disease
Coronary heart disease
Heart disease
Myocardial infarction
Heart attack
Stroke
Mortality
Death
Disab*
Mobility
Activities of daily living
Instrumental activities of daily living
Everyday activit*
Frail*

APPENDIX II. Conference oral presentations

Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Sensory impairments and mortality in older British community-dwelling men: a 10-year follow-up study. Age & Ageing. 2015 44 supplement 2:ii14-ii15. Presented at the British Geriatrics Society scientific spring meeting, Nottingham, 1 May 2015, and at the Society for Social Medicine annual scientific meeting, Dublin, 3 September 2015.

Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Sensory impairments and incident disability in older British community-dwelling men: a 2-year follow-up study. Presented at The Society for Academic Primary Care annual scientific meeting, 29 January 2016.

Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Hearing impairment and incident frailty in older English community-dwelling men and women: a 4-year follow-up study. Journal of Epidemiology and Community Health 2016;70:A38. Presented at Society for Social Medicine 60th annual scientific meeting, York, 15 September 2016 and at the Gerontological Society of America annual scientific meeting, New Orleans, 18 November 2016.

APPENDIX III. Conference poster presentations

Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Social and lifestyle characteristics and burden of ill-health associated with self-reported hearing and vision impairments in older men in the British community: a cross-sectional study. The Lancet. 2014 384:S45. Presented at the UK Public Health Science Conference, Glasgow, 19 November 2014.

Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Sensory impairments and incident disability in older British community-dwelling men: a 2-year follow-up study. The Lancet. 2015 386:S52. Presented at UK Public Health Science Conference, London, 13 November 2015 and at The Wellcome Trust, Longitudinal Studies - Maximising their Value for Ageing Research, Cambridge, 21 July 2015.

Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Vision impairment and risk of frailty: the English Longitudinal Study of Ageing. The Lancet. 2016 388:S70. Presented at the UK Public Health Science Conference, Cardiff, 25 November 2016.

Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Hearing impairment and risk of frailty: the English Longitudinal Study of Ageing. Presented at the NIHR School for Public Health Research annual scientific meeting, London, 23 March 2017.

APPENDIX IV. BRHS questionnaires

The subsequent pages include selected pages of the British Regional Heart Study questionnaires which are relevant to this thesis followed by the general practice medical record review form:

i. Postal questionnaire in 2003
ii. Postal questionnaire in 2005
iii. General Practice medical record review form used for biannual morbidity follow-up in BRHS

Relevant sections of the BRHS 2003 postal questionnaire

1.0 Date of birth ________ day ________ month 19________ year

(This information is necessary for us to ensure that you are the correct recipient)

Conditions affecting the heart or circulation

2.0 Have you **ever** been told by a doctor that you have or have had any of the following conditions?

If you tick **Yes**, please give the year of **last occurrence**

		Yes	No	Year of last occurrence
(a)	Heart attack (coronary thrombosis or myocardial infarction)	☐	☐	________
(b)	Heart failure	☐	☐	________
(c)	Angina	☐	☐	________
(d)	Other heart trouble	☐	☐	________
(e)	High blood pressure	☐	☐	________
(f)	High blood cholesterol	☐	☐	________
(g)	Aortic Aneurysm	☐	☐	________
(h)	Narrowing or hardening of the leg arteries (including claudication)	☐	☐	________
(i)	Deep Vein Thrombosis (clot in the deep leg vein)	☐	☐	________
(j)	Pulmonary Embolism (clot on the lung)	☐	☐	________

Stroke	Yes	No	Year of last occurrence
3.0 Have you **ever** been told by a doctor that you have had a stroke?	☐	☐	________
If **Yes,**			
3.1 Did the symptoms last for more than 24 hours?	☐	☐	
3.2 Have you made a complete recovery from your stroke?	☐	☐	
3.3 Following your stroke, do you still need any help in carrying out everyday activities?	☐	☐	

Investigations and special treatment for conditions affecting the heart and circulation

4.0 Have you **ever** had one of the following?

		Yes	No	Year of last occurrence
4.1	A referral to a heart specialist	☐	☐	_______
4.2	A referral to a chest pain clinic	☐	☐	_______
4.3	An exercise ECG (“stress” or “treadmill”) test	☐	☐	_______
4.4	Angiogram or X-ray of coronary arteries (using a dye)	☐	☐	_______
4.5	Angioplasty (balloon treatment of coronary artery for angina)	☐	☐	_______
4.6	Coronary artery bypass graft operation (“heart bypass” or “CABG”)	☐	☐	_______
4.7	Other tests, investigations or operations on the heart, arteries or veins?	☐	☐	_______

If **Yes**, please give details:

____

OFFICE USE ☐

Diabetes

	Yes	No	
5.0 Have you **ever** been told by a doctor that you have or have had diabetes?	☐	☐	
If **Yes**,			
5.1 In what year was it first diagnosed?	________ (Year)		
5.2 Do you have any complications of diabetes affecting.......... your feet?	☐	☐	
your nerves?	☐	☐	
your kidneys?	☐	☐	
your eyes?	☐	☐	
5.3 Have your eyes been checked for signs of diabetes? (Please give year of last check)	☐	☐	_______ (Year)

Cancer

6.0 Have you **ever** been told by a doctor that you have or have had cancer? Yes ☐ No ☐

If **Yes**, please give:

(a) Year first diagnosed __________ (b) Cancer Site ____________________ OFFICE USE ☐☐☐☐

Arthritis

7.0 Have you **ever** been told by a doctor that you have or have had arthritis? Yes ☐ No ☐

If **Yes**,

7.1 Type of arthritis (if known), (eg. osteoarthritis, rheumatoid arthritis, other): OFFICE USE ☐

____

7.2 Year first diagnosed ________

7.3 Joint(s) affected:
please tick the relevant box(es)

Knees ☐
Hips ☐
Feet ☐
Hands and/or wrists ☐
Other (please specify) ____________________ OFFICE USE ☐

Other Medical Conditions

8.0 Have you **ever** been told by a doctor that you have or have had any of the following conditions?

If **Yes**, please give the year when **first** diagnosed, if possible

	Yes	No	Year		Yes	No	Year
(a) Asthma	☐	☐	______	(b) Bronchitis	☐	☐	______
(c) Cataract	☐	☐	______	(d) Depression	☐	☐	______
(e) Emphysema	☐	☐	______	(f) Gall bladder disease	☐	☐	______
(g) Gastric, peptic or duodenal ulcer	☐	☐	______	(h) Glaucoma	☐	☐	______
(i) Gout	☐	☐	______	(j) Osteoporosis	☐	☐	______
(k) Parkinson's disease	☐	☐	______	(l) Pneumonia	☐	☐	______
(m) Prostate trouble	☐	☐	______				

(n) Other conditions, please give details: OFFICE USE

______________________________ _______ (year) ☐☐☐☐

______________________________ _______ (year) ☐☐☐☐

Joint pain, swelling or stiffness

9.0 During **the past year** have you had pain, aching, stiffness or swelling on most days for at least one month, in your…

	Yes	No	
(a) Hands or wrists	☐	☐	
(b) Knees	☐	☐	
(c) Hips	☐	☐	
(d) Feet	☐	☐	
(e) Other joint	☐	☐	(please specify)______________________ OFFICE USE ☐

Lower back pain

	Yes	No
10.0 Have you **ever** had pain in your lower back on most days for at least one month?	☐	☐
10.1 If **Yes**, have you had this in the last year?	☐	☐

Fractures and falls

	Yes	No	Please give year
11.0 Have you **ever** fractured your hip?	☐	☐	___________
11.1 Have you **ever** fractured your wrist?	☐	☐	___________
11.2 Have you had a fall in the last 12 months?	☐	☐	

If **Yes**,

(a) how many times? ☐☐ times

(b) Did you receive medical attention for any of these falls? ☐ Yes ☐ No

Chest pain

12.0 Do you **ever** have any pain or discomfort in your chest? Yes ☐ No ☐

If **Yes**,

	Yes	No	Unable to walk on level
(a) When you walk at an ordinary pace on the level, does this produce the pain?	☐	☐	☐

	Yes	No	Unable to walk uphill
(b) When you walk uphill or hurry, does this produce the pain?	☐	☐	☐

Disability

	Yes	No
15.0 Do you have any long-standing illness, disability or infirmity?	☐	☐

("long-standing" means anything which has troubled you over a period of time or is likely to do so)

If **Yes,**	Yes	No
(a) Does this illness or disability limit your activities in any way?	☐	☐
(b) Do you receive a disability allowance?	☐	☐

15.1 Do you currently have difficulty carrying out any of the following activities on your own as a result of a **long term** health problem?

		Yes	No
(a)	Going up or down stairs	☐	☐
(b)	Bending down	☐	☐
(c)	Straightening up	☐	☐
(d)	Keeping your balance	☐	☐
(e)	Going out of the house?	☐	☐
(f)	Walking 400 yards	☐	☐

15.2 Is your present state of health causing problems with any of the following:-

		Yes	No
(a)	Job at work (paid employment)	☐	☐
(b)	Household chores	☐	☐
(c)	Social life	☐	☐
(d)	Sex life	☐	☐
(e)	Interests and hobbies	☐	☐
(f)	Holidays and outings	☐	☐

Eyesight

	Yes	No
16.0 Using glasses or corrective lenses if needed, can you see well enough to recognise a friend at a distance of 12 feet/ four yards (across a road)?	☐	☐
If **No**, can you see well enough to recognise a friend at a distance of one yard?	☐	☐

Hearing

	Yes	No
17.0 Do you use a hearing aid?	☐	☐
17.1 Using a hearing aid if needed, is your hearing good enough to follow a TV programme at a volume others find acceptable?	☐	☐
If **No**, can you follow a TV programme with the volume turned up?	☐	☐

Your Health Overall

Please indicate which statements best describe your health **TODAY.** (Please tick **only one box**)

18.0	General Health:-	Excellent	☐1
		Good	☐2
		Fair	☐3
		Poor	☐4
18.1	Pain/Discomfort:-	I have no pain or discomfort	☐1
		I have moderate pain or discomfort	☐2
		I have extreme pain or discomfort	☐3
18.2	Mobility:-	I have no problems in walking about	☐1
		I have some problems in walking about	☐2
		I am confined to a chair/wheelchair	☐3
18.3	Anxiety/Depression:-	I am not anxious or depressed	☐1
		I am moderately anxious and/or depressed	☐2
		I am extremely anxious and/or depressed	☐3

Sleep:-

18.4 On average, how many hours' sleep do you have each night? ☐☐ hours

18.5 On average, how much sleep (if any) do you have during the daytime? ☐☐ hours

18.6	Do you snore while asleep?	Yes, regularly	☐1
		Yes, occasionally	☐2
		No, never	☐3
		Don't know	☐4

18.7 **Health Scale**

We have drawn a health scale (rather like a thermometer) on which perfect health is 100 and very poor health is 0. Please put a cross (**X**) on the scale to reflect how good or bad your health is today.

Worst Imaginable Health State — Best Imaginable Health State

0 — 10 — 20 — 30 — 40 — 50 — 60 — 70 — 80 — 90 — 100

OFFICE USE ☐☐☐

Physical activity

19.0 Do you make regular journeys every day or most days either walking or cycling?

- No ☐1
- Walk ☐2
- Cycle ☐3
- Both ☐4

(a) How many hours do you normally spend walking (e.g. on errands or for leisure) in an average week? ☐☐ hours

19.1 Which of the following best describes your usual walking pace?

- Slow ☐1
- Steady average ☐2
- Fast ☐3

19.2 How long do you spend cycling in an average week? ☐☐ hours

19.3 Compared with a man who spends four hours on most weekends on activities such as: walking, gardening, household chores, DIY projects, how physically active would you consider yourself?

- Much more active ☐1
- More active ☐2
- Similar ☐3
- Less active ☐4
- Much less active ☐5

19.4 Do you take active sporting physical exercise such as running, swimming, dancing, golf, tennis, squash, jogging, bowls, cycling, hiking, etc.?

- No ☐1
- Occasionally (less than once a month) ☐2
- Frequently (once a month or more) ☐3

(a) If you ticked **frequently** please state type of activities:

OFFICE USE ☐☐

____

(b) How many times a **month** (on average) do you take part in these activities? (give overall total)

In winter ☐☐ times

In summer ☐☐ times

19.5 Do you engage in exercises to increase muscle strength and endurance such as lifting weights, doing push-ups, using exercise machines?

- Yes ☐
- No ☐

If Yes, on average how many hours per week do you engage in these exercises? ☐☐ hours per week

Cigarette smoking

		Yes	No
20.0	Do you smoke cigarettes at present?	☐	☐

If **Yes**, please answer the following questions:

20.1 How many cigarettes do you smoke a day at present? ☐☐

20.2 If hand-rolled, how much tobacco do you use a week? ☐☐ oz / ☐☐☐ grams

		Yes	No
20.3	Do you want to give up smoking?	☐	☐
20.4	Have you tried to stop smoking?	☐	☐

20.5 Have you been offered any of the following to help you stop smoking?

	Yes	No
(a) Advice from a health professional (e.g. doctor or nurse)	☐	☐
(b) Referral to a stop-smoking clinic	☐	☐
(c) Nicotine replacement treatment (including sprays, patches etc)	☐	☐
(d) Zyban tablets	☐	☐
(e) Other treatment (please specify) ______________________		

OFFICE USE ☐

21.0 Have you changed your cigarette smoking habits during the past four years?

- No ☐1
- Yes, increased ☐2
- Yes, cut down ☐3
- Yes, given up ☐4

21.1 **If you have given up smoking** in the last four years, were any of these factors important?

	Yes	No
(a) Advice from a health professional (e.g. doctor or nurse)	☐	☐
(b) Referral to a stop-smoking clinic	☐	☐
(c) Nicotine replacement treatment (including sprays, patches etc)	☐	☐
(d) Zyban tablets	☐	☐
(e) Illness or ill-health	☐	☐
(f) Cost of cigarettes	☐	☐
(g) Other factors (please specify) ______________________		

OFFICE USE ☐

Pipe and cigar smoking

		Yes	No
22.0	Do you currently smoke a pipe?	☐	☐
22.1	Do you currently smoke cigars?	☐	☐

Activities of daily living

The following questions will help us to understand difficulties people may have with various everyday activities

28.0 What is the furthest you can walk on your own without stopping and without discomfort?

- 200 metres or more ☐1
- More than a few steps but less than 200 metres ☐2
- Only a few steps ☐3

28.1 Can you walk up and down a flight of 12 stairs without resting?

- Yes ☐1
- Only if I hold on and take a rest ☐2
- Not at all ☐3

28.2 Can you, when standing, bend down and pick up a shoe from the floor?

- Yes ☐
- No ☐

29.0 Please indicate if you have difficulty doing any of the following activities:	No difficulty	Some difficulty	Unable to do or need help
Reaching or extending your arms above shoulder level	☐	☐	☐
Pulling or pushing large objects like a living room chair	☐	☐	☐
Walking across a room	☐	☐	☐
Getting in and out of bed on your own?	☐	☐	☐
Getting in and out of a chair on your own?	☐	☐	☐
Dressing and undressing yourself on your own?	☐	☐	☐
Bathing or showering?	☐	☐	☐
Feeding yourself, including cutting food?	☐	☐	☐
Getting to and using the toilet on your own?	☐	☐	☐
Lifting and carrying something as heavy as 10 lbs, for example a bag of groceries	☐	☐	☐
Shopping for personal items such as toilet items or medicine by yourself	☐	☐	☐
Doing light housework such as washing up	☐	☐	☐
Preparing your own meals by yourself	☐	☐	☐
Using the telephone by yourself	☐	☐	☐
Taking medications by yourself	☐	☐	☐
Managing money (e.g. paying bills etc)	☐	☐	☐
Using public transport on your own	☐	☐	☐
Driving a car on your own	☐	☐	☐

Time spent on various activities

30.0 Approximately how many **hours each week** (if any) do you spend:

			Tick box if you never do
Looking after wife/partner?	☐☐	hours per week	☐
Looking after other adult family member or friend?	☐☐		☐
Looking after grandchildren?	☐☐		☐
In paid work?	☐☐	hours per week	☐
In voluntary work?	☐☐		☐
On housework?	☐☐	hours per week	☐
On gardening?	☐☐		☐
In a pub or club?	☐☐	hours per week	☐
Attending religious services?	☐☐		☐
Playing cards, games, or bingo?	☐☐	hours per week	☐
Visiting the cinema/restaurants/sporting events?	☐☐		☐
Watching television/videos?	☐☐	hours per week	☐
Reading?	☐☐		☐
Attending class or course of study?	☐☐		☐

31.0 Do you go on day or overnight trips…

- Never ☐1
- Sometimes ☐2
- Often ☐3

31.1 Have you been on holiday in the last year? Yes ☐ No ☐

Thank you very much for completing the questionnaire.

Please return it to us, along with the blue consent form, in the envelope provided.

No stamp is needed.

Relevant sections of the BRHS 2005 postal questionnaire

Breathlessness

		Yes	No	Unable to walk
15.0	Do you ever get short of breath walking with other people of your own age on level ground?	$\square_1$	$\square_2$	$\square_3$
15.1	On walking uphill or upstairs, do you get more breathless than people of your own age?	$\square_1$	$\square_2$	$\square_3$
15.2	Do you ever have to stop walking because of breathlessness?	☐	☐	
15.3	In the **past year** have you at any time been awoken at night by an attack of shortness of breath?	☐	☐	

Cough and Wheeze

		Yes	No
15.4	Do you usually bring up phlegm (or spit) from your chest first thing in the morning in the winter?	☐	☐
15.5	Do you bring up phlegm like this on most days for as much as 3 months in the winter each year?	☐	☐

15.6 In the **past two years** have you had a period of increased cough and phlegm lasting for 3 weeks or more?

Yes, once $\square_1$
Yes, twice or more $\square_2$
Never $\square_3$

		Yes	No
15.7	Does your chest ever sound wheezy or whistling?	☐	☐
15.8	If Yes, does this happen on most days or nights?	☐	☐

15.9 How many times in the past year have you had a chest infection requiring antibiotic treatment from your doctor?

None $\square_1$
Once $\square_2$
More than once $\square_3$

Eyesight

		Yes	No
16.0	Using glasses or corrective lenses if needed, can you see well enough to recognise a friend at a distance of 12 feet/ four yards (across a road)?	☐	☐
16.1	If No, can you see well enough to recognise a friend at a distance of one yard?	☐	☐

16.2 In the **past two years** has your sight:

deteriorated $\square_1$
improved $\square_2$
stayed the same $\square_3$

6

Hearing

		Yes	No
16.3	Is your hearing good enough to follow a TV programme at a volume others find acceptable (using a hearing aid if needed)?	☐	☐
16.4	If No, can you follow a TV programme with the volume turned up?	☐	☐

16.5 In the **past two years** has your hearing:

deteriorated $\square_1$
improved $\square_2$
stayed the same $\square_3$

		Yes	No	Occasionally
16.6	Do you use a hearing aid?	$\square_1$	$\square_2$	$\square_3$

Leg Pain

		Yes	No
17.0	Do you get pain or discomfort in your leg or legs when you walk?	☐	☐

If Yes,

		Yes	No	Office Use
17.1	Do you know the cause of the pain?	☐	☐	
	If Yes, please state cause			☐
17.2	Does this pain ever begin when you are standing still or sitting?	☐	☐	

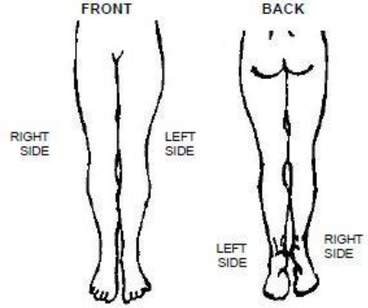
		Yes	No	Unable to walk
17.3	Do you get the pain if you walk uphill or hurry?	$\square_1$	$\square_2$	$\square_3$
17.4	Do you get the pain walking at an ordinary pace on the level?	$\square_1$	$\square_2$	$\square_3$

17.5 What happens to the pain if you stand still?

Usually continues more than 10 minutes $\square_1$
Usually disappears in 10 minutes or less $\square_2$

17.6 Please mark on the diagram below where you get the pain.

FRONT BACK



Office Use
L ☐
R ☐

7

21.5 Is the alcohol which you drink usually taken (Please tick whichever apply)

before meals	☐1
with meals	☐1
after meals	☐1
separate from meals	☐1

21.6 Have you changed your alcohol intake in the **last two years**?

No	☐1
Yes, increased	☐2
Yes, cut down	☐3
Yes, given up	☐4

21.7 If you have **CUT DOWN** or **GIVEN UP**, was this due to (Please tick whichever apply)

Personal choice	☐1
Doctor's advice	☐1
Illness or ill health	☐1
Health precaution	☐1
Being on medication	☐1
Financial reasons	☐1
Other	☐1

Disability

		Yes	No
22.0	Do you have any **long-standing** illness, disability or infirmity?	☐	☐

"long-standing" means anything which has troubled you over a period of time or is likely to do so

If Yes,

		Yes	No
a	Does this illness or disability limit your activities in any way?	☐	☐
b	Do you receive a disability allowance?	☐	☐

22.1 Do you currently have difficulty carrying out any of the following activities on your own as a result of a **long term** health problem?

		Yes	No
a	Going up or down stairs	☐	☐
b	Bending down	☐	☐
c	Straightening up	☐	☐
d	Keeping your balance	☐	☐
e	Going out of the house	☐	☐
f	Walking 400 yards	☐	☐

22.2 Is your present state of health causing problems with any of the following:-

		Yes	No	Does not apply
a	Job at work paid employment	☐1	☐2	☐3
b	Household chores	☐	☐	
c	Social life	☐	☐	
d	Sex life	☐	☐	
e	Interests and hobbies	☐	☐	
f	Holidays and outings	☐	☐	

Activities of daily living

The following questions will help us to understand difficulties people may have with various everyday activities

31.0 What is the furthest you can walk on your own without stopping and without discomfort?

200 yards or more	☐1
More than a few steps but less than 200 yards	☐2
Only a few steps	☐3

31.1 Can you walk up and down a flight of 12 stairs without resting?

Yes	☐1
Only if I hold on and take a rest	☐2
Not at all	☐3

31.2 Can you, when standing, bend down and pick up a shoe from the floor?

Yes	☐1
No	☐2

32.0	Please indicate if you have difficulty doing any of the following activities:	No difficulty 1	Some difficulty 2	Unable to do or need help 3
a	Reaching or extending your arms above shoulder level	☐	☐	☐
b	Pulling or pushing large objects like a living room chair	☐	☐	☐
c	Walking across a room	☐	☐	☐
d	Getting in and out of bed on your own	☐	☐	☐
e	Getting in and out of a chair on your own	☐	☐	☐
f	Dressing and undressing yourself on your own	☐	☐	☐
g	Bathing or showering	☐	☐	☐
h	Feeding yourself, including cutting food	☐	☐	☐
i	Getting to and using the toilet on your own	☐	☐	☐
j	Lifting and carrying something as heavy as 10 lbs, for example a bag of groceries	☐	☐	☐
k	Shopping for personal items such as toilet items or medicine by yourself	☐	☐	☐
l	Doing light housework such as washing up	☐	☐	☐
m	Preparing your own meals by yourself	☐	☐	☐
n	Using the telephone by yourself	☐	☐	☐
o	Taking medications by yourself	☐	☐	☐
p	Managing money (e.g. paying bills etc)	☐	☐	☐
q	Using public transport on your own	☐	☐	☐
r	Driving a car on your own	☐	☐	☐
s	Gripping with hands (eg. opening a jam jar)	☐	☐	☐

General Practice medical record review form used for biannual morbidity follow-up in BRHS

BRHS (men) Record Review 2015 1

Serial No:
Name:
Address
DOB:
NHS No:

Please tick if address is correct ☐

New address:

<u>THE QUESTIONS ON THIS PAGE (1-6) RELATE TO THE PERIOD FROM 1ST JANUARY 2014 TO DATE</u>

		YES	NO	
1	Is the above patient still registered with you?	☐	☐	
2	Has he **consulted** you since 1st January 2014?	☐	☐	
3	Was any consultation for a **<u>new episode</u>** of:	**YES**	**NO**	(day, month, year)
	***Myocardial Infarction** (MI) Heart attack, Coronary thrombosis	☐	☐	Date: ....*
	***Acute Coronary Syndrome**	☐	☐	Date: ....*
	Angina Exertional or stress related chest pain	☐	☐	Date: ....
	***Stroke** Cerebrovascular accident (CVA), cerebral thrombosis, haemorrhage, embolism	☐	☐	Date: ....*
	Transient Ischaemic Attack (TIA) Cerebrovascular disturbance (<24 hours); leaving no residual damage	☐	☐	Date: ....
	Diabetes (NIDDM Type 2 / IDDM Type 1)	☐	☐	Date: ....
	***Heart Failure** Congestive Cardiac Failure - (CCF) or Left Ventricular Failure - (LVF)	☐	☐	Date: ....*
	Other Cardiovascular disease:			
	Peripheral Arterial Disease (PAD,PVD) Intermittent claudication, lower limb ischaemia	☐	☐	Date: ....
	Aortic Aneurysm rupture, dissection	☐	☐	Date: ....
	***Deep Vein Thrombosis** (DVT) blood clot in the leg	☐	☐	Date: ....*
	***Pulmonary Embolism** (PE) blood clot in the lung	☐	☐	Date: ....*

*** If Yes, please send a <u>copy of the hospital letter or discharge summary</u>**

		YES	NO	
4	Has he been referred to a Consultant for any new cardiovascular condition?	☐	☐	Date: ....
	Diagnosis :			
5	Have any of the following procedures taken place:	**YES**	**NO**	
	Coronary Artery Bypass Graft (CABG)	☐	☐	Date: ....
	Coronary Angioplasty (PTCA) Percutaneous coronary angioplasty, balloon treatment. Insertion of stents ☐	☐	☐	Date: ....
6	Has he had a Cancer diagnosis?	☐	☐	Date: ....
	Site:			

		YES	NO	
7	Has there been a diagnosis of:			
	Atrial Fibrillation	☐	☐	Date: ....
	Dementia	☐	☐	Date: ....
	If yes, please give details of the type of dementia:-			
	Vascular dementia	☐		
	Alzheimer's disease	☐		
	Other, please give details	☐		....
	Dementia type not known	☐		

British Regional Heart Study, Department of Primary Care & Population Health, UCL Medical School, Royal Free Campus, Rowland Hill Street, London NW3 2PF.
Tel: 020 7830 2335 Fax: 020 7794 1224 Email: l.lennon@ucl.ac.uk

APPENDIX V. ELSA questionnaires

The subsequent pages include selected pages of the English Longitudinal Study of Ageing questionnaires covering questions on sensory impairments and the frailty components used in this thesis:

i. Interview questionnaire at wave 2 in 2004
ii. Physical examination at wave 2 in 2004
iii. Interview questionnaire at wave 4 in 2008
iv. Physical examination at wave 4 in 2008

Interview questionnaire at wave 2 in 2004

[Loop: Responses to HEEYE are recorded in variables HEEYE1 to HEEYE2]
Is [yourname[pnum]] eyesight (using glasses or corrective lens if
[heshe[pnum]] use[s[PNum]] them)...
INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?
6 SPONTANEOUS: Registered or legally blind

*IF IAskPx[PNum] <> Yes AND Heeye <> Blind [(IAskPx[PNum] <>
Yes) AND (Heeye <> Blind)]*

HEFRND
[Loop: Responses to HEFRND are recorded in variables HEFRND1 to HEFRND2]
How good is your eyesight for seeing things at a distance, like recognising
a friend across the street (using glasses or corrective lens if [heshe[pnum]]
use[s[PNum]] them)? Would you say it is...
INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

HEPAP
[Loop: Responses to HEPAP are recorded in variables HEPAP1 to HEPAP2]
How good is your eyesight for seeing things up close, like reading
ordinary newspaper print (using glasses or corrective lens if
[heshe[pnum]] use[s[PNum]] them)? Would you say it is...
INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

END FILTER

*IF IW1[PNum].HeOpt = RESPONSE AND NOT None IN
IW1[PNum].HeOpt [(IW1[PNum].HeOpt = RESPONSE) AND NOT (None*

removed?
1 Yes
2 No

END FILTER

*IF catarac IN IW1[PNum].HeOpt OR catarac IN HeOpt AND HeOpC =
Yes OR IW1[PNum].Hecat <> RESPONSE [((catarac IN
IW1[PNum].HeOpt) OR (catarac IN HeOpt)) AND ((HeOpC = Yes) OR
(IW1[PNum].Hecat <> RESPONSE))]*

HECAT
[Loop: Responses to HECAT are recorded in variables HECAT1 to HECAT2]
[Have] [heshe[PNum]][ever] had cataract surgery?
1 Yes
2 No

END FILTER

HEHEAR
[Loop: Responses to HEHEAR are recorded in variables HEHEAR1 to HEHEAR2]
Is [yourname[pnum]] hearing (using a hearing aid if [heshe[PNum]]
use[s[PNum]] one)...
INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

IF IAskPx[PNum] <> Yes [IAskPx[PNum] <> Yes]

HEHRA
[Loop: Responses to HEHRA are recorded in variables HEHRA1 to HEHRA2]
Do you find it difficult to follow a conversation if there is background
noise, such as TV, radio or children playing (using a hearing aid as
usual)?
1 Yes
2 No

*IF Hehear IN [Fair, Poor] OR HeHra = Yes [(Hehear IN [Fair, Poor])
OR (HeHra = Yes)]*

| | | | | | | |
| | | | | | | HEHRB
| | | | | | | *[Loop: Responses to HEHRB are recorded in variables HEHRB1 to HEHRB2]*
| | | | | | | Have you told a doctor or nurse about your hearing problems?
| | | | | | | 1 Yes
| | | | | | | 2 No
| | | | | | |
| | | | | | | *IF HeHrb = Yes [HeHrb = Yes]*
| | | | | | | |
| | | | | | | | HEHRC
| | | | | | | | *[Loop: Responses to HEHRC are recorded in variables HEHRC1 to HEHRC2]*
| | | | | | | | When you told the doctor or nurse about your hearing problems, did
| | | | | | | | he or she refer you to an ear specialist to check your hearing?
| | | | | | | | INTERVIEWER: PROBE - 'By ear specialist we mean an ENT doctor, an ear nose and
| | | | | | | | throat doctor, an otolaryngologist, or an audiologist. An audiologist may perform
| | | | | | | | an extensive hearing test.'
| | | | | | | | 1 Yes
| | | | | | | | 2 No
| | | | | | | |
| | | | | | | | HEHRD
| | | | | | | | *[Loop: Responses to HEHRD are recorded in variables HEHRD1 to HEHRD2]*
| | | | | | | | Has any doctor or nurse or ear specialist recommended a hearing
| | | | | | | | aid?
| | | | | | | | 1 Yes
| | | | | | | | 2 No
| | | | | | | |
| | | | | | | | *IF HeHrd = Yes [HeHrd = Yes]*
| | | | | | | | |

| | | | | | | | | HEHRE
| | | | | | | | | *[Loop: Responses to HEHRE are recorded in variables HEHRE1 to HEHRE2]*
| | | | | | | | | Did you get a hearing aid?
| | | | | | | | | 1 Yes
| | | | | | | | | 2 No
| | | | | | | | |
| | | | | | | | | *IF HeHre = Yes [HeHre = Yes]*
| | | | | | | | | |
| | | | | | | | | | HEHRF
| | | | | | | | | | *[Loop: Responses to HEHRF are recorded in variables HEHRF1 to HEHRF2]*
| | | | | | | | | | Did an ear specialist or doctor or nurse teach you how to use
| | | | | | | | | | your hearing aid?

| | | | | | | | | | 1 Yes
| | | | | | | | | | 2 No
| | | | | | | | | |
| | | | | | | | | | HEHRG
| | | | | | | | | | *[Loop: Responses to HEHRG are recorded in variables HEHRG1 to HEHRG2]*
| | | | | | | | | | Do you use your hearing aid?
| | | | | | | | | | 1 Yes
| | | | | | | | | | 2 No
| | | | | | | | | |
| | | | | | | | | END FILTER
| | | | | | | | |
| | | | | | | | END FILTER
| | | | | | | |
| | | | | | | END FILTER
| | | | | | |
| | | | | | END FILTER
| | | | | |
| | | | | END FILTER
| | | | |
| | | | END FILTER
| | | |
| | | END FILTER
| | |
| | | LOOP FOR Perno:= 1 TO 2
| | | |
| | | | *IF Session[Perno] = Yes [Session[Perno] = Yes]*
| | | | |
| | | | | *IF IAskPx[PNum] <> Yes AND QHD.QAHD.P[PNum].DhAge >= 65*

| | | | | *[(IAskPx[PNum] <> Yes) AND (QHD.QAHD.P[PNum].DhAge >= 65)]*
| | | | | |
| | | | | | HEBPCHK
| | | | | | *[Loop: Responses to HEBPCHK are recorded in variables HEBPCH1 to HEBPCH2]*
| | | | | | In the past year, has any doctor or nurse checked your blood pressure?
| | | | | | 1 Yes
| | | | | | 2 No
| | | | | |
| | | | | END FILTER
| | | | |
| | | | | *IF IW1[PNum].HeDiaa = RESPONSE AND NOT None IN*
| | | | | *IW1[PNum].HeDiaa [(IW1[PNum].HeDiaa = RESPONSE) AND NOT (None*
| | | | | *IN IW1[PNum].HeDiaa)]*

[Loop: Responses to HEACTA are recorded in variables HEACTA1 to HEACTA2]
SHOW CARD S
We would like to know the type and amount of physical activity involved in your daily life. Do you take part in sports or activities that are vigorous...
INTERVIEWER: Read out...
1 ...more than once a week,
2 once a week,
3 one to three times a month,
4 hardly ever, or never?

HEACTB
[Loop: Responses to HEACTB are recorded in variables HEACTB1 to HEACTB2]
SHOW CARD S
And do you take part in sports or activities that are moderately energetic...
INTERVIEWER: Read out...
1 ..more than once a week,
2 once a week,
3 one to three times a month,
4 hardly ever, or never?

HEACTC
[Loop: Responses to HEACTC are recorded in variables HEACTC1 to HEACTC2]
SHOW CARD S
And do you take part in sports or activities that are mildly energetic...
INTERVIEWER: Read out...
1 ..more than once a week,
2 once a week,
3 one to three times a month,
4 hardly ever, or never?

END FILTER

END FILTER

HETSET

INTERVIEWER:The Health section is finished. Please enter 1 here to make the program store the current time and date.
Range: 1..1
[Don't Know and Refusal are not allowed]

LOOP FOR Perno:= 1 TO 2

SHOW CARD AX
Considering all the efforts that I have put into caring for someone, I am fully satisfied with what I have gained so far. (Would you say that you strongly agree, agree, disagree or strongly disagree?)
1 Strongly agree
2 Agree
3 Disagree
4 Strongly disagree

ERCARB
[Loop: Responses to ERCARB are recorded in variables ERCARB1 to ERCARB2]
SHOW CARD AX
Considering all the efforts that I have put into caring for someone, I have always received adequate appreciation from others. (Would you say that you strongly agree, agree, disagree or strongly disagree?)
1 Strongly agree
2 Agree
3 Disagree
4 Strongly disagree

END FILTER

END FILTER

PSCEDI
[Loop: Responses to PSCEDI are recorded in variables PSCEDI1 to PSCEDI2]
Now think about the past week and the feelings you have experienced. Please tell me if each of the following was true for you much of the time during the past week.
1 Press and to continue.

PSCEDA
[Loop: Responses to PSCEDA are recorded in variables PSCEDA1 to PSCEDA2]
(Much of the time during the past week), you felt depressed?
INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDB
[Loop: Responses to PSCEDB are recorded in variables PSCEDB1 to PSCEDB2]
(Much of the time during the past week), you felt that everything you did was an effort?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDC
[Loop: Responses to PSCEDC are recorded in variables PSCEDC1 to PSCEDC2]
(Much of the time during the past week), your sleep was restless?
INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDD
[Loop: Responses to PSCEDD are recorded in variables PSCEDD1 to PSCEDD2]
(Much of the time during the past week), you were happy?
INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDE
[Loop: Responses to PSCEDE are recorded in variables PSCEDE1 to PSCEDE2]
(Much of the time during the past week), you felt lonely?
INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDF
[Loop: Responses to PSCEDF are recorded in variables PSCEDF1 to PSCEDF2]
(Much of the time during the past week), you enjoyed life?
INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDG
[Loop: Responses to PSCEDG are recorded in variables PSCEDG1 to PSCEDG2]
(Much of the time during the past week), you felt sad?
INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDH
[Loop: Responses to PSCEDH are recorded in variables PSCEDH1 to PSCEDH2]
(Much of the time during the past week), you could not get going?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

IF TotalPSC >= 5 [TotalPSC >= 5]

PSFEEL
[Loop: Responses to PSFEEL are recorded in variables PSFEEL1 to PSFEEL2]
Have you spoken to a doctor, nurse or mental health professional about these feelings?
1 Yes
2 No

IF PsFeel <> EMPTY AND PsNTimb = EMPTY [PsFeel <> EMPTY AND PsNTimb = EMPTY]

PSNTIMB
[Loop: Responses to PSNTIMB are recorded in variables PSNTIM1 to PSNTIM2]
Time at start of Quality of care section

PSNDATB
[Loop: Responses to PSNDATB are recorded in variables PSNDAT1 to PSNDAT2]
Date at start of Quality of care section

END FILTER

IF PsFeel = Yes AND QHe.QHE4.Qre[PNum].HePsya = EMPTY [(PsFeel = Yes) AND QHe.QHE4.Qre[PNum].HePsya = EMPTY]

PSPSYA
[Loop: Responses to PSPSYA are recorded in variables PSPSYA1 to PSPSYA2]
I have some questions about any treatment you may have had for

[DepFeel]. Did a doctor or nurse suggest that you take medication, or see a mental health professional for counselling?
INTERVIEWER: PROBE - 'This may include seeing a psychiatrist, psychologist, or social worker for counselling or psychotherapy.'
1 Medication
2 Counseling
3 Both medication and counseling
4 None

IF PsPsya <> None [PsPsya <> None]

| | | | END FILTER
| | | |
| | | | **WGTINT**
| | | | NURSE: Now follows the Weight Measurement module. Press and
| | | | to continue.
| | | | Range: 1..1
| | | |
| | | | **RESPWTS**
| | | | NURSE:Measure weight and code. If the respondent weighs more than 130 kg
| | | | (20 ½ stones) do not weigh. Code as weight not attempted. Include 'disguised'
| | | | refusals such as 'It will take too long', 'I have to go out' etc. at code 2: Weight
| | | | refused.
| | | | 1 Weight measured
| | | | 2 Weight refused
| | | | 3 Weight attempted, not obtained
| | | | 4 Weight not attempted
| | | | [Don't Know and Refusal are not allowed]
| | | |
| | | | *IF RespWts = Meas [RespWts = Meas]*
| | | | |
| | | | | **WEIGHT**
| | | | | NURSE:Record weight (in kilograms). Record weight with one decimal
| | | | | digit, using the full stop as decimal point.
| | | | | [Don't Know and Refusal are not allowed]
| | | | |
| | | | | **FLOORC**
| | | | | NURSE CODE: Scales placed on?
| | | | | 1 Uneven floor
| | | | | 2 Carpet
| | | | | 3 Neither
| | | | |
| | | | | **RELWAITB**
| | | | | NURSE: Code one only.
| | | | | 1 No problems experienced, reliable weight measurement obtained

| | | | | Problems arised, measurement likely to be:
| | | | | 2 Reliable
| | | | | 3 Unreliable
| | | | |
| | | | | **MBOOKWT**
| | | | | NURSE:Enter the weight measurement on [rname]'s Measurement Record
| | | | | Card. Weight: [Weight] kg or [Stone] stones [Pound] pounds. If weight
| | | | | looks wrong, go back to 'Weight' and re-weigh.

| | | | | 1 Continue
| | | | |
| | | | ELSE
| | | | |
| | | | | *IF RespWts IN [Ref .. NotAt] [RespWts IN [Ref .. NotAt]]*
| | | | | |
| | | | | | *IF RespWts = Ref [RespWts = Ref]*
| | | | | | |
| | | | | | | **RESNWT**
| | | | | | | NURSE: Give reasons for refusal.
| | | | | | | 1 Cannot see point/Weight already known/Doctor has
| | | | | | | measurement
| | | | | | | 2 Too busy/Taken long enough already/No time
| | | | | | | 3 Respondent too ill/frail/tired
| | | | | | | 4 Considered intrusive information
| | | | | | | 5 Respondent too anxious/nervous/shy/embarrased
| | | | | | | 6 Refused (no other reason given)
| | | | | | | 7 Other
| | | | | | | [Don't Know and Refusal are not allowed]
| | | | | | |
| | | | | | ELSE
| | | | | | |
| | | | | | | *IF RespWts IN [Attmpt .. NotAt] [RespWts IN [Attmpt .. NotAt]]*
| | | | | | | |
| | | | | | | | **NOWTBC**
| | | | | | | | ***[Multiple responses to NOWTBC are recorded in variables NOWTBC1 to NOWTBC8]***
| | | | | | | | NURSE: Code reason for not obtaining weight. CODE ALL THAT
| | | | | | | | APPLY.
| | | | | | | | 1 Respondent is unsteady on feet
| | | | | | | | 2 Respondent cannot stand upright
| | | | | | | | 3 Respondent is chairbound
| | | | | | | | 4 Confined to bed
| | | | | | | | 5 Respondent unable to remove shoes

| | | | | | | | 6 Respondent weighs more than 130 kg
| | | | | | | | 7 Ill or in pain
| | | | | | | | 8 Scales not working
| | | | | | | | 9 Other - specify
| | | | | | | | [Don't Know and Refusal are not allowed]
| | | | | | | |
| | | | | | | | *IF Is this the edit version? = Yes AND Other IN NoWtBC [(Edit =*

| | | | | | | | | Yes) AND (Other IN NoWtBC)]
| | | | | | | | | |
| | | | | | | | | | CNOWTBC
| | | | | | | | | | *[Multiple responses to CNOWTBC are recorded in variables CNOWTB1 to CNOWTB2]*
| | | | | | | | | | EDITOR: Code reason for not obtaining weight. CODE ALL
| | | | | | | | | | THAT APPLY.
| | | | | | | | | | 1 Respondent is unsteady on feet
| | | | | | | | | | 2 Respondent cannot stand upright
| | | | | | | | | | 3 Respondent is chairbound
| | | | | | | | | | 4 Confined to bed
| | | | | | | | | | 5 Respondent unable to remove shoes
| | | | | | | | | | 6 Respondent weighs more than 130 kg
| | | | | | | | | | 7 Ill or in pain
| | | | | | | | | | 8 Scales not working
| | | | | | | | | | 9 Other - specify
| | | | | | | | | | [Don't Know and Refusal are not allowed]
| | | | | | | | | |
| | | | | | | | | END FILTER
| | | | | | | | |
| | | | | | | | | *IF Other IN NoWtBC AND Is this the edit version? <> Yes OR*
| | | | | | | | | *CNoWtBC = EMPTY OR Other IN CNoWtBC [(Other IN NoWtBC)*
| | | | | | | | | *AND ((Edit <> Yes) OR (CNoWtBC = EMPTY OR (Other IN*
| | | | | | | | | *CNoWtBC)))]*
| | | | | | | | | |
| | | | | | | | | | NOWATCO
| | | | | | | | | | NURSE: Please specify other reason.
| | | | | | | | | | STRING 60
| | | | | | | | | |
| | | | | | | | | END FILTER
| | | | | | | | |
| | | | | | | | END FILTER
| | | | | | | |
| | | | | | | END FILTER
| | | | | | |
| | | | | | | EWTCH

| | | | | | NURSE:Ask the respondent for an estimated weight. Will it be given in
| | | | | | kilograms or in stones and pounds? If respondent doesn't know weight
| | | | | | use . If respondent isn't willing to give weight use .
| | | | | | 1 Kilograms
| | | | | | 2 Stones and pounds
| | | | | |

NatCen
National Centre for Social Research

P8158
Version 2

HEALTH AND LIFESTYLES OF PEOPLE AGED 50 AND OVER

GRIP STRENGTH

Serial number [| | | | | | | | |] Ck [ ] Person [|]

Dominant hand: *(please tick one)*

Left [ ] Right [ ]

Enter Measurements Below:

1st measurement non-dominant hand			
1st measurement dominant hand			
2nd measurement non-dominant hand			
2nd measurement dominant hand			
3rd measurement non-dominant hand			
3rd measurement dominant hand			

NatCen
National Centre for Social Research

Serial number | | | | | | | | | | Ck

P2158

HEALTH AND LIFESTYLES OF PEOPLE AGED 50 AND OVER TIMED WALK

First person:	No	Name
Time for first walk:		•
Time for second walk:		•
Second person:	No	Name
Time for first walk:		•
Time for second walk:		•

- Assess safety
- Level floor
- No obstacles
- Walking aids acceptable
- Low-heeled shoes or trainers
- Start timer when first foot touches floor **beyond** line
- Stop when first foot touches floor **beyond** line

Version 2

Is eyesight (using glasses or corrective lenses if use them)...

INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?
6 SPONTANEOUS: Registered or legally blind

IF (IAskPx <> Yes) AND (HeEye <> Blind) [IAskPx <> Yes AND HeEye <> 6]

HEFRND

How good is your eyesight for seeing things at a distance, like recognising a friend across the street
(using glasses or corrective lenses if use them)?

Would you say it is...

INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

HEPAP

How good is your eyesight for seeing things up close, like reading ordinary newspaper print
(using glasses or corrective lenses if use them)?

Would you say it is...

INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

END OF FILTER

IF types of eye conditions = RESPONSE) AND NOT (96 = IFFW[PNum].HeOpt)) AND (IAskPx <> Yes) [IFFW[PNum].HeOpt = RESPONSE AND NOT 96 = IFFW[PNum].HeOpt AND IAskPx <> Yes]

LOOP FOR idx:= 1 TO 4

Is hearing (using a hearing aid if use one)...

INTERVIEWER: Read out...
1 ...excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

IF Is this a proxy respondent? <> Yes [IAskPx <> Yes]

HEHRA

Do you find it difficult to follow a conversation if there is background noise, such as TV, radio or children playing (using a hearing aid as usual)?
1 Yes
2 No

HESLPA
SHOW CARD C2

How often do you have difficulty falling asleep?

INTERVIEWER: Count as yes if cannot get to sleep for at least 30 minutes.
1 Not during the last month
2 Less than once a week
3 Once or twice a week
4 Three or more times a week

HESLPB
SHOW CARD C2

How often do you wake up several times in the night?
1 Not during the last month
2 Less than once a week
3 Once or twice a week
4 Three or more times a week

HESLPD
SHOW CARD C2

How often do you wake up after your usual amount of sleep feeling tired and worn out?
1 Not during the last month
2 Less than once a week
3 Once or twice a week
4 Three or more times a week

HESLPE

HETBD

(How much tobacco do you normally smoke a day at weekends?)

INTERVIEWER: Enter amount.
Range: 0..997

END OF FILTER

END OF FILTER

END OF FILTER

END OF FILTER

LOOP FOR Perno:= 1 TO 2

IF QInd.Session = Yes [Session = Yes]

HEACTA

SHOW CARD C20

We would like to know the type and amount of physical activity involved in daily life.

take part in sports or activities that are vigorous...

INTERVIEWER: Read out...
1 ...more than once a week,
2 once a week,
3 one to three times a month,
4 hardly ever, or never?

HEACTB

SHOW CARD C20

And take part in sports or activities that are moderately energetic...

INTERVIEWER: Read out...
1 ..more than once a week,
2 once a week,
3 one to three times a month,
4 hardly ever, or never?

HEACTC

SHOW CARD C20

And take part in sports or activities that are mildly energetic...

INTERVIEWER: Read out...
1 ..more than once a week,
2 once a week,
3 one to three times a month,
4 hardly ever, or never?

END OF FILTER

END OF FILTER

LOOP FOR Perno:= 1 TO 2

IF ((Session[Perno] = Yes) AND (ISex = female)) AND (IAskPx <> Yes) [Session = Yes AND ISex = female AND IAskPx <> Yes]

IF (IFFW.RetrFlag <> Yes) OR (((IFFW.RetrFlag = Yes) AND @/About how old were you when <> RESPONSE) AND @/Were you... <> RESPONSE)) OR @/In the past 12 months have y = Yes)) [IFFW[PNum].RetrFlag <> Yes OR IFFW[PNum].RetrFlag = Yes AND IFFW[PNum].HeMen <> RESPONSE AND IFFW[PNum].HEMEB <> RESPONSE OR IFFW[PNum].HePee = Yes]

HEMIN

The next set of questions are just for women and ask about menstrual periods and issues to do with reproductive organs.

INTERVIEWER: Press <1> and <Enter> to continue.
Range: 1..1

END OF FILTER

IF (IFFW.RetrFlag <> Yes) OR @/About how old were you when <> RESPONSE) AND @/Were you... <> RESPONSE)) [IFFW[PNum].RetrFlag <> Yes OR IFFW[PNum].HeMen <> RESPONSE AND IFFW[PNum].HEMEB <> RESPONSE]

HEMEN

About how old were you when you had your first menstrual period?

INTERVIEWER: If cannot give exact age, code 95 and ask age band at the next question.
Range: 0..95

PSCEDI

Now think about the past week and the feelings you have experienced.
Please tell me if each of the following was true for you much of the time during the past week.
1 Press <1> and <Enter> to continue.

PSCEDA

(Much of the time during the past week), you felt depressed?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDB

(Much of the time during the past week), you felt that everything you did was an effort?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDC

(Much of the time during the past week), your sleep was restless?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDD

(Much of the time during the past week), you were happy?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDE

(Much of the time during the past week), you felt lonely?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDF

(Much of the time during the past week), you enjoyed life?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDG

(Much of the time during the past week), you felt sad?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSCEDH

(Much of the time during the past week), you could not get going?

INTERVIEWER: Prompt if necessary - 'Would you say yes or no?'
1 Yes
2 No

PSAGF

How old do you feel that you are?

INTERVIEWER: Enter age in years.
Range: 1..150

PSAGL
What age would you like to be?

INTERVIEWER: Enter age in years.
Range: 1..150

PSTSET

INTERVIEWER: The Psychosocial section is finished.

Please enter 1 here to make the program store the current time and date.
Range: 1..1
[Don't Know and Refusal are not allowed]

END OF FILTER

Physical examination at wave 4 in 2008

WEIGHT MODULE

WGTINT @
NURSE: Now follows the Weight Measurement module.
Press <1> and <Enter> to continue.
Range: 1..1

RESPWTS
NURSE: Measure weight and code.
If the respondent weighs more than 130 kg (20 ½ stones) do not weigh.
Code as weight not attempted.
Include 'disguised' refusals such as 'It will take too long', 'I have to go out' etc. at code 2:
Weight refused.
1 Weight measured
2 Weight refused
3 Weight attempted, not obtained
4 Weight not attempted
[Don't know and refusal are not allowed]

IF Whether weight measurement was attempted or obtained = Measured [RespWts = 1]
|
| **WEIGHT**
| NURSE: Record weight (in kilograms).
| Record weight with one decimal digit, using the full stop as decimal point.
| [Don't know and refusal are not allowed]
|
| **FLOORC**
| NURSE CODE: Scales placed on?
| 1 Uneven floor
| 2 Carpet
| 3 Neither
|
| **RELWAITB**
| NURSE: Code one only.
| 1 No problems experienced, reliable weight measurement obtained
| Problems arised, measurement likely to be:
| 2 Reliable
| 3 Unreliable
| ***[Responses to RELWAITB are recorded in variable RELWAIT]***
|
| **MBOOKWT @**
| NURSE: Enter the weight measurement on [^Name of respondent]'s Measurement
| Record Card.
| Weight: [^Weight - kg] kg or [^Weight - stone] stones [^Weight - pounds] pounds.
| If weight looks wrong, go back to 'Weight' and re-weigh.
| 1 Continue
|
ELSE IF Whether weight measurement was attempted or obtained = [Refused, attempted but not obtained, not attempted] [RespWts = [2 , 3, 4]]
|
| *IF Whether weight measurement was attempted or obtained = Refused [RespWts = 2]*
| |
| | **RESNWT**
| | NURSE: Give reasons for refusal.
| | 1 Cannot see point / Weight already known / Doctor has measurement
| | 2 Too busy / Taken long enough already / No time
| | 3 Respondent too ill / frail / tired
| | 4 Considered intrusive information
| | 5 Respondent too anxious / nervous / shy / embarrassed
| | 6 Refused (no other reason given)
| | 7 Other
| | [Don't Know and Refusal are not allowed]
| |
| *ELSE IF Whether weight measurement was attempted or obtained = [attempted but not obtained, not attempted] [RespWts = [3 , 4]]*
| |
| | **NOWTBC**
| | NURSE: Code reason for not obtaining weight.
| | CODE ALL THAT APPLY.
| | 1 Respondent is unsteady on feet
| | 2 Respondent cannot stand upright
| | 3 Respondent is chairbound
| | 4 Confined to bed
| | 5 Respondent unable to remove shoes
| | 6 Respondent weighs more than 130 kg
| | 7 Ill or in pain
| | 8 Scales not working
| | 9 Other - specify
| | [Don't Know and Refusal are not allowed]
| | ***[Multiple responses to NOWTBC are recorded in variables NOWTBC1 to NOWTBC4]***
| | ***[Code maximum 8 out of 9 possible responses]***
| |
| | *IF Reason for not obtaining weight measurement = Other [NoWtBC = 9]*
| | | **NOWATCO @**
| | | NURSE: Please specify other reason.
| | | String 60
| | |
| | END FILTER
| |
| END FILTER
|
| **EWTCH**
| NURSE: Ask the respondent for an estimated weight.
| Will it be given in kilograms or in stones and pounds?
| If respondent doesn't know weight use <Ctrl K>.
| If respondent isn't willing to give weight use <Ctrl R>.
| 1 Kilograms

32 33

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P8796

HEALTH AND LIFESTYLES OF PEOPLE AGED 50 AND OVER

GRIP STRENGTH

Serial number | Ck | Person

Dominant hand: (*please tick one*)

Left ☐ Right ☐

Enter Measurements Below:

1st measurement non-dominant hand	
1st measurement dominant hand	
2nd measurement non-dominant hand	
2nd measurement dominant hand	
3rd measurement non-dominant hand	
3rd measurement dominant hand	

NatCen
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Serial number | Ck

HEALTH AND LIFESTYLES OF PEOPLE AGED 50 AND OVER
TIMED WALK

First person:	No	Name
Time for first walk:		•
Time for second walk:		•
Second person:	No	Name
Time for first walk:		•
Time for second walk:		•

- Assess safety
- Level floor
- No obstacles
- Walking aids acceptable
- Low-heeled shoes or trainers
- Start timer when first foot touches floor **beyond** line
- Stop when first foot touches floor **beyond** line

D2

APPENDIX VI. Thesis publications

The subsequent pages include five papers based on the findings of this thesis published in peer-reviewed journals:

1. Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Socio-demographic characteristics, lifestyle factors and burden of morbidity associated with self-reported hearing and vision impairments in older British community-dwelling men: a cross-sectional study. Journal of Public Health. 2016;38(2):e21-8

2. Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Sensory impairments and cardiovascular disease incidence and mortality in older British community-dwelling men: a 10-year follow-up study. Journal of the American Geriatrics Society. 2016;64(2):442-4

3. Liljas, AEM., Wannamethee SG., Whincup, PH., Papacosta, O., Walters, K., Iliffe, S., Lennon, LT., Carvalho, LA. & Ramsay, SR. Hearing impairment and incident disability and all-cause mortality in older British community-dwelling men. Age & Ageing. 2016;45(5):662-7

4. Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Self-reported hearing impairment and incident frailty in English community-dwelling older adults: a 4-year follow-up study. Journal of the American Geriatrics Society. 2017;65(5):958-65

5. Liljas, AEM., Carvalho, LA., Papachristou, E., De Oliveira, C., Wannamethee SG., Ramsay, SR. & Walters, K. Self-reported vision impairment and incident pre-frailty and frailty in English community-dwelling older adults: a 4-year follow-up study. Journal of Epidemiology and Community Health. 2017;71(11):1053-8

Paper 3.

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Age and Ageing 2016; 45: 661–666
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Hearing impairment and incident disability and all-cause mortality in older British community-dwelling men

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Abstract

Background and objective: hearing impairment is common in older adults and has been implicated in the risk of disability and mortality. We examined the association between hearing impairment and risk of incident disability and all-cause mortality.
Design and setting: prospective cohort of community-dwelling older men aged 63–85 followed up for disability over 2 years and for all-cause mortality for 10 years in the British Regional Heart Study.
Methods: data were collected on self-reported hearing impairment including hearing aid use, and disability assessed as mobility limitations (problems walking/taking stairs), difficulties with activities of daily living (ADL) and instrumental ADL (IADL). Mortality data were obtained from the National Health Service register.
Results: among 3,981 men, 1,074 (27%) reported hearing impairment. Compared with men with no hearing impairment, men who could hear and used a hearing aid, and men who could not hear despite a hearing aid had increased risks of IADL difficulties (age-adjusted OR 1.86, 95% CI 1.29–2.70; OR 2.74, 95% CI 1.53–4.93, respectively). The associations remained after further adjustment for covariates including social class, lifestyle factors, co-morbidities and social engagement. Associations of hearing impairment with incident mobility limitations, incident ADL difficulties and all-cause mortality were attenuated on adjustment for covariates.
Conclusion: this study suggests that hearing problems in later life could increase the risk of having difficulties performing IADLs, which include more complex everyday tasks such as shopping and light housework. However, further studies are needed to determine the associations observed including the underlying pathways.

Keywords: ageing, older adults, hearing impairment, disability, mortality

Introduction

Hearing impairment increases with age and has been associated with chronic conditions including cardiovascular disease (CVD) and poor quality of life [1, 2]. Demographic changes mean that people are living longer with chronic diseases and associated physical limitations affecting independent living and overall well-being [3]. Disability in later life often occurs first as mobility limitations (for example, difficulties walking or climbing stairs) [4]. Other forms of disability refer to disablement in tasks essential to caring for oneself (basic activities of daily living [ADL], e.g. bathing, dressing) and more complex tasks that refer to living independently in the community (instrumental activities of daily living [IADL], e.g. shopping, telephoning) [4]. Earlier studies have shown an association between hearing impairment and mobility limitations [5] including increased risks of subsequent mobility limitations among older adults with hearing impairment [6, 7]. Previous research has also shown an association between hearing impairment and incident ADL deficits in hospital-based samples of older people [8, 9]. Hearing impairment has furthermore been associated with an increased risk of incident IADL; however, findings are inconsistent [6, 10–12]. In addition, it has been suggested that hearing impairment increases the risk of all-cause mortality [2], but some studies have shown no association after adjustment for demographic factors, physical functioning and cognition [12, 13].

It is important to understand the influence of hearing impairment on disability including activities of daily living to establish the impact of hearing impairment on functional independence in later life. Therefore, we investigated the association of self-reported hearing impairment with subsequent mobility limitations, ADL, IADL and all-cause mortality in a representative sample of older British men aged 63–85 followed up for 2 years for disability and 10 years for mortality. We also examined whether these associations were independent of age, social class, lifestyle factors and co-morbidities known to be associated with hearing impairment including CVD, hypertension and diabetes [1, 14].

Methods

Study design and participants

This study uses data from the British Regional Heart Study (BRHS), a prospective study in a socioeconomically and geographically representative sample of 7,735 middle-aged men drawn from 24 general practices representing all major British Regions [15]. The men were recruited in 1978–80 and have regularly been followed up since. For this study, baseline data on 3,981 men, then aged 63–85, were obtained through self-reported questionnaires in 2003. Ethical approval was obtained from relevant local research ethics committees.

Hearing impairment

Questions on hearing impairment included 'Do you use a hearing aid?' and 'Using a hearing aid if needed, is your hearing good enough to follow a TV programme at a volume others find acceptable?' with answer options yes/no [16], and allowed for participants to be divided into four groups: could follow TV and used no hearing aid (could hear, no aid [no hearing impairment]) (reference group), could follow TV and used hearing aid (could hear, used aid), could not follow TV and did not use hearing aid (could not hear, no aid), and could not follow TV and used hearing aid (could not hear, used aid).

Outcome measures

All men were followed up for mobility limitations and activities of daily living (ADL) and instrumental ADL (IADL) from 2003 to 2005 and for all-cause mortality from 2003 to 2013. Two questions asking whether they had problems taking the stairs and problems walking 400 yards with answer options yes/no were used to assess mobility limitation. Reporting problems with one or both was classified as having mobility limitations. ADL was classified as having some difficulty or in need of help undertaking one or more of the following activities: bathing, dressing, eating, getting in or out of bed or chair, toileting and/or walking across a room [17]. IADL was based on reporting some problem or in need of help undertaking cooking, shopping, using public transport, managing money and/or using the telephone [18]. Incidence was determined as having no previous mobility limitation, ADL and IADL, respectively. Mortality data were collected from the National Health Service register. Binary outcomes assessed in the current analyses were for incident mobility limitations, difficulties in ADL, IADL and all-cause mortality.

Covariates

Covariates included socioeconomic and lifestyle factors including social class, social engagement, cigarette smoking, obesity and physical activity. Co-morbidity-related covariates included doctor-diagnosed CVD (coronary thrombosis, myocardial infarction, angina and/or stroke), hypertension and diabetes analysed dichotomously. Participants were divided into manual and non-manual social class based on the longest held occupation of subjects at study entry using the Registrar Generals' Social Class Classification. The men were grouped into non-smokers, ex-smokers and current smokers. Being obese was defined as having a body mass index (BMI) of 30 kg/m^2 and over [19]. Physical activity scores were based on exercise type and frequency categorised as none, occasional, light, moderate, moderately vigorous and vigorous [20], where none or occasional activity was classified as being inactive. Other covariates included social engagement, doctor-diagnosed depression and difficulty keeping balance. Low social engagement was classified as doing three or fewer activities part of a 9-item social engagement scale on a weekly basis: voluntary work, go to the pub or a club, attend religious services, play cards or games, visit the cinema, restaurants or sports events, attend a class or course of study, and, sometimes go on day or overnight trips, and been on a holiday in the last year [21]. Depression and reporting not being able to keep balance were analysed dichotomously. Data on all covariates were collected at baseline (2003).

Statistical analyses

Logistic regression was used to assess the associations of hearing impairment with incident mobility limitations and difficulties in ADLs and IADLs. Odds ratios (OR) with 95% confidence intervals (CI) were obtained using no hearing impairment (could hear, no aid) as reference group. Survival analysis was used to examine the association between hearing impairment and mortality, and Cox proportional hazards regression was used to calculate hazard ratios (HR) with 95% CIs. We also performed Cox regression using age as the time variable. The test confirmed that the proportionality hazards assumption was met. Participants who did not answer any of the hearing-related questions ($n = 38$) were excluded. Participants free from mobility limitations and difficulties in ADLs and IADLs at baseline were followed up for each of these types of disability. Models were adjusted for age, social class, lifestyle factors and co-morbidities. A Bonferroni correction was applied for multiple comparisons, and findings remained significant. All analyses were carried out using SAS version 9.3 software (SAS Institute, Inc., Cary, NC, USA).

Results

In 2003, 3,981 men aged 63–85 completed the questionnaire (82% response rate). Of these, 3,108 men had no previous mobility limitations, 3,346 men had no previous ADL and 3,410 men had no previous IADL. At 2-year follow-up, there were 238 (8%) new cases of mobility limitations, 260 (8%) new cases of ADL and 207 (6%) new cases of IADL. All 3,981 men were also followed for all-cause mortality over 10 years during which 1,463 (37%) deaths occurred. Characteristics of participants by hearing impairment are shown in Table 1. Table 2 presents odds ratios (OR) with 95% CIs for incident mobility limitations, ADL and IADL for hearing impairment. Compared with men with no hearing impairment, men who could not hear and used a hearing aid had over a twofold greater risk of mobility limitations at 2-year follow-up (age-adjusted OR 2.24, 95% CI 1.29–3.89). The association remained after further adjustment for social class, lifestyle factors and co-morbidities (OR 1.89, 95% CI 1.04–3.41) but was attenuated upon adjustment for social engagement. Men who could not hear, irrespective of using hearing aid, had greater risks of developing problems performing ADL compared with men with no hearing impairment (OR 1.74, 95% CI 1.19–2.55; OR 2.01, 95% CI 1.16–3.46). The association was attenuated after further adjustment among men who used an aid but remained in those who could not hear and did not use hearing aid even after further adjustment for social engagement (OR 1.68, 95% CI 1.11–2.55). However, the association was attenuated after further adjustment for mobility limitations (OR 1.49, 95% CI 0.97–2.29). Compared with men with no hearing impairment, those who could hear and used a hearing aid and those who could not hear despite aid were more likely to develop IADL problems (OR 1.86, 95% CI 1.29–2.70; OR 2.74, 95% CI 1.53–4.93). These associations are of particular interest as they remained after further adjustment including social engagement (OR 2.00, 95% CI 1.34–2.99; OR 2.61, 95% CI 1.38–4.96) and also after further adjustment for mobility limitations, depression and poor balance (OR 2.03, 95% CI 1.35–3.07; OR 2.77, 95% CI 1.43–5.36). Further analyses of the associations between hearing impairment and individual components of IADL showed that men who could hear and used a hearing aid and men who could not hear despite aid were both more likely to experience problems, in particular undertaking shopping and light housework, even after further adjustment including social engagement. Men who could hear and used aid were also more likely to have problems using public transport. Only those who could not hear despite aid had increased risks of difficulty cooking (OR 2.03, 95% CI 1.05–3.94), but the association was attenuated after full adjustment (results not presented). Men who could hear and used aid and men who could not hear despite aid were more likely to have problems telephoning with over fourfold increased risks in men who could not hear despite aid (OR 4.53, 95% CI 2.25–9.10). The association remained in men who could

Table 1. Percentages and numbers for socioeconomic and lifestyle characteristics, co-morbidities and mean age by hearing impairment in a cohort of British men aged 63–85 in 2003

% (n)	Overall	No hearing impairment	Hearing impairment groups			P-value
		Could hear, no aid	Could hear, used aid	Could not hear, no aid	Could not hear, used aid	
Totals	100 (3,981)	73 (2,931)	12 (482)	11 (424)	4 (160)	
Covariates						
Manual social class	51 (1,962)	48 (1,317)	53 (245)	63 (263)	60 (90)	<0.01
Current smokers	10 (369)	10 (284)	7 (33)	13 (54)	9 (15)	0.67
Ex-smokers	60 (2,345)	58 (1,692)	66 (314)	58 (244)	68 (115)	
Never smoked	30 (1,174)	31 (870)	27 (131)	29 (123)	22 (37)	
Physical inactivity	38 (1,450)	36 (971)	44 (196)	41 (157)	54 (67)	0.06
Obese	17 (638)	16 (445)	13 (61)	21 (85)	26 (42)	<0.01
CVD	27 (1,067)	26 (720)	32 (153)	26 (112)	43 (72)	<0.01
Hypertension	39 (1,547)	38 (1,092)	41 (196)	39 (163)	46 (78)	0.24
Diabetes	10 (393)	10 (281)	9 (45)	10 (41)	11 (19)	0.89
Age						
Mean age in years ± SD	72 (5.4)	72 (5.3)	76 (5.4)	72 (5.4)	74 (5.4)	

Table 2. Odds ratios (OR) with 95% CIs for associations between incidence of mobility limitations, ADL and IADL and hearing impairment in British men aged 63–85 in 2003 followed up for 2 years to 2005

		No hearing impairment	Hearing impairment		
		Could hear, no aid	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
Limitations in mobility	n (%)	158 (7)	39 (11)	23 (9)	17 (16)
Model 1	OR (95% CI)	1.00	1.40 (0.95–2.05)	1.16 (0.73–1.83)	2.24 (1.29–3.89)
Model 2		1.00	1.40 (0.92–2.12)	1.26 (0.79–2.03)	1.89 (1.04–3.41)
Model 2 + social engagement[a]		1.00	1.41 (0.93–2.14)	1.24 (0.77–2.00)	1.79 (0.98–3.27)
ADL		161 (7)	41 (10)	37 (11)	17 (15)
Model 1		1.00	1.30 (0.90–1.88)	1.74 (1.19–2.55)	2.01 (1.16–3.46)
Model 2		1.00	1.25 (0.82–1.90)	1.76 (1.16–2.66)	1.62 (0.90–2.94)
Model 2 + social engagement[a]		1.00	1.25 (0.83–1.87)	1.68 (1.11–2.55)	1.58 (0.87–2.88)
IADL		126 (6)	44 (11)	19 (6)	15 (15)
Model 1		1.00	1.86 (1.29–2.70)	1.09 (0.66–1.79)	2.74 (1.53–4.93)
Model 2		1.00	2.03 (1.36–3.01)	1.01 (0.59–1.75)	2.56 (1.35–4.86)
Model 2 + social engagement[a]		1.00	2.00 (1.34–2.99)	0.95 (0.54–1.67)	2.61 (1.38–4.96)
IADL components					
Shopping		73 (3)	31 (7)	17 (5)	13 (9)
Model 1		1.00	2.05 (1.32–3.20)	1.63 (0.95–2.80)	2.80 (1.50–5.23)
Model 2		1.00	1.96 (1.20–3.19)	1.56 (0.87–2.82)	2.39 (1.22–4.69)
Model 2 + social engagement[a]		1.00	2.01 (1.23–3.28)	1.46 (0.80–2.68)	2.30 (1.15–4.60)
Light housework		66 (2)	25 (6)	12 (3)	12 (8)
Model 1		1.00	1.93 (1.19–3.12)	1.24 (0.66–2.32)	3.00 (1.61–5.60)
Model 2		1.00	1.76 (1.05–2.95)	1.05 (0.54–2.05)	2.73 (1.39–5.36)
Model 2 + social engagement[a]		1.00	1.80 (1.07–3.04)	1.02 (0.52–2.00)	2.73 (1.39–5.36)
Telephoning		43 (2)	17 (4)	7 (2)	11 (8)
Model 1		1.00	1.85 (1.03–3.32)	1.10 (0.49–2.47)	4.53 (2.25–9.10)
Model 2		1.00	1.64 (0.88–3.04)	0.75 (0.29–1.93)	3.92 (1.90–8.09)
Model 2 + social engagement[a]		1.00	1.74 (0.93–3.26)	0.78 (0.30–2.03)	4.29 (2.02–9.13)
Managing money		59 (2)	16 (4)	10 (3)	14 (9)
Model 1		1.00	1.27 (0.71–2.25)	1.13 (0.57–2.23)	3.68 (1.99–6.82)
Model 2		1.00	1.29 (0.71–2.35)	0.97 (0.45–2.07)	3.49 (1.84–6.62)
Model 2 + social engagement[a]		1.00	1.32 (0.72–2.41)	0.95 (0.44–2.04)	3.68 (1.94–6.98)
Using public transport		75 (3)	33 (8)	13 (4)	7 (5)
Model 1		1.00	1.98 (1.28–3.06)	1.28 (0.68–2.38)	1.42 (0.64–3.19)
Model 2		1.00	1.97 (1.23–3.16)	1.16 (0.61–2.20)	1.33 (0.58–3.05)
Model 2 + social engagement[a]		1.00	1.93 (1.20–3.11)	1.13 (0.59–2.14)	1.36 (0.60–3.13)

Model 1: adjusted for age; Model 2: adjusted for age, social class, BMI, smoking, physical activity, CVD, hypertension and diabetes.

[a]Social engagement was defined as doing three or fewer of the following activities on a weekly basis: voluntary work, go to the pub or a club, attend religious services, play cards or games, visit the cinema, restaurants or sports events, attend a class or course of study, and, sometimes go on day or overnight trips, and been on a holiday in the last year.

Table 3. Hazard ratios (HR) with 95% CIs for associations between all-cause mortality and hearing impairment in British men aged 63–85 in 2003 followed up for 10 years to 2013

		No hearing impairment	Hearing impairment		
		Could hear, no aid	Could hear, used aid	Could not hear, no aid	Could not hear, used aid
	Rates/1,000 (n)	39 (974)	54 (236)	48 (169)	58 (78)
Model 1	HR (95% CI)	1.00	1.03 (0.84–1.19)	1.19 (1.01–1.40)	1.18 (0.85–1.49)
Model 2		1.00	1.01 (0.84–1.19)	1.12 (0.93–1.34)	1.14 (0.89–1.45)

Model 1: adjusted for age; Model 2: adjusted for age, social class, BMI, smoking, physical activity, CVD, hypertension and diabetes.

not hear despite aid after further adjustment including social engagement (OR 4.29, 95% CI 2.02–9.13) and after further adjustment for mobility limitations, depression and poor balance (OR 4.29, 95% CI 2.00–9.18). The associations between hearing impairment and IADL were further analysed without the component of difficulty telephoning. Age-adjusted findings showed that men who could hear and used a hearing aid and men who could not hear despite an aid were more likely to develop difficulties in IADLs (results not presented). The association remained in men who could hear with aid only, after full adjustment including social engagement. None of the hearing impairment groups were associated with difficulties taking medications (results not presented).

Table 3 shows hazard ratios (HR) with 95% CIs for all-cause mortality associated with hearing impairment. Compared with men with no hearing impairment, those who could not hear and did not use a hearing aid had a significantly greater risk of all-cause mortality (HR 1.19, 95% CI 1.01–1.40) but the association was attenuated on further adjustments. No other hearing impairment group was associated with increased risk of all-cause mortality. These findings were confirmed when using age as the time scale.

Discussion

This study investigated the association of hearing impairment with incident disability (mobility limitations, ADL, IADL) and all-cause mortality in older British men. Our findings show that men with hearing impairment had greater risks in particular of disability affecting IADLs. The associations observed between hearing impairment and incident mobility limitations, incident ADL and all-cause mortality were attenuated on further adjustment for covariates.

The association between hearing impairment and mobility limitations was attenuated particularly on adjustment for social engagement. Communication problems due to hearing impairment may restrict social engagement [7]. Being socially engaged can motivate maintenance of physical functioning [22], reducing the risk of incident disability [23]. Only men who could not hear and did not use a hearing aid had greater risk of subsequent ADL deficits after adjustment including social engagement. However, the association was attenuated after further adjustment for mobility limitations. In contrast, men who could hear with an aid and men who could not hear despite an aid had increased risks of subsequent IADL difficulties and the associations remained after further adjustment. The associations also remained statistically significant after further adjustment for mobility limitations, depression and poor balance. This suggests that hearing impairment has a greater impact on IADLs which involve more complex tasks (such as shopping and light housework) than basic tasks including ADL and mobility limitations [24]. However, this finding should be interpreted with caution as the association between not being able to hear despite an aid and subsequent IADL was driven by difficulty telephoning. Also, the observed associations between hearing impairment and IADL could be explained by residual confounding due to unmeasured factors such as cognitive functioning, which is important for complex IADL tasks [13, 25]. The degradation hypothesis suggests that a decline in hearing impairment in older age increases the demands on cognitive functioning [8]. Previous research also suggests that family members may steer older relatives with poor physical and cognitive functions away from responsibilities and tasks such as IADLs [8]. Further, lack of consistent findings across the hearing impairment groups and incident IADL with no association observed in those 'unable to hear, no aid' suggests that this group may consist of a combination of men with a hearing problem who did not use a hearing aid due to, for instance, lack of access to health services and audiology assessments, reluctance to wear an aid, a perception that aids are unhelpful and men whose hearing problem is not improved by an aid. Finally, the association observed could be due to inflammation, which is related to both hearing impairment and disability [26, 27].

Men who could not hear and did not use hearing aid had greater risks of all-cause mortality compared with men with no hearing impairment. However, the association was attenuated after adjustment for social class, lifestyle factors and co-morbidities. This is consistent with earlier studies demonstrating no association after adjustment for potential confounders including social class and physical functioning [12, 13].

Strengths and limitations

The major strengths of this study are that it was a large socioeconomically representative cohort with negligible loss to follow-up for disability and mortality [15]. In addition, the cohort was followed up for 2 years for disability and for 10 years for mortality, and the models were adjusted for several confounding variables.

Limitations include that hearing impairment was self-reported rather than objectively measured. However, the questions used have been validated against objective measures [16]. Furthermore, previous research has demonstrated comparable findings when investigating both self-reported (defined as ever had deafness or trouble hearing with one or both ears) and measured hearing impairment and 10-year mortality risk [12]. Further, the question on hearing aid use did not specify whether the participants have been offered a hearing aid and chosen not to use it or whether they do not have a hearing aid at all. Further, despite the large sample, the number of participants in each hearing impairment group with disability was small which might have reduced the statistical power of the study. Furthermore, hearing impairment was measured at baseline only, and no information on the primary cause of and change in hearing impairment were investigated. Finally, the study was in older men, predominantly of white British ethnic origin, and generalisation of findings to women and to other ethnic groups is limited.

Conclusions and implications

In summary, our study shows that older men who could follow TV and used a hearing aid have greater risks of disability affecting IADLs, which are important for maintaining functional independence in later life. The inconsistent findings across the hearing impairment groups further suggest that it may not be hearing *per se* underlying the association. Future longitudinal studies are required to further assess the association between hearing impairment and incident disability, taking cognitive impairment and inflammation into account.

Key points

- Hearing problems in later life may increase the risk of having difficulties performing IADLs.
- Inconsistent findings across the hearing impairment groups suggest that something may be underlying the association with IADLs.
- The association of hearing impairment and all-cause mortality was attenuated on adjustment for covariates.

Conflicts of interest

None declared.

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Paper 4.

Self-Reported Hearing Impairment and Incident Frailty in English Community-Dwelling Older Adults: A 4-Year Follow-Up Study

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OBJECTIVES: To examine the association between hearing impairment and incident frailty in older adults.

DESIGN: Cross-sectional and longitudinal analyses with 4-year follow-up using data from the English Longitudinal Study of Ageing.

SETTING: Community.

PARTICIPANTS: Community-dwelling individuals aged 60 and older with data on hearing and frailty status (N = 2,836).

MEASUREMENTS: Hearing impairment was defined as poor self-reported hearing. Having none of the five Fried frailty phenotype components (slow walking, weak grip, self-reported exhaustion, weight loss and low physical activity) was defined as not frail, having one or two as prefrail, and having three or more as frail. Participants who were not frail at baseline were followed for incident prefrailty and frailty. Participants who were prefrail at baseline were followed for incident frailty.

RESULTS: One thousand three hundred ninety six (49%) participants were not frail, 1,178 (42%) were prefrail, and 262 (9%) were frail according to the Fried phenotype. At follow-up, there were 367 new cases of prefrailty and frailty among those who were not frail at baseline (n = 1,396) and 133 new cases of frailty among those who were prefrail at baseline (n = 1,178). Cross-sectional analysis showed an association between hearing impairment and frailty (age- and sex-adjusted odds ratio (OR) = 1.66, 95% confidence interval (CI) = 1.37–2.01), which remained after further adjustments for wealth, education, cardiovascular disease, cognition, and depression. In longitudinal analyses, nonfrail participants with hearing impairment were at greater risk of becoming prefrail and frail at follow-up (OR = 1.43, 95% CI = 1.05–1.95), but the association was attenuated after further adjustment. Prefrail participants with hearing impairment had a greater risk of becoming frail at follow-up (OR = 1.64, 95% CI = 1.07–2.51) even after further adjustment.

CONCLUSION: Hearing impairment in prefrail older adults was associated with greater risk of becoming frail, independent of covariates, suggesting that hearing impairment may hasten the progression of frailty. J Am Geriatr Soc 65:958–965, 2017.

Key words: hearing impairment; frailty; older adults; aging

Hearing impairment is common in later life and is estimated to affect 20% of adults in Great Britain aged 60 and older.[1,2] Age-related hearing impairment has been associated with comorbidity, disability, and poor quality of life, affecting independent living and overall well-being.[3,4] As the population ages,[5] hearing impairment becomes an increasingly important public health concern. Another common health concern in later life is frailty.[6,7] Frailty is a clinical syndrome that refers to the body's inability to respond adequately to stressors because of multisystem impairments and lack of physiological reserve, increasing the risk of adverse outcomes including falls, hospitalization, institutionalization, and mortality.[6-9] Frailty is often described as a dynamic state along a continuum from normal aging to death,[10] and transition between frailty states is common.[11] Prefrailty is an intermediate stage between having no prevalent frailty and being frail,[7] and an acute medical event or psychological stress that exceeds the individual's capacity for recovery

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often precipitates the transition from prefrail to frail.[11,12] One of the most commonly used frailty measures in the community setting is the Fried phenotype, which has been deemed suitable for identification of community-dwelling older adults at risk of frailty and has been found to be associated with disability, mortality, and hospitalization.[7,13,14] The Fried phenotype consists of five components: unintentional weight loss, weak grip, slow walking speed, exhaustion, and low levels of physical activity.[7] A score of 0 refers to no frailty, 1 to 2 indicates prefrailty, and 3 or more is defined as frail. Research has shown that prefrail older adults have twice the risk of becoming frail as nonfrail older adults.[7]

Studies suggest that hearing impairment is associated with frailty[15,16] and its consequences, including functional decline[17] and incident falls.[17] A previous study found an association between self-reported hearing impairment and frailty in older women but not men, but the study was cross-sectional.[18] The Health, Aging and Body Composition study found an association between hearing impairment and incident frailty at 10-year follow-up, but only two measures were used to define frailty (slow walking, inability to rise from a chair).[19] None of these previous studies considered social interaction in the analyses, a factor associated with hearing impairment and frailty that might have mediated the associations observed.[20] Moreover, little is known about the incidence of prefrailty and frailty. It is important to investigate the relationship between hearing impairment and frailty to determine whether prevention and treatment of hearing impairment in older age could minimize the burden of frailty on the individual and society. The current study examined the relationship between poor hearing and prefrailty and frailty in a nationally representative sample of community-dwelling older people in England and the relationship between poor hearing and subsequent incident prefrailty and frailty over 4 years.

METHODS

Study Design and Participants

This study used data from the English Longitudinal Study of Ageing (ELSA), a prospective study of a nationally representative sample of 11,392 men and women aged 50 and older who participated in the Health Survey for England in 1998, 1999, or 2001.[21] The sample was drawn by postcode sector and stratified according to proportion of households in nonmanual socioeconomic groups and has been followed up every 4 years since 2004 with a nurse visit during which measurements of physical function were taken and an interview conducted on morbidity and lifestyle. For the purposes of this study, the study sample was restricted to participants with data on items in the Fried phenotype, including walking speed, which have only been measured in participants aged 60 and older. In 2004, interview and nurse data were obtained from 4,248 of 5,918 participants from the original study sample (core members) aged 60 and older. Complete data on hearing impairment, covariates, and frailty was obtained from 2,836 of these participants (67%) in 2004 and on frailty in 2008, who constituted the current study sample. Ethical approval was obtained from the Multicentre Research and Ethics Committee.

Hearing Impairment

Hearing impairment was measured using a self-reported, validated question previously demonstrated to be accurate when compared with objectively measured hearing[22] asking participants to rate their hearing (using a hearing aid if they used one) as excellent, very good, good, fair, or poor. Reporting excellent, very good, or good hearing was classified as having good hearing, and this group formed the reference group. Experiencing fair or poor hearing was considered poor hearing.

Assessment of Frailty

Frailty status was assessed in 2004, and participants were followed up for frailty from 2004 to 2008. Frailty was based on the five components of the Fried phenotype: weight loss, weak grip, slow walking, exhaustion, and low physical activity.[7] These components were operationalized using definitions identical or very similar to those in the original phenotype studies.[7,23] Weight loss was defined as loss of 10% or more of body weight in the last 4 years or a current body mass index (BMI) of less than 18.5 kg/m^2. Weak grip was assessed using a dynamometer with the maximum handgrip strength measure out of three attempts on each side used for analysis. Weak grip was classified as being in the lowest quintile of the sex- and BMI-adjusted distribution. Slow walking speed was measured as the mean time of two measurements taken to complete an 8-foot walk at usual pace. Height was divided at the sex-specific median to categorize those in the lowest sex- and height-specific quintile of the distribution as having slow walking speed. Participants in wheelchairs or who were bed bound, unable to walk because of health problems, or unable to walk alone were also counted as having slow walking. Exhaustion was defined as a positive response to either of the two statements "Felt that everything I did was an effort in the last week" or "Could not get going in the last week" from the Center for Epidemiologic Studies Depression Scale (CES-D).[24] Low physical activity was based on three questions about the frequency with which participants undertook vigorous, moderate, and mild exercise. Each question had four response options (more than once a week, once a week, one to three times a month, hardly ever or never) that were combined according to the amount and intensity of exercise involved. Reporting exercising hardly ever or never, mild exercise only, or moderate exercise a maximum of one to three times a month was classified as low physical activity. Frailty was defined as the presence of three or more of the five frailty components. Prefrailty was defined as the presence of one or two components. No prevalent frailty was defined as having none of the frailty components. The Fried phenotype was used because it incorporates a definition of prefrailty and frailty and is suitable for identification of community-dwelling older adults at risk of frailty.[13,14]

Covariates

Age, sex, wealth, education, cardiovascular disease (CVD), smoking, hypertension, diabetes mellitus, history of falls, cognitive function, depression, and lack of companionship were considered as covariates. Age was grouped into 60 to 69, 70 to 79, and 80 and older. Total net nonpension wealth (financial, housing, physical wealth) of the household is presented according to quintile. Education was defined as having an intermediate or higher qualification versus no qualification. CVD has previously been associated with hearing impairment and frailty, so doctor-diagnosed CVD (myocardial infarction, angina pectoris, stroke) and doctor-diagnosed CVD-related comorbidities including diabetes mellitus and hypertension were considered as potential covariates and analyzed dichotomously.[25] Participants who reported that they had fallen in the last 12 months were classified as having had a fall. Smoking was defined as reporting being a current smoker and analyzed dichotomously. Cognitive function was measured using a validated 24-point cognitive scale on time orientation and immediate and delay recall and analyzed continuously.[26] The recall tests included a list of 10 words presented to participants, who were asked to recall as many words as possible immediately after the list was read and then again after an approximately 5-minute delay during which they completed other survey questions. Questions on orientation to the day, date, month, and year were obtained from the Mini-Mental State Examination (MMSE) and assessed by asking participants to report the day, date, month, and year.[27,28] Factors that may be on the causal pathway of hearing impairment and frailty were also considered, including depression and lack of companionship. Depression symptoms were based on the six questions on mood from the validated eight-item version of the CES-D, excluding the two questions on exhaustion that form part of the frailty phenotype definition.[24] Scoring positively on two or more items indicated having depression symptoms and was analyzed dichotomously. Lack of companionship some of the time or often were combined and compared with no lack of companionship.

Statistical Analyses

Logistic regression was used to assess the cross-sectional relationships between hearing impairment and prefrailty and frailty combined. Logistic regression was also used to determine relationships between hearing impairment and incident prefrailty in participants without prevalent frailty at baseline between hearing impairment and incident frailty in participants with prefrailty at baseline followed for 4 years. Incident prefrailty and frailty in those without frailty at baseline were combined because of the small number of new frailty cases in this group (n = 24). Odds ratios (ORs) with 95% confidence intervals (CIs) were obtained using good hearing as the reference. Age, sex, and covariates that were significantly associated with hearing impairment in the nonfrail (Table 2) and prefrail groups (Table 3) (wealth, education, CVD, cognitive function) and that have consistently been associated with hearing impairment and frailty in previous studies, such as depression, were included in the statistical analyses.[29,30] If a positive association was demonstrated between hearing impairment and incident frailty, supplementary analyses were conducted to explore whether lack of companionship as a marker of social isolation and as a potential mechanism underlying the causal pathway between poor self-reported hearing and frailty might explain this.[31] All analyses were performed using SPSS version 22 (IBM Corp., Armonk, NY).

RESULTS

In 2004, 2,836 adults aged 60 and older completed an interview and underwent a nurse assessment. The prevalence of hearing impairment was 23% (n = 643), and 56% (n = 1584) of participants were men. One thousand three hundred ninety-six participants (49%) were not frail, 1,178 (42%) were prefrail, and 262 (9%) were frail at baseline. At 4-year follow-up, there were 367 new cases of prefrailty (n = 343) and frailty (n = 24) among those who were not frail at baseline and 133 new cases of frailty among those who were prefrail at baseline.

Cross-sectional Associations of Hearing Impairment and Frailty at Baseline

Table 1 shows the characteristics of all participants and prevalence of frailty at baseline (2004) according to hearing impairment. Participants with poor hearing were more likely to be older, male, and less wealthy; have no educational qualification; have been diagnosed with CVD or diabetes mellitus; and have poorer cognitive function, symptoms of depression, and a history of falls than those with good hearing. Of older adults with poor hearing, 45% (n = 291) were prefrail, and 14% (n = 87) were frail, and of those with good hearing, 40% (n = 887) were prefrail, and 8% (n = 175) were frail.

Cross-sectional analyses of the relationship between frailty and hearing impairment showed that participants who were prefrail or frail were more likely to have poor hearing (age- and sex-adjusted OR = 1.66, 95% CI = 1.37–2.01), and the association remained after further adjustment for wealth, education, CVD, cognition, and depression (OR = 1.41, 95% CI = 1.14–1.73). The relationship was further examined in a subsample of 2,663 participants with data on lack of companionship, and the association remained after additional adjustment for lack of companionship (OR = 1.44, 95% CI = 1.16–1.79). Additional analyses of the relationships between hearing impairment and prefrailty and frailty separately showed that frailty (OR = 1.52, 95% CI = 1.25–1.86) and prefrailty (OR = 2.32, 95% CI = 1.67–3.24) were significantly associated with hearing impairment. An interaction between hearing impairment and sex was tested for, and no association was found.

Longitudinal Associations Between Hearing Impairment and Incident Prefrailty and Frailty

Two cohorts were constructed for longitudinal analyses—not frail at baseline and prefrail at baseline. Table 2 shows the characteristics of participants in the first cohort who were not frail at baseline according to hearing impairment. In this cohort, self-reported hearing impairment was statistically significantly associated with older age, male sex, less wealth, no educational qualification, and poorer cognitive

Table 1. Age, Sex, Socioeconomic and Lifestyle Characteristics, Comorbidities, Falls, and Frailty Status in a Cohort of English Men and Women Aged 60 and Older in 2004 (Baseline)

Covariate	Overall, n = 2,836	Good Hearing, n = 2,193 (77%)	Poor Hearing, n = 643 (23%)	P-Value
Age, n (%)				
60–69	1,526 (54)	1,266 (58)	260 (40)	<.001
70–79	1012 (36)	726 (33)	286 (45)	
≥80	298 (11)	201 (9)	97 (15)	
Male, n (%)	1,584 (56)	894 (41)	358 (56)	<.001
Wealth quintile, n (%)				
1 (lowest)	396 (14)	290 (13)	106 (17)	<.001
2	541 (19)	383 (18)	158 (25)	
3	562 (20)	430 (20)	132 (21)	
4	615 (22)	499 (23)	116 (18)	
5 (highest)	690 (24)	567 (26)	123 (19)	
No educational qualification, n (%)	1,086 ± 38	797 ± 36	289 ± 45	<.001
Smoker, n (%)	308 (11)	226 (10)	82 (13)	.08
Body mass index, kg/m^2, mean ± SD	27.8 (4.8)	27.8 (4.8)	27.8 (4.8)	.67
Hypertension, n (%)	1,302 (46)	984 (45)	318 (50)	.40
Cardiovascular disease, n (%)	499 (18)	348 (16)	151 (24)	<.001
Diabetes mellitus, n (%)	251 (9)	175 (8)	76 (12)	<.001
Cognitive function, mean ± SD[a]	13.7 ± 3.3	14.0 ± 3.2	12.9 ± 3.4	<.001
Depression symptoms, n (%)	653 (23)	480 (22)	173 (27)	<.001
History of falls, n (%)	882 (31)	657 (30)	225 (35)	.02
Frailty status, n (%)				
Nonfrail	1,396 (49)	1,131 (52)	265 (41)	<.001
Prefrail	1,178 (42)	887 (40)	291 (45)	<.001
Frail	262 (9)	175 (8)	87 (14)	<.001

[a]According to a 24-point cognitive scale on orientation to time and immediate and delayed recall.[26]
SD = standard deviation.

Table 2. Age, Sex, Socioeconomic and Lifestyle Characteristics, Comorbidities, and Falls in a Cohort of English Men and Women Aged 60 and Older with No Frailty in 2004

Covariate	Overall, n = 1,396	Good Hearing, n = 1,131 (81%)	Poor Hearing, n = 265 (19%)	P-Value
Age, n (%)				
60–69	864 (62)	743 (66)	121 (46)	<.001
70–79	459 (33)	336 (30)	123 (46)	
≥80	73 (5)	52 (5)	21 (8)	
Male, n (%)	785 (56)	603 (53)	182 (69)	<.001
Wealth quintile, n (%)				
1 (lowest)	112 (8)	83 (7)	29 (11)	.01
2	204 (15)	154 (14)	50 (19)	
3	278 (20)	218 (20)	60 (23)	
4	346 (25)	293 (26)	53 (20)	
5 (highest)	436 (31)	368 (33)	68 (26)	
No educational qualification, n (%)	420 (30)	321 (28)	99 (37)	.04
Smoker, n (%)	103 (7)	82 (7)	21 (8)	.69
Body mass index, kg/m^2, mean ± SD	27.2 ± 3.9	27.2 ± 3.9	27.3 ± 4.1	.85
Hypertension, n (%)	560 (40)	450 (40)	110 (42)	.61
Cardiovascular disease, n (%)	195 (14)	150 (13)	45 (17)	.12
Diabetes mellitus, n (%)	90 (6)	70 (6)	20 (8)	.42
Cognitive function, mean ± SD[a]	14.2 ± 3.3	14.4 ± 3.1	13.6 ± 3.2	<.001
Depression symptoms, n (%)	149 (11)	117 (10)	32 (12)	.41
History of falls, n (%)	347 (25)	278 (25)	69 (26)	.62

[a]According to a 24-point cognitive scale on orientation to time and immediate and delayed recall.[26]
SD = standard deviation.

function. Symptoms of depression; history of falls; CVD; and CVD risk factors including smoking, BMI, hypertension, and diabetes mellitus were not associated with hearing impairment. Table 3 presents the characteristics of participants in the second cohort, who were prefrail at baseline, according to hearing impairment. In those who were prefrail at baseline, hearing impairment was associated with older age, male sex, CVD, and poorer cognitive

Table 3. Age, Sex, Socioeconomic and Lifestyle Characteristics, Comorbidities, and Falls in a Cohort of English Men and Women Aged 60 and Older with Prefrailty in 2004

Covariate	Overall, n = 1,178	Good Hearing, n = 887 (75%)	Poor Hearing, n = 291 (25%)	P-Value
Age, n (%)				
60–69	568 (48)	458 (52)	110 (38)	<.001
70–79	455 (39)	327 (37)	128 (44)	
≥80	155 (13)	102 (12)	53 (18)	
Male, n (%)	413 (35)	261 (29)	152 (52)	<.001
Wealth quintile, n (%)				
1 (lowest)	195 (17)	144 (16)	51 (18)	.28
2	264 (22)	189 (22)	75 (26)	
3	242 (21)	182 (21)	60 (21)	
4	236 (20)	180 (21)	56 (19)	
5 (highest)	230 (20)	184 (21)	46 (16)	
No educational qualification, n (%)	507 (43)	372 (42)	135 (46)	.18
Smoker, n (%)	162 (14)	116 (13)	46 (16)	.24
Body mass index, kg/m^2, mean ± SD	27.9 ± 4.8	28.0 ± 4.9	27.8 ± 4.4	.48
Hypertension, n (%)	583 (50)	430 (49)	153 (53)	.23
Cardiovascular disease, n (%)	213 (18)	144 (16)	69 (24)	<.001
Diabetes mellitus, n (%)	121 (10)	86 (10)	35 (12)	.26
Cognitive function, mean ± SD[a]	13.7 ± 3.4	13.8 ± 3.3	12.5 ± 3.4	<.001
Depression symptoms, n (%)	362 (31)	266 (30)	96 (33)	.32
History of falls, n (%)	396 (34)	291 (33)	105 (36)	.31

[a]According to a 24-point cognitive scale on orientation to time and immediate and delayed recall.[26]
SD = standard deviation.

Table 4. Associations Between Incidence of Prefrailty and Frailty and Hearing Impairment in English Men and Women Aged 60 and Older in 2004 Followed for 4 Years to 2008

Models for Adjustment	Odds Ratio (95% Confidence Interval) for Poor Hearing
No prevalent frailty at baseline[a]	
Model 1 (M1): age and sex	1.43 (1.05–1.95)
Model 2 (M2): M1 + wealth and education	1.32 (0.96–1.82)
Model 3 (M3): M2 + CVD	1.32 (0.96–1.82)
Model 4 (M4): M3 + cognition	1.31 (0.95–1.80)
Model 5 (M5): M4 + depression	1.32 (0.96–1.81)
Prefrail at baseline[b]	
Model 1 (M1): age and sex	1.64 (1.07–2.51)
Model 2 (M2): M1 + wealth and education	1.63 (1.06–2.52)
Model 3 (M3): M2 + CVD	1.62 (1.05–2.51)
Model 4 (M4): M3 + cognition	1.58 (1.02–2.45)
Model 5 (M5): M4 + depression	1.57 (1.01–2.44)

[a]Followed up for prefrailty and frailty. Good hearing, n = 1,131 (prefrail or frail at follow-up, n = 280 (25%)); poor hearing, n = 265 (prefrail or frail at follow-up, n = 87 (33%)).
[b]Followed-up for frailty. Good hearing, n = 887 (frail at follow-up, n = 91 (10%)); poor hearing, n = 291 (frail at follow-up, n = 42 (14%)).
CVD = cardiovascular disease.

function. No significant associations were observed between hearing impairment and wealth, education, smoking, BMI, hypertension, diabetes mellitus, symptoms of depression, or falls.

Table 4 presents the findings of incident prefrailty and frailty in participants who were not frail at baseline and of incident frailty in those who were prefrail at baseline. Of participants who were not frail at baseline, those with poor hearing were at greater risk of being prefrail or frail at 4-year follow-up (age- and sex-adjusted OR = 1.43, 95% CI = 1.05–1.95) than those with good self-reported hearing. The association was attenuated after further adjustment for wealth and education. Of participants who were prefrail at baseline, those who reported poor hearing were at greater risk of developing frailty than those with good hearing (age- and sex-adjusted OR = 1.64, 95% CI = 1.07–2.51). This association remained after further adjustment for wealth, education, CVD, cognition, and depression. The association was further examined in a subsample of 1,088 prefrail participants with data on lack of companionship followed up for incident frailty over 4 years. Poor hearing remained associated with greater risk of frailty (OR = 1.72, 95% CI = 1.08–2.76) after further adjustment for lack of companionship.

DISCUSSION

This study investigated the association between hearing impairment and incident frailty in older adults. The results show that prefrail older adults with self-reported poor hearing are at greater risk of becoming frail than prefrail older adults with good hearing. The association observed remained after adjustment for covariates. To the best of the authors' knowledge, this is the first study to investigate hearing impairment and incident frailty using the Fried phenotype.

In the longitudinal analyses, poor self-reported hearing was significantly associated with greater risk of becoming prefrail and frail, although adjustment for markers of socioeconomic position (wealth and education) attenuated

this. Lower socioeconomic position has consistently been associated with greater risk of frailty, an association largely explained by chronic diseases, depression, psychosocial factors, and lower income.[12–14] Manual social class, chronic diseases, and psychosocial factors have also been associated with hearing impairment,[2,4] which may explain why the association observed was not independent of socioeconomic status. In contrast, hearing impairment was associated with greater risk of developing frailty in prefrail older adults, and the association remained after further adjustment for covariates. This finding is consistent with those of a previous longitudinal study showing an association between hearing impairment and difficulty getting out of chair and slow gait speed,[19] suggesting that hearing impairment may increase the risk of future frailty in older adults already showing signs of frailty. An important aspect of the current study results is that the association between hearing impairment and incident frailty was observed in individuals who were prefrail but not in those who were not frail at baseline. Poor hearing may therefore be a particular problem in older adults who have started to become frail, suggesting that hearing impairment hastens the progression of frailty. This supports the cumulative deficit model of frailty,[33] suggesting that poor subjective hearing adds to other accumulating health deficits in increasing the risk of frailty. These findings suggest that hearing impairment may be an important deficit to consider.

In the cross-sectional analyses, hearing impairment was associated with prefrailty and frailty separately and combined. The longitudinal finding confirms the directionality of the association observed in the cross-sectional analysis and supports the possibility that hearing impairment may increase the risk of frailty, although several factors could explain the association observed in the longitudinal study. For example, it has been hypothesized that social support may help to minimize the effect of loss of physiological reserve associated with frailty.[20] Nevertheless, communication problems due to hearing impairment may restrict social engagement and therefore access to social support.[31] Consequently, prefrail individuals with hearing impairment may not be able to benefit from the positive effects of social support in preventing further decline. Unmeasured comorbidities such as anxiety[36] or comorbidities that were poorly assessed in the ELSA, including self-reported doctor-diagnosed CVD and limited aspects of cognition (further discussed below), conditions associated with hearing impairment and frailty[4,7,37] may also explain the relationship. Finally, the association could be due to shared pathological pathways such as inflammation, which is related to hearing impairment and frailty.[38,39]

Strengths and Limitations

The major strengths of this study are that it was a large sample taken from a representative cohort of the community-dwelling English population aged 60 and older.[40] A prospective study design was used, participants were followed for 4 years for prefrailty and frailty, and the models were adjusted for several important potential confounding factors. Limitations include that hearing impairment was self-reported rather than objectively measured, although the question used has been validated against objective measures, and hearing prevalence was comparable with national estimates and previous studies using objective measures.[1,4,26,41] Hearing depends on good cognitive function.[17,42] Cognitive function based on orientation and immediate and delayed recall was adjusted for, although a limitation of this study was that other aspects of cognitive function or measures of dementia were not available. The investigations, therefore, did not fully account for the role of cognition or dementia in explaining the association between hearing impairment and frailty. Because of data limitations, a slightly modified version of the validated Fried phenotype was used to assess frailty. Although objectively measured data on weight loss over time were used, intentional and unintentional weight loss could not be differentiated, and levels of physical activity referred to frequency and intensity of exercise, without information on calorie consumption. Nevertheless, data were obtained through interviews and nurse assessments, and the findings on prevalence of frailty are comparable with those in the original Fried phenotype study.[7] The current study was restricted to the two-thirds of ELSA participants with data on frailty measurements at baseline and follow-up. Nonrespondents tended to be older and in poorer health, suggesting that prevalence rates of hearing impairment, prefrailty, and frailty might have been higher in nonrespondents.[40] Data on hearing aid use were not available, restricting information on any preventable action that participants may have taken. Hearing impairment was measured only at baseline, and no information on the primary cause of and change in hearing impairment were investigated. Finally, ELSA includes people predominantly of white British ethnic origin, and generalization of findings to other ethnic groups is therefore limited.

Implications

The finding that hearing impairment in prefrail older adults increases the risk of becoming frail is of public health importance because hearing impairment and frailty affect a large proportion of older adults.[1,7] Identifying and actively managing hearing impairment in prefrail older adults may have potential to delay development of frailty. Poor hearing might to some extent be corrected; a population-based study showed that only 15% of older adults with objectively assessed hearing impairment use a hearing aid.[43] Self-reported hearing impairment may be remediable in that it can be addressed with hearing aids, cochlear implants, and interventions aiming to optimize social and environmental conditions for hearing.[44,45] The progression from prefrailty to frailty appears to be predominately an end-stage, presaging death,[7] although frailty is potentially preventable if targeted in the early stages[7,11,46] through interventions such as physical exercise[47–49] previously shown to be effective in prefrail individuals.[47,48] Avoiding frailty could reduce adverse health outcomes such as falls, hospitalization, institutionalization, and the associated financial costs. Addressing hearing problems in prefrail individuals may therefore be critical and has the potential to reduce the burden of poor health on individuals and society.

A second implication of these findings is that hearing impairment could be an important component of assessments aimed at identifying individuals at risk of frailty.

Few assessments or indices such as the Frailty Index include hearing impairment.[30] The current findings suggest that future research using such indices to identify those with potential frailty should consider including hearing impairment because it was found to be predictive of the change from prefrailty to frailty. Further research is warranted on the possible mechanisms of frailty in hearing-impaired older adults.

CONCLUSIONS

Self-reported hearing impairment is associated with prefrailty and frailty in older age. Furthermore, prefrail older adults with poor hearing have a greater risk of becoming frail in the following 4 years, suggesting that hearing impairment may exacerbate the progression of frailty in individuals who are already prefrail.

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Paper 5.

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Self-reported vision impairment and incident prefrailty and frailty in English community-dwelling older adults: findings from a 4-year follow-up study

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ABSTRACTS

Background Little is known about vision impairment and frailty in older age. We investigated the relationship of poor vision and incident prefrailty and frailty.

Methods Cross-sectional and longitudinal analyses with 4-year follow-up of 2836 English community-dwellers aged ≥60 years. Vision impairment was defined as poor self-reported vision. A score of 0 out of the 5 Fried phenotype components was defined as non-frail, 1–2 prefrail and ≥3 as frail. Participants non-frail at baseline were followed-up for incident prefrailty and frailty. Participants prefrail at baseline were followed-up for incident frailty.

Results 49% of participants (n=1396) were non-frail, 42% (n=1178) prefrail and 9% (n=262) frail. At follow-up, there were 367 new cases of prefrailty and frailty among those non-frail at baseline, and 133 new cases of frailty among those prefrail at baseline. In cross-sectional analysis, vision impairment was associated with frailty (age-adjusted-and-sex-adjusted OR 2.53, 95% CI 1.95 to 3.30). The association remained after further adjustment for wealth, education, cardiovascular disease, diabetes, falls, cognition and depression. In longitudinal analysis, compared with non-frail participants with no vision impairment, non-frail participants with vision impairment had twofold increased risks of prefrailty or frailty at follow-up (OR 2.07, 95% CI 1.32 to 3.24). The association remained after further adjustment. Prefrail participants with vision impairment did not have greater risks of becoming frail at follow-up.

Conclusion Non-frail older adults who experience poor vision have increased risks of becoming prefrail and frail over 4 years. This is of public health importance as both vision impairment and frailty affect a large number of older adults.

INTRODUCTION

Vision impairment is common in later life.[1] The most prevalent eye conditions in older age are age-related macular degeneration and cataract, affecting 53% and 36% of British adults aged ≥75 years, respectively.[2] The rapid growth in the number of older adults in the UK poses a significant public health challenge to improve the health of the older population.[3] A particular concern in the older population is the development of frailty, estimated to affect between 4% and 17% of adults aged ≥65 years, depending on how it is measured.[4] Frailty is characterised by an ageing-associated decline in multiple physiological systems reducing the body's reserve and functional capacity, increasing the vulnerability to adverse outcomes including falls, hospitalisation, institutionalisation and mortality.[5-8] Frailty is often regarded as a dynamic state along a continuum ranging from normal ageing to death,[9] and older adults transition between frailty states.[10] Prefrailty is an intermediate stage between being non-frail and frail,[7] and the transition towards frailty often ensues from an acute medical event or psychological stress.[10 11]

Vision impairment in older age has been associated with increased risks of adverse health outcomes including functional decline,[12 13] but little is known about the relationship between vision impairment and frailty. Previous cross-sectional research has shown an association between visual acuity, contrast sensitivity, cataract and frailty indicators including gait speed, grip strength and chair stands in middle-aged and older adults.[14 15] Cross-sectional analyses of community-dwelling older adults have also showed an association between cataract and Fried frailty phenotype.[16] However, few studies have investigated incidence of prefrailty as well as frailty, and explored the role of possible mediators such as depression and social isolation, associated with vision impairment and increased risks of frailty.[17 18] Therefore, we examined the relationship of poor vision with the risk of incident prefrailty and frailty over 4 years adjusting for confounders and exploring possible mediators in a nationally representative sample of community-dwelling English men and women aged ≥60 years.

METHODS

Study design and participants

In this study, data from the English Longitudinal Study of Ageing (ELSA) was used. ELSA is a prospective study of a nationally representative sample of men and women aged ≥50 years drawn from the Health Survey for England in 1998, 1999 or 2001.[19] Participants have been followed-up every 2 years for an interview on health and lifestyle and every 4 years from 2004 participants have also been invited to a physical examination. In the present study, we included participants with data on vision impairment, covariates and the Fried phenotype in 2004 and on frailty in 2008. Participants aged <60 years in 2004 were furthermore excluded as the frailty component walking speed was only assessed in participants aged ≥60 years. This generated a sample of 2836 women and men aged ≥60

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years (67% of original study sample) used for our analyses. All participants provided informed consent and ethical approval for ELSA was obtained from the Multicentre Research and Ethics Committee.

Vision impairment

Vision impairment was assessed by asking participants whether their eyesight was excellent, very good, good, fair or poor using glasses or corrective lens if they normally do so. Good vision was defined as reporting excellent, very good or good eyesight and was used as the reference group. Reporting fair or poor eyesight was classified as poor vision. The question on self-experienced eyesight has previously demonstrated a significant association with objectively measured eyesight.[20]

Assessment of frailty

Participants' frailty status was first assessed in 2004 and then again in 2008, which allowed for participants to be followed-up for 4 years. Frailty was based on the five components of the Fried phenotype: weight loss, weak grip strength, slow walking, exhaustion and low physical activity.[7] Identical or very similar definitions of the components to those in the original phenotype studies were operationalised.[7 21] Weight loss was defined as either loss of ≥10% of body weight in the last 4 years or current body mass index (BMI) <18.5 kg/m^2. Grip strength was assessed using a grip gauche three times for each hand and the maximum handgrip strength measure out of a total of six attempts was used for the analysis. Weak grip strength was classified as being in the lowest quintile of the distribution, after taking sex and BMI into account. Slow walking speed was based on the mean of the time taken to complete an 8-feet walk at their usual pace from two measurements. The lowest sex-specific and height-specific quintile of the study sample distribution, and those in wheelchairs, bed bound, unable to walk due to health problems or unable to walk alone were classified as having slow walking speed. Exhaustion was defined as giving positive responses to any of the two questions "Felt that everything I did was an effort in the last week" or 'Could not get going in the last week' from the Center for Epidemiologic Studies Depression Scale (CES-D).[22] Low physical activity was based on frequency and intensity in exercise by asking participants how often they undertook vigorous, moderate and mild exercise (more than once a week, once a week, one to three times a month, hardly ever or never). Reporting exercising hardly ever or never, doing mild exercise only or doing moderate exercise a maximum of one to three times a month was classified as low physical activity. Frailty was defined as the presence of three or more of the five frailty components. Prefrailty was defined as the presence of one or two components. No prevalent frailty was defined as having none of the frailty components. The Fried phenotype was used because it incorporates both prefrailty and frailty and is a widely used definition suitable for identification of community-dwelling older adults at increased risk of frailty.[23 24]

Covariates

Variables considered as covariates included age, sex, wealth, education, cardiovascular disease (CVD), smoking, hypertension, diabetes, history of falls, cognitive function, depression and lack of companionship. Age was grouped into 60–69 years, 70–79 years and ≥80 years. Wealth was based on total net non-pension wealth (financial, housing and physical wealth) of the household presented by quintiles. Education was defined as having an intermediate or higher qualification compared with no qualification. Self-reported doctor-diagnosed CVD (myocardial infarction, angina and/or stroke), diabetes and hypertension were analysed dichotomously. History of falls was based on participants reporting fallen down in the last 12 months. Smoking was defined as reporting being a current smoker or current non-smoker. Cognitive function was assessed using a validated 24-point cognitive scale on time orientation (4 points), immediate recall (10 points) and delayed recall (10 points) and analysed continuously.[25] For the recall tests, participants were presented with a list of 10 words of which they were asked to recall as many words as possible immediately after the list was read, and then again after an approximately 5 min delay during which they completed other survey questions. Data on time orientation were obtained from the Mini Mental Status Examination and assessed by asking participants to report today's day, date, month and year verbally.[26 27] Factors that may be on the causal pathway of vision impairment and frailty such as depression and social interaction were also considered. Depression symptoms were based on the six questions on mood not part of the frailty component exhaustion from the validated 8-item version of CES-D.[22] Reporting two or more items were defined as having depression symptoms and analysed dichotomously. Feeling lack of companionship some of the time or often were combined and compared with feeling no lack of companionship.

Statistical analyses

Logistic regression was used to determine cross-sectional relationships of vision impairment with prefrailty and frailty combined. Logistic regression was also used to determine the odds of incident prefrailty and frailty combined over 4 years follow-up in non-frail participants at baseline with poor self-reported vision compared with those with good vision. Similarly, we determined the odds of incident frailty in participants prefrail at baseline, followed-up for 4 years. Analyses also included investigating possible reverse relationships in participants prefrail and/or frail at baseline and non-frail at follow-up, and participants frail at baseline and prefrail at follow-up. Good vision was used as the reference group. The statistical analyses were adjusted for age, sex and covariates significantly associated with vision impairment in participants non-frail and prefrail at baseline (wealth, CVD, diabetes, cognitive function, falls) (table 1) and for covariates that have consistently been associated with both vision impairment and frailty in previous research, such as educational level and depression.[7 17 28] Where a positive association was demonstrated between vision impairment and frailty, supplementary analyses were conducted to explore if the association might be explained by lack of companionship, a marker of social isolation associated with both vision impairment and frailty.[17 18] All analyses were carried out using SPSS (V.22, IBM, Armonk, New York, USA).

RESULTS

In 2004, 2836 adults (56% men) aged ≥60 years completed an interview and a physical examination. Self-reported vision impairment was prevalent in 12% (n=339) of the participants. Half of the participants (n=1396) (49%) had no prevalent frailty, 1178 (42%) were prefrail and 262 (9%) were frail. Those who were prefrail or frail at baseline were excluded to determine incident frailty. The participants were followed for 4 years during which a total of 367 new cases of prefrailty (n=343) and frailty (n=24) among those without prevalent frailty at baseline were reported. In addition, there were 133 new cases of frailty in participants prefrail at baseline.

Table 1 Age, sex, socioeconomic and lifestyle characteristics, comorbidities and falls and prevalence of non-frailty, prefrailty and frailty in a cohort of English men and women aged 60 years and over in 2004 (baseline)

	Overall	Good vision	Poor vision	p Value
Totals, (n)%	2836 (100)	2497 (88)	339 (12)	
Covariates				
Age in years, (n)%				
60–69	1526 (54)	1400 (56)	126 (37)	<0.01
70–79	1012 (36)	865 (35)	147 (43)	
80+	298 (11)	232 (9)	66 (20)	
Male gender, (n)%	1584 (56)	1121 (45)	131 (39)	0.02
Wealth, (n)%				
1 (lowest)	396 (14)	309 (12)	87 (26)	<0.01
2	541 (19)	452 (18)	89 (27)	
3	562 (20)	505 (20)	57 (17)	
4	615 (22)	563 (23)	52 (16)	
5 (highest)	690 (24)	643 (26)	47 (14)	
No educational qualification, (n)%	1086 (38)	915 (37)	171 (50)	<0.01
Smoker, (n)%	308 (11)	250 (10)	58 (17)	<0.01
Body mass index, mean±SD	27.8 (4.6)	27.7 (4.5)	28.3 (4.8)	0.02
Hypertension, (n)%	1302 (46)	1123 (45)	179 (53)	<0.01
Cardiovascular disease, (n)%	499 (18)	400 (16)	99 (29)	<0.01
Diabetes, (n)%	251 (9)	197 (8)	54 (16)	<0.01
Cognitive function, mean±SD	13.7 (2.3)	13.9 (2.3)	12.8 (2.2)	<0.01
Depression symptoms, (n)%	652 (23)	536 (22)	117 (35)	<0.01
History of falls, (n)%	882 (31)	742 (30)	140 (41)	<0.01
Frailty prevalence at baseline (2004), n(%)				
Non-frail, n(%)	1296 (46)	1203 (52)	93 (27)	<0.01
Prefrail, n(%)	1178 (42)	1010 (40)	168 (50)	<0.01
Frail, n(%)	262 (9)	184 (7)	78 (23)	<0.01

Cross-sectional associations of vision impairment and frailty at baseline

Table 1 presents the characteristics of all participants in 2004 (baseline) by vision impairment. In comparison to participants with good vision, those with poor vision were more likely to be older, male gender, less wealthy, no educational qualification, smoker, higher BMI, diagnosed with hypertension, CVD and diabetes, a history of falls, poorer cognitive function and depression symptoms. Half of older adults with poor vision (50%, n=168) were prefrail and 23% (n=78) were frail, in comparison 40% (n=1010) of older adults with good vision were prefrail and 7% (n=184) were frail.

OR with 95% CI for the cross-sectional associations between vision impairment and frailty are presented in table 2. The cross-sectional associations between vision impairment and frailty at baseline showed that participants with poor vision had over twofold greater odds of being prefrail or frail compared with participants with good vision (age-adjusted and sex-adjusted OR 2.53, 95%CI 1.95 to 3.30) and the association remained after further adjustment for wealth, education, CVD, diabetes, falls, cognition and depression (OR 1.72, 95%CI 1.30 to 2.29). The association remained after additional adjustment for lack of companionship in a subsample of 2663 participants with such data (OR 1.65, 95%CI 1.22 to 2.22). Cross-sectional analyses of the relationships between vision impairment and prefrailty and frailty separately showed that both prefrailty (OR 2.10, 95%CI 1.59 to 2.77) and frailty (OR 4.83, 95%CI 3.30 to 7.06) were statistically significantly associated with vision impairment (see online supplementary appendix table S1). In supplementary analyses on individual, frailty components vision impairment was associated with exhaustion, low physical activity and slow gait speed on adjustment for multiple covariates suggesting the associations observed were not driven by a single frailty component. Vision impairment was also associated with age-adjusted and sex-adjusted odds for weak grip but attenuated after further adjustment for wealth and education. Weight loss was not associated with vision impairment (see online supplementary appendix table S2). There was no interaction between vision impairment and gender.

Table 2 ORs with 95% CIs for cross-sectional associations between frailty (prefrailty and frailty combined) and vision impairment in English men and women aged 60 years and over in 2004

	Good vision	Poor vision
Participants with prefrailty and frailty combined, n (%)	1194 (48)	246 (73)
Models for adjustment	OR	OR (95% CI)
Age-adjusted and sex-adjusted	1.00	2.53 (1.95–3.30)
Multi-adjusted*	1.00	1.72 (1.30–2.29)

*Multi-adjusted=adjusted for age, sex, wealth, education, cardiovascular disease, diabetes, falls, cognition, depression.

Longitudinal associations of vision impairment with incident prefrailty and frailty

Longitudinal analyses were carried out in non-frail participants at baseline (excluding participants with prefrailty and frailty)

Table 3 Age, sex, socioeconomic and lifestyle characteristics, comorbidities and falls in a cohort of English men and women aged 60 years and over with no frailty and with prefrailty, respectively, in 2004 (baseline)

	1296 participants with no frailty in 2004				1178 participants prefrail in 2004			
	Overall	Good vision	Poor vision	p Value	Overall	Good vision	Poor vision	p Value
Total, n (%)	1296 (100)	1203 (93)	93 (7)		1178 (100)	1010 (86)	168 (14)	
Age in years, n (%)								
60–69	864 (67)	827 (69)	37 (40)	<0.01	568 (48)	502 (50)	66 (39)	<0.01
70–79	459 (33)	415 (32)	44 (47)		455 (39)	388 (38)	67 (40)	
80+	73 (6)	61 (5)	12 (13)		155 (13)	120 (12)	35 (21)	
Male gender, n (%)	785 (56)	734 (56)	51 (55)	0.78	413 (35)	348 (35)	65 (39)	0.29
Wealth, n (%)								
1 (lowest)	112 (9)	94 (7)	18 (20)	<0.01	195 (17)	158 (16)	37 (23)	<0.01
2	204 (15)	191 (15)	13 (14)		264 (22)	215 (21)	49 (30)	
3	278 (20)	262 (20)	16 (18)		240 (21)	207 (21)	35 (22)	
4	346 (25)	326 (25)	20 (22)		236 (20)	212 (21)	24 (15)	
5 (highest)	426 (31)	412 (32)	14 (26)		230 (20)	212 (21)	18 (11)	
No education, n (%)	420 (30)	383 (29)	37 (40)	0.04	507 (43)	426 (42)	81 (48)	0.14
Smoker, n (%)	103 (7)	94 (7)	9 (10)	0.38	162 (14)	133 (13)	29 (17)	0.15
Body mass index, mean±SD	27.2 (3.9)	27.2 (3.9)	27.1 (4.4)	0.70	27.8 (4.8)	27.6 (4.8)	28.3 (4.7)	0.22
Hypertension, n (%)	560 (40)	517 (40)	43 (46)	0.21	580 (50)	491 (49)	92 (55)	0.14
Cardiovascular disease, n (%)	195 (14)	173 (13)	22 (24)	0.01	213 (18)	172 (17)	41 (24)	0.02
Diabetes, n (%)	98 (8)	80 (6)	10 (11)	0.08	121 (10)	92 (9)	29 (17)	<0.01
Cognitive function, mean±SD	14.2 (2.3)	14.3 (2.1)	13.5 (2.2)	0.03	13.7 (2.4)	13.6 (2.4)	12.8 (2.2)	<0.01
Depression symptoms, n (%)	149 (11)	136 (11)	13 (14)	0.29	362 (31)	302 (30)	60 (36)	0.11
History of falls, n (%)	347 (25)	320 (25)	27 (29)	0.34	396 (34)	326 (32)	70 (42)	0.02

and participants with prefrailty at baseline. Table 3 presents the characteristics of participants who were non-frail and prefrail, respectively, at baseline by vision impairment. In non-frail participants, poor vision was associated with advanced age, lower wealth, no educational qualification, CVD and lower cognitive function. Participants prefrail at baseline with poor vision were associated with advanced age, lower wealth, CVD, diabetes, lower cognitive function and falls.

Table 4 shows OR with 95% CIs for incident prefrailty and frailty in participants non-frail at baseline, and incident frailty in those prefrail at baseline. Among participants non-frail at baseline, those who reported poor vision had a twofold increased risk of becoming prefrail or frail at 4-year follow-up (age-adjusted and sex-adjusted OR 2.07, 95%CI 1.32 to 3.24) compared with participants with good vision. The association remained after further adjustment for wealth, education, CVD, diabetes, falls, cognition and depression. Additional analysis was carried out in a subsample of 1338 non-frail participants with data on lack of companionship. In this analysis, vision impairment remained associated with increased risks of prefrailty and frailty after further adjustment for lack of companionship (OR 1.98, 95%CI 1.23 to 3.19). Vision impairment was not associated with an increased risk of frailty in older adults prefrail at baseline (OR 1.34, 95%CI 0.82 to 2.19). Analyses of possible reverse relationships showed no associations after adjustment for covariates.

Table 4 ORs with 95% CIs for associations between incidence of prefrailty and frailty with vision impairment in English men and women aged 60 years and over in 2004 followed-up for 4 years to 2008

	Good vision	Poor vision
No prevalent frailty at baseline	n=1203	n=93
Prefrail or frail at follow-up, n (%)	324 (25)	43 (46)
Models for adjustment	OR	OR (95% CI)
Age-adjusted and sex-adjusted	1.00	2.07 (1.32–3.24)
Multi-adjusted*	1.00	1.86 (1.17–2.95)
Prefrail at baseline	n=1010	n=168
Frail at follow-up, n (%)	107 (11)	26 (16)
Models for adjustment	OR	OR (95% CI)
Age-adjusted and sex-adjusted	1.00	1.34 (0.82–2.19)

*Multi-adjusted=adjusted for age, sex, wealth, education, cardiovascular disease, diabetes, falls, cognition, depression.

DISCUSSION

In this study, we examined the association of vision impairment with incident frailty in older age. Our findings show that non-frail older adults with self-reported poor vision have increased risks of becoming prefrail or frail compared with non-frail older adults with good vision. Vision impairment, however, was not significantly associated with incident frailty in those already prefrail at baseline. This is to our knowledge the first study investigating the relationship between vision impairment and incident frailty using the Fried phenotype.

The longitudinal analyses showed that non-frail older adults with vision impairment had nearly twice the risk of becoming prefrail and frail compared with those with good vision on adjustment for covariates. This is consistent with earlier cross-sectional population-based studies of middle-aged and older community-dwelling adults investigating the association between objectively measured vision impairment[14] and cataract,[18] respectively, and frailty assessed using a frailty score consisting of slow gait speed, low expiratory flow rate, poor handgrip strength and inability to perform chair stands. In contrast, prefrail participants with vision impairment did not have an increased risk of developing frailty. This is similar to a previous cross-sectional study on vision problems defined as having cataracts and frailty defined as the Fried phenotype reporting that cataract was associated with prefrailty but not with frailty.[14] This finding suggests that vision impairment may be of particular importance in the onset of the early stages of frailty, rather than progression in those already prefrail.

Several factors could explain the longitudinal relationship observed. Vision impairment is associated with a range of comorbidities known to be associated with frailty such as CVD and diabetes.[29] In our study, the associations remained after adjustment for several comorbidities including diabetes, CVD and depression, and while some residual confounding is possible due to lack of adjustment of potential confounding factors, the relationship observed could also be explained by factors on the causal pathway between vision impairment and frailty such as social isolation. Being socially engaged may reduce the impact of loss of physiologic reserve associated with frailty.[18] Vision impairment has also been associated with being socially isolated,[17] and vision impaired older adults may not therefore be able to benefit from the positive effects of social support in preventing frailty. Our supplementary analysis of a subsample with data on companionship suggests that this does not fully explain the relationship observed; however, we had insufficient data to also explore the role of social activities and social networks. Finally, it is possible that shared pathological pathways such as inflammation, which has been associated with both vision impairment and frailty,[30 31] may in part explain the association observed.

Strengths and limitations

A major strength of the study is that data are from a nationally representative cohort of community-dwelling English women and men aged ≥60 years.[32] Also, participants were followed-up for 4 years for prefrailty and frailty, and the models were adjusted for several important confounding factors. Limitations include that vision impairment was self-reported rather than objectively measured. However, the question used has been against objective measures,[20] and the finding is comparable to national estimates.[1] In this study, a slightly modified version of the validated Fried phenotype was used due to limitations in the data. Levels of physical activity referred to frequency and intensity of exercise without information on calorie consumption and the ELSA data did not allow differentiating between intentional and unintentional weight loss. However, the data used were obtained through an interview and physical examination and the prevalence of frailty in this study is comparable to the original Fried phenotype study.[7] Another limitation is that our study was restricted to the two-thirds of ELSA participants with data on frailty measurements at both baseline and follow-up. Of 5918 participants aged ≥60 years in 2004, 1670 were lost to follow-up in 2008. Non-respondents were more likely to be older and have poorer health compared with respondents. This raises potential selection bias, suggesting that prevalence of vision impairment, prefrailty and frailty might have been higher among non-respondents. Furthermore, in our study vision impairment was measured at baseline only and we did not investigate the primary cause of or change in vision impairment. Finally, the ELSA cohort comprised predominantly of white British people and the findings may not be generalisable to other ethnic groups.

What is already known on this subject

Vision impairment is common in later life and associated with a range of adverse health outcomes including comorbidities, physical disability and poor social interaction affecting overall well-being and independent living. Vision impairment may furthermore play a role in the development of frailty, another common health concern in older age. However, evidence on the prospective relationship between vision impairment and development of frailty is sparse.

What this study adds

Our findings show that compared with non-frail participants with no vision impairment, non-frail participants with vision impairment had a twofold increased risk of becoming prefrail or frail at follow-up and the association remained after further adjustment for wealth, education, cardiovascular disease, diabetes, falls, cognition and depression. These findings suggest that vision impairment in older age contributes towards the development of frailty. Given the rapidly increasing number of older adults, addressing age-related vision problems may be important to prevent older adults from becoming frail, which further affects the chances of functional independence in later life.

Implications

The association observed between vision impairment in non-frail older adults and increased risks of becoming prefrail and frail is important from a public health perspective as both vision impairment and frailty affect a large number of people in later life.[1 4] Vision impairment is often preventable and modifiable.[33] For instance, a healthy lifestyle may reduce the risks of developing macular degeneration. Also, cataract surgery can significantly improve visual functioning.[34] The findings of this study support previous research suggesting that early diagnosis and treatment of vision impairment could prevent non-frail older adults with vision impairment to enter the early stage of frailty.[14] Reducing the risk of frailty is essential as frailty decreases the chances of independent living, negatively affecting the health and well-being of the individual and increasing the financial costs of healthcare to society.[7 35 36]

CONCLUSIONS

This study shows that self-reported poor vision is associated with the onset of prefrailty and frailty in later life. Preventing and treating vision impairment in later life may have the potential to delay the development of frailty.

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