LONDON'S GLOBAL UNIVERSITY

Socioeconomic Impacts on Healthy Ageing in the US, England, China and Japan

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Thesis submitted for the degree of Doctor of Philosophy

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June 2019

Acknowledgements

University College London Overseas Research Scholarships (UCL–ORS) and the China Scholarship Council (CSC, award number 201608060385) funded my PhD studies. I would like to thank the CSC and UCL for supporting me while I carried out my PhD work at UCL. I am particularly grateful to UCL for providing me with travel expenses to attend conferences and an impressive range of research-related training courses during the past four years.

I would like to acknowledge my data sources, which provided me with good-quality data for my thesis. They are the Health and Retirement Study (HRS), the English Longitudinal Study of Ageing (ELSA), the China Health and Retirement Longitudinal Study (CHARLS) and the Japanese Study of Ageing and Retirement (JSTAR).

The HRS was developed by a team of researchers based at the University of Michigan, supported by the National Institute on Aging (NIAU01AG009740) and the Social Security Administration. The HRS data were made available through the HRS website at http://hrsonline.isr.umich.edu/.

ELSA was developed by a team of researchers based at NatCen Social Research, University College London, and the Institute for Fiscal Studies. The data were collected by NatCen Social Research. The funding was provided by the National Institute of Ageing in the USA, and by a consortium of UK government departments coordinated by the Office for National Statistics. The ELSA data were made available through the UK Data Archive at http://www.data-archive.ac.uk/.

CHARLS was supported by the Behavioural and Social Research division of the National Institute on Aging (grant numbers 1-R21-AG031372-01, 1-R01-AG037031-01 and 3-R01AG037031-03S1); the Natural Science Foundation of China (grant numbers 70910107022, 71130002 and 71273237); the World Bank (contract numbers 7145915 and 7159234); the China Medical Board, and Peking University. The CHARLS data were made available through the CHARLS website at http://charls.pku.edu.cn/en.

JSTAR was conducted by the Research Institute of Economy, Trade and Industry (RIETI), Hitotsubashi University, and the University of Tokyo. JSTAR datasets are distributed by RIETI in Tokyo (see https://www.rieti.go.jp/en/projects/jstar/).

The developers, funders and archives of the HRS, ELSA, CHARLS and JSTAR do not bear any responsibility for the analyses or interpretations presented in my PhD thesis.

I would also like to acknowledge the individuals who made the completion of my PhD studies possible. First among these are my supervisors, Professor Amanda Sacker and Professor Hynek Pikhart, to whom I am extremely grateful for contributing their time, energy and ideas, and for giving me warm encouragement during my master's and PhD studies, as well as critical comments on my publications and PhD thesis. My upgrade report examiner, Professor Rebecca Hardy, also had an important role to play in influencing the direction of my project.

I am grateful to my line manager, Professor Martin Bobak. He offered me a part-time job for the past three years, from which I benefited by enhancing my skills in data management.

I am proud to have been a member of the International Centre for Lifecourse Studies (ICLS) during my time at UCL. My contacts with ICLS researchers through weekly seminars and centre days were instrumental in informing my research ideas and supporting me through the PhD.

Additionally, I would like to thank my lovely friends in the UK and overseas for their help and company.

Finally, my deepest gratitude goes to my parents and my younger brother for their generous support and love.

Declaration of Originality

I, Wentian Lu, declare that the contents of this thesis are my own work. Where the work of others has been used, this has been indicated and appropriately referenced.

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Abstract

Background and Aims

Healthy ageing has become a popular topic worldwide. So far, a consensus definition of healthy ageing has not been reached. Socioeconomic position (SEP) is an important determinant of healthy ageing. Previous studies have indicated that people in advantaged SEPs are more likely to achieve healthy ageing than people in disadvantaged SEPs. However, only rare studies have compared the magnitude of socioeconomic inequalities in healthy ageing across countries. This thesis aims to conduct a cross-country comparison of socioeconomic inequalities in healthy ageing in the US, England, China and Japan.

Data Sources

The data are from the Health and Retirement Study (HRS), the English Longitudinal Study of Ageing (ELSA), the China Health and Retirement Longitudinal Study (CHARLS) and the Japanese Study of Ageing and Retirement (JSTAR). The analysis includes 10305 HRS respondents (waves 7–12, 2004–2014), 6590 ELSA respondents (waves 1–7, 2002–2015), 5930 CHARLS respondents (waves 1, 2 and 4, 2011–2015) and 1935 JSTAR respondents (waves 1–3, 2007–2011) aged 60 years or more at baseline.

Methods

A healthy ageing index (HAI) was created as the main outcome. Education, income, wealth and occupation were included as the main exposures. Data harmonisation was conducted. A two-fold fully conditional specification algorithm was employed to deal with missing data in socioeconomic indicators and covariates (Chapter 2). Pearson's r and Cronbach's α were calculated to check the HAI's test-retest reliability and internal consistency respectively. A Receiver Operating Characteristic curve analysis and a Cox proportional hazards model were applied to test the HAI's predictive performance on mortality risks (Chapter 3). Multilevel modelling was applied to assess the longitudinal relationships between SEPs and the HAI, allowing for random slopes and intercepts. Socioeconomic rank scores were derived and the slope indices of inequality were calculated to compare the magnitude of inequalities in healthy ageing by education, income and wealth across countries (Chapter 4). Path analysis was used to assess the mediating effects of occupation, income, wealth, smoking and drinking on the

relationship between education and healthy ageing. The total, direct and indirect effects of education, occupation, income and wealth on healthy ageing were also calculated (Chapter 5).

Results

Japanese and English participants achieved healthier ageing than American and Chinese participants. A positive socioeconomic gradient in healthy ageing existed in all countries. The socioeconomic inequality in healthy ageing was relatively small in Japan. In China, the inequality in healthy ageing, especially by education, is daunting.

Education was a universally influential socioeconomic predictor of healthy ageing, and is likely to be an independent predictor of healthy ageing among the ageing population across all countries. There were complex pathways from education to healthy ageing in the four countries. The positive effects on healthy ageing of improving education should not be neglected.

Wealth inequality in healthy ageing was greater in England than in any other country. Wealth was more influential than income in predicting inequalities in healthy ageing in the US, England and Japan, while income was more influential than wealth in China.

Labour force non-participation (e.g. retirement, disability) had negative effects on healthy ageing in the US. Chinese people in paid and stable work were healthier than those in unpaid farming work in later life.

Implications

This research provides sufficient theoretical and methodological guidelines for the development of well-suited assessments of healthy ageing in the area of public health. These guidelines will be useful for policymakers to capture key elements of healthy ageing when developing ageing policies for older people’s health, social participation and security. This research also provided a unique opportunity to conduct a multinational comparison of socioeconomic impacts on healthy ageing between Western and Asian countries, which has never been done before. Identifying influential socioeconomic indicators of healthy ageing in each country is instructive for exploring universal and country-specific public health practices to support healthy ageing in both Western and Asian countries.

Impact Statement

This PhD project has achieved the goal of comparing socioeconomic inequalities in healthy ageing in the US, England, China and Japan, based on evidence from four national longitudinal studies of ageing. The results of this research will contribute to knowledge about the measurement of healthy ageing and the assessment of socioeconomic impacts on healthy ageing in both Western and Asian countries.

For researchers who are interested in the study of healthy ageing, this research provides sufficient theoretical evidence to recommend domains and established scales to measure healthy ageing comprehensively worldwide. The strategies that have been developed to harmonise socioeconomic and health indicators might be useful for future comparative studies in the field of social epidemiology. The advanced statistical methods employed in this research, including a two-fold fully conditional specification algorithm for multiple imputation and multilevel modelling, might become a template for future studies that need to impute missing data and apply time-varying variables appropriately in a longitudinal analysis. Furthermore, this research suggests several future directions for the study of healthy ageing, including the use of more country-specific health indicators and the exploration of weighted calculations for a healthy ageing index; a focus on other social determinants of healthy ageing, such as early-life socioeconomic positions or more refined measures of income (e.g. salary, pension income, later-life earnings) and wealth (e.g. family inheritance, pension income, property ownership); the inclusion of other health behaviours (e.g. dietary intake, physical exercise); a comparison of inequalities in healthy ageing across generations; and an exploration of the relationship between healthy ageing and mortality risks.

For policymaking, this research provides convincing theoretical and methodological guidelines for the development of well-suited assessments of healthy ageing in the area of public health. These guidelines might be useful for policymakers to capture key elements of healthy ageing when developing ageing policies in social, economic and civic affairs, and to optimise opportunities for older people's health, social participation and security. Moreover, this research presents quantitative evidence regarding socioeconomic inequalities in healthy ageing within and across countries. An improved understanding of the determinants of healthy ageing is an important public health goal. The identification of the most influential socioeconomic predictors of healthy ageing, and the establishment of what mediates the effects of education on healthy ageing in each country, is instructive for exploring universal and country-specific public health practices to support healthy ageing in both Western and Asian countries.

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Introduction

This PhD project aims to explore socioeconomic impacts on healthy ageing after the age of 60, based on four longitudinal studies of ageing in the US, England, China and Japan. The thesis addresses this research question in multiple aspects. First, a multidimensional measurement of healthy ageing at the individual level is developed, based on a comprehensive review of theories, domains and measurements of healthy ageing. The reliability and validity of this measurement is also checked. Second, this thesis employs multiple socioeconomic indicators to examine the longitudinal relationship between socioeconomic position and healthy ageing after the age of 60 in the four countries. Trajectories of healthy ageing by socioeconomic position are predicted to visualise the declining trends of healthy ageing with age. A comparative analysis is also conducted to assess the magnitude of the socioeconomic inequalities in healthy ageing across countries, and to identify the most influential predictor(s) of healthy ageing in each country. Third, mediating effects in the relationship between education and healthy ageing are evaluated to identify pathways from education to healthy ageing in the four countries.

This thesis comprises six chapters. A brief synopsis of the chapters is presented below.

- Chapter 1 describes the demographic transitions and challenges in the US, UK, China and Japan; summarises the theories, domains, measurements and determinants of healthy ageing; introduces the concept and indicators of socioeconomic position; and discusses previous studies of socioeconomic inequalities in healthy ageing worldwide and pathways between socioeconomic position and healthy ageing. The main research gaps, aims and hypotheses are also outlined.
- Chapter 2 introduces the data sources, sample selection, socioeconomic exposures, healthy ageing index and covariates, and discusses harmonisation strategies, missing data, multiple imputation and weight adjustments.
- Chapter 3 checks the reliability and validity of the healthy ageing index, including its test-retest reliability, internal consistency and predictive validity.
- Chapter 4 assesses the longitudinal relationships between education, income, wealth, occupation and healthy ageing indices after 60 years of age in the four countries, predicts trajectories of healthy ageing by socioeconomic position, and

identifies the most influential socioeconomic indicator(s) of healthy ageing in each country.

- Chapter 5 assesses the mediating effects of occupation, income, wealth, smoking and drinking on the relationship between education and healthy ageing in the four countries. It outlines a conceptual framework for pathways from education to healthy ageing, and it calculates the total, direct and indirect effects of education, occupation, income and wealth on healthy ageing in the four countries.
- Chapter 6 is an overall discussion chapter. It summarises key findings, and it discusses the strengths and limitations, policy implications and future directions of this research. The ending offers a final conclusion.

Chapter 1 Background

1.1 What Is Ageing?

Ageing is a process that relates to a gradual accumulation of molecular and cellular damage that is largely beyond human control [1]. Over the long term, this molecular and cellular damage contributes to a gradual decrease in physiological reserves, a general decline in individual capacities, and an increase in multi-morbidities or diseases [2]. Changes in the ageing process are neither linear nor consistent. For example, some individuals aged 60 years are still in good health, while others at the same age suffer from illnesses and impairments. On the one hand, the biological mechanisms of ageing are controlled by human genes; on the other hand, different biological changes are influenced by diverse social environments and individual behaviours [2]. The process of ageing involves not only biological but also social responses, such as dealing with the loss of close relationships or shifts in social roles and capabilities (e.g. changes in work patterns and relationships with adult children) [2, 3].

There are interactions between biological and social changes in the ageing process. First, social changes can shape the physical and mental capacities of older people by influencing their available lifestyle options, contributing to changes in biological response. For example, a UK study suggested that retirement allows people more time to socialise, eat better and conduct physical exercise, leading to better health conditions than before [4]. However, another study indicated that many people will live alone when they grow older, which might increase their risk of depression or loneliness and affect their health status negatively [5]. Second, biological changes in the human body affect the physical and cognitive capacities that permit older people to do things that they want to do. For instance, physical impairments in old age might limit people's access to public transport and retail outlets, which might in turn discourage older people from remaining engaged in their local communities and maintaining supportive social networks [6].

Most developed countries define an old person as someone with a chronological age of 60 years or more [3]. However, this definition does not relate well to the situation in developing countries. In many developing countries, socially constructed meanings of age play a more important role in definitions of the threshold for old age [7]. For example, many countries in Africa accept a chronological age of 50–55+ years as defining the elderly, based on their economic and political background [3]. Currently, the United Nations has not adopted a standard criterion to define old age globally; researchers usually use the criterion of 60 years or more to refer to the ageing population [3].

1.2 An Ageing Society

The number of people aged 60 years or over is expected to rise, from 962 million globally in 2017 to 2.1 billion in 2050 and 3.1 billion in 2100. This is a faster growth rate than all the younger age groups [8].

Currently, Europe is the global region most affected by ageing challenges [9]. The percentage of people aged 60 years and older is projected to increase from 20% in 1998 to 35% in 2050 in Europe [9]. In the UK, the percentage of people aged 65 years and older increased from 14.1% to 17.8% between 1975 and 2015, and it is projected to grow to nearly a quarter of the population by 2045 [10]. In Germany, the percentage of people aged 60 years and older will increase, from 27.1% in 2013 to 39.6% by 2050 [11].

Other regions such as North America and Asia are also experiencing a rapid increase in the ageing population [9]. In the US, the population aged 65 and over increased from 35.9 million in 2003 to 44.7 million in 2013 (a 24.7% increase), and it is projected to more than double by 2060 [12]. Japan has the most aged population in the world: 33% of the whole population was more than 60 years old in 2015 [13]. This percentage will increase to 42.5% by 2050 [14]. The median age among the Japanese population was 45.9 years in 2013 and will increase to 53.4 years by 2050 [11]. As the most populous country in the world, China is also experiencing an obvious demographic transition. The percentage of people aged 60 years and over is expected to increase, from 12.4% (168 million) in 2010 to 28% (402 million) by 2040 [15].

In these countries, ageing can be seen as a success story for public health policies, socioeconomic development and medical advancements in relation to disease and injury; but it also challenges countries to adapt in order to maximise older people's health and functional capacities, and to maintain their social participation and security [16]. For example, it has been reported that in early 2009, the treatment and care of British people with long-term conditions accounted for around 50% of all GP appointments, 64% of outpatient appointments, 70% of inpatient bed days, and 70% of total healthcare and social care expenditure [17]. The cost of providing healthcare for Americans aged 65 or more was three to five times higher than for younger people in 2013 [18]. The ratio of the working-age (i.e. 20–64) to the non-working-age population in Japan will decrease, from 2.8 in 2008 to 1.2 by 2050 [11]; in China it will decrease from 2.6 in 2010 to 1.6 by 2050 [19]. The distinct decrease in this ratio is a serious issue, because the fewer people there are of working age, the fewer there are who can support schools, retirement and disability pensions, healthcare, nursing homes and other social services for the youngest and oldest populations. Approaches regarding how to transform the ageing population from burden to productivity are important.

1.3 Healthy Ageing

1.3.1 Theories of Healthy Ageing

"Healthy ageing" has become a popular topic worldwide in past decades. The term is often used interchangeably with other terms such as "active", "successful" or "productive" ageing. I use the term "healthy ageing" because health (as defined by the World Health Organization (WHO)) includes physical and mental health as well as social well-being [20].

Healthy ageing refers to the process of optimising opportunities for health, participation and security so as to enhance quality of life as people age [21]. It assumes that ageing is a valuable process which permits older people to make crucial contributions to society, leading to personal fulfilment and economic growth. It also shifts traditional stereotypes of "old age", and views the phenomenon of ageing as an opportunity [21]. Theories of healthy ageing are various in the literature.

In 44 BCE, the Roman philosopher Cicero praised healthy ageing in his essay "On Old Age". He said that old age "is respectable as long as it asserts itself, maintains it rights, is subservient to no one", indicating that old age is not a phase of decline and loss, but an opportunity for positive changes in later life [22].

In the late 20th century, many gerontologists exclusively emphasised the role of chronological age in determining individuals' health, concentrating on average age-related losses across age groups, and neglecting the substantial heterogeneity of individuals' health conditions within each age group. This heterogeneity is determined by both intrinsic and extrinsic factors in ageing. Intrinsic factors are physiological factors such as carbohydrate metabolism, bone density or cognitive function; extrinsic factors are psychosocial factors such as autonomy, control or social support [23]. In 1987, Rowe and Kahn defined "successful ageing" on the basis of a psychosocial model. They distinguished between "usual" and "successful" ageing. Usual ageing is age-intrinsic, non-pathological but high-risk, and focuses on physiological functions and the normal decline of functioning with increased age. Successful ageing is low-risk but high-functioning, and implies that extrinsic as well as intrinsic factors play an important role in maintaining individuals' health within each age group; that is, ageing characteristics are age-related rather than age-dependent [23]. In 1997 Rowe and Kahn set three standards of successful ageing: "low probability of disease and disease-related disability and related risk factors"; "high cognitive and physical functional capacity"; and "active engagement with life" [24]. In 2015, they suggested adding societal-level principles to define successful ageing: for example, providing more opportunities for employment, voluntary work and social activities for the elderly, which creates new rules and responsibilities for them; having more trust in the ageing workforce, as they have accrued knowledge and have a heightened capacity for problem-solving; and putting more investment into training and educational programmes for the elderly, rather than excluding them due to their chronological age [25].

In 1990, Baltes and Baltes proposed the "selective optimisation with compensation" (SOC) model of successful ageing. Due to ageing loss, individuals may experience restrictions in various functional capabilities, especially cognitive, emotional and physical capabilities. However, individuals may prioritise capabilities in other, new or transformed areas and set new life goals, due to environmental demands and their own motivations, skills and natural capacities. This adaptive procedure can be dubbed "selection". Individuals will also take advantage of their remaining functions and maximise their chosen lifecourse, both qualitatively and quantitatively. This is "optimisation", which reflects people's behaviours. Furthermore, when people are dealing with situations or goals with insufficient internal capabilities, they may take advantage of external compensatory strategies to cope with internal incapacities – for example, using a hearing aid for hearing loss, which is a mental or technological "compensation" [26].

In 2014, Kuh and colleagues set out three principles to define healthy biological ageing: "survival to old age", "delay in the onset of chronic diseases and disabilities" and "optimal functioning for the maximal time period" [27]. They also suggested that continued social participation – for example, through voluntary/paid work, physical activities or keeping in touch with friends/relatives – is important in order for the elderly to have an active and meaningful later life, since the social environment that we inhabit across our lives determines the ageing process [27].

The WHO has also conceptualised healthy ageing during the past decades. In 2002, the WHO defined active ageing as "the process of optimising opportunities for health, participation and security in order to enhance the quality of life as people age", which highlighted the importance of the social environment for achieving active ageing [21]. In 2015, the WHO defined healthy ageing as "the process of developing and maintaining the functional ability that enables well-being in older age". These functional abilities are health-related attributes that allow people to do what they have reason to value. Our personal characteristics (e.g. gender or ethnicity), social norms (e.g. occupation, education, wealth or social security) and other behavioural and environmental factors (e.g. smoking, drinking, deprivation or air pollution) across our lifespan can affect later health characteristics such as physiological risk factors, diseases, injuries and broader geriatric syndromes. The cumulative effects of these health characteristics determine one's intrinsic capacities, which comprise all the physical and mental capabilities that an individual can draw on. Intrinsic capacities and their interaction with the environment (i.e. all the factors in the extrinsic world that form the context of an individual's life) determine a person's functional ability, and consequently govern the attainment of well-being (happiness, security and fulfilment) [2].

So far, a consensus definition of healthy ageing has not been reached. There are differences and similarities among all these theories. The theory of healthy biological ageing and Rowe and Kahn's theory provide clear standards for researchers to measure healthy ageing. Disease, disability, functional capacity and social engagement are key components proposed by both healthy biological ageing theory and Rowe and Kahn's psychosocial model. An extra standard given by the healthy biological ageing theory is longevity – survival to old age – indicating the importance of attaining a healthy life expectancy for ageing populations. Baltes and Baltes's SOC model and the WHO concepts introduce disciplines that should be followed when setting public health strategies to achieve healthy ageing in different cultural settings. The WHO 2015 healthy ageing model and Baltes and Baltes's SOC model define healthy ageing from an ecological perspective, indicating that healthy ageing is a process that promotes resilience. The WHO 2012 active ageing model also recommends providing more social opportunities for the ageing population. This recommendation was also proposed by Rowe and Kahn in 2015. Both Rowe and Kahn and the WHO emphasise the importance of social environmental impacts on the achievement of healthy ageing.

Kuh’s theory of healthy biological ageing mostly focuses on longevity, the absence of diagnosed chronic diseases, and the minimisation of functional deterioration and disability. Rowe and Kahn’s theory involves the psychosocial components of healthy ageing. However, both hold the opinion that social engagement and mental capacities are as important as biological factors, since ageing characteristics are age-related rather than age-dependent. Psychological and social well-being are measured in order to examine the effects of self-efficacy, social roles and social support on functional well-being. Older people have fewer friends and family, and are more likely to feel isolated and lonely; but they benefit more than younger generations from participation in social activities and interactions with others, which contributes to better emotional regulation and greater well-being [28].

Rowe and Kahn also highlight the importance of social structure, suggesting that more social opportunities should be provided for older people. The WHO 2012 active ageing model similarly emphasises the importance of providing more social opportunities for the elderly. The WHO 2015 healthy ageing model uses the term “environment” to cover all components of healthy ageing in the external world at different levels, such as neighbourhood environment, people’s relationships, and social policies and services. In future research it is essential to consider environmental indicators of healthy ageing, since the interaction between a person and their social environment can explain most of the variability in intrinsic capacities in older age [29].

Some researchers have criticised Rowe and Kahn’s three standards for providing a “perfect” definition, since Rowe and Kahn excluded older people who showed any evidence of incapacity, and retained only those who had no illness or impairment [30]. Several studies likewise classify healthy agers by only categorising individuals who are free of any impairment or illness in the healthy ageing group [31-38]. According to Baltes and Baltes’s SOC theory, many older people have impairments in one or more domains, but they may still be capable of taking advantage of their remaining capacities and compensating for any losses or limitations. SOC focuses on the importance of resilience, allowing self-efficacy and growth in the context of increased biological vulnerability and reduced capabilities. Similarly to Baltes and Baltes, the WHO 2015 healthy ageing model also recognises older people's ability to maintain and improve a level of functional ability in the face of adversity. It says that seniors might preserve some functional skills without drawing on them at particular points in time, and that these preserved skills may contribute to their resilience. Therefore, when measuring healthy ageing, researchers need to consider whether a "disease-free" ageing status is achievable, to ensure that their classification of healthy agers does not import any selection bias.

1.3.2 Domains and Measurements of Healthy Ageing

Lara et al. have developed five fundamental domains of a healthy ageing phenotype in lifestyle-based intervention studies [39]. These are physiological and metabolic health, physical capability, cognitive function, social well-being and psychological well-being. The WHO has also proposed that focusing on trends in the prevalence of chronic diseases alone is not enough for the assessment of healthy ageing [2]. More functioning-based evaluations in physical, cognitive and physiological domains are needed to evaluate healthy ageing in a comprehensive way [2].

Previous studies have explored the extent of healthy ageing based on different definitions of healthy ageing. Previous literature reviews of healthy ageing have also summarised these definitions of healthy ageing [40, 41]. One of these lists the specific methods that have been used to measure successful ageing, but it mainly discusses the variability in the prevalence of successful agers and the heterogeneity in the sampling and measurements of successful ageing [42]. To my knowledge, no research has attempted to identify the important domains of healthy ageing, or to make suggestions as to the choice of methods or scales to measure each domain in order to measure healthy ageing quantitatively and comprehensively.

Therefore, I conducted a comprehensive literature review on the domains and measurements of healthy ageing in epidemiological studies, to check in each epidemiological study the domains and established scales or measures applied to measure healthy ageing, to discuss the strengths and weaknesses of different approaches to the evaluation of healthy ageing, and to recommend domains and measurements to assess healthy ageing comprehensively.

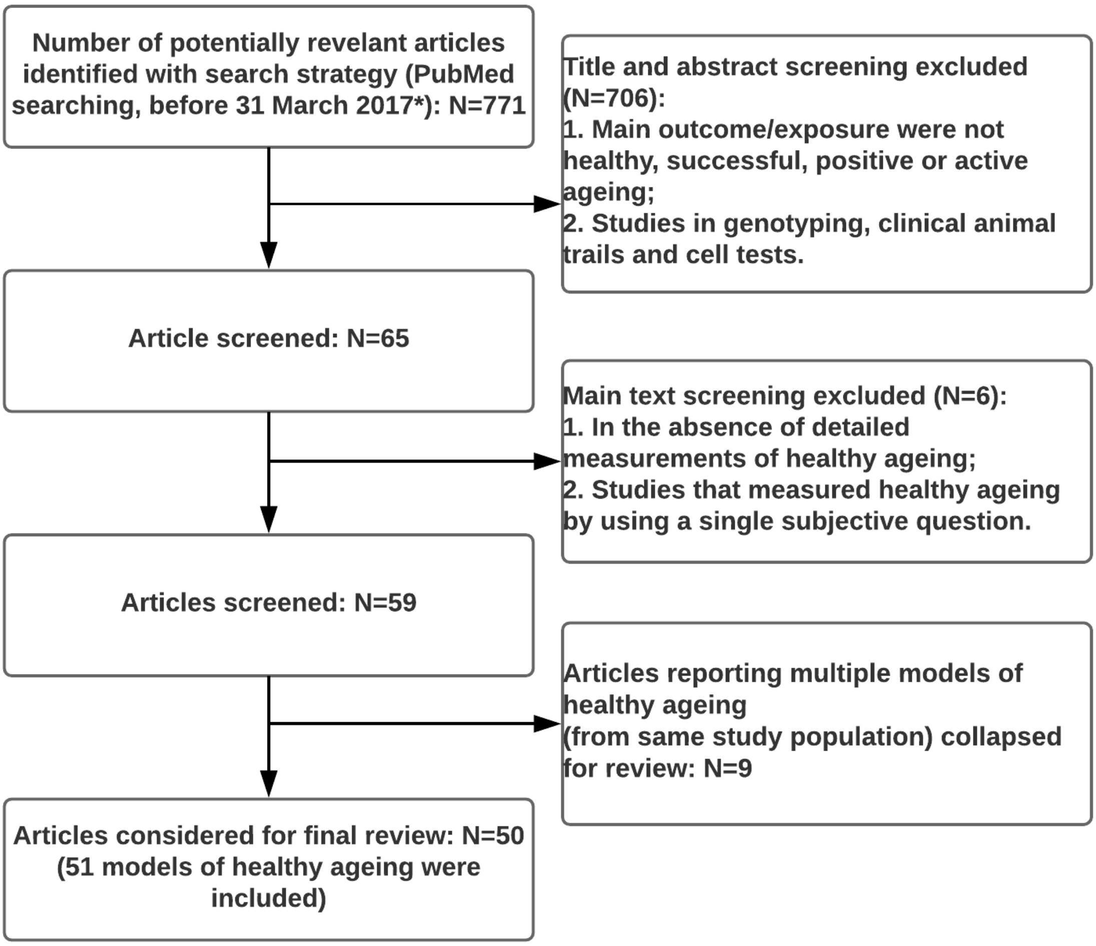
The PubMed database was searched up to 31 March 2017. All peer-reviewed articles published worldwide in English before that date were eligible for inclusion. The keywords were “healthy ageing”, “measurement” and several related terms: “successful ageing”, “productive ageing”, “active ageing”, “ageing phenotype”, “assessment”, “evaluation” and “definition”. These phrases were used with both “ageing” and “aging” spelling conventions. Equations were linked with both “or” and “and”.

The articles were epidemiological studies. The main outcome or exposure was healthy, successful, positive or active ageing. Theoretical definitions provided in the absence of detailed measurements of healthy ageing were excluded. Studies in genotyping, clinical animal trials and cell tests, and studies that measured healthy ageing by using a single subjective question (e.g. “how do you view healthy ageing?”) were excluded.

A standardised protocol was employed to evaluate the quality of each study [43]. Four questions were asked of each article. Does the study design yield a representative sample of the defined target population? Were the measures of healthy ageing reliable and valid? Were features of sampling design accounted for in the analysis? Did they report results with confidence intervals (CIs)?

The detailed screening process is presented in Figure 1-1.

Figure 1-1 Screening Process for Studies' Inclusion



Domains of Healthy Ageing

Fifty articles were selected for analysis. The review covered 23 countries or regions. Most articles mentioned the variability of definitions of healthy ageing, but only some of them explicitly clarified the definitions they were using to measure healthy ageing. Nineteen studies applied Rowe and Kahn's three standards. The measurements of healthy ageing in each study were multidimensional. Table 1-1 lists the domains of healthy ageing used in each article. Figure 1-2 summarises the number of articles measuring each domain in my review.

Table 1-1 Domains of healthy ageing in each article

Countries	Studies	*N*	Phy. [a]	Cog. [a]	Met. [a]	Psy. [a]	Soc. [a]	Gen. [a]	Sec. [a]	Hea. [a]	Oth.[a]
US	Women's Health Initiative [44]	*71039*	✓	✓			✓	✓			✓
	Health and Retirement Study [c] [45]	*9236*	✓	✓	✓	✓	✓				
	Health and Retirement Study [c] [46]	*9068*	✓	✓	✓						
	Health and Retirement Study [c] [47]	*17230*	✓	✓	✓	✓	✓				
	Nun Study [48]	*636*	✓	✓				✓			
	ORANJ BOWL Panel [49]	*5688*	✓		✓			✓			
	Successful AGing Evaluation Study [50]	*1006*		✓	✓	✓		✓			✓
	- [51]	*200*				✓					✓
	The Georgia Centenarian Study [c] [52]	*306*	✓	✓			✓	✓			
	Framingham Offspring Study [53]	*1348*		✓	✓						
Mainland China	Shanghai Successful Ageing Project [54]	*14000*	✓	✓		✓					
	Chinese Longitudinal Healthy Longevity Survey [55]	*11095*	✓	✓		✓		✓			
	2013 Survey on Life and Opinions of Older Adults in Shanghai [c] [56]	*1962*						✓			✓
	The China Health and Retirement Longitudinal Study [c] [31]	*5667*	✓	✓	✓	✓	✓				
Hong Kong, China	The Hong Kong Centenarian Study [c] [57]	*120*	✓	✓		✓	✓	✓	✓		
Taiwan	- [58]	*903*									✓
UK	Whitehall II Study [59]	*3044*	✓	✓	✓	✓					
	British Longitudinal Survey of Ageing [c, e] [60]	*999*	✓		✓		✓		✓		
	Cambridge City over-75 Cohort Study [61]	*2610*	✓	✓		✓		✓			
	The West of Scotland Twenty-07 Study [c] [62]	*1733*	✓	✓	✓		✓				

Countries	Studies	*N*	Phy. [a]	Cog. [a]	Met. [a]	Psy. [a]	Soc. [a]	Gen. [a]	Sec. [a]	Hea. [a]	Oth.[a]
	English Longitudinal Study of Ageing [63]	*1906*									✓
Canada	International Mobility in Ageing Study [b, d] [64]	*779*	✓		✓		✓	✓	✓		
			✓	✓	✓	✓	✓	✓			
	Canadian Community Health Survey: Healthy Ageing [c] [65]	*8154*	✓	✓	✓		✓				
	Manitoba Follow-up Study [66]	*2043*									✓
	- [c] [32]	*320*									✓
Mexico	Health, Wellbeing, and Ageing Study [c] [67]	*3116*	✓	✓	✓	✓	✓				
	Coyoacan Cohort [c] [34]	*935*	✓	✓	✓		✓				
Singapore	Singapore Longitudinal Ageing Study Cohort [68]	*1281*	✓	✓		✓	✓	✓			
	- [69]	*1540*									✓
Portugal	Portuguese Project on Active Ageing [c] [70]	*1322*	✓	✓	✓	✓	✓		✓	✓	
	Oporto Centenarian Study & Beira Interior Centenarian Study [71]	*80*	✓	✓	✓	✓	✓				
Brazil	GENESIS Project [72]	*400*				✓					
	Ageing, Gender, and Quality of Life Study [36]	*335*	✓	✓	✓			✓		✓	
France	SUpplémentation en Vitamines et Minéraux AntioXydants Study [73]	*3005*									✓
	SUpplémentation en Vitamines et Minéraux AntioXydants Study [c] [33]	*2329*	✓	✓		✓					✓
Australia	Melbourne Collaborative Cohort Study [c] [74]	*5512*	✓		✓	✓					✓
	The Blue Mountains Eye Study [c] [35]	*3654*	✓	✓	✓	✓					
Netherlands	The Longitudinal Ageing Study Amsterdam [c] [75]	*3107*	✓	✓		✓	✓	✓			

Countries	Studies	*N*	Phy. [a]	Cog. [a]	Met. [a]	Psy. [a]	Soc. [a]	Gen. [a]	Sec. [a]	Hea. [a]	Oth.[a]
	Rotterdam Study [76]	*3527*	✓	✓	✓	✓	✓				
Cross-countries	EU COURAGE Project (Finland, Poland and Spain) [77]	*7987*	✓	✓	✓	✓	✓		✓	✓	
	Survey of Health, Ageing and Retirement in Europe (Netherlands, Germany, Italy, Spain, Poland and Hungary) [37]	*11048*	✓					✓			
Mediterranean islands	The Mediterranean Islands Study [78]	*2663*	✓		✓	✓	✓		✓	✓	
Spain	Octabaix Project [79]	*328*	✓	✓							
Norway	Nord-Trøndelag Health Study [38]	*5773*	✓	✓	✓	✓	✓				
Germany	- [80]	*450*	✓	✓	✓	✓	✓	✓			
Italy	Italian Multi-centric Studies on Centenarians [c] [81]	*602*	✓	✓	✓						
Thailand	- [82]	*453*									✓
South Korea	- [83]	*262*									✓
Japan	Aichi Gerontological Evaluation Study [84]	*22829*	✓	✓				✓			
Nigeria	The Biafran War Generation [85]	*453*									✓

[a] Phy. = physical capabilities; Cog. = cognitive function; Met. = metabolic and physiological health; Psy. = psychological well-being; Soc. = social well-being; Gen. = general health status; Sec. = security; Hea. = health behaviours; Oth. = others: Short Form Survey or health indices.

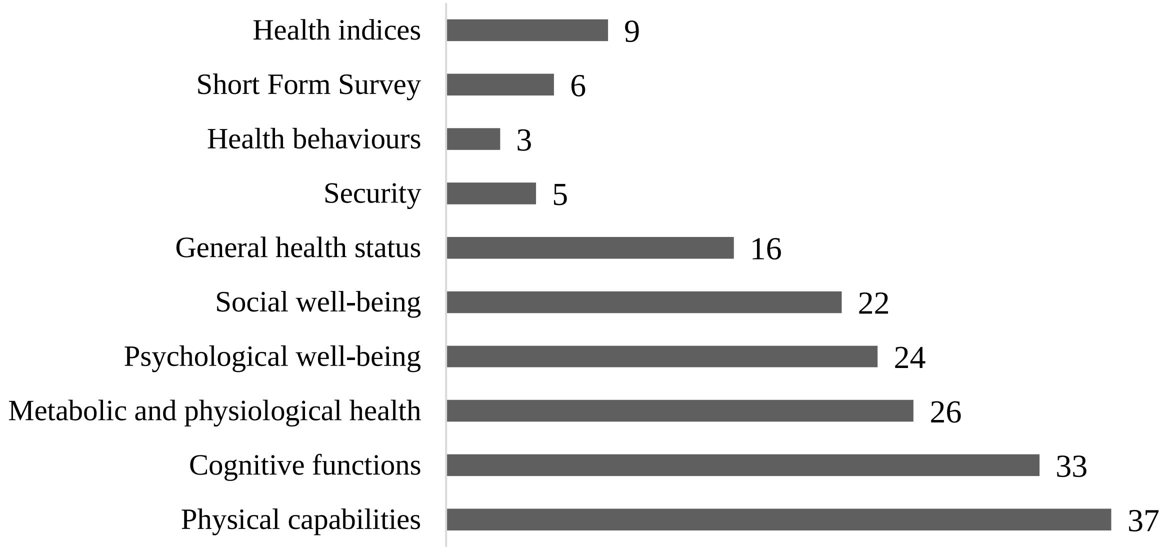
[b] This article compared two models of healthy ageing: WHO and psychological models.

[c] Articles applied Rowe and Kahn’s three standards.

[d] Articles applied WHO’s active ageing model

[e] Article applied Kuh’s theory of healthy biological ageing

Figure 1-2 Number of papers measuring each domain



Thirty-seven studies measured physical capabilities. Cognitive functions were included in 33 studies. Twenty-six studies assessed metabolic and physiological health. Twenty-four studies assessed psychological well-being. Twenty-two studies measured social well-being.

Physical capability is the degree to which a person can manage the physical tasks of daily living [86]. In 2002, the WHO published its international classification of functioning, disability and health, which aims to help make evaluations of physical capabilities among the ageing population [87]. The National Health Service (NHS) in the UK gave reasons for measuring physical functioning among older adults, saying that measurements of physical functioning indicate older people's current health status and predict their future health and relevant health outcomes, such as disability or use of healthcare/social care utilities (e.g. nursing home admission and hospitalisation) [88].

Cognitive function refers to the intellectual process by which one becomes aware of, perceives or comprehends ideas. It is related to knowledge, attention, memory, judgement, evaluation and more [86]. Cognitive functions and mental capacities are also predictors of health and well-being for the elderly. Many studies have confirmed their relationship with longevity, physical health, quality of life, social engagement and more [89]. The WHO Mental Health Action Plan 2013–2020 indicates that older people with mental disorders will experience disproportionately higher rates of disability and mortality [90]. In 2012, the WHO compared the benefits of undertaking cognitive and psychosocial interventions among older adults with dementia, suggesting that these interventions significantly improve older individuals' cognitive functions and well-being in later life [91].

With increased age, a progressive functional decline in most physiological systems and a rising prevalence of chronic pathologies will occur. Maintaining physiological function is essential not only for the absence of chronic diseases, but also for the well-being of the ageing population, which also helps reduce the burden on medical care services and systems [92]. It is necessary to make the assessment of physiological function an integral part of national data collection efforts, in order to monitor trends in healthy life expectancies, especially for older adults [93].

Additionally, being actively engaged with life and other people predicts well-being, especially among older adults [28]. People's social networks and contacts will change with increased age. Older people have fewer friends, families and neighbours, and less time left in life to spend with them [94]. However, they benefit more from participating in social activities, since positive social engagement contributes to better emotional regulation and higher well-being [28]. It has been proved that social engagement is closely connected with physical capability, cognitive function, chronic illness, mortality and other outcomes [95].

Sufficient studies have found an association between these five domains and morbidity or mortality among the ageing population. For example, higher blood pressure and low-density lipoprotein cholesterol and fasting glucose contribute to adverse cardio-metabolic events in older age [96]. A meta-analysis has indicated that weaker grip strength, slower walking speed, and poorer performance in chair-rise and standing balance tests in older people are all associated with an increased risk of all-cause mortality [97]. Another study among the community-dwelling elderly showed that cognitive decline, especially among the younger elderly, has a significantly adverse impact on longevity [98]. Moreover, social-emotional support – such as receiving verbal encouragement, getting married or participating in social activities – is positively associated with neuroendocrine function and physical performance among the ageing population [99].

However, components of healthy ageing are complicated due to the various definitions of healthy ageing. A few studies also include other components to assess healthy ageing, such as general health status including mortality [84], self-rated health [36, 37, 44, 48, 55, 57, 61, 64, 68, 75, 80], subjective feelings regarding successful ageing [49, 50, 52, 56], security including socioeconomic security [57, 60, 64, 70, 78] and environmental security [60, 77], and health behaviours including smoking, drinking and/or medication intake [36, 70, 77]. Questions about self-rated health or subjective feelings about successful ageing can only provide supplementary information about healthy ageing, as they cannot capture specific characteristics. In relation to security and health behaviours, many studies mainly recognise these as social determinants of healthy ageing, rather than as components of it. For example, one study indicates that people with higher educational attainment are more likely to achieve healthy ageing [77]. Another study suggests that participants with lower incomes will attain lower healthy ageing scores [82]. Consuming more fibre-rich food or following nutritional intake guidelines has also proven to be beneficial for healthy ageing [33, 35, 73, 78].

Therefore, physical capabilities, cognitive function, metabolic and physiological health, psychological well-being and social well-being are important domains which have been frequently employed in the literature to assess healthy ageing.

Measurements of Healthy Ageing

Table 1-2 presents the measurements used by the reviewed studies in each domain of healthy ageing. Table A 1 in the appendices briefly introduces all the established scales in this review.

Table 1-2 Measurements used by the reviewed studies in each domain of healthy ageing

Dimensions	Methods	Studies
Physical capabilities	Basic/Instrumental Activities of Daily Livings	[31, 33, 34, 36, 38, 44-46, 48, 52, 54, 56, 57, 59-61, 64, 65, 67, 68, 70, 71, 74, 76, 80, 81, 100]
	Grip strength	[44, 62, 70]
	Walking speed	[44, 59, 64]
	Balance tests	[64]
	Chair rise tests	[44, 64]
	Other functional limitations	[31, 34, 36, 45-47, 67, 75, 101]
	Physical activity	[77, 78]
	Disability	[62, 77]
Cognitive functions	Mini Mental State Examination	[33, 34, 36, 44, 48, 52-54, 56, 57, 61, 67, 68, 70, 71, 75, 76, 81, 100]
	Alice Heim 4 Test of General Intelligence	[62]
	Wechsler Adult Intelligence Scale-Revised	[80]
	Montreal Cognitive Assessment Scale	[64]
	Modified Telephone Interview for Cognitive Status	[31, 50]
	Subjective Cognitive Failures Questionnaire	[50]
	Canadian Community Health Survey-Healthy Ageing Cognition Module	[65]
	Japanese cognitive impairment standards	[84]
	Processing speed	[45, 46, 80]
	Short-term memory	[45-48, 77]
	Working memory	[33, 59, 77]
	Verbal fluency	[33, 59, 77]
	Orientation to time	[45, 46]
	Self-reported memory	[38]
Metabolic and Physiological health	Self-reported absence of chronic diseases	[31, 34-36, 38, 45-47, 59, 60, 62, 64, 65, 67, 71, 74, 76, 77, 80, 81, 101]
	Systolic blood pressure	[53, 59]
	Self-reported hypertension	[35, 46]
	Cardiovascular risk assessment	[78]
	Lung function	Forced expiratory volume [53, 59] Peak expiratory flow [70]
	Glucose metabolism	[53]
	Biomarkers	[53]
	BMI	[46, 78]

Dimensions	Methods	Studies
	Body pain	[49, 76]
	Self-rated vision and audition	[70]
	Sleeping problems	[70]
Psychological well-being	Centre for Epidemiological Studies-Depression Scale	[31, 33, 45, 47, 51, 64, 75, 76]
	Geriatric Depressive Screening Scale	[57, 67, 68, 71, 78]
	9-item Patient Health Questionnaire	[50]
	WHO Composite International Diagnostic Interview	[77]
	Hospital Anxiety and Depression Scale	[38]
	Life Satisfaction Inventory	[51, 68, 70, 80]
	Satisfaction with Life Scale	[71]
	WHO Quality of Life	Brief version [60] 100-item version [70, 72]
	Flanagan Quality of Life Scale	[72]
	General Health Questionnaire	[60, 70]
	Kessler Psychological Distress Scale	[74]
	Connor-Davidson Resilience Scale	[50]
	University of California Loneliness Scale	[80]
	Tenacious Goal Pursuit and Flexible Goal Adjustment Scales	[80]
	Environmental Mastery Scale	[80]
	Positive and Negative Affect Schedule	[80]
	Life Orientation Test-Revised	[50, 70]
	Purpose in Life Test	[51]
	Overall life satisfaction	[56, 75]
	Self-rated quality of life	[77]
	Personality, extroversion, openness, happiness and loneliness	[70]
	Maintenance of interest and absence of loneliness and optimism	[61]
	Control and coping	[77]
	Self-rated mood status	[54]
Social well-being	Participation in social activities or meetings	[31, 34, 38, 44, 47, 52, 57, 60, 62, 68, 71, 75, 80]
	Social networks of family, friends and neighbours	[34, 44, 45, 47, 62, 67, 71, 75, 77, 78]
	Emotional support	Have family or friends to confide in [57, 76] Being helped/supported in life [60]

Dimensions	Methods	Studies
	Instrumental support	[60]
	Marital status	[45, 47, 62, 67]
	Paid work status	[34, 38, 45, 47, 64, 65, 67]
	Subjective autonomy	[80]
	Lubben Social Network Scale	[70]
	Classic Circle-diagram	[80]
	De Jong-Gierveld Loneliness Scale	[75]
	Oslo 3 Support Scale	[77]
General health status	Self-rated health	[36, 37, 44, 48, 55, 57, 61, 64, 68, 75, 80]
	Subjective feeling regarding successful ageing	[49, 50, 52, 56]
	Mortality	[84]
Security	Socioeconomic security	Income or financial status [57, 60, 64, 70, 78]
		Educational attainment [70, 78]
	Environmental safety	Feel safe [77]
		Rate facilities and problems [60]
Health behaviours	Smoking, drinking and (or) medication intake	[36, 70, 77]
	The Mediterranean Diet Score	[78]
Short Form Survey and health indices	Health indices	[32, 51, 56, 63, 66, 69, 82, 83, 85]
	Short Form-36 Health Survey (SF-36)	[33, 44, 50, 58, 73, 74]

Physical Capabilities

Activities of Daily Livings (ADLs) and Instrumental Activities of Daily Livings (IADLs) are frequently used instruments to measure physical capabilities [31, 33, 34, 36, 38, 44-46, 48, 52, 54, 56, 57, 59-61, 64, 65, 67, 68, 70, 71, 74, 76, 80, 81, 100]. One community-based study endorsed the application of (I)ADLs, saying that they can describe a broader range of needs among the elderly [102]. Another community-based study also recognised IADLs as a good discriminator of physical incapacities, but expressed concern that items such as food preparation, housekeeping and laundry were highly relevant to women, resulting in reporting bias among men [103].

Grip strength [44, 62, 70], walking speed [44, 59, 64], balance tests [64], chair-rise tests [44, 64] and other functional limitation tests (e.g. mobility, large-muscle or fine motor skills) [31, 34, 36, 45-47, 67, 75, 101] were also applied to measure physical capabilities. A hospital-based study preferred to use these direct observations of performance, as patients consistently overrated their own abilities in (I)ADLs [104].

Studies also employed physical activity [77, 78] and disability [62, 77] to measure physical capabilities. Physical activity is difficult to measure accurately, as it comprises work, transport and entertainment activities. More importantly, when asking participants about physical activities, researchers sometimes used terms such as "exercise" or "fitness" rather than "activity", but these terms are not interchangeable [105]. For the absence of disability, established scales including the WHO Disability Assessment Schedule version II and the Office of Population Censuses and Surveys Disability Scales were applied [62, 77]. But neither of these measures physical disabilities alone: the two scales both measure disability in other respects, such as cognitive disability, or disability in self-care activities or getting along with others [106].

Therefore, ADLs and IADLs are recommended for community-based studies to predict physical capabilities. Also, it is better to include direct observations of performance to improve predictability, especially when measuring physical capabilities among men.

Cognitive Functions

The Mini-Mental State Examination (MMSE) scale was frequently applied to measure cognitive functions in previous studies [33, 34, 36, 44, 48, 52-54, 56, 57, 61, 67, 68, 70, 71, 75, 76, 81, 100]. It is valid for identifying severe cognitive impairment, but it is not influential to mild cognitive impairment, and it should not be used as a diagnostic tool to identify early signs of dementia [107, 108]. One potential reason for this is that the tests of memory and executive functions in the MMSE are quite limited. The MMSE has no recognition paradigms, vision, personal or working memory measures, and no tests of the capacity to abstract or judge social situations [108]. Researchers compared the MMSE with the Montreal Cognitive Assessment Scale (MoCA), indicating that MoCA has more reliable psychometric properties to detect mild cognitive impairment or dementia [109]. Researchers have suggested using the MMSE along with other measures to enhance the validity of cognitive function evaluations [108]. For example, the MMSE could be applied together with tests of short-term memory (immediate or delayed word recall), working memory (digital spanning forwards and backwards), verbal fluency (an animal-naming task) or orientation to time (specifying month, date, year, day of week or season). Previous studies have used the MMSE along with tests of short-term memory [48] or verbal fluency and working memory [33], which might provide more detailed information about participants' cognitive functions.

Metabolic and Physical Health

In the domain of metabolic and physical health, many articles asked questions about the self-reported absence of diseases [31, 34-36, 38, 45-47, 59, 60, 62, 64, 65, 67, 71, 74, 76, 77, 80, 81, 101]. However, little previous research has discussed the validity of these questions. One study suggested that men were more likely to over-report stroke but under-report malignancies; women tended to over-report malignancies and arthritis; and older age was associated with both over- and under-reporting of cardiac diseases, over-reporting of stroke and under-reporting of arthritis [110]. Apart from asking questions about the absence of diseases, one study also added tests for systolic blood pressure, forced expiratory volume (l/m^2), fasting glucose, C-reactive protein and creatinine to provide more objective results [59]. Two studies used body mass index (BMI) as a surrogate measure of body fat [46, 78]. However, researchers argued that ageing is accompanied by a progressive increase in the ratio between fat and lean body mass, and BMI fails to detect the "conversion" of lean to fat tissue [111]. Only two studies measured body pain [49, 76], sleeping problems [70] and/or self-reported vision and audition [70], although these are important indicators of frailty for the ageing population [112]. In summary, I cannot deny that the self-reported absence of chronic diseases might involve reporting bias, but it has frequently been used in many previous studies. Objective tests for cardiovascular and lung function, glucose metabolism, sleeping problems, vision, audition and body pain are able to provide more accurate information on individuals' metabolic and physical health.

Psychological Well-being

Various psychological scales have been applied to measure psychological well-being in the literature (Table 1-2). The validity of psychological scales has been confirmed in previous studies. For example, the Centre for Epidemiological Studies Depression Scale (CES-D) is capable of distinguishing the severity of depressive symptoms and providing valid information for psychiatric treatment [113]. The Geriatric Depressive Screening Scale (GDS) is internally consistent with the Hamilton Rating Scale for Depression or the Zung Self-Rating Depression Scale, and is significantly correlated with the Research Diagnostic Criteria for depression [114]. The Satisfaction with Life Scale (SWLS) is moderately to highly correlated with subjective well-being, and is suitable for different age groups [115]. However, different studies have used different terminology to specify what they measure, even on the same scales, and items are used interchangeably across studies – for example, "depression" and "depressive symptoms", "distress" and "disorder", or "emotional", "psychological" and "mental" well-being. None of the screening scales reflects a specified conceptual domain. Researchers fail to explain conceptually what they are attempting to measure. Therefore, it is difficult to conduct comparisons across studies. When researchers are choosing scales to measure psychological well-being, it is necessary to clearly distinguish among the concepts behind the measurements, rather than only focusing on the validity and reliability of the scales.

Social Well-being

Measurements of social well-being are fuzzy, and there are no clear boundaries between them. Norms and expectations of social well-being vary across different cultures and social classes. The commonest way to avoid these issues is to focus on measuring specific social roles. There is agreement on several social behaviours, such as being involved in the community or paid employment, doing housework, being a parent or spouse, or having leisure activities [116]. Many studies measured these social behaviours by asking questions about the frequency of engaging in social activities or meetings [31, 34, 38, 44, 47, 52, 57, 60, 62, 68, 71, 75, 80], helping others [60], paid work status [34, 38, 45, 47, 64, 65, 67] and marital status [45, 47, 62, 67]. Recent research also emphasises the importance of participating in creative activities for healthy ageing, suggesting that developing a long-term and substantial interest in a hobby, with the goal of attaining skills, may improve older people's adaptation to later life [117].

Health Indices and the Short Form Health Survey

Health indices have been developed and applied to measure healthy ageing [32, 51, 56, 63, 66, 69, 82, 83, 85]. They are designed to summarise different aspects of health in an overall score, with the aim of developing health metrics to assess healthy ageing comprehensively. The Short Form Health Survey (SF-36) is also used in several studies [33, 44, 50, 58, 73, 74]. Rather than dichotomising healthy and unhealthy ageing, health indices and the SF-36 determine healthy ageing on the basis of a continuous rating, which mostly avoids the risk of only recognising participants with no incapacity as healthy agers. However, all the studies calculated the final score simply by summing each indicator score, potentially resulting in inaccurate assessments of participants' health, since a participant's severe illness in one domain will be neglected if the person gets an intermediate sum score due to better health in other domains. Some researchers hold a similar opinion, stating that respondents can attain an intermediate score in many ways, which does not provide interpretable information on health [118]. However, it is rare for epidemiologists to consider how to calculate the parameters of each health indicator. Therefore, the evaluation of validity and reliability becomes important for demonstrating whether scores on a scale actually represent the individual characteristics that they are supposed to measure, especially when the scale is to measure intelligence, depression or cognitive function [119]. Researchers usually collect data or use secondary data to assess the validity and reliability of their measurements.

Reliability refers to the consistency of a measurement, and includes test-retest reliability (over time), internal consistency (across items) and inter-rater reliability (across different observers) [119]. Test-retest reliability is used to assess the consistency of scores over time. The assumption is that for each respondent, his/her scores on a measurement over time will be highly correlated. Internal consistency is used to evaluate the consistency of a respondent's responses across items on a multiple-item measure. Researchers need to identify whether different indicators to construct an individual's health score are correlated with each other. Inter-rater reliability is used to check the consistency of different observers' judgements when measuring a performance in the same study sample.

Validity is the extent to which the scores on a measure represent the construct intended. This includes face validity, content validity, criterion validity and construct validity [120]. Face validity checks whether a measurement includes the items it is purported to measure. For example, a self-esteem questionnaire should have a question about whether the individual sees him or herself as a person of worth. Face validity is usually assessed informally, as it depends on researchers' subjective expectations. Content validity refers to comprehensiveness, assessing whether the questions selected for a questionnaire cover the theme conceptually. It is difficult to assess quantitatively. Criterion validity indicates whether scores on a measurement agree with a definitive or "gold standard" measurement of the same construct. It consists of concurrent validity and predictive validity, depending on whether the criterion refers to a current or future state. Concurrent validity can be evaluated by comparing a measure with other similar measures – for example, comparing results from a questionnaire on self-reported physical capabilities with the results of physical performance tests. Predictive validity tests the association between scores on a measure and subsequent patient outcomes, such as mortality or discharge, in a prospective study. Many researchers have applied the criterion validity to check their measurements' diagnostic capabilities. For example, a study among Chinese community-dwelling older adults assessed the criterion validity of the Chinese Tilburg Frailty Indicator by measuring the frailty index and phenotypic classification of frailty as criteria [121]. Another study in Germany compared scores between short and long forms of the revised Mini Nutritional Assessment in relation to mortality and functional change, to evaluate the predictive validity of the short form [122]. Construct validity checks whether a measurement measures the construct (such as pain, quality of life or happiness) it claims to be measuring. Construct validity cannot be proved definitively, as gold standards do not exist for these measurements to rely on. Factor analyses have frequently been used to evaluate the construct validity of scales. For example, one study assessed the construct validity of the CES-D score in patients with systemic sclerosis by using confirmatory factor analysis, demonstrating that the four-factor model of the CES-D fitted the study sample better than the alternative models [123].

In summary, psychosocial components are as important as biological components in healthy ageing. Also, researchers need to think about whether a “disease-free” ageing status is achievable in their samples, to avoid selection bias when identifying healthy agers. Physical capabilities, cognitive function, metabolic and physiological health, psychological well-being and social well-being are more frequently used domains than others. ADLs and IADLs are recommended for community-based studies to predict physical capabilities. It is also better to test direct observations of performance, such as grip strength, walking speed, balance and the chair-rise test, to improve predictability, especially when measuring physical capabilities among men. The MMSE is not the most appropriate scale to evaluate cognitive function, but it can provide a brief cognitive screening test, and it has been used in this way in a number of population-based studies. Its application along with other cognitive tests, especially in memory and executive functions, is recommended. Self-reported absence of chronic diseases may result in reporting bias, but it has been used in many studies. It is better to have objective tests for cardiovascular and lung functions, glucose metabolism, sleeping problems, vision, audition and body pain. However, BMI may not be an appropriate indicator of body composition for the ageing population. When one is choosing scales to measure psychological well-being, rather than only focusing on the validity and reliability of scales, it is more important to clearly distinguish the concepts behind the measurements. Measurements of social well-being are fuzzy, but measurements of specific social roles are common in previous research. When developing health indices or applying the SF-36 to measure healthy ageing, it is recommended that one should consider the parameters of each health indicator, since different indicators may play different roles for individuals in promoting healthy ageing. However, studies about calculating the parameters of health indicators are scarce. The validity and reliability of health indices should be checked.

1.3.3 Determinants of Healthy Ageing

The WHO Active Ageing Policy Framework proposes culture and gender as two “cross-cutting” determinants of healthy ageing [21].

Culture determines how a given society views older people and the ageing process. The diversity of cultures contributes to differences in the perception of healthy ageing within and across countries. For example, a comparative study investigated cultural perspectives on ageing and well-being in the US and Japan, indicating that older

Japanese people had stronger perceptions of personal growth and interpersonal well-being than older Americans, due to the age-supportive culture in Japan [124]. Another comparative study in the US and UK suggested that older Americans had a greater sense of personal control than the British, which operates as a psychological resource to reduce medium or mild levels of disability among older Americans [125].

Gender differences in health perceptions and behaviours and in physiological health have been observed in many studies. For example, the comparative study in the US and Japan also found that women in both countries showed higher interpersonal well-being but lower hedonic well-being [124]. A systematic review of the clustering of health behaviours found that males were more likely to have riskier patterns of behaviour including smoking, poor nutrition, excess alcohol consumption and physical inactivity [126]. Another study in Germany suggested that compared with males, female participants had a higher percentage of body fat. Obesity-triggered inflammation may therefore have a greater impact on the development of insulin resistance and type 2 diabetes in females; C-reactive protein has a stronger positive association with the incidence of type 2 diabetes among females [127].

Apart from culture and gender, the WHO also considers other determinants in cultural, economic, ethnic and clinical settings.

First, personal determinants such as age, race and marital status have an impact on healthy ageing [21]. For example, from 1990 to 2005, the rates of all-cause mortality were continuously higher among the non-Hispanic black population in the US compared with the non-Hispanic white population [128]. In terms of marital status, previous studies suggest a positive association between being married or cohabiting and healthy ageing [54, 77]. Additionally, it is well known that younger adults tend to be healthier than older adults [77].

Second, health and social service-related determinants, such as health promotion, disease prevention and long-term care services, can affect the achievement of healthy ageing [21]. For example, to maintain and promote healthy ageing, it is necessary for older people to have regular medical check-ups to attain advice and treatment [129]. A study in the US suggested that moving towards universal health coverage might reduce disparities in hypertension management, which would benefit the American ageing population’s health as a whole [130].

Third, behavioural determinants of healthy ageing are also emphasised by the WHO [21]. Many studies have proved that lifestyle behaviours such as smoking, drinking, physical activity, sleep duration and nutritional intake determine healthy ageing [54, 68, 73, 74, 131]. For example, one systematic review suggested that more physical activities and non-smoking could delay the onset of disability in later life among men; conducting physical exercise could help prevent cognitive decline among older men and women; and unhealthy dietary intake was significantly associated with an increased risk of coronary heart disease [131]. Another study found that sleeping seven to eight hours per day was positively associated with healthy ageing [54].

Moreover, physical environmental factors are also regarded as important determinants of healthy ageing [21]. In the literature review, physical environmental determinants such as housing, neighbourhood environment, clean water/air and safe food were closely related to healthy ageing [68, 132]. For instance, a study in the UK found that a perception of good-quality local facilities (e.g. social/leisure facilities for older people, rubbish collection, health services, transport, proximity to shops or somewhere nice to walk) and high levels of neighbourliness (e.g. knowing or trusting people) was strongly associated with good health and functioning, whereas a perception of problems in the area (noise, crime, air quality, rubbish/litter, traffic, graffiti) contributed to worse health [132].

Finally, socioeconomic determinants of healthy ageing are also emphasised by the WHO [21]. Sufficient evidence has demonstrated close associations between socioeconomic factors such as income, occupation or education and healthy ageing [54, 77, 84]. People with higher educational attainments, incomes and occupational positions are more likely to achieve healthy ageing [54, 77, 84].

Researchers hold the opinion that socioeconomic factors are the most distal social determinants of individuals' health, which affect human health and well-being through biological, psychosocial, behavioural and lifecourse pathways [133, 134]. Focusing on socioeconomic determinants of health enables researchers to explore numerous exposures, resources and susceptibilities that may affect health [135].

1.4 Socioeconomic Position

Socioeconomic position (SEP) is defined as "the social and economic factors that influence what positions individuals or groups hold within the structure of a society"

[135]. Another term, “socioeconomic status” (SES), is also widely used and defined as “the relative position of a family or individual on a hierarchical social structure, based on their access to or control over wealth, prestige and power” [136]. SES centrally involves the idea of a ranking from “top to bottom” in the social hierarchy. Bartley suggested that the measurement of social position should include both social status and social class, treating social status as one dimension of social position [137]. Therefore, the term “SEP” seems to be more inclusive, as it covers the concepts of social class, social status and material conditions (such as income and ownership of assets). I will first discuss the concepts of social class, social status and material conditions, and then I will summarise the socioeconomic indicators that have been employed in epidemiological studies.

1.4.1 Social Class

There is debate over the classification of social class. The first prominent theories came from Marx and Weber. They divide occupations into groups according to typical employment relations: owners (who own assets such as factories or firms) and workers (who provide labour for owners, managers or supervisors) [138]. However, Lynch and Kaplan give more detail on the distinction between Marx and Weber: Marx focused on how social relations under capitalism entail exploitation and conflict between owners and workers, while Weber emphasised that the capitalist means of production generate different sets of skills, knowledge and assets that determine an individual’s “life chances” such as occupation, education and income [139]. The Functionalist approach to social stratification was also developed largely on the basis of Weber’s perspective. This approach indicates that a bureaucratically managed capitalist system is the primary driving force behind stratification into social class; the values, motivations and aspirations of individuals in society are secondary determinants of that stratification [139].

Another theory is Wright’s three principles for the classification of social class, which is also an attempt to conceptualise a Marxist theory of social class: the ownership of property “organisational assets” (e.g. managers can access great benefit from the labour of the workers they supervise) and “credentialed skill” (e.g. those without any property assets can offer skills and qualifications in exchange for a position where they will have a high level of “organisational assets”) [140].

Finally, Erikson and Goldthorpe distinguish two basic forms of employment contract: the “service contract” for managerial and professional workers, who have more job security, more salary increments and a progressive career; and the “labour contract” for those who are supervised and who have little autonomy, lower job security and lower salary increments [141]. The Erikson-Goldthorpe (E-G) Schema resembles Weber’s theory, proposing that many occupations have mixed conditions (e.g. job security, salary increments); thus, when one is allocating these occupations into different classes, decisions must be made regarding which occupations most closely resemble each other. Later on, another scheme was developed known as the National Statistics Socio-Economic Classification (NS-SEC), based on the principle of the E-G schema; it has been frequently applied in many studies [137].

1.4.2 Social Status

Social status is the rank of an individual in society, which centrally involves the idea of hierarchy [137]. In the US, education has been widely used as a measure of social status, since it is a way of raising a person’s rank in society [137, 142]. A highly educated professor can be regarded as having higher social status than a manager [137]. Hollingshead summarised four indices for measuring social status: education, occupation, gender and marital status [142]. Bartley suggested using separate measures in one study, which can ensure, for example, that one examines different health conditions among people with the same educational attainments but different levels of income [137]. In the UK in the 1970s, Stewart and colleagues designed the Cambridge Scale. Unlike the measures used in the US, this scale measured class structure by observing the ways in which people clustered, on the assumption that people who clustered together would regard each other as having equal standing in society [143]. The most commonly used measure of social position in UK research on health inequalities is the Registrar-General’s Social Class Scheme (RGSC), which has six categories: professional, managerial, skilled non-manual, skilled manual, semi-skilled manual and unskilled manual [144]. Unlike the NS-SEC, the RGSC is usually regarded as a hierarchy to predict social status [137].

1.4.3 Material Conditions

The impacts of material assets on health have been generally understood since the 19th century in industrial society: the provision of clean water, shelter, adequate calories and waste removal was an important factor in socioeconomic differences in life expectancy during that time [139]. Research and policies focused on changing the material conditions associated with poverty [139]. However, in the late 20th century, new material conditions – such as car or property ownership, having a home with a garden, or eating healthy food – were considered to be part of the context of increasing life expectancy and improving general health. Material conditions are related to individual health behaviours, psychological states and social circumstances [145].

Individual income directly relates to material conditions. An adequate income provides a better quality of goods, skills and even labour (of others), which all positively influence individuals' health conditions; conversely, poverty negatively affects both parents and children by bringing hardship and stress, as well as social isolation and exclusion [146]. For the ageing population, sufficient income can also buffer the negative impacts of stressful life events: after the death of a spouse, the mortality rate is lower among persons with higher incomes [147].

Wealth and material assets, such as land or buildings, investments in stocks and bonds, pensions and others, are also used as measures of material conditions [139]. These are deemed sensitive predictors of SEP among the ageing population, as older adults gradually withdraw from the labour market and have already accumulated relative long-term wealth and materials, especially after the age of 65 [139].

1.4.4 Socioeconomic Indicators in Epidemiological Studies

A variety of socioeconomic measures have been used in epidemiological studies. The choice of appropriate socioeconomic indicators depends on the timing in individuals' lifecourses and the participants' demographic characteristics, economic backgrounds and regional customs/culture. I have summarised the socioeconomic indicators used in previous publications yielded by longitudinal studies of ageing in the US, England, China and Japan. Table 1-3 presents a summary of socioeconomic indicators in the four countries. This PhD thesis also conducts data analyses based on these four longitudinal studies of ageing (see Chapter 2 for a detailed introduction to the four studies).

Table 1-3 A summary of socioeconomic indicators in the four countries

Studies	Indicators	Measures
US - Health and Retirement Study	Total household wealth [130, 148-150]	The net value of all assets (savings, net stock value, mutual funds, bonds, real estate value, own business share, owned cars minus liabilities) minus the net value of all debts for the respondent and his or her spouse/partner and divided into quartiles or tertiles
	Education [130, 149-154]	Education in years: 0–12, 13–15 and ≥16 years
	Annual household income [130, 149, 150, 153, 154]	A sum across all sources of income (e.g. employment income, pensions, social security, stocks and others) and divided by a weighted number of persons living in the household
	Life course cumulative SES [153]	A childhood SES index was imputed by calculating the average of standardized parents' education, father's occupation, and family financial well-being; then it was dichotomized at the median; together with the dichotomized respondent's education and household income, a combination of them was divided into four categories-low position on all three measures, low position on two measures (high on one), low position on one measure (high on two) and high position on all three measures
	Childhood SEP: parental education [152, 153]	Less than high school (<9 years), high school (9-12 years) and college or higher (≥13 years); Single question "whether your parents had ≥8 years of education or not?"
	Childhood SEP: father's occupation [151]	Professional (manager or administrator; reference category), craftsman, farmer or farm manager, clerical or sales worker, operative (e.g. machine or transport worker), and service worker or labourer
	Childhood SEP: subjective childhood SEP [150]	A self-report of overall childhood socioeconomic status (e.g. 'pretty well off', 'average or varied', and 'poor')
England - English Longitudinal Study of Ageing	Total net non-pension household wealth [155-160]	The value of financial, physical and housing wealth owned by the household (houses, businesses, any other physical assets, and all forms of savings and investments) minus debt

	Total household income [158, 160, 161]	The total weekly income of the participants and their partners adjusted for household size, and transformed into quintiles or tertiles
	Occupational class [158-163]	UK National Statistics Socioeconomic Classification (NS-SEC)
	Education [154, 161, 162]	A level or higher degree, secondary and no qualification; Total years of full-time education: a level lower than “O-level” or equivalent (typically 0-11 years of schooling), qualified to a level lower than “A-level” or equivalent (typically 12-13 years of schooling), and a higher qualification (typically >13 years of schooling)
	Index of multiple deprivation score [160, 161]	Assessing financial strains and lack of local resources, ranges from 0 to 9
	Subjective social status [158, 160]	Asking participants to place themselves on a ladder with 10 rungs that represented the societal hierarchy from bottom to top
	Childhood SEP: father’s education [158]	Single question: “What was your father’s (or main carer’s) main occupation when you were 14?”
China - China Health and Retirement Longitudinal Study	Education [164-166]	Illiterate, less than primary but can read and write, primary school, and junior high or more; Little or no schooling, some primary school, junior high school or greater; Illiterate, some schooling up to elementary, and junior high or more
	Income [166-168]	Annual household spending categorised into three levels: low (household spending of <¥1000/year), moderate (¥1000–¥5000) and high (¥5000 or more); Annual household spending categorised into four quartiles; Log of household per capita expenditure (log pce)
	Wealth [165]	Household luxury items, which were indicated by a count of 17 items (e.g. refrigerator, washing machine, and TV) that the household owned; Housing quality was measured by an index that summed quality of seven types of amenities (toilet, electricity, running water, shower/bath facility, fuel, phone, and internet connection)
	Pension benefit [164]	Income from public and private pension programmes, and was classified into four categories: no pensions, and low, medium & high benefits

	Household asset and infrastructure deficiency [164]	An index derived from principal components analysis of dozens of asset or infrastructure variables. For example the infrastructure deficiency included nine indicators in four areas: connectedness, sewer, waste management and electricity
	Support from children [165]	Receiving financial support from children: divided the total amount received in the previous year into tertiles, labelled as low, medium, and high levels of support
	Health insurance [165]	Yes vs. No health insurance
Japan - Japanese Study of Aging and Retirement	Household income [169-171]	Annual net household income adjusted for household size to predict income; Net annual income, including the earnings, pension income and private transfer at individual level; Rents and housing benefits received; Business income at household level
	Wealth and portfolio composition [169-171]	Financial assets (sum of deposits, bonds and stocks minus non-mortgage liabilities); Real assets (homeownership, value of housing and land minus the current amount of mortgage loans)
	Consumption [170]	Four items such as food consumption at home, eating out, total amount of expenditure on nondurable goods and service in a usual month during past one year, as well as durable goods purchased in the past one year
	Educational attainment [170]	Elementary (6 years) or junior high school (3 years), senior high school (3 years), 2-year college, special training school, university, graduate school (master's degree) and graduate school (doctorate)

Generally, in the four countries, wealth [130, 148-150, 155-160, 165, 169-171], income [130, 149, 150, 153, 154, 158, 160, 161, 166-171] and education [130, 149-154, 161, 162, 164-166, 170] are frequently used as important indicators of SEP among the ageing population. Father's occupation [151, 158] and parental education [152, 153] are used as main measures to assess SEP in childhood in many publications on the four countries. In a few publications, multiple socioeconomic indicators are included.

Among the American ageing population, education [130, 149-154], annual household income [130, 149, 150, 153, 154] and total household wealth [130, 148-150] are the top three most popular measures of SEP. However, researchers have suggested that compared with education and income, wealth is the strongest predictor of mortality risk among the ageing population in the US [149]. A potential reason is that in the US, wealth brings both a feeling of security and also objective security against sudden major health costs, which goes beyond income level [149]. However, education is more frequently used than wealth among the ageing population. Education is regarded as a key mechanism involved in raising a person's status in the US [137, 142]. Educational inequality in earlier life has a critical bearing on status and well-being in old age, since illiteracy and low education usually produce the exclusion and impoverishment of older people; opportunities for education and lifelong learning are key factors in the social environmental that enhance health, independence and productivity in older age [172].

Among the English ageing population, non-pension wealth [155-160] and occupational position [158-163] are used more frequently than total household income [158, 160, 161] to measure SEP. One study has suggested that the most robust indicator of current SEP among the ageing population in England is total net non-pension household wealth, as this captures financial and other resources in older age the most accurately [173]. The Index of Multiple Deprivation (which assesses financial strains and lack of local resources) [160, 161] and subjective social status [158, 160] are also applied to the ageing population in several publications.

Among the Chinese ageing population, previous publications show no preference regarding the choice of socioeconomic indicators. However, some country-specific indicators are applied to measure SEP, including support from children [165], health insurance [165], pension benefits [164], household assets and infrastructure deficiency [164].

In Japan, home ownership is frequently used among the ageing population [169-171], since Japan is a home ownership-oriented society. Within older populations, economic conditions relating to residential property ownership have become noticeably differentiated, leading to considerable socioeconomic stratification among elderly people in Japan [174]. Additionally, the consumption of food and goods during the previous year [170] is considered in one publication as a country-specific measure of SEP among the ageing Japanese population.

The strengths and limitations of socioeconomic indicators have been discussed in the literature. Wealth is linked to social class more strongly than income, but it is difficult to calculate because of the multiple factors that contribute to its assessment [175]. Income is a sensitive area of enquiry for research, and non-responses on income are a frequent problem [176]. Although occupation is regarded as a major structural link between education and income, it may not be a feasible measure for people who have had weak attachments to the labour market throughout adulthood, or for those who work in an agricultural society [175, 177]. Moreover, education is a less sensitive socioeconomic indicator of health conditions among individuals who live below the poverty threshold, since poor people generally have low levels of educational attainment [178]. In some developing countries, education might not be a sensible socioeconomic indicator among older generations, especially in contexts where most older people are less educated.

Lynch and Kaplan suggest that one’s choice socioeconomic indicators depends on how one believes the association between SEP and health conditions operates: through exploitation, scarcity of tangible resources, a lack of prestige that causes poor health, or some combination of these [139]. Another study suggests that researchers should consider utilising a range of socioeconomic measures when studying health inequalities in later life [160]. Bartley also points out that it is a waste of effort and resources to try to reduce inequalities in a certain disease by giving people more money if it is actually working conditions that are related to that disease [137].

Therefore, it is meaningful for an epidemiological study to use a range of socioeconomic indicators, and to evaluate which of those indicators is the most relevant and influential determinant of health outcomes in a given population. This approach will be more instructive for policymaking, enabling policymakers to make valid decisions about how to resolve socioeconomic inequalities in health outcomes.

1.5 Socioeconomic Inequalities in Healthy Ageing

A literature review in 2010 identified six future areas for the long-term study of ageing, based on 51 longitudinal studies of ageing worldwide; socioeconomic inequality in health and well-being among the ageing population was one of those six areas [179]. During the past decade, research questions regarding socioeconomic inequalities in healthy ageing have been discussed in many articles worldwide. In general, older people with disadvantaged SEPs are less likely to achieve healthy ageing than those with advantaged SEPs in many countries [37, 45, 54, 62, 77, 84].

From a lifecourse perspective, the relationship between SEP and health in later life can be explained by at least three hypotheses: "critical period", "accumulation of risks" and "social mobility". The "critical period" is the only time period during which an exposure can have adverse or protective effects on development and subsequent disease outcomes [180]. A well-known example is the Barker hypothesis, which assumes that adult disease risks are determined *in utero*, with maternal nutrition playing an important role [181]. Disadvantaged social circumstances in early life and poor maternal nutrition during pregnancy contribute to impaired foetal growth and an increased risk of coronary heart disease in later life [181]. The "accumulation of risk" model outlines how "life course exposures or insults gradually accumulate through episodes of illness and injury, adverse environment conditions and health damaging behaviour" [180]. A typical example of the "accumulation of risk" model is a study on the accumulation of factors influencing respiratory illness in members of a national birth cohort and their offspring: the accumulation of clustered risks, including illness, poor social circumstances and atmospheric pollution, contributed to an increased risk of adult respiratory problems; and in the offspring generation, parental smoking, illness and disadvantaged social class became risk factors for early-life chest illness [182]. The "social mobility" hypothesis considers how persons' social structures change during a lifecourse, including intergenerational mobility (having a different SEP from one's parents) and intragenerational mobility (experiencing a change in SEP within one's own lifecourse) [183]. A study from Finland in 1994 indicated that men who went from a low-income childhood to a high-income adulthood had the same mortality risks as those whose SEP was high in both childhood and adulthood; those who were in socioeconomically disadvantaged groups as both children and adults were about twice as likely to die as those whose SEP improved [184].

However, studies have applied different measures of healthy ageing due to the inconsistency in definitions of healthy ageing, since no consensus definition of healthy ageing has been reached in the literature. For example, one US study applying Rowe and Kahn's theory defined healthy ageing as no major diseases or disability, good cognitive and physical functioning, and active engagement in social activities [45]. But another study from Japan included mortality and loss of healthy life to assess healthy ageing [84].

Therefore, even though these studies commonly find a positive relationship between SEP and healthy ageing, it is still difficult to compare the magnitude of socioeconomic inequalities in healthy ageing across countries, since different measures of healthy ageing make the results non-comparable. The magnitude of socioeconomic inequalities in healthy ageing across countries may be different due to variations in political, cultural, economic and epidemiological histories [185]. It is necessary to discover the extent to which such inequalities are modifiable across countries, as this will be instructive for exploring universal and region-specific public health practices to support healthy ageing.

1.6 Pathways Between SEP and Healthy Ageing

SEP as a distal social determinant of health affects human health and well-being through biological, psychosocial, behavioural and lifecourse pathways [133, 134]. For example, sufficient evidence has shown that education can influence health outcomes through different pathways.

First, greater educational attainment contributes to better health by improving health behaviours such as being more physically active and smoking less. For example, a study reported that from 1990 to 2004, binge drinking, smoking and physical inactivity were more prevalent among individuals who were less educated in the US [186]. Another study in China indicated that less-educated older people were more likely to have a moderately or severely unbalanced diet, such as insufficient intake of vegetables, fruit, milk, soybean and water but an over-intake of oil and salt [187].

Second, greater educational attainment increases one's chances of attaining better occupational positions with a higher income, which are related to better health. For example, in the UK in 2014, an individual with no upper secondary education earned 30% less than someone with an upper secondary education [188]. In the US, for young adults with a bachelor’s degree, median earnings were 64% higher than for those with a high-school diploma [189]. The unemployment rate in the US in 2017 was less than 2.5% among people with a bachelor’s degree or above, but more than 6% among those without a high-school diploma [190]. A study in East Asia also showed that a more equal distribution of education contributed to a significant reduction in income inequality, since the income Gini coefficient was positively associated with the education Gini coefficient from 1980 to 2015 [191]. People with higher incomes are more likely to live in better housing and a better neighbourhood environment, and to accumulate wealth more quickly, contributing to better health and well-being [192].

Third, parental education influences children’s health and development during childhood, as well as children’s educational attainment, which can eventually affect children’s health in adulthood and later life. For example, studies in China have reported that higher maternal education is closely related to a lower risk of infant mortality and child disability, since better-educated mothers more actively seek prenatal care and use professional delivery assistance [193, 194]. A study in the UK also suggested that parental education was an important determinant of children’s education, since increasing parental education had a positive effect on children’s preschool assessments and high-stakes examinations at age 16 [195].

In the literature, it is also suggested that different pathways are interrelated. For example, higher incomes enable individuals to obtain healthcare when needed [196] and to maintain positive health behaviours [197], which can promote good health. Higher maternal education is closely associated with financial advantages such as higher household incomes or better housing quality, which are beneficial for children’s health and development during their adulthood [198].

In social and lifecourse epidemiology, covariates on the causal pathways between main exposure and outcome are mediators. These are defined as associated with the main exposure (*a*) and outcome (*c*) respectively, and as being on the causal pathway (*a to b to c*) [199]. With complete mediation, the total effect of the main exposure on the outcome is transmitted through mediators, so the main exposure has no direct effect on the outcome; with partial mediation, the total effect of the main exposure on the outcome is not fully mediated, so there remains a direct effect, while an indirect effect is transmitted though the mediators [200].

Mediation analysis often explores the mechanism between social factors and health outcomes by explaining the mediating effects of proximal determinants (e.g. middle- or later-life socioeconomic, health behavioural and biological factors) on associations between distal determinants (e.g. early-life socioeconomic and environmental factors) and health [201, 202].

However, in the literature, not all studies on the relationships between SEP and health outcomes in later life focus on examining mediating affects. Many studies only adjust for covariates such as other socioeconomic and health behavioural factors as confounders [148, 152, 154, 157, 159, 164, 203]. Unlike a mediator, a confounder is associated with main exposure and outcome respectively, but it is not on the casual pathway [204]. For example, one study examined the relationships between income and education and self-reported prevalence rates of chronic diseases in the US and England, adjusting for health behaviours as confounders [154].

Researchers are of the opinion that it is not always clear whether a variable is a confounder or a mediator; the distinctions drawn between the two might be different across study samples [199]. Factors such as gender, age and ethnicity are potential confounders for the SEP-healthy ageing relationship; but the roles of health behaviours and biomarkers in the relationship between SEP and healthy ageing might not be as straightforward [199]. Some researchers build different models by gradually adding covariates into a model for adjustment. For example, one study applied this approach to testing three multivariate models of the relationship between childhood SEP and risk of stroke in later ages: model 1 was adjusted for age, gender, ethnicity and marital status; model 2 was adjusted for all the covariates in model 1 plus adulthood SEP, to check whether the association between childhood SEP and risk of stroke would change; model 3 adjusted for all the covariates in model 2 plus smoking, BMI and chronic conditions, to examine whether childhood SES was an independent predictor of risk of stroke [152]. This approach is able to check whether the unadjusted main exposure-outcome association is attenuated, which could help to identify potential mediators if this association is evidently attenuated [199].

In summary, pathways between SEP and health outcomes in later age are complex and interrelated. Distinguishing between confounders and mediators might be difficult and different across study samples. Health behaviours and other socioeconomic factors were treated as confounders in the relationship between SEP and health outcomes in many studies. Adjusting for covariates as potential confounders to check whether the unadjusted main exposure-outcome association is attenuated is an applicable way of ascertaining potential mediators for further mediation analysis.

1.7 Cross-Country Comparisons

The literature includes studies that conduct cross-country comparisons in socioeconomic inequalities in healthy ageing. However, each of these is based on a single database, and the regions are restricted to European countries. For example, Perales and colleagues assessed factors associated with healthy ageing in Finland, Poland and Spain, finding that Finnish participants achieved healthy ageing better than Polish and Spanish participants, and that higher education and occupation were commonly associated with higher levels of healthy ageing in the three countries [77]. Sowa and colleagues conducted another comparative study on healthy ageing in Europe, finding an educational gradient in healthy ageing in southern and central-eastern European countries, and an income gradient in healthy ageing among females in western European countries [37]. To my knowledge, no studies in the literature to date have compared socioeconomic inequalities in healthy ageing among countries from different continental regions in the world.

Researchers have suggested that Europe offers excellent opportunities for comparative research, since good data on health inequalities are often available [205]. However, the conduct of comparative research should not be driven by data alone; countries outside Europe with large ageing populations also need to explore strategies to eliminate socioeconomic inequalities in healthy ageing.

Evidence shows that for life expectancy at birth, Japan, the US and China ranked as the top three among countries with populations greater than 100 million in 2017 [206], but the percentages of the working-age population had continuously decreased in all three countries up to that date [207]. Similarly to high-income European countries, labour force ageing in the US and Japan is also likely to be substantial over the next decades. Between 1995 and 2030, the share of workers aged 60 years and older was expected to rise, from 12.5% and 5.8% to 30.1% and 16.1% in Japan and the US respectively; this is similar to or larger than the increase in the average share (from 4.7% to 17.1%) in Organization for Economic Cooperation Development (OECD) Europe [208]. The number of older workers aged 60 years or more is unclear in China, but it too will increase in future decades as the retirement ages for both genders increase [209]. Therefore, as three of the top five economies in the world (the others being the UK and Germany), the US, Japan and China also need a healthy ageing population in order to transform ageing challenges into productivity and to permit older people to contribute to society [21]. Ensuring a successful demographic transition among the world's top economies may be beneficial to the world economy.

Therefore, I aim to conduct a comparison between Europe and other top economic countries with regard to socioeconomic inequalities in healthy ageing. This may be instructive for exploring universal and region-specific public health practices to support healthy ageing worldwide. The WHO also suggests that ageing research needs to be better coordinated across countries, to discover the most cost-effective approaches to maintain older people's health and well-being [210]. Researchers from countries including the US, England, China and Japan are currently conducting nationally representative longitudinal studies of ageing; these are sister ageing studies, and they commonly incorporate measures of health, economic status, family and well-being [170, 173, 211, 212]. Therefore, employing these four studies, which contain nationally representative samples of older people in the four countries, provides a unique opportunity to conduct a multinational comparison of socioeconomic determinants of healthy ageing, on a scale not done before.

1.8 Main Gaps, Aims and Hypotheses

To sum up: healthy ageing has become a popular topic worldwide. So far, a consensus definition of healthy ageing has not been reached. Measurements of healthy ageing are various, within and across countries. Previous studies have indicated that SEP is an important determinant of healthy ageing; people in advantaged SEPs are more likely to achieve healthy ageing than people in disadvantaged SEPs. However, only rare studies have compared the magnitudes of socioeconomic inequalities in healthy ageing across countries. On the one hand, different measures of healthy ageing make results non-comparable. On the other hand, the studies that compare socioeconomic inequalities in healthy ageing across countries are all based on a single database, and the regions in these studies are restricted to European countries.

Therefore, my PhD project aims to develop a common approach to assess people's healthy ageing status comprehensively across countries, and it conducts a cross-country comparison of socioeconomic inequalities in healthy ageing by including countries from different continental regions (the US, England, China and Japan). Specifically, the main objectives of this PhD project are:

1. To create a multidimensional and quantitative measure of healthy ageing at the individual level, and to check the reliability and validity of the measurement of healthy ageing, based on the four longitudinal studies of ageing (Chapters 2 and 3).
2. To evaluate longitudinal relationships between SEP and healthy ageing after 60 years in the US, England, China and Japan, to compare socioeconomic gradients in healthy ageing, and to identify the most influential socioeconomic predictor(s) of healthy ageing within and across countries (Chapter 4).
3. To construct a conceptual framework for pathways from education to healthy ageing, and to identify mediators in the relationship between education and healthy ageing in each country. This is because socioeconomic factors are distal determinants of health that might affect human health and well-being through biological, psychosocial, behavioural and lifecourse pathways (Chapter 5).

Following on from the literature review, I have several hypotheses, as follows:

1. Previous studies worldwide commonly indicate that older people in disadvantaged SEPs are less likely to achieve healthy ageing than those in advantaged SEP in many countries [37, 45, 54, 62, 77, 84]. Therefore, for this project, the first hypothesis is that within each country, participants with lower levels of education, income and wealth, and with disadvantaged occupational positions, have lower healthy ageing index (HAI) scores than those with higher levels of education, income and wealth, and advantaged occupational positions.
2. Another hypothesis is that education is an influential predictor of inequalities in healthy ageing in the US, as it is a key mechanism involved in raising a person's status in the US [137, 142]; but education is not an influential predictor in China, as older Chinese people are generally illiterate or low-educated [178].
3. Across countries, I also hypothesise that low- or middle-income countries such as China have greater socioeconomic inequalities in healthy ageing [213], while countries such as England and Japan, which have been covered by free or low-cost national health services, have lesser socioeconomic inequalities in healthy

ageing [214, 215]. Chinese participants' healthy ageing profiles are worse than those of participants in the US, England and Japan.

4. Regarding the potential mediation of the relationship between education and healthy ageing, according to the literature, education can influence health outcomes through material, psychosocial and behavioural pathways [186-198]. Therefore, the hypothesis is that socioeconomic indicators including occupation, income and wealth, and health behaviours including smoking and drinking, are mediators on the pathway from education to healthy ageing.

This chapter has introduced background knowledge regarding demographic transitions, healthy ageing, SEP and socioeconomic inequalities in healthy ageing, within and across countries. The main gaps, aims and hypotheses have also been outlined. Before I move on to conduct the data analysis to test the hypotheses, achieve the main aims and fill the research gaps, the next chapter will focus on the study design and data manipulation. The overall study design, main exposures and outcomes, missing data, multiple imputation and weighting adjustment will be discussed.

(Note: some of the contents of Section 1.3 Healthy Ageing have been published. Please refer to Wentian Lu, Hynek Pikhart, Amanda Sacker; Domains and Measurements of Healthy Aging in Epidemiological Studies: A Review, *The Gerontologist*, gyn029, https://doi.org/10.1093/geront/gny029.)

Chapter 2 Data

2.1 Overall Study Design

My PhD research uses datasets from four longitudinal studies on ageing, with a combined sample size of 24760 respondents aged 60 years and more at baseline.

The Health and Retirement Study (HRS) is a longitudinal panel study that surveys a representative sample of around 20000 Americans aged 50 years or over at baseline. Mixed interviews (in person and by telephone) have been carried out every two years since 1992. It explores the changes in labour force participation and the health transitions that individuals undergo towards the end of their working lives and in the years that follow. Since 1992, the study has collected information about income, work, assets, pension plans, health insurance, disability, physical health and functioning, cognitive functioning, and healthcare expenditures [211].

The English Longitudinal Study of Ageing (ELSA) began in 2002, recruiting around 12000 participants aged 50 or more, and has revisited the sample every two years since then. ELSA integrates information about the economic, social, psychological, community and health experiences of older people in England. Face-to-face interviews and self-completion assessments are carried out in all waves; nurse visits were undertaken in waves 2 (2004–2005), 4 (2008–2009) and 6 (2012–2013) to collect anthropometric data and test the physical performance of participants aged 50 and over [173].

The China Health and Retirement Longitudinal Study (CHARLS) aims to collect a nationally representative sample of Chinese residents every two years. It started in 2011 and includes around 18000 individuals aged 45 or older at baseline. CHARLS collects data on demographics, family structure and changes, health status and functioning, biomarkers, healthcare and insurance, work, retirement and pensions, income and consumption, assets (individual and household), and information at community level [212].

The Japanese Study of Ageing and Retirement (JSTAR) is a panel survey that recruited around 8000 people aged 50 or older in 2007. Data collected in this survey includes information on the economic, social and health conditions of elderly people. The first investigation was carried out in five cities: Adachi, Kanazawa, Shirakawa, Sendai and

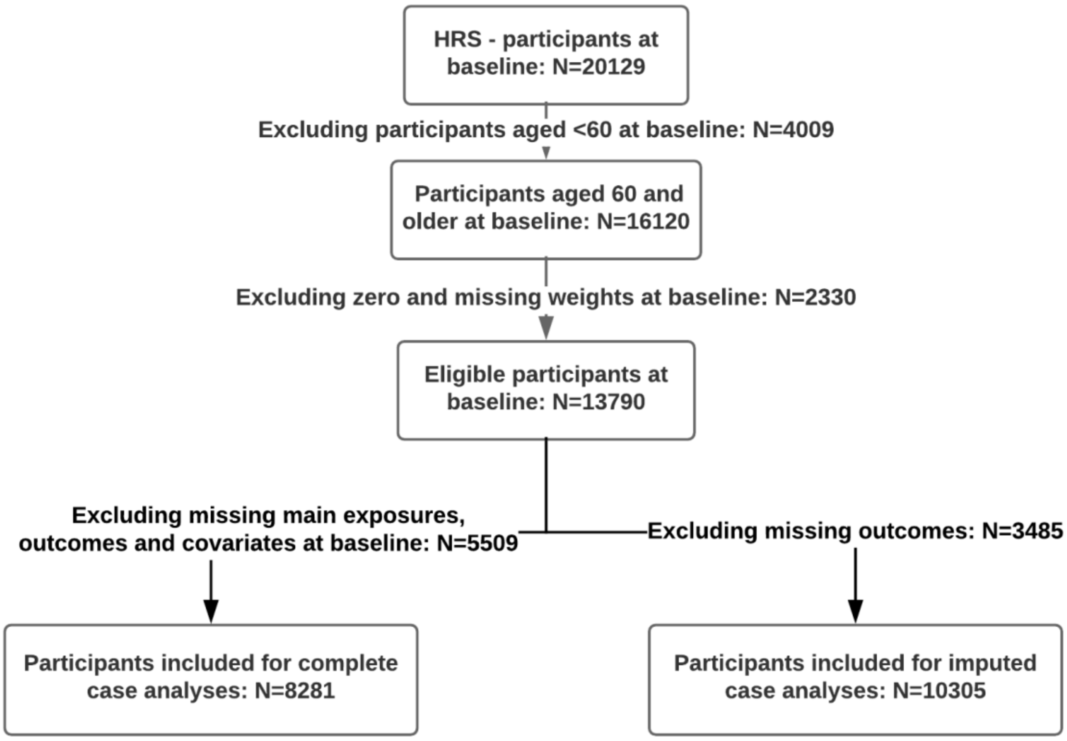
Takikawa. The second wave (2009) added another two cities: Tosu and Naha. The third wave (2011) newly investigated another three cities: Chofu, Tondabayashi and Hiroshima. Only around 3800 respondents in the original five cities (Adachi, Kanazawa, Shirakawa, Sendai and Takikawa) have been followed up for all three waves (2007–2011) [170].

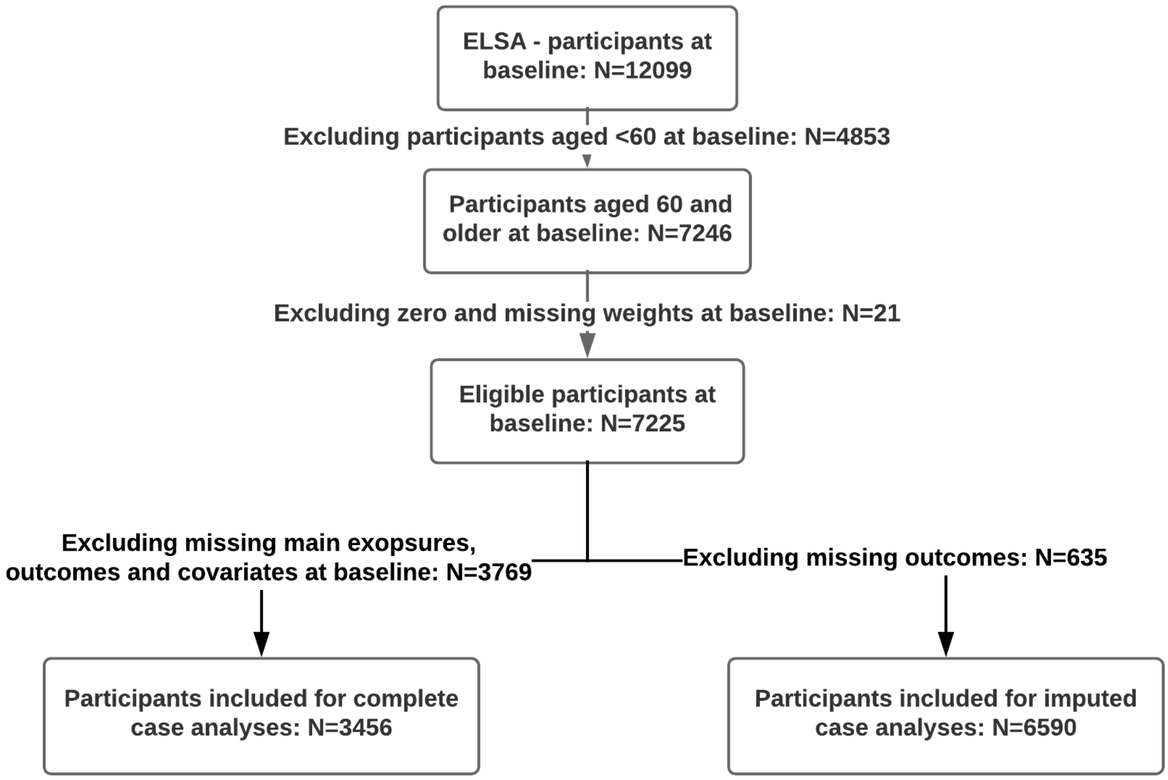
Figure 2-1 shows the sample selection procedure I used for each country. In each country, participants without baseline weights were excluded, since they were booster samples [216-219]. Participants aged less than 60 years at baseline were also excluded, as researchers usually use 60 years and more to refer to the ageing population in the literature [3]. Respondents with zero weights at each wave in the HRS and ELSA were also excluded, as those respondents were non-sample individuals (including core partners, new and younger partners) and came from the unweighted base [220, 221].

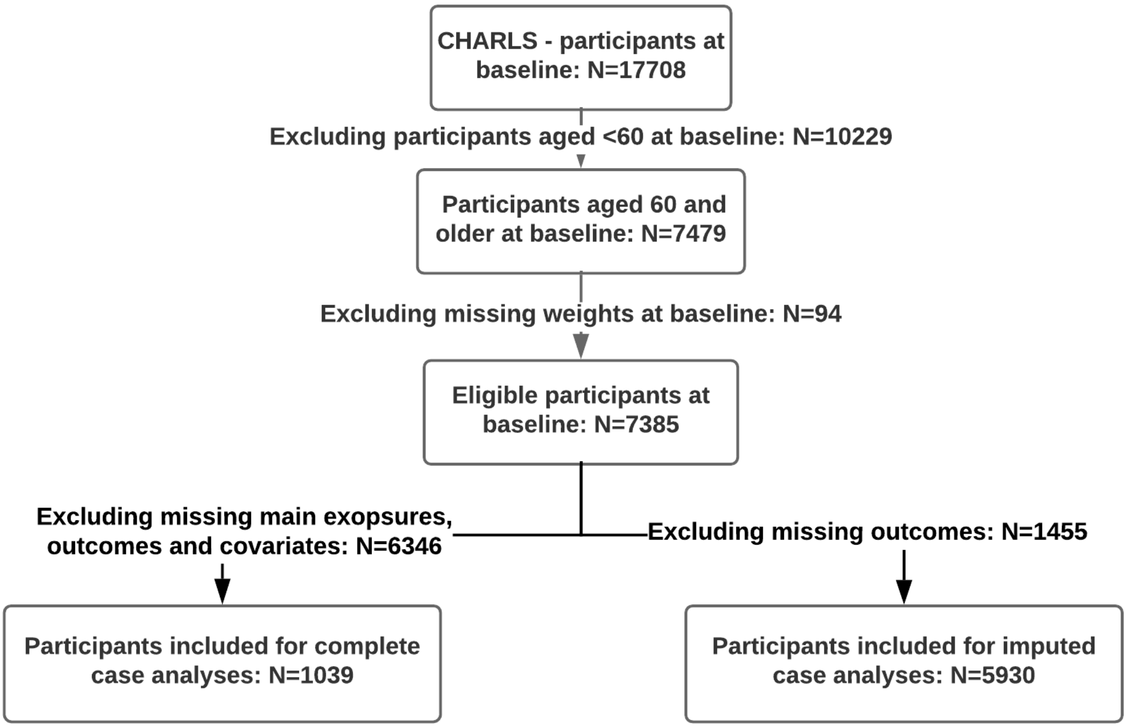
For the HRS, the analysis included data from waves 7–12 (2004–2014). Wave 7 rather than wave 1 of the HRS was used as the baseline wave. The reason is that some variables, such as social well-being-related variables, only started being recorded from 2004 (wave 7) in the HRS. For ELSA, data from waves 1–7 were used. In CHARLS, data from waves 1, 2 and 4 were included. Wave 3 of CHARLS was a life history survey, and is not eligible for the current longitudinal analysis. In JSTAR, only participants from the original five cities from waves 1–3 were included.

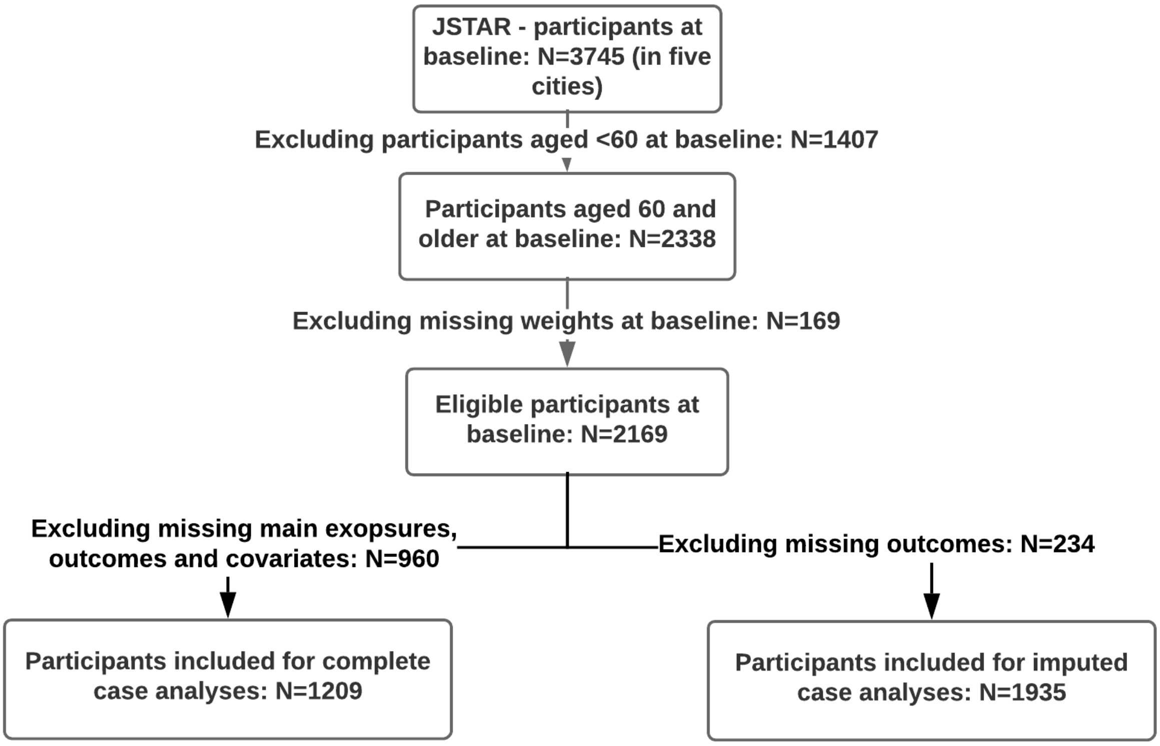
When I conducted the imputed case analyses, records with missing values in outcomes of healthy ageing were excluded. Only missing main exposures and covariates were imputed. When I conducted the complete case analyses, missing values in the main exposures, covariates and outcomes of healthy ageing were all excluded. Ultimately, this research comprised 10305 HRS respondents (waves 7–12, 2004–2014), 6590 ELSA respondents (waves 1–7, 2002–2015), 5930 CHARLS respondents (waves 1, 2 and 4, 2011–2015) and 1935 JSTAR respondents (waves 1–3, 2007–2011) at baseline for the imputed case analyses. For the complete case analyses, there were 8281, 3456, 1039 and 1209 respondents left at baseline in the HRS, ELSA, CHARLS and JSTAR respectively. The complete cases were mainly used for sensitivity analyses. More details of the complete case analyses are discussed in Chapter 4.

Figure 2-1 Sample selection procedure in HRS, ELSA, CHARLS and JSTAR






CHARLS - participants at baseline: N=17708
Excluding participants aged <60 at baseline: N=10229
Participants aged 60 and older at baseline: N=7479
Excluding missing weights at baseline: N=94
Eligible participants at baseline: N=7385
Excluding missing main exopsures, outcomes and covariates: N=6346
Excluding missing outcomes: N=1455
Participants included for complete case analyses: N=1039
Participants included for imputed case analyses: N=5930


JSTAR - participants at baseline: N=3745 (in five cities)
Excluding participants aged <60 at baseline: N=1407
Participants aged 60 and older at baseline: N=2338
Excluding missing weights at baseline: N=169
Eligible participants at baseline: N=2169
Excluding missing main exopsures, outcomes and covariates: N=960
Excluding missing outcomes: N=234
Participants included for complete case analyses: N=1209
Participants included for imputed case analyses: N=1935

Harmonised datasets from the Gateway to Global Aging Data website [222] were used where possible. Not all of the variables in the analysis came from that website, since the harmonisation of some variables needed for this project had not been completed, and some variables were only semi-harmonised, despite notable differences in measures and categories. Instead, many variables were taken from the four original databases and harmonised for analysis in this project. For all variables from wave 4 of CHARLS, a full harmonisation was conducted, since the harmonised dataset on the Gateway to Global Aging Data website was not available to the public in 2016. Moreover, a common approach to measuring healthy ageing was created to allow the tracking of individuals' healthy ageing status over time and across populations.

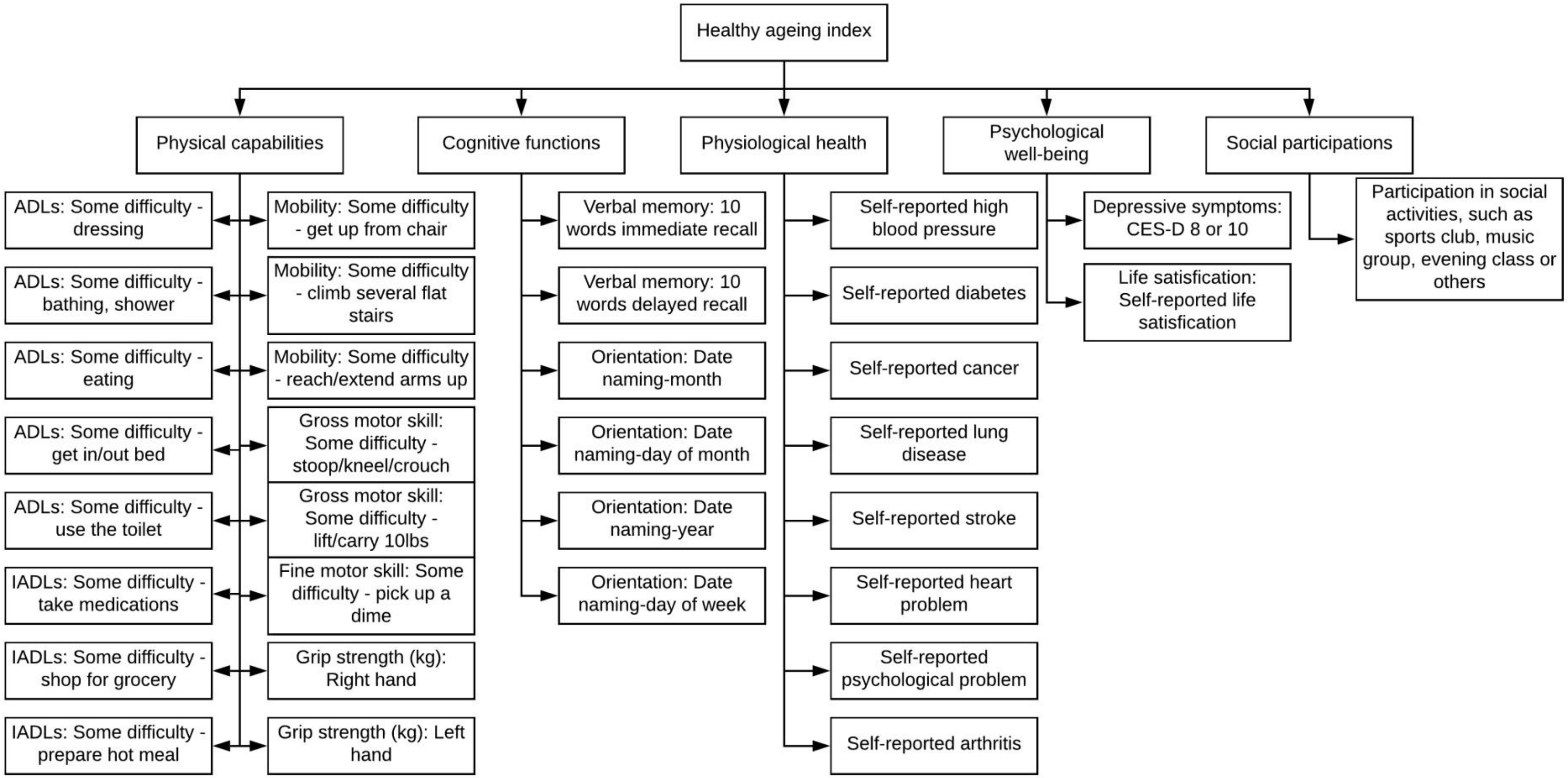
2.2 Construction of a Healthy Ageing Index

In the literature review in Chapter 1, three key principles were summarised for creating a quantitative and comprehensive measurement of healthy ageing at the individual level. The first principle is measuring healthy ageing in a multidimensional way. Physical capabilities, cognitive function, physiological health, psychological well-being and social well-being are five domains that have been frequently measured in previous studies to measure healthy ageing comprehensively. The second principle is taking resilience into account. Only classifying older people who are absolutely disease-free as healthy agers may cause selection bias, as many older people are capable of taking advantage of their current capacities to deal with their illnesses or impairments. The third principle is selecting representative scales to evaluate each domain of healthy ageing. Scales or methods should reflect a specified conceptual domain. Some controversial health indicators, such as BMI or physical activity, should be avoided.

Additionally, for this PhD project, the measurement of healthy ageing had to be compatible across the four countries. To conduct a cross-country comparison, the same health indicators had to be selected for each country. Harmonisation strategies had to be developed to make participants' healthy ageing comparable across the four countries.

Following these principles, a measurement containing physical, cognitive, physiological and psychosocial components of healthy ageing was created to evaluate healthy ageing in a multidimensional way. Figure 2-2 shows all the health indicators that were used to develop the measurement of healthy ageing. Physical capabilities, cognitive function, physiological health, psychological well-being and social participation were included as the five domains of healthy ageing. According to the literature review, ADLs and IADLs are recommended for community-based studies to predict physical capabilities. It is also better to test direct observations of performance, such as grip strength, walking speed, balance and the chair rise test, to improve predictability (see Section 1.3.2). Therefore, physical capabilities were measured by ADLs and IADLs, as well as mobility (ability to get up from a chair, climb several flights of stairs, and reach/extend arms upwards), gross motor skills (ability to stoop/kneel/crouch, or to lift/carry 10 lbs), fine motor skills (ability to pick up a coin) and grip strength (per kg, each hand; the score for participants who were too ill to do the tests was 0). Measures of cognitive function were diverse across countries. Applying the MMSE along with cognitive tests in memory and executive functions, as suggested in the literature review (see Section 1.3.2), cannot be fully achieved in each country. Cognitive function included universal tests: word recall (immediate and delayed recall) and date naming (month, day of month, year, day of week) tests to measure short-term memory and orientation to time. Questions about self-reported absence of chronic diseases (high blood pressure, diabetes, cancer, lung disease, stroke, heart problems, psychological problems and arthritis) were included for physiological health, since they have been frequently used in many studies (see Section 1.3.2). Objective measures of physiological health, such as cardiovascular and lung functions or glucose metabolism as recommended in the review (see Section 1.3.2), were not universal for the four countries. Psychological well-being took depressive symptoms and general attitudes to life into consideration, measuring these using the CES-D scale and a question about self-reported life satisfaction respectively. Each psychological measure focused on a clear conceptual domain (see Section 1.3.2). It is recommended that social participation should be measured in terms of specific social roles (see Section 1.3.2). Therefore, questions were included about participation in a variety of social activities, such as social or sports clubs, exercise classes, music groups, Neighbourhood Watch and more.

Figure 2-2 Health indicators in each domain of healthy ageing



An healthy ageing index (HAI) consisting of 33 health indicators was developed as a continuous variable. Details of the coding are shown in Table 2-1. All health indicators were harmonised to make the HAI comparable across the four countries. Each health indicator was dichotomised or organised into quartiles or quintiles, and then coded for the interval 0–100. For each individual, the scores on all indicators were summed and divided by the total number of measured indicators to yield an HAI score ranging from 0 to 100. A higher score indicates healthier status.

In terms of social participation, every country asked a range of different questions on participation in social activities, such as participation in a political party, trade union, environmental group, tenants' group, residents' group, Neighbourhood Watch, Church or other religious group, charitable association, music group or evening class, social club, sports club or exercise class. The HRS and CHARLS asked about the frequency of attending each activity, ELSA gave a yes/no choice for each question about social participation, and JSTAR counted the time spent on each activity. Therefore, I decided to generate a dichotomous variable for each country, asking participants whether they participated in any social activities (yes/no).

Predicted values were used for several indicators, as those indicators were missing in several waves or measured using different approaches in the four countries. Grip strength (both hands) was only measured in waves 2, 4 and 6 of ELSA, and self-reported life satisfaction was not measured in wave 1 of ELSA. Therefore, growth curve models with age, age^2, gender and waves were used to predict unobserved values for grip strength and self-reported life satisfaction [223]. The variables of the delayed word recall test and an item of ADLs (some difficulty in dressing) in wave 3 of JSTAR were also predicted, using mean values of the first two waves.

The ranges of CES-D scores were different between the HRS and ELSA (0–8) and the CHARLS and JSTAR (0–30). The sum CES-D scores were organised into quintiles in the four countries. The percentages of participants at each depressive level were checked and found to be similar in the HRS, ELSA and JSTAR. However, CHARLS presented a higher proportion of respondents with higher scores (more depressed), especially among women and those with lower levels of education and income. This may be reasonable, since a previous study based on CHARLS has indicated that women and socioeconomically disadvantaged individuals (i.e. those with low incomes and education) are more likely to have higher depressive scores than men and socioeconomically advantaged individuals [166]. Therefore, even though different ranges of CES-D scores were used between the HRS and ELSA and the CHARLS and JSTAR, participants at the same depressive level by quintile across countries may be comparable.

Table 2-1 Harmonisation strategies of health indicators in the four countries

Variables	Categories	Scores
Verbal Memory - 10 words immediate recall	0-10	0-2=0 3-4=25 5-6=50 7-8=75 9-10=100
Verbal Memory - 10 words delayed recall	0-10	0-2=0 3-4=25 5-6=50 7-8=75 9-10=100
Orientation - date naming- month	0.incorrect 1.correct	0=0 1=100
Orientation - date naming- day of month	0.incorrect 1.correct	0=0 1=100
Orientation - date naming- year	0.incorrect 1.correct	0=0 1=100
Orientation - date naming- day of week	0.incorrect 1.correct	0=0 1=100
ADL: some diff. in dressing	0. No 1. Yes	0=100 1=0
ADL: some diff. in bathing, shower	0. No 1. Yes	0=100 1=0
ADL: some diff. in eating	0. No 1. Yes	0=100 1=0
ADL: some diff. in get in/out bed	0. No 1. Yes	0=100 1=0
ADL: some diff. in using the toilet	0. No 1. Yes	0=100 1=0
ADL: some diff. in taking medications	0. No 1. Yes	0=100 1=0
ADL: some diff. in shop for grocery	0. No 1. Yes	0=100 1=0
ADL: some diff. in prepare hot meal	0. No 1. Yes	0=100 1=0
Some diff. in get up from chair	0. No 1. Yes	0=100 1=0
Some diff. in climb several flat stairs	0. No 1. Yes	0=100 1=0
Some diff. in reach/extend arms up	0. No 1. Yes	0=100 1=0
Some diff. in stoop/kneel/crouch	0. No 1. Yes	0=100 1=0
Some diff. in lift/carry 10lbs	0. No 1. Yes	0=100 1=0
Some diff. in pick up a dime	0. No 1. Yes	0=100 1=0
Grip strength (kg) – Left hand	kg (quintiles)	1=0 2=25 3=50

		4=75 5=100
Grip strength (kg) – Right hand	kg (quintiles)	1=0 2=25 3=50 4=75 5=100
CES-D score*	0-8 (quintiles)	1=100 2=75 3=50 4=25 5=0
CES-D score**	0-30 (quintiles)	1=100 2=75 3=50 4=75 5=0
Self-reported life satisfaction	0. Very satisfied 1. Satisfied 2. Somewhat satisfied 3. Unsatisfied 4. Very unsatisfied	0=100 1=75 2=50 3=25 4=0
High blood pressure	0. No 1. Yes	0=100 1=0
Diabetes	0. No 1. Yes	0=100 1=0
Cancer	0. No 1. Yes	0=100 1=0
Lung disease	0. No 1. Yes	0=100 1=0
Stroke	0. No 1. Yes	0=100 1=0
Heart problem	0. No 1. Yes	0=100 1=0
Psychological problem	0. No 1. Yes	0=100 1=0
Arthritis	0. No 1. Yes	0=100 1=0
Participations in social activities	0.No 1. Yes	0=0 1=100

* CES-D scores for HRS and ELSA ** CES-D scores for CHARLS and JSTAR

Developing an index to measure healthy ageing in a continuous way is advantageous, as it avoids the risk of only classifying people who are "disease-free" as healthy agers. Healthy ageing was not defined through a binary answer (yes/no), but was assessed on a score ranging from 0 to 100. However, inaccurate assessments of health status might exist for individuals who attained an intermediate score, since participants can attain an intermediate score in different ways; this does not provide interpretable information on health. Another disadvantage is that only indicators measured by the same or very similar established scales or methods were included in each domain to calculate the HAI. For example, for cognitive function, the animal naming task (verbal fluency) and the counting backwards test (processing speed) were not included, as they were not available in all four countries. But a unified approach is important for comparative purposes. Only verbal memory (word recall) and orientation (date-naming) tests were retained. The exclusion of indicators might result in an underestimation of each individual's healthy ageing status.

Therefore, the reliability and validity of the HAI must be checked before it is used to assess socioeconomic inequalities in healthy ageing in the four countries. The question of whether this HAI acceptably predicts older people's health characteristics must be answered. Chapter 3 will assess the test-retest reliability, internal consistency and predictive validity of this HAI.

2.3 Harmonised Socioeconomic Indicators

Education, income and wealth are common socioeconomic indicators that have frequently been used in previous studies based on the HRS, ELSA, CHARLS and JSTAR; however, occupation has only been used in studies based on the HRS and ELSA (see Section 1.4.4). According to Weber's theory of social class, occupation (like education and income) is determined by an individual's skills, knowledge and assets [139]. Occupational measures such as the NS-SEC and RGSC in ELSA, and the 1980 U.S. Census Occupation (which is similar to the RGSC [224]) in the HRS, are important indicators of social class, since they were developed on the basis of important theories of social class – including Wright's three principles for the classification of social class, and the E-G schema, which emphasises the significance of job security and salary increments in the allocation of individuals to different social groups (see Section 1.4.1).

Furthermore, I discussed in Chapter 1 that it is more meaningful for an epidemiological study to use a range of socioeconomic indicators and to evaluate which of these indicators is the most relevant and influential determinant of health outcomes in a given population. This approach will be more instructive for policymaking, enabling policymakers to make valid decisions to resolve socioeconomic inequalities in health outcomes. Therefore, I decided to include four common socioeconomic measurements in the four countries: education, income, wealth and occupation.

Specifically, the baseline variable of education and the time-varying variables of income, wealth and occupation were used as the main exposures in my analysis. I tested a range of socioeconomic indicators in each country to evaluate which was the most relevant and influential predictor of inequalities in healthy ageing in a given population. Harmonisation was conducted to make the indicators and results comparable across the countries.

2.3.1 Education

Education was measured by the highest educational qualification achieved during adulthood. However, educational categories in the four countries were different, due to the diversity of the educational systems. Harmonisation was carried out based on the International Standard Classification of Education, 1997 version (ISCED-97). The ISCED organises information on education in different countries and makes it comparable at an international level; it is a statistical framework designed as an international standard by the United Nations Educational, Scientific and Cultural Organization (UNESCO) [225]. Mappings to the 1997 version of the ISCED were applied in this analysis for the purpose of educational standardisation, since this version is more appropriate for matching older people's educational backgrounds [225]. The education variable was ultimately harmonised into primary education or less (PR), lower secondary education (LO), upper secondary education (UP), post-secondary non-tertiary education (PO), first-stage tertiary education or more (FI), and others (OT, in ELSA only).

2.3.2 Income

Total household income in the last calendar year and family size were used to calculate the adjusted household income in each wave. The total household income was a combination of an individual's and their spouse's employment earnings (after tax), pension fees, public old age pension, capital income, other government transfers and more. Within each wave in each country, respondents might answer income-related questions in different years of interview. For example, in wave 2 of ELSA, some participants were interviewed in 2004, but others were interviewed in 2005. Thus data on income might come from different years in the same wave. Therefore, inflation was considered using the consumer price index (CPI) provided by the World Bank for adjustment, to make income values comparable across years [226, 227]. After the adjustment for inflation, the OECD square root adjustment, which divides household income by the square root of household size, was also applied to impute individual incomes [228]. Finally, the adjusted individual incomes were organised into quintiles, ranging from the highest to the lowest level in each country.

2.3.3 Wealth

Wealth was assessed using total family assets (including any secondary residence). This was the sum of the net values of the primary residence, secondary residence and other property after payment of all debts, business, non-housing financial wealth, physical assets and others. As with income variables, inflation adjustment using the CPI was made in each wave in each country [226, 227]. Finally, quintiles of wealth were also produced, ranging from the highest to the lowest level in each country.

2.3.4 Occupation

Current job was used to measure each individual's SEP based on occupation. The occupation-based measures in the four countries were very different. The 1980 U.S. Census Occupation was used in the HRS, including categories such as managerial specialty operators, professional specialty operators or technical supporters, sales, clerical or administrative supporters, service work and others [224]. For participants who had not been in work since they entered the cohort, their labour force status was identified instead of their occupation; this was categorised as retired, unemployed (for those who had just quit their last job and were looking for another), disabled, and not in the labour force (for those who were not retired, unemployed or disabled). Thus a new occupational variable was derived by including both occupational and labour force information. ELSA categorised occupations based on the UK's NS-SEC, which groups individuals into categories including higher managerial and professional employers, lower managerial and professional employers, intermediate employees, small employers and own account workers, lower supervisory, craft and related employees, employees in semi-routine occupations, employees in routine occupations and never worked persons [229]. No occupation-based SEP variables were available in CHARLS; a new variable was therefore derived by capturing information from the original variables for major employment type, working status and current position. Thus the current job's SEP among the Chinese population was divided into five categories: officials/managers/leaders or clerks/paid workers, self-employed workers, unpaid family business, others, and agricultural work only (no paid jobs, self-employed activities or unpaid family business work). For JSTAR, the Japan Standard Occupational Classification (JSOC) was applied to measure SEP. This includes administrative and managerial workers, professional and engineering workers, clerical workers, sales workers and others [230]. The United Nations Statistics Division explains that it is not applicable to link the JSOC to international standards [231].

There are obvious disparities in occupational classifications across countries. Limited publications provide harmonising strategies for occupational variables across countries. One study proposes a new theory-based social classification in Japan, which recodes the JSOC into three categories [232]. Another study mentions a potential harmonisation between the 1980 U.S. Census Occupation and the RGSC but not the NS-SEC in the UK [233]. It seems that a full harmonisation across the four countries is not achievable.

Table A 2 presents more detail on both the harmonised and original categories of socioeconomic indicators.

3.2.3 Harmonised Covariates

Both baseline and time-varying covariates were considered as potential confounders or mediators. All of the variables were also harmonised or nearly harmonised. The baseline covariates known to be associated with SEP and health are gender (female versus male), ethnicity (e.g. white/Caucasian versus black/African-American and others in the HRS), self-rated health in childhood (excellent, very good, good, fair, poor) and father's occupation (e.g. from managerial and professional specialty occupations to operators, fabricators and labourers in the HRS). The time-varying covariates considered were: age, marital status (married/partnered, separated/divorced/single, widowed), smoking status (current smoker, never smoked, previous smoker) and frequency of drinking (e.g. days of drinking per week in the last year) [54, 57, 58, 68, 74, 77]. In ELSA, the question about frequency of drinking was not asked at wave 1. Instead, a drinking variable at wave 0 was used to provide baseline information on the frequency of drinking. Table A 2 presents more detail on the categories of both harmonised and original covariates.

2.4 Missingness

2.4.1 Response Rates and Characteristics of Non-responders and Responders

The baseline response rates of individuals were 81.6% in the HRS [211], 67% in ELSA [173], 80.5% in CHARLS [212] and 60% in JSTAR [170]. In follow-up waves, some of the baseline respondents became non-responders but alive, non-responders and died in this or previous waves, non-responders without information about their living status, and others. I calculated the response rates in follow-up waves based on the baseline samples finally selected in the four countries (N=10305 in HRS, 6590 in ELSA, 5930 in CHARLS and 1935 in JSTAR). Figure 2-3 shows the response rates at each follow-up wave in each country. The response rates were 85.64%, 77.40%, 65.37%, 58.36% and 48.50% at waves 8–12 in HRS; 77.24%, 64.76%, 53.61%, 48.97%, 41.26% and 35.11% at waves 2–7 in ELSA; 77.05% and 65.14% at waves 2 and 4 in CHARLS; and 58.04% and 57.98% at waves 2 and 3 in JSTAR.

Figure 2-3 Response rates at each follow-up wave in each country

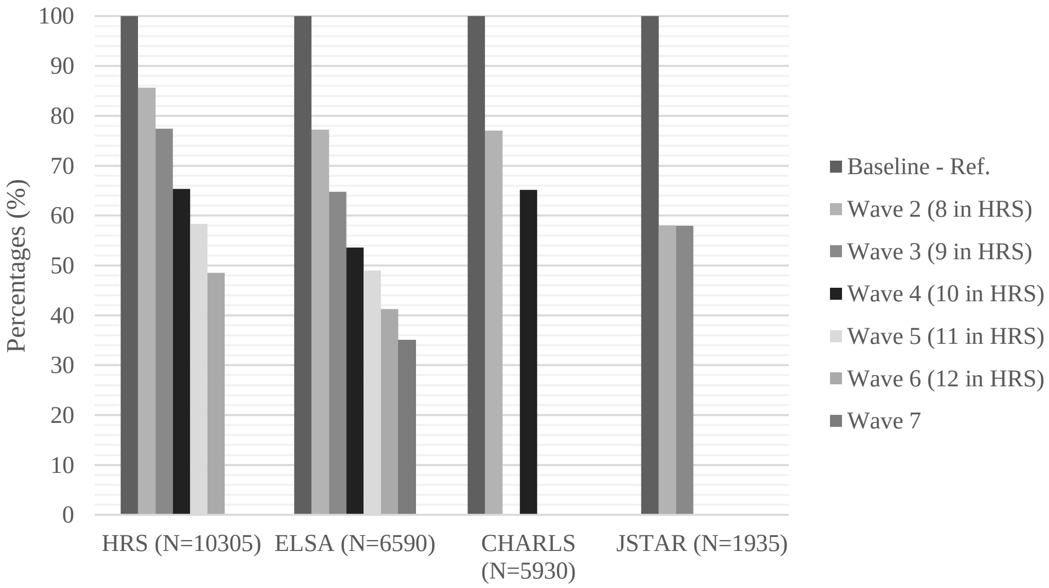


Table 2-2 shows the baseline characteristics of responders and non-responders in follow-up waves. Items in bold are for characteristics that pertained more among non-responders at each wave. Only the top and bottom categories of occupation, father's occupation and frequency of drinking are presented in the table. In the HRS and ELSA, compared with responders, non-responders were more likely to be old, male, ethnic minorities, widowed, previous/current smokers, and non-drinkers, as well as to have primary education or less, medium/poor self-rated health in childhood, and low income or wealth. In CHARLS, compared with responders, non-responders were more likely to be old, male, widowed, previous/non-smokers and non-drinkers, at both the top and bottom levels of education, income and wealth, as well as to have the most disadvantaged occupational positions, but to have good self-rated health in childhood. In JSTAR, compared with responders, non-responders were more likely to be female, widowed/unmarried, smokers, non-drinkers, at both the top and bottom levels of income, and to have the most disadvantaged occupational positions.

Table 2-2 Baseline characteristics of non-responders (N) and responders (R) in follow-up waves in each country

Percentages (%) or mean	HRS (N=10305)					ELSA (N=6590)						CHARLS (N=5930)		JSTAR (N=1935)	
Variables	**W 8**	**W9**	**W10**	**W11**	**W12**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W2**	**W3**	**W2**	**W3**
Age															
N	**76**	**76**	**76**	**76**	**75**	**73**	**73**	**73**	**73**	**73**	**73**	**71**	**71**	67	67
R	**71**	**71**	**70**	**69**	**69**	**71**	**70**	**70**	**69**	**68**	**68**	**68**	**68**	67	67
Gender															
Male															
N	**47.73**	**47.72**	**46.30**	**46.31**	**46.48**	**47.81**	**47.76**	**47.72**	**47.59**	**47.33**	**46.99**	**51.08**	**52.64**	45.12	45.72
R	**42.45**	**41.93**	**41.68**	**41.16**	**40.19**	**44.42**	**43.80**	**43.17**	**42.82**	**42.49**	**42.08**	**50.09**	**49.60**	49.78	50.46
Female															
N	52.27	52.28	53.70	53.69	53.52	52.19	52.24	52.28	52.41	52.67	53.01	48.92	47.36	**54.88**	**54.28**
R	57.55	58.07	58.32	58.84	59.81	55.58	56.20	56.83	57.18	57.51	57.92	49.91	50.40	**50.22**	**49.54**
Ethnicity															
Majority															
N	79.03	82.13	82.46	82.22	82.60	95.73	96.42	96.62	96.78	97.14	97.13	0.00	**93.44**	-	-
R	83.33	83.02	83.02	83.21	83.06	98.03	98.07	98.18	98.19	97.90	98.08	93.14	**93.10**	-	-
Minority															
N	**20.97**	**17.87**	**17.54**	**17.78**	**17.40**	**4.27**	**3.58**	**3.38**	**3.22**	**2.86**	**2.87**	0.00	6.56	-	-
R	**16.67**	**16.98**	**16.98**	**16.79**	**16.94**	**1.97**	**1.93**	**1.82**	**1.81**	**2.10**	**1.92**	6.86	6.90	-	-
Education															
FI															
N	15.31	15.62	16.27	16.55	16.98	5.53	5.67	6.02	6.47	6.86	7.44	**3.88**	**3.33**	**13.51**	**11.80**
R	21.61	22.16	22.83	23.40	24.17	10.15	10.96	11.55	11.69	11.90	11.90	**1.68**	**1.64**	**10.26**	**10.65**
PO															
N	-	-	-	-	-	6.66	7.11	7.87	7.85	8.15	8.17	**3.88**	**3.40**	3.51	3.89
R	-	-	-	-	-	11.67	12.37	12.61	13.14	13.50	14.58	**2.79**	**2.82**	5.29	5.44
UP															
N	51.31	50.82	49.17	49.60	50.40	3.16	3.59	3.57	3.61	3.78	3.88	**2.84**	**3.00**	**41.93**	**41.47**
R	52.63	52.87	53.85	54.12	54.20	4.83	4.90	5.13	5.26	5.27	5.40	**1.98**	**1.86**	**39.08**	**38.72**
LO															
N	**21.94**	**22.86**	**23.62**	**23.65**	**22.63**	14.95	15.38	15.68	16.22	16.59	16.61	33.36	32.20	40.70	42.50
R	**18.05**	**17.45**	**16.36**	**15.54**	**15.06**	19.28	19.86	20.36	20.30	20.39	21.17	35.60	36.08	44.75	44.48
PR															
N	**11.43**	**10.70**	**10.94**	**10.20**	**10.00**	**61.29**	**59.56**	**57.89**	**57.02**	**55.54**	**54.62**	56.05	**58.07**	0.35	0.34

Percentages (%) or mean	HRS (N=10305)					ELSA (N=6590)						CHARLS (N=5930)		JSTAR (N=1935)	
Variables	**W 8**	**W9**	**W10**	**W11**	**W12**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W2**	**W3**	**W2**	**W3**
R	**7.71**	**7.52**	**9.96**	**6.94**	**6.58**	**43.37**	**40.93**	**39.20**	**38.10**	**37.37**	**35.20**	57.96	**57.59**	0.63	0.70
OT															
N	-	-	-	-	-	8.41	8.69	8.96	8.83	9.07	9.27	-	-	-	-
R	-	-	-	-	-	10.71	10.98	11.14	11.52	11.58	11.75	-	-	-	-
Income															
Highest															
N	14.71	13.67	12.85	13.29	13.77	14.02	15.22	15.33	14.86	14.97	15.20	**24.62**	**24.55**	0.00	**22.68**
R	20.66	21.49	22.96	23.82	25.14	21.92	22.74	23.91	25.34	26.70	28.72	**19.27**	**18.82**	19.71	**19.02**
2nd															
N	16.28	15.65	16.57	16.75	17.57	17.06	17.98	18.03	17.61	17.64	18.15	**21.20**	**20.63**	0.00	19.24
R	20.46	21.02	22.96	21.85	22.01	20.95	21.16	21.66	22.50	23.15	23.36	**19.64**	**19.65**	20.23	20.47
3rd															
N	16.81	18.39	19.39	**20.15**	**20.36**	**20.21**	**21.04**	**20.60**	**21.12**	**21.54**	**21.43**	18.26	16.78	0.00	18.21
R	20.40	20.38	21.42	**19.92**	**19.70**	**19.95**	**19.42**	**19.51**	**18.85**	**17.96**	**17.41**	20.44	21.01	20.04	20.47
4th															
N	**24.10**	**24.71**	**23.83**	**23.55**	**23.17**	**22.78**	**22.19**	**22.99**	**22.47**	**22.69**	**22.08**	17.08	17.10	0.00	17.53
R	**19.49**	**18.89**	**18.42**	**17.98**	**17.39**	**19.09**	**18.73**	**17.47**	**17.42**	**16.39**	**16.18**	20.46	20.74	19.97	20.55
Lowest															
N	**28.10**	**27.57**	**27.36**	**26.26**	**25.14**	**31.61**	**25.93**	**23.05**	**23.95**	**23.16**	**23.13**	18.85	**20.94**	0.00	**22.34**
R	**18.99**	**18.22**	**16.96**	**16.43**	**15.76**	**18.09**	**17.95**	**17.44**	**15.90**	**15.80**	**14.32**	20.20	**19.77**	20.04	**19.50**
Wealth															
Highest															
N	14.97	15.61	15.45	15.71	16.17	14.83	15.25	14.87	15.19	15.56	15.79	**25.59**	**24.00**	**21.22**	**20.42**
R	20.62	21.02	21.87	22.43	23.14	21.67	22.73	24.32	25.01	25.94	27.68	**19.12**	**18.97**	**19.16**	**19.21**
2nd															
N	17.20	16.91	17.34	17.49	17.70	16.71	17.75	18.36	17.63	18.23	18.65	17.48	19.00	**20.27**	19.43
R	20.34	20.72	21.09	21.42	21.89	21.06	21.29	21.37	22.46	22.36	22.44	20.39	20.26	**19.75**	20.18
3rd															
N	18.06	19.31	19.39	19.61	19.65	18.15	19.74	19.59	18.95	19.38	19.67	16.78	16.50	**17.40**	17.08
R	20.26	20.18	20.27	20.25	20.31	20.61	20.16	20.36	21.11	20.85	20.62	20.44	20.83	**17.26**	17.43
4th															
N	**21.21**	**20.72**	**20.88**	**20.99**	**21.13**	**23.07**	**21.89**	**21.70**	**22.00**	**21.86**	**21.45**	16.78	18.44	19.89	20.05
R	**19.80**	**19.78**	**19.57**	**19.37**	**18.99**	**18.98**	**18.88**	**18.53**	**17.87**	**17.47**	**17.29**	20.53	20.42	24.21	25.10
Lowest															

Percentages (%) or mean	**HRS (N=10305)**					**ELSA (N=6590)**						**CHARLS (N=5930)**		**JSTAR (N=1935)**	
Variables	**W 8**	**W9**	**W10**	**W11**	**W12**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W2**	**W3**	**W2**	**W3**
N	**28.56**	**27.46**	**26.93**	**20.99**	**25.35**	**27.25**	**25.37**	**25.48**	**26.23**	**24.97**	**24.43**	**23.36**	**22.06**	**21.22**	**23.02**
R	**18.99**	**18.30**	**17.20**	**16.54**	**15.67**	**17.68**	**16.93**	**15.42**	**13.54**	**13.39**	**11.97**	**19.52**	**19.52**	**19.62**	**18.08**
Occupation															
Highest															
N	4.76	4.17	4.26	4.34	4.45	5.89	5.79	5.98	6.02	6.03	6.43	**0.37**	0.00	**7.65**	6.29
R	8.11	8.58	9.18	9.68	10.45	8.28	8.79	9.13	9.42	9.90	9.99	**0.10**	0.14	**6.89**	7.63
Lowest															
N	2.25	1.80	1.75	1.73	2.02	**22.08**	**21.29**	**21.31**	**21.14**	**20.69**	**20.06**	**93.66**	**92.84**	**60.68**	**61.12**
R	3.23	3.43	3.69	3.91	4.03	**16.02**	**15.32**	**14.30**	**13.74**	**13.27**	**12.82**	**90.30**	**90.32**	**56.31**	**55.00**
Marital status															
Married or partnered															
N	54.17	52.84	52.90	53.68	55.43	60.61	62.58	61.19	59.68	59.89	59.72	70.18	70.84	80.49	81.53
R	63.87	65.14	66.89	67.99	68.88	64.00	63.51	64.83	66.81	67.54	69.47	78.59	79.10	83.45	83.44
Separated, divorce, single															
N	**12.87**	**12.69**	12.28	12.22	12.12	**12.23**	11.14	11.38	**12.02**	11.68	**11.92**	2.16	2.22	**5.75**	**5.13**
R	**12.46**	**12.46**	12.59	12.66	12.82	**11.63**	12.15	12.12	**11.53**	11.91	**11.52**	2.26	2.26	**4.58**	**4.72**
Widowed															
N	**32.96**	**34.48**	**34.81**	**34.10**	**32.46**	**27.16**	**26.28**	**27.43**	**28.30**	**28.42**	**28.36**	**27.66**	**26.94**	**13.76**	**13.34**
R	**23.67**	**22.40**	**20.52**	**19.35**	**18.30**	**24.37**	**24.34**	**23.04**	**21.67**	**20.55**	**19.00**	**19.14**	**18.65**	**11.97**	**11.84**
Smoking															
Never smoke															
N	35.77	36.33	37.21	36.65	37.22	31.74	31.49	31.64	31.63	31.94	32.70	**61.78**	58.76	54.46	53.88
R	42.41	42.93	43.52	44.53	45.34	35.97	36.92	37.71	38.37	38.93	39.03	**59.21**	59.76	55.22	55.77
Ever smoked, now no smoke															
N	**49.83**	**50.33**	**49.49**	**49.66**	**48.99**	**51.53**	**51.56**	**51.95**	**52.12**	**51.84**	**51.55**	**13.12**	**15.75**	25.84	26.21
R	**46.03**	**45.54**	**45.20**	**44.63**	**44.37**	**50.39**	**50.15**	**49.60**	**49.17**	**49.12**	**49.07**	**11.35**	**10.56**	26.86	26.84
Smoke															
N	**14.40**	**13.34**	**13.30**	**13.70**	**13.79**	**16.73**	**16.94**	**16.41**	**16.25**	**16.22**	**15.75**	25.10	25.49	**19.70**	**19.90**
R	**11.56**	**11.53**	**11.28**	**10.84**	**10.29**	**13.64**	**12.93**	**12.69**	**12.46**	**11.95**	**11.90**	29.44	29.68	**17.93**	**17.39**
Drinking															
No drinking															
N	**76.50**	**76.79**	**76.29**	**75.35**	**74.30**	**43.48**	**41.09**	**40.47**	**41.09**	**40.69**	**40.12**	**87.34**	**85.42**	**46.24**	**46.78**
R	**69.65**	**68.90**	**67.97**	**67.59**	**67.19**	**34.39**	**34.03**	**33.36**	**31.95**	**31.16**	**30.19**	**81.33**	**81.33**	**43.39**	**42.39**
Drink every day															

Percentages (%) or mean	**HRS (N=10305)**					**ELSA (N=6590)**						**CHARLS (N=5930)**		**JSTAR (N=1935)**	
Variables	**W 8**	**W9**	**W10**	**W11**	**W12**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W2**	**W3**	**W2**	**W3**
N	7.64	7.18	7.51	7.61	**8.01**	16.51	17.64	17.06	16.97	17.17	17.66	7.78	9.06	22.18	22.52
R	7.75	7.87	7.84	7.81	**7.52**	18.08	17.73	18.23	18.45	18.40	17.77	11.99	12.01	22.95	22.90
Self-rated health in child															
Excellent															
N	46.56	47.57	46.26	46.43	46.54	**35.79**	**33.33**	28.10	27.33	26.21	27.98	8.61	**10.24**	-	-
R	49.23	49.26	50.04	50.37	50.92	**29.46**	**29.62**	29.84	30.27	31.16	30.81	9.62	**9.28**	-	-
Very good															
N	**26.61**	**26.11**	**26.64**	**26.85**	**26.92**	**37.89**	33.33	**37.91**	**36.27**	**39.05**	**37.25**	36.84	36.45	-	-
R	**25.87**	**25.91**	**25.66**	**25.44**	**25.15**	**34.92**	35.00	**34.58**	**34.64**	**33.18**	**33.38**	36.87	36.97	-	-
Good															
N	**20.38**	**20.56**	**20.86**	**20.48**	**20.21**	15.79	**33.33**	22.22	**24.84**	**23.22**	22.24	**31.73**	**30.85**	-	-
R	**18.67**	**18.46**	**18.03**	**17.94**	**17.74**	22.97	**22.78**	22.87	**22.21**	**22.59**	23.17	**28.50**	**28.46**	-	-
Fair															
N	**5.00**	4.52	**4.89**	**4.89**	**5.07**	7.37	-	7.41	7.20	7.83	8.61	16.22	15.36	-	-
R	**4.83**	4.92	**4.83**	**4.82**	**4.67**	8.79	8.76	8.94	9.18	9.16	8.85	17.41	17.72	-	-
Poor															
N	**1.45**	1.23	1.35	1.36	1.26	3.16	-	**4.36**	**4.35**	3.69	**3.91**	6.61	7.10	-	-
R	**1.40**	1.45	1.43	1.44	1.53	3.86	3.85	**3.77**	**3.70**	3.91	**3.79**	7.61	7.57	-	-
Father's occupation															
Highest															
N	13.26	12.93	12.38	11.92	11.75	5.93	7.04	7.44	7.39	7.66	7.82	0.00	**5.01**	0.00	**31.45**
R	13.43	13.52	13.84	14.26	14.77	10.35	10.55	10.81	11.22	11.42	11.92	4.39	**4.30**	28.62	**27.96**
Lowest															
N	20.67	**21.77**	21.54	**21.97**	22.16	**3.11**	**2.90**	**3.27**	**3.10**	**3.06**	**2.97**	75.00	77.04	0.00	**16.61**
R	21.82	**21.68**	21.76	**21.54**	21.31	**2.74**	**2.79**	**2.46**	**2.55**	**2.52**	**2.57**	80.26	80.70	15.38	**15.09**

2.4.2 Missing Data for Health Indicators

There was missing data for health indicators among respondents in all countries. Table 2-3 presents percentages of missing data for each health indicator at each wave in the four countries. Indicators with more than 20% missing data are in bold. Generally, indicators for grip strength, self-reported life satisfaction and participation in social activities in the HRS, ELSA and CHARLS, and for self-reported absence of chronic diseases in CHARLS, contained more missing values than any other health indicators. In the HRS, only random subsamples to measure grip strength, self-reported life satisfaction and participation in social activities were selected [234]. In CHARLS, data from the fourth wave had not been fully published and harmonised by mid-2017.

Table 2-4 shows the distribution of respondents by numbers of missing health indicators. In the HRS, respondents mainly lost two, four and five indicators, while in other countries, respondents mainly lost two and three indicators. In the fourth wave of CHARLS and the third wave of JSTAR, there were no observations without missing indicators. Moreover, only a small proportion of respondents had no missing indicators in the HRS and other waves of JSTAR. The valid sample sizes for calculating an HAI score by summing all indicators for each person in those waves were very small, resulting in a decreased power of analysis. Therefore, to attain more valid samples, a cut-off was set in each country. Respondents who had missing indicators that were equal to or less than the cut-off were selected for calculating the HAI, in order to keep more than 70% of the participants in each country. The cut-off was six indicators in the HRS, and three indicators in ELSA, JSTAR and the first two waves of CHARLS. For the fourth wave of CHARLS, compared with the first two waves, the date-naming year test, self-reported questions about chronic diseases, and questions about participation in social activities had more missing values. Therefore, the cut-off was 10 indicators for the fourth wave of CHARLS, since participants mainly had six to 10 missing indicators. The missing values were replaced by relevant mean values. This approach was applied by a previous study to develop the Clinical Frailty Scale, where the missing values of deficits were replaced using the mean values to develop a frailty index [112]. Items in bold in Table 2-4 are for percentages of participants who were included as valid samples (those with numbers of missing items that were equal to or less than the cut-off in each country).

Ultimately, more than 70% of samples were valid to calculate the HAI scores at each wave in each country.

Figure ***2-4*** summarises the percentages of valid HAI scores at each wave in each country. For the HRS, at waves 7–12, there were 10305 of 13790 (74.7%), 10665 of 12267 (86.9%), 10099 of 11164 (90.5%), 8825 of 9758 (90.4%), 8007 of 8787 (91.1%) and 6783 of 7557 (89.8%) valid HAIs respectively. For ELSA, there were 6590 of 7225 (91.2%), 5147 of 5443 (94.6%), 4310 of 4568 (94.4%), 3570 of 3910 (91.3%), 3266 of 3531 (94.6%), 2753 of 3090 (89.1%) and 2340 of 2552 (91.7%) valid HAIs at waves 1–7 respectively. For CHARLS, there were 5930 of 7385 (80.3%), 5216 of 6319 (82.5%) and 4389 of 5848 (75.1%) valid HAIs at waves 1, 2 and 4 respectively. For JSTAR, the valid HAIs at waves 1–3 were 1935 of 2169 (89.2%), 1189 of 1622 (73.3%) and 1179 of 1292 (91.3%) respectively. Additionally, there were 4494, 1890, 3582 and 913 respondents in the HRS, ELSA, CHARLS and JSTAR respectively who participated in all waves and had valid HAIs at all waves. These are used to check the reliability and validity of the HAI in Chapter 3.

Table 2-3 Percentages of missingness for each health indicator at each wave in the four countries

Percentages (%)	HRS (N=13790)						ELSA (N=7225)							CHARLS (N=7385)			JSTAR (N=2169)		
Health indicators	Wave 7	Wave 8	Wave 9	Wave 10	Wave 11	Wave 12	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7	Wave 1	Wave 2	Wave 4	Wave 1	Wave 2	Wave 3
Words immediate recall	8.3	5.6	5.4	6.4	5.3	5.0	3.7	1.6	2.2	2.7	2.9	2.7	2.3	**20.0**	10.2	9.0	9.5	15.7	**35.5**
Words delayed recall	8.3	5.6	5.4	6.4	5.3	5.0	3.9	1.5	2.1	2.6	2.9	2.7	2.3	**20.3**	10.2	9.9	16.0	16.0	3.0
Date naming- month	**29.4**	16.3	8.5	6.4	5.3	5.7	3.2	1.4	2.1	2.6	3.0	3.0	2.7	11.3	13.4	0.2	7.3	13.9	1.8
Date naming- day	**29.4**	16.3	8.5	6.4	5.3	5.9	3.2	1.4	2.1	2.6	3.0	3.0	2.7	11.3	13.4	0.2	7.3	13.9	1.8
Date naming- year	**29.4**	16.3	8.5	6.4	5.3	5.5	3.2	1.4	2.1	2.6	3.0	3.0	2.7	11.3	13.4	**23.5**	7.3	13.9	1.8
Date naming- week	**29.4**	16.3	8.5	6.4	5.3	6.5	3.2	1.4	2.1	2.6	3.0	3.0	2.9	11.3	13.4	0.2	7.3	13.9	1.8
ADLs: dressing	0.0	0.1	0.1	0.1	0.1	0.1	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.7	0.2	0.2	0.0	0.0
ADLs: bathing, shower	0.1	0.1	0.1	0.1	0.1	0.1	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.9	0.5	0.2	0.0	0.0
ADLs: eating	0.1	0.1	0.1	0.1	0.1	0.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.7	0.3	0.2	0.0	0.0
ADLs: get in/out bed	0.1	0.1	0.1	0.1	0.1	0.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.7	0.3	0.2	0.0	0.0
ADLs: use the toilet	0.1	0.2	0.2	0.2	0.2	0.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.7	0.3	0.2	0.0	0.0
IADLs: take medicines	2.0	1.3	1.0	1.0	0.8	0.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.0	0.6	2.5	4.8	2.2
IADLs: shopping	4.2	3.4	3.2	2.1	1.9	1.7	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	0.8	2.4	4.7	2.2
IADLs: prepare meal	6.4	5.1	4.7	3.2	2.9	2.4	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.3	0.6	2.5	4.7	2.2
Get up from chair	0.2	0.2	0.2	0.2	0.3	0.3	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.9	0.3	0.2	0.0	0.0
Climb several stairs	11.5	8.1	8.2	4.8	4.7	3.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.8	3.1	1.5	0.2	0.0	0.0
Reach/extend arms up	0.5	0.5	0.4	0.3	0.4	0.3	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.1	0.4	0.2	0.0	0.0
Stoop/kneel/crouch	2.2	1.6	1.6	1.0	1.1	0.9	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.0	0.4	0.2	0.0	0.0
Lift/carry 10lbs	4.6	3.4	3.4	2.2	2.0	1.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1	0.6	0.2	0.0	0.0
Pick up a dime	0.3	0.2	0.3	0.3	0.3	0.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1	0.4	0.2	0.0	0.0
Grip strength (left)	**83.1**	**52.8**	**49.0**	**43.2**	**38.9**	**33.0**	**31.3**	12.2	6.2	10.8	3.5	9.4	1.7	**20.2**	**22.0**	6.2	**92.7**	**68.0**	**55.1**
Grip strength (right)	**83.2**	**52.8**	**48.9**	**43.3**	**38.9**	**33.1**	**31.2**	12.1	6.2	10.6	3.4	9.3	1.8	**20.4**	**22.1**	13.8	11.9	20.0	9.0
CES-D score	8.5	5.6	5.5	6.4	5.4	4.7	3.7	1.7	2.3	2.7	3.2	2.9	2.6	8.5	9.9	0.2	3.7	6.0	2.7
Life satisfaction	**84.0**	**51.5**	**47.4**	**41.5**	**40.7**	**32.0**	**26.9**	11.1	10.7	9.9	8.1	8.4	7.4	**20.2**	10.5	7.6	2.7	5.5	2.9
High blood pressure	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.6	**53.0**	1.3	1.2	0.0
Diabetes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	2.0	**73.1**	1.2	1.4	0.0
Cancer	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.6	**78.3**	1.3	1.5	0.0
Lung disease	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.4	**66.5**	1.3	1.5	0.0
Stroke	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.4	**76.0**	1.3	1.5	0.0
Heart problem	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.6	**65.1**	1.3	1.0	0.0
Psychological problem	0.7	0.1	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.7	**77.7**	1.3	1.5	0.0

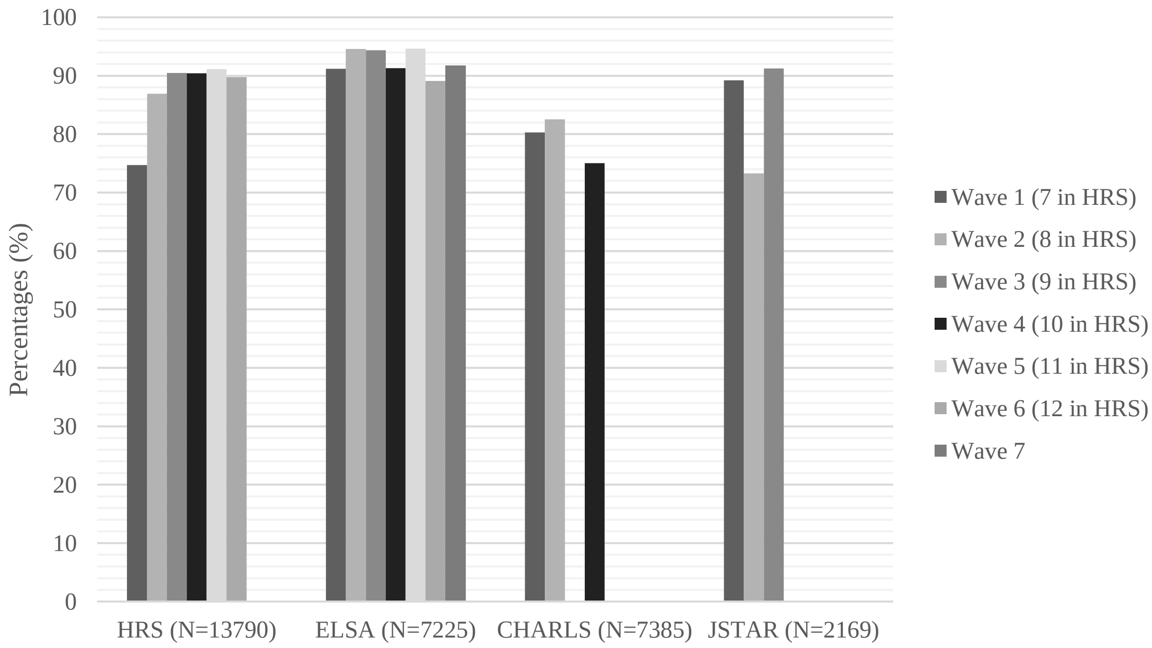
Arthritis	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.3	**43.5**	1.3	1.4	0.0
Participation in activities	**84.2**	**51.1**	**46.9**	**41.1**	**38.9**	**31.6**	15.3	15.3	13.5	11.8	9.7	9.4	8.1	**57.0**	**43.8**	**44.1**	17.9	18.8	18.8

Table 2-4 Distribution of respondents by numbers of missing indicators at each wave in the four countries

Percentages	HRS (N=13790)						ELSA (N=7225)							CHARLS (N=7385)			JSTAR (N=2169)		
Number of missing health indicators	Wave 7	Wave 8	Wave 9	Wave 10	Wave 11	Wave 12	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7	Wave 1	Wave 2	Wave 4	Wave 1	Wave 2	Wave 3
0	**2.41**	**25.03**	**26.95**	**28.86**	**26.85**	**28.34**	**59.14**	**67.78**	**71.85**	**65.91**	**74.20**	**64.76**	**70.26**	**31.58**	**34.61**	-	**0.18**	**0.56**	-
1	**0.74**	**6.61**	**6.70**	**5.04**	**5.75**	**6.05**	**7.83**	**8.47**	**7.09**	**6.50**	**6.91**	**6.63**	**8.11**	**33.81**	**28.01**	-	**65.98**	**49.34**	**24.77**
2	**14.00**	**5.67**	**6.47**	**8.51**	**7.68**	**7.60**	**7.24**	**16.50**	**14.14**	**17.39**	**10.71**	**15.95**	**12.46**	**6.01**	**11.13**	-	**19.09**	**20.25**	**47.52**
3	**4.27**	**1.34**	**1.57**	**1.78**	**1.89**	**1.91**	17.00	1.82	1.27	1.51	0.68	1.75	0.86	8.90	8.83	**0.26**	3.96	4.39	18.96
4	**36.85**	**37.87**	**39.29**	**39.11**	**41.03**	**37.41**	5.05	3.23	2.10	3.76	1.33	3.95	1.14	5.32	1.82	**1.13**	0.69	1.76	1.93
5	**10.01**	**7.85**	**7.57**	**5.85**	**6.33**	**6.60**	0.22	0.20	0.18	0.13	0.14	0.19	0.16	2.38	1.84	**4.46**	0.18	0.38	0.23
6	**6.46**	**2.58**	**1.92**	**1.29**	**1.60**	**1.85**	0.22	0.15	0.02	0.05	0.08	0.19	0.24	1.79	0.89	**10.55**	0.14	0.56	0.62
7	1.30	0.60	0.51	0.36	0.33	0.66	0.25	0.11	0.04	0.08	0.25	0.10	0.24	0.60	1.01	**19.65**	4.70	8.84	1.93
8	13.38	5.66	2.10	0.09	0.07	0.52	0.19	0.06	-	-	-	0.13	0.04	0.80	0.52	**27.65**	2.72	8.34	2.63
9	2.41	0.90	0.96	1.12	0.69	1.23	0.11	0.18	1.36	0.05	3.71	0.06	5.13	1.67	3.42	**17.97**	0.88	1.94	1.32
10	0.37	0.25	0.25	0.37	0.40	0.49	0.33	0.02	0.09	0.03	0.06	0.03	0.04	0.51	0.62	**7.52**	0.41	0.19	-
11	4.79	3.77	3.54	5.36	5.50	5.09	0.54	1.47	1.84	4.58	1.93	6.21	1.29	5.06	5.08	3.10	0.05	0.13	-
12	1.81	1.00	1.15	1.30	1.05	1.35	-	-	-	-	-	-	-	0.28	0.76	2.60	0.05	0.06	-
13	0.80	0.49	0.48	0.55	0.43	0.45	-	-	-	-	-	-	-	0.09	0.25	2.19	0.18	0.50	-
14	0.25	0.19	0.27	0.15	0.16	0.17	-	-	-	-	-	-	-	0.03	0.14	1.81	0.14	1.63	0.08
15	0.07	0.07	0.14	0.12	0.07	0.12	-	-	-	-	-	-	-	0.04	0.05	0.70	0.09	0.19	-
16	0.03	0.06	0.04	0.02	0.07	0.01	-	-	-	-	-	-	-	0.04	0.05	0.07	0.32	0.31	-
17	0.03	0.02	0.04	0.04	-	-	-	-	-	0.03	-	0.03	-	0.04	0.03	0.02	0.05	0.44	-
18	0.01	0.01	0.04	0.03	0.08	0.08	-	-	-	-	-	-	-	0.04	0.05	-	0.05	-	-
19	-	-	0.01	0.01	-	-	-	-	-	-	-	-	-	0.04	0.05	0.03	-	-	-
20	0.01	0.01	-	-	-	-	-	-	-	-	-	-	-	0.03	0.02	0.02	0.14	-	-
21	-	-	0.01	-	-	0.01	-	-	-	-	-	-	-	0.01	-	-	-	-	-
22	0.01	0.01	-	0.01	0.01	0.03	0.26	-	-	-	-	-	-	-	-	0.02	-	0.13	-
23	-	0.01	-	-	-	-	0.04	-	-	-	-	-	0.04	0.03	0.05	0.02	-	-	-
24	-	-	-	-	-	-	0.08	-	-	-	-	-	-	0.04	-	-	-	-	-
25	0.01	0.02	0.01	0.02	0.01	0.03	1.40	0.02	-	-	-	-	-	0.04	0.14	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.03	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-

28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-
29	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	0.05	-	-	-	-
30	-	0.01	-	-	-	-	0.03	-	-	-	-	-	-	-	0.06	-	-	-	-
31	-	-	-	-	-	-		-	-	-	-	-	-	0.05	0.16	0.03	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.14	0.07	-	-	-
33	-	-	-	-	0.01	-	0.04	-	0.02	-	-	-	-	0.72	0.19	0.14	-	-	-

Figure 2-4 Percentages of valid HAI scores at each wave in each country



2.4.3 Missing Data for Socioeconomic Exposures and Covariates

Table 2-5 shows the percentages of missing data for socioeconomic exposures and covariates at each wave in each country. CHARLS and JSTAR had more missing data than the HRS and ELSA, especially on income, wealth, occupation, smoking and father's occupation. For example, the percentage of missing data for baseline wealth in CHARLS was around 29%, and for baseline income in JSTAR was around 29%; the occupational variable at each wave of CHARLS had more than 50% missing values. In ELSA, the variable of self-rated health in childhood had around 50% missing data. Drinking variables at follow-up waves of ELSA had around 20% missing data. Due to the large missingness in ELSA, CHARLS and JSTAR, conducting complete case analyses might exclude a large number of valid samples in the three countries, resulting in a decreased power of analysis. Results based on complete case analyses thus might not be representative in the three countries.

Table 2-5 Percentages of missing data for socioeconomic exposures and covariates at each wave in each country

	HRS (N=10305)						ELSA (N=6590)							CHARLS (N=5930)			JSTAR (N=1935)		
Time-varying variables	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**	**Wave**
Income	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.86	2.56	2.71	2.86	5.95	2.82	15.76	30.78	7.32	29.14	6.29	6.97
Wealth	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.86	2.56	2.71	2.86	2.62	2.82	28.57	53.44	19.05	5.62	34.22	87.85
Occupation	1.83	0.52	0.41	0.19	0.16	0.11	4.38	0.00	0.00	0.00	0.00	0.00	9.09	62.33	61.57	50.85	3.78	6.20	6.89
Age	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marital status	0.06	0.00	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.00	0.03	0.00	0.00	0.08	0.03	2.45	0.00	2.22	3.41
Smoking	0.94	0.87	0.89	0.85	0.82	0.89	1.90	0.07	0.09	1.33	2.15	0.10	0.16	3.63	26.32	45.71	4.47	10.73	4.57
Drinking	0.01	0.02	0.01	0.02	0.01	0.15	1.45	17.31	21.72	21.00	17.87	20.71	21.28	7.33	1.06	0.67	5.76	2.03	5.11
Baseline variables																			
Education	0.01						0.17							0.12			0.46		
Gender	0.00						0.00							0.01			0.00		
Ethnicity	0.02						0.04							14.88			-		
Self-rated health in childhood	5.74						49.22							2.69			-		
Father's occupation	19.62						1.65							46.58			28.91		

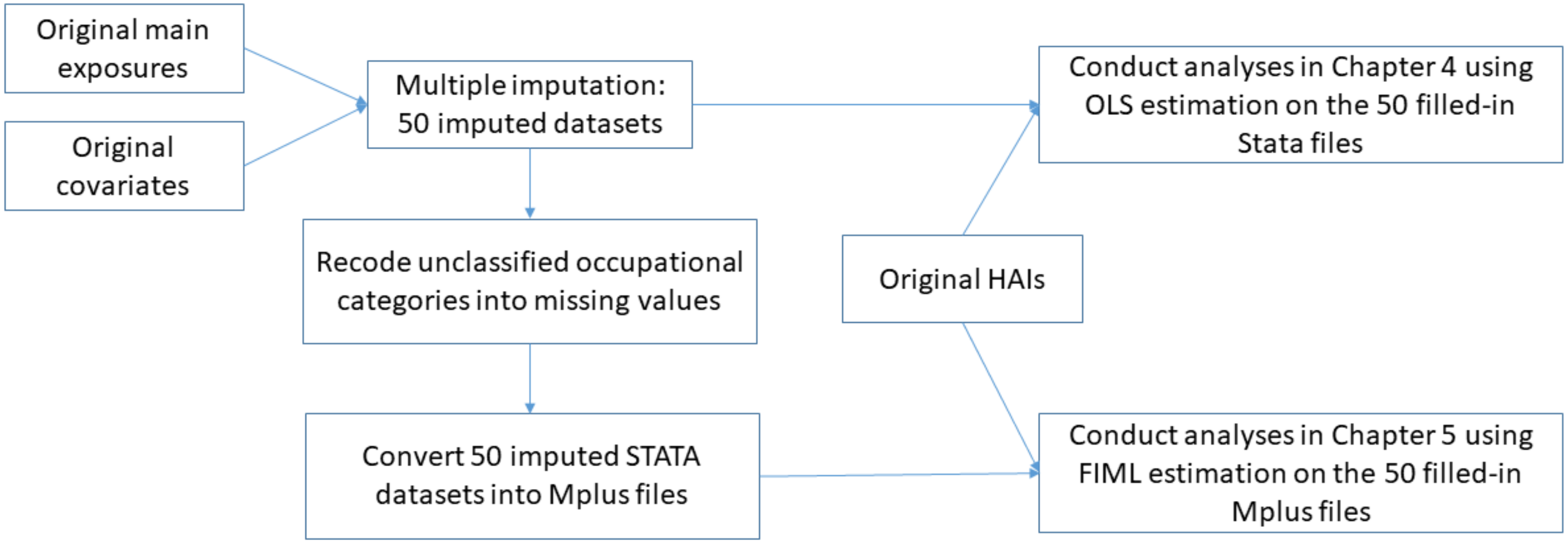
2.5 Approaches to Handling Missing Data

In Chapter 4, multiple imputation was used to deal with missing data in the four countries. Imputation models were built using the two-fold fully conditional specification (FCS) algorithm [235]. The assumption was that all missing values in each wave were missing at random (MAR). HAI scores, socioeconomic exposures, covariates and weighting variables were all included in the imputation model. Age in each wave was used as the timing variable. Compared with the wave number, which assumes that every respondent is measured at exactly the same time point, age is more accurate in measuring changes in HAI over time, as it specifies an entry and exit time for each individual differently. With the two-fold FCS algorithm, interactions between age and other variables were automatically considered in the imputation model. Records with imputed values for non-respondents in each wave were automatically excluded, as the two-fold FCS algorithm only imputed non-responded items within each wave, rather than non-responders (attrition/wave non-response) in that wave. For each country, 50 imputed datasets were created, to ensure that the number of imputation was large enough not to impact on the conclusions or inhibit analysis reproducibility. Previous research also suggests that the number of imputed datasets should be approximately equal to the percentage of incomplete cases [236]. Multiple imputation was performed using Stata SE 15.0 [237].

However, only imputed socioeconomic exposures and covariates are used in Chapter 4. The original HAI values were used for data analyses, since there is a debate over whether or not to apply imputed values of dependent variables in statistical analyses. For example, Little suggests that under MAR, there are no benefits in imputing the outcome [238]. Imputed outcome values might even introduce bias because of simulation error. Some researchers suggest including auxiliary variables in the imputation model. An auxiliary variable is not part of the analysed model but is highly correlated with the outcome [238]. These researchers suggest that if an auxiliary variable is included, imputation can be considerably more efficient than complete case analysis, resulting in more precise estimates and narrower CIs [238]. However, finding an auxiliary variable is not easy, since it must be highly correlated with the outcome in the general population [239]. Moreover, including auxiliary variables in a small sample would still lead to a downward bias of regression coefficients, and would especially decrease precision [239]. Therefore, in my analysis, the JSTAR sample size is relatively small. Potential auxiliary variables that are highly correlated with healthy ageing may also be different across countries. In order to avoid the inaccurate prediction of missing data, the imputation model in my analysis did not include any auxiliary variables. The observed HAIs were applied for the main analyses in Chapter 4.

Mplus 7.4 [240] was mainly used in Chapter 5 to conduct the path analysis. In order to maintain a consistent approach to handling missing data, I converted the 50 imputed STATA datasets into Mplus data files and conducted path analysis based on the imputed datasets. However, I had to recode the unclassified occupational categories, including "others", "retired", "unemployed", "disabled" and "not in the labour force" in the HRS, "never worked" in ELSA, "others" in CHARLS, and "others" and "unclassifiable" in JSTAR as missing values, in order to consider them ordinal and dependent variables in the path analysis [240]; the imputation approach shown in Chapter 5 was otherwise consistent with that in Chapter 4. The full information maximum likelihood (FIML) estimation method [241] was applied to deal with the missing values for the occupational variables in Chapter 5, under the assumptions of missingness at random and multivariate normality. Unlike multiple imputation, the FIML approach does not replace or impute missing values. Instead, it estimates a likelihood function for each case, using only the variables that are observed for that case. All available data were used for parameter estimation, and the likelihood functions were accumulated and maximised across the entire sample in each country [241]. A sensitivity analysis was conducted since the imputed datasets had been changed in Chapter 5 because of recoding unclassifiable occupational categories. The sensitivity analysis checked whether results based on incomplete data estimated by FIML were comparable with results based on augmented data using multiple imputation (further details are discussed in Chapter 5). See Figure 2-5 below for the procedure of handling missing data in Chapters 4 and 5.

Figure 2-5 The procedure of handling missing data in the four countries



2.6 Weighting Adjustment

The four longitudinal studies of ageing all had complex survey designs. Samples were stratified and frequently clustered. I applied weighting adjustment when conducting statistical analyses, to adjust for bias caused by sample designs. However, instead of using the longitudinal weights, baseline weights (at wave 7 for the HRS, and at wave 1 for ELSA, CHARLS and JSTAR) were employed for the four countries. The reason is that the longitudinal weights in the four countries were available only for participants who responded to all waves [216-219]. This project included samples who were recruited at baseline but possibly dropped out in follow-up waves. Therefore, the longitudinal weights were not appropriate for the analysis.

Chapter 3 Reliability and Validity of the HAI

3.1 Introduction

In Chapter 2, I explained how I developed a continuous variable HAI to measure healthy ageing comprehensively. In Chapter 1, I argued that the evaluation of validity and reliability is important for demonstrating whether scores on a scale actually represent the individual characteristics that they are supposed to measure, especially when the scale is to measure intelligence, depression or cognitive function. Therefore, before one can examine the longitudinal relationship between SEP and HAI across countries, the validity and reliability of the HAI need to be checked.

3.2 Objectives

This chapter aims to check the validity and reliability of the HAI. The objectives are:

1. To check the consistency of participants' HAIs across waves (test-retest reliability).
2. To check the consistency of participants' responses across different health indicators (internal consistency).
3. To compare the HAI's predictive performance on mortality risk with the phenotypic classification of frailty (PF), and to check whether the HAI can become an independent predictor of mortality risk among different countries (predictive validity).

3.3 Methods

Data from the HRS, ELSA and CHARLS were used to check the validity and reliability of the HAI. JSTAR was not included, due to the small number of mortality events (N=46). The HAI's test-retest validity was assessed across waves, and internal consistency was assessed for the HAI indicators in each longitudinal study. However, it was not possible to evaluate inter-rater reliability. The reason is that no information on studies' observers and data collectors could be found, as this project uses archived secondary datasets. For the validity check, I assessed the predictive validity of the HAI by employing survival analysis and Receiver Operating Characteristic (ROC) curve analysis to evaluate the HAI's performance in predicting the mortality risk in each country. Here the PF was treated as a criterion measure, since it has been widely demonstrated to be an independent predictor of mortality risk [242-244].

All valid HAIs at each wave in the three countries were included to test internal consistency (see Figure 2-4 in Chapter 2 for detail on sample sizes). Only participants who participated in all waves and had valid HAIs over all waves in the three countries were included to check test-retest reliability (N=4494 in the HRS, 1890 in ELSA and 3582 in CHARLS).

The PF variable was derived from information on five aspects of functional decline. This method was developed by Fried and colleagues [243]. The five aspects are:

1. Shrinking/weight loss: unintentional weight loss of at least 5% of the body weight in the previous wave (kg). Weight loss was calculated as: (weight in previous wave - current measured weight) / (weight in previous wave) = K. If K ≥ 0.05, then the individual meets the criterion for weight loss. Here I used information from waves 6 and 7 in the HRS, waves 0 and 2 in ELSA, and waves 1 and 2 in CHARLS.
2. Weakness/grip strength: average grip strength (kg) of the dominant hand by three grip strength tests, stratified by gender and BMI quartiles. The cut-off criteria for weak grip strength for men were: ≤ 29 kg if BMI ≤ 24; ≤ 30 kg if BMI = 24.1–26; ≤ 30 kg if BMI = 26.1–28; and ≤ 32 kg if BMI > 28. For women, the cut-off was ≤ 17 kg if BMI ≤ 23; ≤ 17.3 kg if BMI = 23.1–26; ≤ 18 kg if BMI = 26.1–29; and ≤ 21 kg if BMI > 29.
3. Poor endurance/exhaustion: two self-reported questions from the CES-D scale: a. whether respondent has felt depressed for much of the time during the past week; b. whether respondent could not get going for much of the time during the past week. If both answers = yes, then the individual meets the criterion for poor endurance/exhaustion.
4. Slowness/walk time: sum of two 2.5-metre (or 98.5-inch) walk tests (in seconds), stratified by gender and height. For men, when height ≤ 173 cm, the cut-off for slow time to walk 5 m is ≥ 7.7 seconds; when height > 173 cm, the cut-off is ≥ 6.6 seconds. For women, when height ≤ 159 cm, the cut-off is ≥ 7.7 seconds; when height >159 cm, the cut-off is ≥ 6.6 seconds.
5. Low activity: four self-reported questions about current working status and frequency of doing mild, moderate or vigorous activities/sports. If a respondent does not work and only does mild activities less than once per week, then they meet the criterion for low activity. In CHARLS, individuals in farming work

were treated as “in work”, since this work requires strength and consumes energy.

Meeting three or more of the criteria above indicates frailty; meeting one or two criteria indicates a pre-frail stage, identifying a subset at high risk of progressing to frailty [243].

One important component of PF – weight loss (kg) – is calculated using values of weights (kg) from two successive waves. Therefore, it is not applicable for deriving the PF variables at the baseline waves of ELSA and CHARLS, as values for the loss of weight would start at the second waves of ELSA and CHARLS. Finally, in ELSA and CHARLS, the PF was derived and compared with the HAI at wave 2 via ROC curve analysis, by including 3548 individuals in ELSA and 3015 individuals in CHARLS. Unlike ELSA and CHARLS, the PF variable at the baseline wave of the HRS was derived from information on weight at waves 6 and 7 (baseline), and compared with the HAI at baseline via ROC curve analysis (N=1837). For the survival analysis, baseline observed HAIs and imputed covariates, as well as mortality events during the follow-up period, were included. The survival analyses were conducted by including 10305, 6590 and 5930 participants in the HRS, ELSA and CHARLS respectively (for details of sample sizes, see Figure 2-1).

3.3.1 Assessment of Test-Retest Reliability

Pearson’s r was calculated for the test-retest correlations of HAIs across waves [119]. In previous research, there is no absolutely acceptable cut-off for test-retest reliability, as the cut-point value depends on the time between test and retest, the length of the test, what is being measured, and the sample characteristics [245]. Some measures are very stable, but others might show changes over time. Price suggests that a correlation of 0.80 or greater should be considered to indicate good or excellent reliability, while a correlation between 0.70 and 0.80 is considered acceptable reliability [119].

3.3.2 Assessment of Internal Consistency

Cronbach’s α was applied to check the internal consistency of the HAI [119]. Cronbach’s α is the mean value of all possible split-half correlations for the health indicators. A value of 0.80 or greater is considered to indicate good or excellent internal consistency, and values between 0.70 and 0.80 acceptable consistency [119].

3.3.3 Assessment of Predictive Validity

ROC curve analysis was applied to evaluate the HAI's performance in predicting mortality risks, and to compare predictive performance between the HAI and PF. This is the most frequently employed method to determine criterion validity [121]. ROC curve analysis quantifies how accurately measurements can discriminate between two health statuses, such as "diseased" and "non-diseased", or "dead" and "alive" [246]. Its curve illustrates the trade-off between sensitivity and (1-specificity). The sensitivity of a test identifies the degree to which the test can sense or detect the presence of disease, and is the proportion of true positives that are correctly identified by the test. The specificity, meanwhile, is the degree to which the test identifies only that disease and not other conditions. It is defined as the proportion of true negatives that are correctly identified by the test. The accuracy of a test is its ability to differentiate the diseased and normal cases correctly, and is the proportion of true positives plus true negatives in all evaluated cases [247]. The area under the ROC curve (AUC) indicates how accurately a measure can distinguish between two diagnostic groups (diseased versus normal). The value of the AUC varies from 0.5 for chance accuracy to 1.0 for perfect accuracy [246]. ROC measures of accuracy and relevant cut-offs to rank accuracy have been widely applied in medical imaging, weather forecasting and information retrieval; however, current epidemiological research has not defined a commonly accepted cut-off for ranking accuracy [248].

A comparison of performance in predicting mortality risks between the HAI and the PF (criterion) was conducted, to see whether the HAI's predictive performance was similar to or better than the PF's. Empirical ROC curves were also drawn for each country, to compare accuracy between the HAI and the PF in predicting a subsequent mortality event.

The relationship between the HAI at baseline and subsequent all-cause mortality was evaluated in the HRS, ELSA and CHARLS. Survival analysis was applied to check the predictive validity of the HAI. The Cox proportional hazards model was employed to produce the predictive estimated hazard ratio (HR) for the HAI. The HR was assumed to be constant over time. In each country, for participants who had mortality events during the follow-up, the survival time was the duration between the date of interview at baseline and the date of the mortality event; for other participants, the censoring time was the duration between the date of interview at baseline and the date of the end of the study follow-up. Univariate analyses were also conducted to assess the unadjusted relationship between the HAI/each covariate and mortality in each country (Table 3-5). For the main relationship between the baseline HAI and a subsequent mortality event, a fully adjusted model was built for each country. Wald tests and both forward and backward selection were employed to help identify potential confounders at baseline and to build the most appropriate final models for survival analyses. See the example below for a Cox proportional hazards model: $h_i(t)$ is the hazard function for individual i, and $h_0(t)$ is the baseline hazard function; x_1 to x_n are covariates; β_1 to β_n are estimated effects of covariates, which are assumed to be constant over time.

$$h_i(t) = h_0(t)exp(\beta_1 x_{i1} + \beta_1 x_{i2} + \cdots + \beta_n x_{in})$$

Finally, baseline covariates including age, gender, ethnicity, education, income, wealth, occupation, marital status, self-rated health in childhood, father's occupation in childhood, smoking and drinking were included for adjustment in each country.

All analyses were performed using Stata SE 15.0 [237], and P < 0.05 was considered statistically significant.

3.4 Results

3.4.1 Sample Characteristics at Baseline

Table 3-1 shows participants' baseline characteristics. On average, Chinese participants were younger but unhealthier than American and English participants. There were more females in the HRS and ELSA, but more males in CHARLS. Participants were mainly white in the HRS and ELSA, and mainly Han in CHARLS. Most participants had an upper secondary education in the HRS, and primary education or less in ELSA and CHARLS. In the HRS, the majority had already retired at baseline (73.39%). In CHARLS, more than 70% of participants conducted unpaid agricultural work only. In ELSA, participants mainly had intermediate occupational positions. In the HRS, ELSA and CHARLS, 42.04%, 40.29% and 20.60% of participants respectively had no spouse. American fathers were mainly in disadvantaged occupational positions, and Chinese fathers mainly did agricultural work. However, English fathers' occupational positions were mainly at intermediate levels. Compared with American and English participants, a greater proportion of Chinese participants reported poor or fair health in childhood. The majority of English and American participants were ex-smokers, while the majority of Chinese participants were non-smokers. However, compared with the HRS and

ELSA, CHARLS had a greater proportion of current smokers and daily alcohol consumers. Participants mainly had pre-frailty in all countries: more than 30% of them had slowness or weakness issues in all countries; 44.52% of Chinese participants had exhaustion issues.

Table 3-1 Baseline characteristics in HRS, ELSA and CHARLS

Variables	HRS (N=10305)	ELSA (N=6590)	CHARLS (N=5930)
HAI (Mean)	75.45	78.40	73.76
Age (Mean)	72	71	68
Gender (%)			
Male	41.23	44.08	51.74
Female	58.77	55.92	48.26
Ethnicity* (%)			
1	83.84	98.29	93.14
2	12.86	1.71	6.86
3	3.30		
Education (%)			
First stage of tertiary or more	20.90	11.05	2.12
Post-secondary non-tertiary	-	12.59	3.24
Upper secondary education	54.10	5.11	2.26
Lower secondary education	16.34	20.07	37.67
Primary education or less	6.66	40.01	54.70
Others	-	11.18	-
Income (%)			
Highest	19.85	20.61	20.18
2nd	20.40	20.44	20.22
3rd	20.50	20.12	20.25
4th	20.17	19.79	20.43
Lowest	19.08	19.04	18.93
Wealth (%)			
Highest	20.52	20.54	20.05
2nd	20.47	20.43	19.81
3rd	20.29	20.35	20.40
4th	19.89	19.71	20.44
Lowest	18.83	18.96	19.30
Occupation (%)**			
1	4.17	8.37	2.08
2	3.79	20.75	2.73
3	1.95	14.19	6.76
4	0.62	11.30	18.28
5	0.87	12.46	70.16
6	1.38	17.04	-
7	5.74	14.20	-
8	73.39	1.69	-
9	0.65	-	-
10	0.78	-	-
11	6.66	-	-
Marital status (%)			
Married or partnered-Ref.	57.96	59.71	79.39
Separated, divorced or single	13.23	11.72	2.19
Widowed	28.81	28.57	18.41
Father's occupation* (%)**			
1	13.47	10.71	4.88
2	10.98	10.46	3.94
3	4.45	35.49	1.96
4	26.86	4.46	4.12
5	21.61	8.28	78.30
6	21.70	27.16	3.69

Variables	HRS (N=10305)	ELSA (N=6590)	CHARLS (N=5930)
7	0.93	0.88	3.11
8	-	2.57	-
Self-rated health in childhood (%)			
Excellent	50.06	29.44	10.18
Very good	25.53	34.64	36.75
Good	18.15	22.90	27.83
Fair	4.84	9.02	17.69
Poor	1.42	4.00	7.56
Smoking status (%)			
Never smoke	43.13	35.86	56.53
Ever smoked, now no smoke	47.94	53.44	12.59
Smoke	8.94	10.70	30.88
Frequency of drinking[****] (%)			
0	69.07	38.02	77.56
1	9.36	13.92	4.20
2	5.08	12.28	4.17
3	3.83	8.56	1.71
4	1.87	5.56	12.36
5	2.03	4.40	-
6	1.04	3.87	-
7	7.73	13.39	-
PF (%)			
No Frailty	32.88	38.10	18.37
Pre-Frailty	53.89	49.68	64.30
Frailty	13.23	12.22	17.33
Components of PF (%)			
Shrinking	19.24	23.39	14.04
Weakness	31.35	37.74	35.45
Exhaustion	8.11	9.67	44.52
Slowness	39.28	30.57	49.47
Low activity	11.42	2.01	1.48

[*] In HRS, 1=White/Caucasian 2=Black/African American 3=Others; In ELSA, 1=White 2=Non-white; In CHARLS, 1=Han 2=Minorities

[**] In HRS, 1=Managerial and professional sociality occupation 2=Technical, sales and administrative support 3=Service occupations 4=Farming, forestry and fishing occupations 5=Precision production, craft and repair 6=Operators, fabricators and labours 7=Others 8=Retired 9=Unemployed 10=Disabled 11=Not in the labour force; In ELSA, 1=Higher managerial and professional employers 2=Lower managerial and professional employers 3=Intermediate employees 4=Small employers and own account workers 5=Lower supervisory, craft and related employees 6=Employees in semi-routine occupations 7=Employees in routine occupations 8=Never worked; In CHARLS, 1=Officials/managers/leaders or Clerks/paid workers 2=Self-employed workers 3=Unpaid family business 4=Others 5=Only agricultural work

[***] In HRS, 1=Managerial and professional speciality occupation 2=Technical, sales and administrative support 3=Services occupation 4=Farming, forestry and fishing occupations 5=Precision productions, craft and repair occupations 6=Operators, fabricators and labours 7=Unclassifiable; In ELSA, 1=Professional or technical 2=Manager, senior official, admin., cleric or secretarial 3=Own business, or skilled trade 4=Service-skilled non-manual 5=Service-skilled manual 6=Others 7=Retired 8=Unemployed, sick or disabled; In CHARLS, 1=Manager 2=Professional and technician 3=Clerk 4=Commercial and service worker 5=Agricultural, forestry, husbandry and others 6=Production and transportation workers 7=Others

[****] In HRS and ELSA, frequency of drinking = days of drinking per week (0=None 1=1 day 2=2 days 3=3 days 4=4 days 5=5 days 6=6 days 7=7 days); In CHARLS, frequency of drinking= times of drinking per month (0=non or less than once per month 1=one to several times per month 2=one to several times per week 3=most days of the week 4=every day of the week

3.4.2 Test-Retest Reliability and Internal Consistency

Table 3-2 presents the correlation between HAIs across waves in the three countries, to indicate the test-retest reliability of the HAI. In the HRS, the correlations between HAIs across two successive waves (in waves 7–12) were 0.811, 0.792, 0.792, 0.820 and 0.812. In ELSA, the correlations between HAIs across two successive waves (in waves 1–7) were 0.847, 0.835, 0.844, 0.845, 0.841 and 0.848. All values were very close to or greater than 0.80, indicating that around 64% (0.8^2) of the observed variance in HAI at one wave could be explained by an HAI at the previous wave. In CHARLS, across three waves, the correlations between HAIs across two successive waves were 0.685 and 0.738, which were close to or greater than 0.70, suggesting that around 49% (0.7^2) of the observed variance at one wave could be explained by an HAI at the previous wave.

Table 3-3 shows the values of Cronbach's α for the HAI at each wave in the three countries, to indicate the internal consistency of the HAI. Across waves in each country, the values of Cronbach's α were all greater than 0.80.

Table 3-2 Correlation between HAIs across waves in HRS, ELSA and CHARLS

HRS (N=4494)	Wave 7	Wave 8	Wave 9	Wave 10	Wave 11	Wave 12	
Wave 7	1.000						
Wave 8	**0.811**	1.000					
Wave 9	0.769	**0.792**	1.000				
Wave 10	0.732	0.771	**0.792**	1.000			
Wave 11	0.697	0.720	0.773	**0.820**	1.000		
Wave 12	0.652	0.693	0.709	0.788	**0.812**	1.000	
ELSA (N=1890)	**Wave 1**	**Wave 2**	**Wave 3**	**Wave 4**	**Wave 5**	**Wave 6**	**Wave 7**
Wave 1	1.000						
Wave 2	**0.847**	1.000					
Wave 3	0.803	**0.835**	1.000				
Wave 4	0.773	0.797	**0.844**	1.000			
Wave 5	0.756	0.763	0.811	**0.845**	1.000		
Wave 6	0.720	0.737	0.790	0.821	**0.841**	1.000	
Wave 7	0.694	0.670	0.750	0.776	0.800	**0.848**	1.000
CHARLS (N=3582)	**Wave 1**	**Wave 2**	**Wave 4**				
Wave 1	1.000						
Wave 2	**0.685**	1.000					
Wave 4	0.680	**0.738**	1.000				

Table 3-3 Scale reliability coefficients for the HAI at each wave in HRS, ELSA and CHARLS

Cronbach's α	Wave 1 (7 in HRS)	Wave 2 (8 in HRS)	Wave 3 (9 in HRS)	Wave 4 (10 in HRS)	Wave 5 (11 in HRS)	Wave 6	Wave 7
HRS	0.819	0.831	0.832	0.833	0.840	0.836	-
ELSA	0.815	0.827	0.829	0.831	0.847	0.851	0.840
CHARLS	0.849	0.834	-	0.858	-	-	-

3.4.3 Predictive Validity

Table 3-4 presents a comparison of predictive performance between PF and HAI by AUCs in each country (including 95% CIs). Figure 3-1 illustrates the empirical ROC curves for PF and HAI in each country. In the HRS and ELSA, there were no significant differences in AUC between PF and HAI ($P > 0.05$), indicating that the accuracy of predicting subsequent mortality risks for the HAI was similar to that for the PF. Also, the two ROC curves in the HRS and ELSA had similar shapes (Figure 3-1), indicating that the HAI might have similar sensitivity and specificity to the PF at each cut-off point. In CHARLS, even though statistically there was no difference in AUC between PF and HAI ($P > 0.05$), Figure 3-1 shows that the ROC curve for PF was slightly superior to the ROC curve for HAI.

Table 3-4 Comparison of predictive performance between PF and HAI by AUCs in each country

Studies	AUCs	Standard Errors	95%CIs	P-values
HRS (N=1837)				
PF-Criterion	0.676	0.011	(0.655 to 0.698)	0.410
HAI	0.687	0.012	(0.662 to 0.711)	
ELSA (N=3548)				
PF-Criterion	0.671	0.010	(0.651 to 0.690)	0.177
HAI	0.684	0.011	(0.664 to 0.705)	
CHARLS (N=3015)				
PF-Criterion	0.628	0.025	(0.580 to 0.678)	0.166
HAI	0.589	0.031	(0.528 to 0.649)	

Figure 3-1 Empirical ROC curves of PF and HAI in HRS (N=1837), ELSA (N=3548) and CHARLS (N=3015)

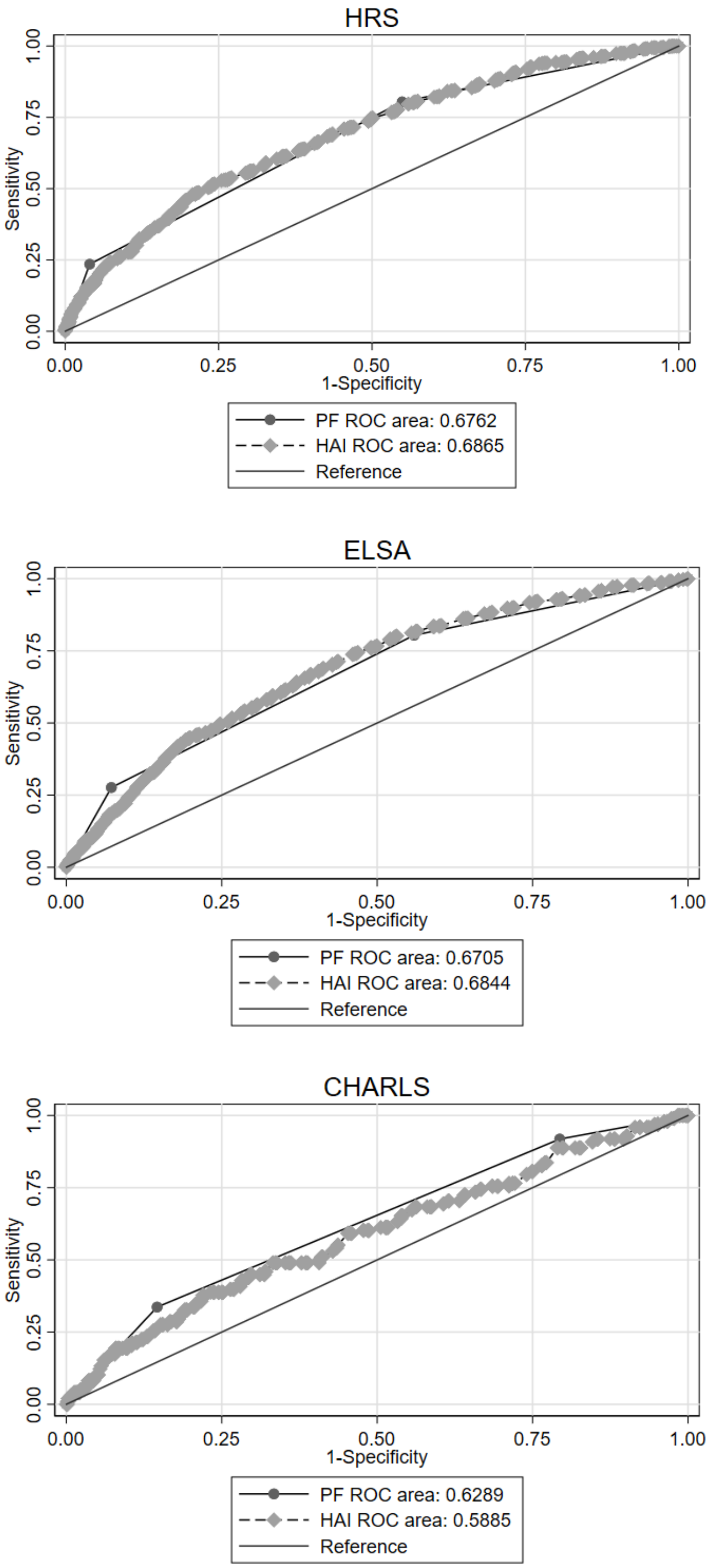


Table 3-5 shows univariate relationships between main exposure and covariates and mortality in each country. In Table 3-5, at any time during follow-up, one unit increase in HAI was associated with a 4.8% (95% CI: 4.6–5.1%), 3.7% (95% CI: 3.4–4.0%) and 3.0% (95% CI: 2.3%–3.7%) reduced rate of experiencing mortality events earlier in the HRS, ELSA and CHARLS respectively. In the HRS and ELSA, compared with white participants, participants from other ethnic groups were less likely to experience mortality events earlier (HR: 0.746 (95% CI: 0.591–0.942) in the HRS and 0.610 (95% CI: 0.405–0.917) in ELSA). Female participants were 21.0% (95% CI: 15.4–26.3%), 21.4% (95% CI: 14.1–28.0%) and 26.5% (95% CI: 8.5–40.9%) less likely to have mortality events earlier than male participants in the HRS, ELSA and CHARLS respectively. In the HRS, the hazard of having earlier death for participants with lower levels of education was higher than that for those with the top level of education. In ELSA, participants with primary education or less were more likely to experience a mortality event younger than those in the top level of education. In each country, participants with lower income and wealth were more likely to experience mortality events earlier than those with top levels of income and wealth. In general, the hazards of dying earlier for participants in disadvantaged occupational groups were higher than for participants in the most advantaged occupational groups in the four countries. Compared with married or partnered participants, those who were single, divorced, separated and widowed were more likely to experience mortality events younger in each country. In the HRS and ELSA, participants who reported poorer health during childhood were more likely to experience mortality events earlier than those who had been in better health. However, in CHARLS, those who reported fair or poor health during childhood were less likely to have hazards of dying earlier. Participants who were current or previous smokers were more likely to die younger than non-smokers. However, the hazard of dying earlier for participants who consumed alcohol every week was lower than for non-alcohol consumers in the HRS and ELSA. In CHARLS, the relationship between alcohol consumption and mortality was not statistically significant.

Table 3-5 Univariate relationships between main exposure/covariates and mortality in each country

Risk factors (mean/%)	HRS (Death=4011 Censored=6292)		ELSA (Death=1963 Censored=4626)		CHARLS (Death=487 Censored=5115)	
	HR (95%CIs)	P-values	HR (95%CIs)	P-values	HR (95%CIs)	P-values
HAI	0.952 (0.949 to 0.954)	<0.001	0.963 (0.960 to 0.966)	<0.001	0.970 (0.963 to 0.977)	<0.001
Age	1.100 (1.095 to 1.105)	<0.001	1.109 (1.103 to 1.116)	<0.001	1.096 (1.082 to 1.110)	<0.001
Ethnicity*						
1-Ref.						
2	1.075 (0.969 to 1.192)	0.173	0.610 (0.405 to 0.917)	<0.001	1.375 (0.837 to 2.259)	0.209
3	0.746 (0.591 to 0.942)	0.014	-		-	
Gender						
Male-Ref.						
Female	0.790 (0.737 to 0.846)	<0.001	0.786 (0.720 to 0.859)	<0.001	0.735 (0.591 to 0.915)	0.006
Education						
First-stage tertiary education or more-Ref						
Post-secondary non-tertiary education	-	-	0.956 (0.768 to 1.191)	0.699	1.817 (0.556 to 5.939)	0.323
Upper secondary education	1.303 (1.185 to 1.432)	<0.001	1.093 (0.832 to 1.435)	0.524	0.755 (0.197 to 2.894)	0.682
Lower secondary education	1.874 (1.680 to 2.090)	<0.001	1.096 (0.905 to 1.328)	0.349	1.377 (0.546 to 3.475)	0.498
Primary education or less	1.793 (1.552 to 2.072)	<0.001	1.812 (1.532 to 2.143)	<0.001	2.121 (0.849 to 5.296)	0.107
Others	-	-	1.131 (0.912 to 1.403)	0.264	-	-
Income						
Highest-Ref.						
Second	1.411 (1.239 to 1.606)	<0.001	1.295 (1.096 to 1.530)	0.002	1.258 (0.830 to 1.905)	0.279
Third	1.920 (1.698 to 2.171)	<0.001	2.085 (1.791 to 2.431)	<0.001	1.495 (0.995 to 2.246)	0.053
Fourth	2.343 (2.077 to 2.642)	<0.001	2.213 (1.899 to 2.579)	<0.001	1.560 (1.069 to 2.277)	0.021
Lowest	2.535 (2.240 to 2.868)	<0.001	2.455 (2.108 to 2.859)	<0.001	1.538 (1.029 to 2.300)	0.036
Wealth						
Highest-Ref.						
Second	1.213 (1.081 to 1.361)	0.001	1.318 (1.125 to 1.545)	0.001	1.238 (0.794 to 1.931)	0.346
Third	1.466 (1.308 to 1.643)	<0.001	1.456 (1.246 to 1.702)	<0.001	1.332 (0.890 to 1.995)	0.164
Fourth	1.693 (1.513 to 1.895)	<0.001	1.951 (1.680 to 2.267)	<0.001	1.252 (0.853 to 1.838)	0.250
Lowest	2.171 (1.946 to 2.422)	<0.001	2.594 (2.242 to 3.001)	<0.001	1.406 (0.909 to 2.174)	0.125
Occupation**						
1-Ref.						
2	1.084 (0.819 to 1.434)	<0.001	1.219 (0.987 to 1.506)	0.065	1.444 (0.305 to 6.846)	0.643
3	1.097 (0.802 to 1.500)	<0.001	1.253 (1.003 to 1.567)	0.047	2.264 (0.635 to 8.070)	0.207

Risk factors (mean/%)	HRS (Death=4011 Censored=6292)		ELSA (Death=1963 Censored=4626)		CHARLS (Death=487 Censored=5115)	
	HR (95%CIs)	P-values	HR (95%CIs)	P-values	HR (95%CIs)	P-values
4	1.893 (1.242 to 2.885)	0.573	1.502 (1.194 to 1.889)	0.001	3.320 (1.044 to 10.558)	0.042
5	1.311 (0.846 to 2.032)	0.561	1.796 (1.448 to 2.228)	<0.001	2.390 (0.768 to 7.434)	0.132
6	1.389 (0.988 to 1.951)	0.003	1.557 (1.260 to 1.923)	<0.001	-	-
7	2.712 (0.877 to 8.385)	0.226	1.857 (1.506 to 2.291)	<0.001	-	-
8	2.863 (2.346 to 3.496)	0.058	2.576 (1.476 to 4.496)	0.001	-	-
9	1.419 (0.708 to 2.844)	0.083	-		-	-
10	2.812 (1.940 to 4.074)	<0.001	-		-	-
11	2.683 (2.151 to 3.346)	<0.001	-		-	-
Marital status						
Married or partnered-Ref.						
Separated, divorced or single	1.193 (1.066 to 1.336)	0.002	1.159 (1.003 to 1.338)	0.045	1.960 (1.130 to 3.402)	0.017
Widowed	1.793 (1.666 to 1.930)	<0.001	1.820 (1.655 to 2.002)	<0.001	1.864 (1.462 to 2.375)	<0.001
Self-rated health in childhood						
Excellent-Ref.						
Very good	1.074 (0.987 to 1.168)	0.099	1.208 (1.051 to 1.389)	0.008	0.744 (0.533 to 1.037)	0.081
Good	1.135 (1.034 to 1.247)	0.008	1.255 (1.056 to 1.492)	0.010	0.718 (0.511 to 1.011)	0.058
Fair	1.149 (0.976 to 1.353)	0.095	1.201 (0.957 to 1.505)	0.113	0.545 (0.359 to 0.827)	0.004
Poor	1.036 (0.776 to 1.384)	0.81	1.487 (1.110 to 1.993)	0.008	0.418 (0.252 to 0.695)	0.001
Father's occupation* **						
1-Ref.						
2	1.109 (0.950 to 1.294)	0.191	1.112 (0.898 to 1.377)	0.331	0.758 (0.235 to 2.443)	0.641
3	1.202 (0.977 to 1.478)	0.082	1.216 (1.023 to 1.446)	0.027	1.090 (0.241 to 4.938)	0.911
4	1.336 (1.177 to 1.516)	<0.001	1.127 (0.863 to 1.470)	0.380	0.894 (0.310 to 2.583)	0.836
5	1.180 (1.033 to 1.349)	0.015	1.273 (1.023 to 1.583)	0.030	1.274 (0.610 to 2.660)	0.517
6	1.237 (1.082 to 1.413)	0.002	1.389 (1.166 to 1.655)	<0.001	0.917 (0.281 to 2.995)	0.886
7	0.834 (0.484 to 1.440)	0.515	0.720 (0.378 to 1.371)	0.317	1.238 (0.410 to 3.739)	0.704
8	-	-	1.406 (1.042 to 1.896)	0.026	-	
Smoking status						
Never smoke-Ref.						
Ever smoked, now no smoke	1.370 (1.272 to 1.475)	<0.001	1.407 (1.269 to 1.559)	<0.001	2.363 (1.800 to 3.102)	<0.001
Smoke	1.553 (1.385 to 1.743)	<0.001	1.635 (1.430 to 1.870)	<0.001	1.505 (1.179 to 1.922)	0.001
Frequency of drinking******						
0-Ref.						

Risk factors (mean/%)	HRS (Death=4011 Censored=6292)		ELSA (Death=1963 Censored=4626)		CHARLS (Death=487 Censored=5115)	
	HR (95%CIs)	P-values	HR (95%CIs)	P-values	HR (95%CIs)	P-values
1	0.735 (0.644 to 0.840)	<0.001	0.780 (0.687 to 0.885)	<0.001	0.963 (0.506 to 1.832)	0.907
2	0.673 (0.561 to 0.807)	<0.001	0.667 (0.568 to 0.783)	<0.001	0.968 (0.548 to 1.711)	0.912
3	0.664 (0.546 to 0.807)	<0.001	0.586 (0.481 to 0.713)	<0.001	0.462 (0.127 to 1.678)	0.240
4	0.696 (0.529 to 0.916)	0.01	0.637 (0.500 to 0.813)	<0.001	0.887 (0.651 to 1.209)	0.447
5	0.567 (0.421 to 0.763)	<0.001	0.543 (0.406 to 0.726)	<0.001	-	-
6	0.674 (0.463 to 0.979)	0.039	0.484 (0.347 to 0.674)	<0.001	-	-
7	0.977 (0.866 to 1.102)	0.702	0.834 (0.738 to 0.942)	0.004	-	-

[*] In HRS, 1=White/Caucasian 2=Black/African American 3=Others; In ELSA, 1=White 2=Non-white; In CHARLS, 1=Han 2=Minorities

[**] In HRS, 1=Managerial and professional sociality occupation 2=Technical, sales and administrative support 3=Service occupations 4=Farming, forestry and fishing occupations 5=Precision production, craft and repair 6=Operators, fabricators and labours 7=Others 8=Retired 9=Unemployed 10=Disabled 11=Not in the labour force; In ELSA, 1=Higher managerial and professional employers 2=Lower managerial and professional employers 3=Intermediate employees 4=Small employers and own account workers 5=Lower supervisory, craft and related employees 6=Employees in semi-routine occupations 7=Employees in routine occupations 8=Never worked; In CHARLS, 1=Officials/managers/leaders 2=Clerks/paid workers 3=Self-employed workers 4=Others 5=Only agricultural work

[***] In HRS, 1=Managerial and professional speciality occupation 2=Technical, sales and administrative support 3=Services occupation 4=Farming, forestry and fishing occupations 5=Precision productions, craft and repair occupations 6=Operators, fabricators and labours 7=Unclassifiable; In ELSA, 1=Professional or technical 2=Manager, senior official, admin., cleric or secretarial 3=Own business, or skilled trade 4=Service-skilled non-manual 5=Service-skilled manual 6=Others 7=Retired 8=Unemployed, sick or disabled; In CHARLS, 1=Manager 2=Professional and technician 3=Clerk 4=Commercial and service worker 5=Agricultural, forestry, husbandry and others 6=Production and transportation workers 7=Others

[****] In HRS and ELSA, frequency of drinking = days of drinking per week (0=None 1=1 day 2=2 days 3=3 days 4=4 days 5=5 days 6=6 days 7=7 days); In CHARLS, frequency of drinking= times of drinking per month (0=non or less than once per month 1=one to several times per month 2=one to several times per week 3=most days of the week 4=every day of the week

Table 3-6 shows the longitudinal relationship between baseline HAIs and subsequent mortality events in each country. All results were statistically significant ($P < 0.001$). At any time during follow-up, one unit increase in HAI was associated with a 3.8%, 2.5% and 2.3% reduction in the risk of experiencing a mortality event in the HRS, ELSA and CHARLS respectively. In the HRS, ELSA and CHARLS, HAIs at baseline ranged from 17.33 to 98.42, 20.76 to 99.24, and 23.48 to 99.24 respectively. There were around 81.09-unit (HRS), 78.48-unit (ELSA) and 75.76-unit (CHARLS) differences between the most and least healthy persons. Therefore, it was estimated that compared with the healthiest person, the least healthy person would be 3.08, 1.96 and 1.74 times more likely to die younger in the HRS, ELSA and CHARLS respectively.

Table 3-6 HAI at baseline and risk of subsequent mortality event by country

Studies	Fully adjusted Model*		
	Hazard Ratios (95% CIs)	S.E.	P-values
HRS	0.962 (0.959 to 0.966)	0.002	<0.001
ELSA	0.975 (0.972 to 0.979)	0.002	<0.001
CHARLS	0.977 (0.969 to 0.985)	0.004	<0.001

* Models were adjusted for age, gender, ethnicity, marital status, education, income, wealth, occupation, self-rated health in childhood, father's occupation in childhood, smoking and frequency of drinking at baseline.

3.4 Discussion

3.4.1 Summary of Results

In summary, the values of Pearson's r were all close to or greater than 0.80 in the HRS and ELSA, and 0.70 in CHARLS. The values of Cronbach's α were all greater than 0.80 in the three countries. The HAI's accuracy of predicting subsequent mortality events was 0.687 in the HRS, 0.684 in ELSA and 0.589 in CHARLS. All P-values were larger than 0.05, indicating that there were no significant differences in AUC between the PF and HAI. However, the ROC curve for the HAI was slightly superior to that for the PF in CHARLS. For the longitudinal relationships between baseline HAIs and subsequent mortality events in the three countries, after full adjustments, at any time during follow-up, a one-unit increase in HAI was associated with a 3.8%, 2.5% and 2.3% reduction in the risk of experiencing a mortality event younger in the HRS, ELSA and CHARLS respectively.

3.4.2 Overall Reliability and Predictive Validity of the HAI

The HAI's test-retest reliability and internal consistency reached acceptable or good levels in the three countries, suggesting that individuals' HAIs were consistent across waves, and that their responses were also consistent across health indicators in each wave. The overall reliability of the HAI was above an acceptable level. Therefore, the analysis can have confidence that an individual's HAI represents his/her true health status.

The epidemiological research in the literature has not defined a common confidence level for accuracy [248]. One study defined AUC ≥ 0.65 as a moderate and consistent level of accuracy for predicting adverse health outcomes such as disability, healthcare utilisation and depression [121]. Therefore, AUC values might indicate a good predictive validity for the HAI in the three countries.

Regarding the survival analyses, baseline HAIs were closely related to the risk of experiencing a subsequent mortality event in the three countries, even after full adjustments. The baseline HAIs predicted a risk of 11-year, 14-year and five-year mortality in the HRS, ELSA and CHARLS respectively, and found that one unit increase in HAI was associated with a 3.8%, 2.5% and 2.3% reduction in the risk of experiencing a mortality event younger in the HRS, ELSA and CHARLS respectively. Therefore, the HAI may be considered an independent predictor of mortality risk in the three countries.

The analysis indicated that the HAI can represent the true health status of individuals aged 60 and more, and can predict subsequent mortality events accurately across countries. This finding is very important for population-based studies. The HAI may be applied as a preliminary screening of healthy agers among older people in both Western and Asian countries. It provides a multidimensional perspective on healthy ageing, and it uses health indicators which do not need to include biomarkers and are often available in studies and patients' reports. Therefore, it is beneficial for the promotion of comprehensive interventions to prevent adverse health outcomes, especially mortality, among the ageing population.

Unlike PF, the HAI does not include either BMI or physical activity as health indicators. The reasons are: researchers have argued that ageing is accompanied by a progressive increase in the ratio between fat and lean body mass, and BMI fails to detect the "conversion" of lean to fat tissue [111]; and physical activity is difficult to measure accurately, as it occurs during work, transport and entertainment activities [105].

Rockwood and colleagues also developed a frailty index (FI) to measure older people's frailty status by including around 70 health indicators [112]. The current HAI includes a few similar health indicators to the FI, especially in physical capabilities and cognitive function. However, unlike the FI, this HAI also includes indicators such as self-reported life satisfaction and participation in social activities, in order to assess healthy ageing from a psychosocial perspective, which has been emphasised in some theories of healthy ageing [24, 27].

The biological processes underpinning mortality risk are expected to be similar in the US, England and China. According to the theory of healthy biological ageing, the onset of chronic diseases and disabilities will be accelerated among unhealthy agers, and will then have impacts on immune dysfunction, neuroendocrine dysregulation and sarcopenia, which will eventually cut the length of longevity [27].

In terms of the demographic and social determinants of mortality risk, the current analyses considered age, gender, marital status, education, income, wealth, self-rated health in childhood, smoking and drinking. Previous research has found evidence that these distal factors affect the biological elements of health and longevity through material, psychosocial and behavioural pathways [249]. However, more different country-specific contributors to mortality might exist. For example, different health insurance coverage in the US, UK and China may affect survival status differently in the ageing population [250, 251].

3.5 Limitations

Some limitations need to be raised. First, missingness might cause selection bias and underestimate the impacts of risk factors on health outcomes. For example, only 1837 cases were included to derive the PF in the HRS, since grip strength and walking speed were only tested among a small subgroup [234]. However, the distribution of frailty, pre-frailty and no-frailty samples was similar to the distributions in several other studies in the US [243, 252, 253]. Therefore the PF missingness might not affect the validity of the result.

Second, compared to HRS and ELSA, the test-retest correlations between HAIs across waves in CHARLS were relatively low (around 0.7). This might be due to a high proportion of missing values in health indicators in CHARLS. In the fourth wave of CHARLS in particular, questions about chronic diseases had 53% to 78% missing values. Even though these missing values had been replaced by mean values from the previous two waves, the measurement of healthy ageing may become less stable in later waves of CHARLS.

The third limitation is the representativeness of the PF in CHARLS. Standards of PF were established on the basis of a Western population, which might not be appropriate for identifying frailty among Asian people. Therefore, the AUC for HAI was slightly smaller than for PF in CHARLS, but statistically there was no difference between two AUCs.

Fourth, more criteria could be applied to demonstrate and enhance the criterion validity of the HAI. For example, many studies apply the SF-36 to measure healthy ageing (see Chapter 2). Comparisons of scores between the SF-36 and HAI could be conducted. However, the current analysis is based on a strategy of harmonisation. Valid criteria must be available in each country, which constrains the choice.

Finally, in terms of the relationship between covariates and mortality, those in CHARLS who reported poorer health in childhood were less likely to experience a mortality event younger. According to the distribution of non-responders outlined in Chapter 2 (see Table 2-2), Chinese participants with better self-rated health in childhood were more likely to be non-responders. Here a selective survival bias might exist: children who had poor health might have died earlier, thereby altering the distribution of self-rated health in childhood among survivors and reducing the amount of variation in the risk factor, which in turn might decrease the strength or even change the direction of the association [254]. The hazard of dying earlier for participants who consumed alcohol was also lower than for those who drank no alcohol in the HRS and ELSA. This might be due to a selection effect. Healthy older persons are able to continue drinking alcohol. Those who consumed no alcohol during the survey years might have had serious alcohol problems before but stopped drinking alcohol after entering the study, due to serious health problems [255].

3.6 Conclusions

In conclusion, the overall reliability of the HAI reaches an acceptable level. The HAI also has good predictive validity and can be treated as an independent predictor of mortality risk in later life. It can be applied as a preliminary screening of healthy ageing among people older than 60 years in both Western and Asian countries. Further research based on more longitudinal studies worldwide, with fewer missing values, a wider age range and more referenced criteria, are necessary to enhance the demonstration of the HAI's validity and reliability.

This chapter has confirmed the validity and reliability of the HAI. The HAI can be applied as a robust measure of healthy ageing across countries. The next chapter will to assess the longitudinal relationship between SEP (education, income, wealth and occupation) and HAIs within and across countries.

Chapter 4 Longitudinal Relationships between SEP and HAIs in the Four Countries

4.1 Introduction

In Chapter 1, I established that only rare studies in the literature have compared the magnitude of socioeconomic inequalities in healthy ageing across countries. Different measures of healthy ageing make results incomparable. Studies that have compared socioeconomic inequalities in healthy ageing across countries are all based on single databases, and the regions in these studies have been restricted to European countries. In Chapter 2 I developed a universal HAI to assess people's healthy ageing comprehensively across countries, and in Chapter 3 I checked the validity and reliability of the HAI, finding that its overall reliability and predictive validity were acceptable. In this chapter, I examine the longitudinal relationship between SEP and HAIs after 60 years of age in the US, England, China and Japan, to compare the magnitude of socioeconomic inequalities in healthy ageing across countries.

4.2 Objectives and Hypotheses

This chapter aims to assess the longitudinal relationship between SEP and HAI after 60 years of age in the US, England, China and Japan, based on evidence from the HRS, ELSA, CHARLS and JSTAR. Specifically, the objectives are:

1. To evaluate the longitudinal relationship between socioeconomic indicators (including education, income, wealth and occupation) and HAIs after 60 years of age in each country (by conducting univariate and multilevel modelling analyses).
2. To identify the most influential socioeconomic indicator(s) of healthy ageing in each country (by calculating socioeconomic rank scores and slope indices of inequality).

The hypotheses are:

1. In the four countries, participants with lower levels of education, income and wealth and in disadvantaged occupational positions have lower HAIs than those with higher levels of education, income and wealth and in advantaged occupational positions.

2. Education is an influential predictor of inequalities in healthy ageing in the US, but not an influential predictor in China.
3. China has greater socioeconomic inequalities in healthy ageing, while England and Japan have lesser socioeconomic inequalities in healthy ageing; Chinese participants' healthy ageing profiles are worse than those of participants from any other country.

4.3 Methods

The sample sizes were 10305 in the HRS, 6590 in ELSA, 5930 in CHARLS and 1935 in JSTAR (see Figure 2-1 in Chapter 2 for details of the sample selection). Imputed socioeconomic indicators and covariates, and original HAIs, were used for the data analyses. All variables were harmonised to make results comparable across countries (see Chapter 2 for detailed information on multiple imputation and harmonisation). Here the HAI in each country was $\log_e$-transformed, since HAI scores were left-skewed [256] (see Figure A 1 in the appendices for the HAI distribution at each wave in each country).

4.3.1 Univariate Analyses

Univariate analyses were conducted between each socioeconomic indicator and covariate and $\log_e$-transformed HAIs at baseline in each country. It is not feasible to use the t-test with imputed data; instead, linear regression was applied to assess the associations of socioeconomic exposures and covariates with $\log_e$-transformed HAIs. Rubin's rules [257] were employed to estimate the average model parameters from multiply imputed data, and to adjust coefficients and standard errors for the variability between imputation. Table 4-2 presents basic characteristics of participants by calculating the proportions of categories and mean values for baseline variables. Table 4-3 shows the coefficients, 95% CIs and P-values for the baseline associations between socioeconomic indicators and covariates and $\log_e$-transformed HAIs in the four countries.

4.3.2 Multilevel Modelling

Multilevel modelling was used to estimate a growth curve model of healthy ageing by each socioeconomic indicator in the four countries, allowing for random intercepts and slopes, and using a maximum-likelihood algorithm. An advantage of applying a multilevel approach is that the methodology is capable of handling attrition and wave non-response, unequal time spaces, and the inclusion of time-varying and between-individual covariates that are either continuous or discrete measures [258]. Age cohort models (repeat age models controlling for year of birth) were estimated with minimal, partial and full adjustment. The purpose of building three adjusted models was to check whether the association between SEP and healthy ageing is attenuated, which offered an opportunity for identifying potential mediators [199]. But distinguishing between confounding and mediation may be different across study samples, and further mediation analysis is needed [199]. Therefore, in this chapter, all covariates are treated as potential confounders. The next chapter will discuss the mediating effect between education and healthy ageing in detail, based on path analysis. Wald tests together with results from univariate analyses also helped to identify potential confounders and interactions to build the most appropriate final models. The minimally adjusted models included age, age^2, cohort, $cohort^2$, and interactions between age and main exposure, and age and cohort. The partially adjusted models added personal characteristics including gender, ethnicity, marital status, childhood SEP (father's occupation) and self-rated health in childhood (which is unavailable in JSTAR), as well as interactions between gender and the main exposure, and age and marital status. The fully adjusted model added other socioeconomic indicators and health behaviours (smoking and drinking), as well as interactions between age and other socioeconomic indicators, and age and smoking. Table 4-1 presents details of the adjustments for the three models in the four countries.

Table 4-1 Details of the adjustments for the three models in the four countries

Main exposures	Minimally adjusted models	Partially adjusted models	Fully adjusted models
Education	Age, age^2, cohort and cohort^2, and interactions between age and education, and age and cohort.	Covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood*, and interactions between gender and education, and age and marital status.	Covariates and interactions in partially adjusted model plus income, wealth, occupation, smoking and drinking, and interactions between age and income, age and wealth, age and occupation, and age and smoking.
Income	Age, age^2, cohort and cohort^2, and interactions between age and income, and age and cohort.	Covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood*, and interactions between gender and income, and age and marital status.	Covariates and interactions in partially adjusted model plus education, wealth, occupation, smoking and drinking, and interactions between age and education, age and wealth, age and occupation, and age and smoking.
Wealth	Age, age^2, cohort and cohort^2, and interactions between age and wealth, and age and cohort.	Covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood*, and interactions between gender and wealth, and age and marital status.	Covariates and interactions in partially adjusted model plus education, income, occupation, smoking and drinking, and interactions between age and education, age and income, age and occupation, and age and smoking.
Occupation	Age, age^2, cohort and cohort^2, and interactions between age and occupation, and age and cohort.	Covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood*, and interactions between gender and occupation, and age and marital status.	Covariates and interactions in partially adjusted model plus education, income, wealth, smoking and drinking, and interactions between age and education, age and income, age and wealth, and age and smoking.

* The variable for self-rated health in childhood is unavailable in JSTAR.

In the results, the coefficients for main exposures indicate cross-sectional relationships between main exposures and HAIs at 60 years; the coefficients for interactions between main exposures and age indicate rates of decline in healthy ageing trajectories by main exposures after 60 years.

However, the Intra-Class Correlation Coefficient (ICC) [259], which describes the magnitude of the total variance at the secondary level, cannot be calculated for random effects in this analysis. Fitting a growth curve model with random slopes results in estimation of two random terms at the individual level; a set of intercept residuals and a set of residuals for each set of random slopes. Therefore, the ICC's simplicity as a measure of clustering is diminished since it becomes a function of several predictor variables if they have random coefficients at either level [260].

The following is an example of a multilevel model adjusted for age, age^2, cohort and $cohort^2$ only (equations 1–3). $Log_e(HAI_{ij})$ indicates the log_e-transformed HAI in wave i for individual j. In equation 1, every individual's healthy ageing trajectory is modelled as a function of age, age^2, cohort and $cohort^2$. Age and age^2 are time-varying. Cohort takes the value of each birth year. The intercept β_{0j} is made up of two parts: the fixed part γ_{00}, representing the mean intercept; and the random part U_{0j}, representing individual deviations from the mean intercept (equation 2). Similarly, the coefficient for age is made up of two parts: the fixed part γ_{10}, representing the mean slope; and the random part U_{1j}, representing individual deviations from the mean slope (equation 3). The cohort-specific residual term or random error for each individual, ε_{ij}, is assumed to be normally distributed with a mean at 0. The random coefficients U_{0j} and U_{1j} are not estimated directly; instead, the variance of U_{0j} and U_{1j} captures individual variations in baseline log_e-transformed HAIs and changes in log_e-transformed HAIs with age respectively.

$$Log_e(HAI_{ij}) = \beta_{0j} + \beta_{1j}age_{ij} + \beta_2 age_{ij}^2 + \beta_3 cohort_j + \beta_4 cohort_j^2 + \varepsilon_{ij} \quad (1)$$

$$\beta_{0j} = \gamma_{00} + U_{0j} \quad (2)$$

$$\beta_{1j} = \gamma_{10} + U_{1j} \quad (3)$$

Trajectories of $Log_e(HAI)$ by different categories of socioeconomic indicator were drawn, based on the fully adjusted multilevel model in each country. Here, rather than using the "average case" approach, which sets the values of other covariates to their respective sample means, the "observed value" approach was applied to draw conditional trajectories. This approach holds each covariate at the observed value for each individual in the sample, calculates the relevant predicted marginal effect for each individual, and averages over all cases [261]. The "average case" approach seeks to understand the effect of the main exposure on the main outcome for the average case in a sample, while the "observed value" approach aims to obtain an estimate of the average effect of the main exposure in the population. Using the "average case" approach to predict marginal effects may bring prediction bias, especially when predicting the marginal effects for cases in a very small subsample group. The reason is that predictions based on the sample mean across all independent variables may not represent typical cases, and may not even actually exist in a population [261]. The "observed value" approach – predicting trajectories which hold each covariate at the observed value for each respondent in the sample – is able to buffer the bias brought by skewed sample distribution. The 95% CIs of the predicted trajectories will be wider for small subsample groups. The HAI trajectories between the ages of 60 and 90 years were drawn for the HRS, ELSA and CHARLS. However, in JSTAR, only trajectories for the ages 60–79 years were drawn, since there were no Japanese participants aged more than 79 years.

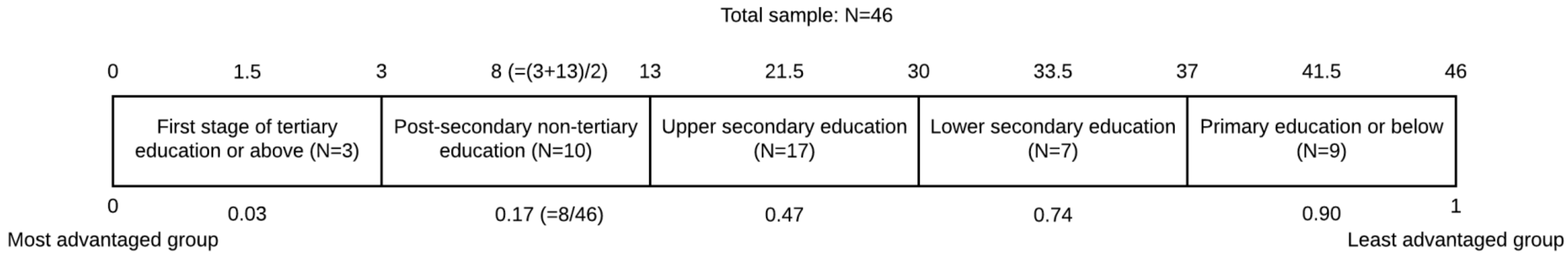
4.3.3 Socioeconomic Rank Score and Slope Index of Inequality

To compare socioeconomic inequalities in healthy ageing across countries, standardised socioeconomic rank scores were derived, based on distributions of the education, income and wealth variables in each country [262]. A limitation of this method is that the rank score can only be applied for socioeconomic variables whose categories are ordered in accordance with a strict hierarchical ranking [262]. Therefore, occupational variables in the four countries are not eligible for generating rank scores, since they are not ranked hierarchically. In order to build a strictly hierarchical rank, participants in an "other" education category in ELSA were reallocated into other educational classifications, based on their years of schooling. Sixteen, 13, 11 and less than 11 years of schooling were respectively treated as equivalent to the first-stage tertiary education or more, upper secondary education, lower secondary education, and primary education or less. Figure 4-1 gives a hypothetical example using educational classification to derive a socioeconomic rank score.

The steps in the calculation of the socioeconomic rank score were as follows:

1. The sample of interest in each country was sorted, from the most advantaged to the least advantaged groups, based on the classification of education, income or wealth.
2. The number of cases in each socioeconomic group was counted (see example: N=3, 10, 17, 7 or 9 in Figure 4-1).
3. A midpoint value was calculated for each category of socioeconomic group (see example: 8 = (3+13) / 2 in Figure 4-1).
4. Each midpoint was divided by the total sample size to generate a standardised socioeconomic rank score, ranging from 0 to 1 (see example 0.17 = 8/46 in Figure 4-1).

Figure 4-1 A hypothetical example using educational classification to derive a socioeconomic rank score



After I calculated the standardised socioeconomic rank scores for education, income and wealth in each country, fully adjusted multilevel modelling analyses were conducted to calculate the Slope Index of Inequality (SII). The covariates were age, age^2, cohort, cohort^2, gender, ethnicity, self-rated health in childhood (unavailable in JSTAR), father's occupation, marital status, smoking and drinking. The predicted trajectory of HAI by age based on the fully adjusted multilevel model in each country was also presented, to compare older people's healthy ageing profiles across countries.

The SII was used to compare the magnitude of inequalities in healthy ageing by education, income and wealth within and across countries. The SII represents the linear regression coefficient, which expresses the health inequalities between the most and least advantaged socioeconomic groups in terms of rate differences [263]. It is a measure of absolute differences in health status, or of the frequency of a health problem when an individual moves from the highest to the lowest SEP. Larger values reflect greater inequalities. In this project, the SII was interpreted as the percentage of difference in predicted mean HAI scores when the socioeconomic rank score changed from 0 to 1 (i.e. when individuals moved from the most to the least advantaged education, income and wealth groups), which considered the entire socioeconomic distribution and the sample size of each category to be comparable across countries. The SIIs for education, income and wealth at age 60 years in each country were calculated. The interactions between age and education, income and wealth in the multilevel models predicted the trend of change in the SII thereafter.

4.3.4 Sensitivity Analyses

The variable of self-rated health in childhood was not available in JSTAR. Therefore, the analyses that had built fully adjusted models were repeated without adjusting for self-rated health in childhood, based on imputed datasets in the HRS, ELSA and CHARLS. The results without adjustment for self-rated health in childhood were compared with the original results (section 4.4.2), to check whether excluding self-rated health in childhood would significantly modify the main exposure-outcome associations. Furthermore, fully adjusted multilevel models were estimated, based on complete case analyses in the four countries. The complete results were compared with the imputed results outlined in section 4.4.2, to test the robustness of the multilevel models after the multiple imputation had been conducted.

All analyses were performed using Stata SE 15.0 [237], and $P < 0.05$ was considered statistically significant.

4.4 Results

4.4.1 Sample Characteristics at Baseline

Participants' baseline characteristics in each country are presented in Table 4-2. Chinese and Japanese participants tended to be younger than American and English participants. The values of baseline Log_e(HAI) were 4.33, 4.36, 4.30 and 4.45, and the geometric mean values for baseline HAI were 75.65, 78.40, 73.76 and 85.22 in the HRS, ELSA, CHARLS and JSTAR respectively. Japanese participants seemed to be healthier than any other participants. There were more American, English and Japanese female participants, but more Chinese male participants. Participants were mainly white in the HRS and ELSA, and Han in CHARLS. Most participants had upper secondary education in the HRS, primary education or less in ELSA and CHARLS, and upper or lower secondary education in JSTAR. In the four countries, fewer than 20% of participants were in the lowest income and wealth quintiles. In the HRS, the majority had already retired at baseline (73.39%). In CHARLS, most participants were in unpaid agricultural work only (70.16%). In JSTAR, 57.06% of participants were in unclassifiable occupational positions; 22.25% of participants were in the most disadvantaged occupations. In ELSA, participants mainly had intermediate occupational positions. Among English participants, 1.69% had never worked. In the HRS, ELSA, CHARLS and JSTAR respectively, 42.04%, 40.29%, 20.60% and 17.00% of participants had no spouse. American participants' fathers had mainly been in disadvantaged occupational positions (around 70%), and Chinese fathers had mainly been in agricultural work when their children were teenagers (78.30%). However, English fathers' occupational positions were mainly at intermediate levels (around 70%). There were no specific classifications of occupational position in JSTAR, but most participants' fathers had been employed (28.75%) or self-employed (52.46%). Most participants reported good or excellent health in childhood in the HRS, ELSA and CHARLS. However, compared with American and English participants, a greater proportion of Chinese individuals reported poor or fair health in childhood. American and English participants were mainly ex-smokers, while Chinese and Japanese participants were mainly non-smokers. However, compared with American, English and Japanese participants, there was a greater proportion of current smokers among Chinese participants. Although participants were mainly non-drinkers in each country, greater proportions of daily alcohol consumers were found in CHARLS and JSTAR.

Table 4-2 Sample characteristics at baseline by country

Variables	HRS (N=10305)	ELSA (N=6590)	CHARLS (N=5930)	JSTAR (N=1935)
Log_e(HAI) (Mean)	4.33	4.36	4.30	4.45
HAI (Mean)	75.65	78.40	73.76	85.22
Age (Mean)	72	71	68	67
Gender (%)				
Male	41.23	44.08	51.74	48.59
Female	58.77	55.92	48.26	51.41
Ethnicity* (%)				
1	83.84	98.29	93.14	-
2	12.86	1.71	6.86	-
3	3.30			-
Education (%)				
First stage of tertiary or more	20.90	11.05	2.12	10.59
Post-secondary non-tertiary	-	12.59	3.24	5.20
Upper secondary education	54.10	5.11	2.26	39.70
Lower secondary education	16.34	20.07	37.67	43.86
Primary education or less	6.66	40.01	54.70	0.65
Others	-	11.18	-	-
Income (%)				
Highest	19.85	20.61	20.18	19.32
2nd	20.40	20.44	20.22	20.29
3rd	20.50	20.12	20.25	20.39
4th	20.17	19.79	20.43	20.41
Lowest	19.08	19.04	18.93	19.59
Wealth (%)				
Highest	20.52	20.54	20.05	19.84
2nd	20.47	20.43	19.81	20.23
3rd	20.29	20.35	20.40	18.47
4th	19.89	19.71	20.44	21.52
Lowest	18.83	18.96	19.30	19.94
Occupation (%)**				
1	4.17	8.37	2.08	6.94
2	3.79	20.75	2.73	13.29
3	1.95	14.19	6.76	22.25
4	0.62	11.30	18.28	0.46
5	0.87	12.46	70.16	57.06
6	1.38	17.04	-	-
7	5.74	14.20	-	-
8	73.39	1.69	-	-
9	0.65	-	-	-
10	0.78	-	-	-
11	6.66	-	-	-
Marital status (%)				
Married or partnered-Ref.	57.96	59.71	79.39	83.00
Separated, divorced or single	13.23	11.72	2.19	4.60
Widowed	28.81	28.57	18.41	12.40
Father's occupation* (%)**				
1	13.47	10.71	4.88	28.75
2	10.98	10.46	3.94	52.46
3	4.45	35.49	1.96	3.09
4	26.86	4.46	4.12	15.70
5	21.61	8.28	78.30	-
6	21.70	27.16	3.69	-
7	0.93	0.88	3.11	-

Variables	HRS (N=10305)	ELSA (N=6590)	CHARLS (N=5930)	JSTAR (N=1935)
8	-	2.57	-	-
Self-rated health in childhood (%)				
Excellent	50.06	29.44	10.18	-
Very good	25.53	34.64	36.75	-
Good	18.15	22.90	27.83	-
Fair	4.84	9.02	17.69	-
Poor	1.42	4.00	7.56	-
Smoking status (%)				
Never smoke	43.13	35.86	56.53	55.60
Ever smoked, now no smoke	47.94	53.44	12.59	27.04
Smoke	8.94	10.70	30.88	17.36
Frequency of drinking[****] (%)				
0	69.07	38.02	77.56	43.54
1	9.36	13.92	4.20	12.45
2	5.08	12.28	4.17	6.42
3	3.83	8.56	1.71	15.59
4	1.87	5.56	12.36	22.01
5	2.03	4.40	-	-
6	1.04	3.87	-	-
7	7.73	13.39	-	-

[*] In HRS, 1=White/Caucasian 2=Black/African American 3=Others; In ELSA, 1=White 2=Non-white; In CHARLS, 1=Han 2=Minorities; No ethnicity variable in JSTAR

[**] In HRS, 1=Managerial and professional sociality occupation 2=Technical, sales and administrative support 3=Service occupations 4=Farming, forestry and fishing occupations 5=Precision production, craft and repair 6=Operators, fabricators and labours 7=Others 8=Retired 9=Unemployed 10=Disabled 11=Not in the labour force; In ELSA, 1=Higher managerial and professional employers 2=Lower managerial and professional employers 3=Intermediate employees 4=Small employers and own account workers 5=Lower supervisory, craft and related employees 6=Employees in semi-routine occupations 7=Employees in routine occupations 8=Never worked; In CHARLS, 1=Officials/managers/leaders or Clerks/paid workers 2=Self-employed workers 3=Unpaid family business 4=Others 5=Only agricultural work; In JSTAR, 1=Highest 2=Intermediate 3=Lowest 4=Others 5=Unclassifiable

[***] In HRS, 1=Managerial and professional speciality occupation 2=Technical, sales and administrative support 3=Services occupation 4=Farming, forestry and fishing occupations 5=Precision productions, craft and repair occupations 6=Operators, fabricators and labours 7=Unclassifiable; In ELSA, 1=Professional or technical 2=Manager, senior official, admin., cleric or secretarial 3=Own business, or skilled trade 4=Service-skilled non-manual 5=Service-skilled manual 6=Others 7=Retired 8=Unemployed, sick or disabled; In CHARLS, 1=Manager 2=Professional and technician 3=Clerk 4=Commercial and service worker 5=Agricultural, forestry, husbandry and others 6=Production and transportation workers 7=Others; In JSTAR, 1=Employed (including public employee), 2=Self-employed (including self-employed farmer) 3= Others 4= No work (including father passed away when participants was 15 years)

[****] In HRS and ELSA, frequency of drinking = days of drinking per week (0=None 1=1 day 2=2 days 3=3 days 4=4 days 5=5 days 6=6 days 7=7 days); In CHARLS, frequency of drinking= times of drinking per month (0=non or less than once per month 1=one to several times per month 2=one to several times per week 3=most days of the week 4=every day of the week; In JSTAR, frequency of drinking= times of drinking per month (1=None 2=A few times in month 3=1-2 in a week 4=3-4 in a week 5=5-6 in a week 5=Every day)

Table 4-3 presents the baseline relationship between each socioeconomic indicator and covariate and $\log_e$-transformed HAIs in each country. In the four countries, participants who were older, female, of an ethnic minority background (including non-white in HRS and ELSA, and non-Han Minorities in CHARLS), had no spouse, and reported poorer health in childhood had lower HAIs at baseline than those who were younger, male and ethnic majority, had a spouse, and reported better health in childhood. Participants who had lower levels of education, income and wealth in the four countries also had lower HAIs at baseline. For example, compared with those with a first-stage tertiary education or more, persons with a primary education or less had 13.7% (95% CI: 12.4–15.0%), 12.3% (95% CI: 10.9–13.7%), 15.7% (12.3–19.1%) and 9.2% (4.0–14.3%) lower HAIs at baseline in the HRS, ELSA, CHARLS and JSTAR respectively. In terms of the baseline relationship between occupation and HAIs, significant results were mainly found in the HRS and ELSA. For example, in the HRS, disabled participants had 30.7% (95% CI: 27.6–33.9%) lower HAIs than those in managerial and professional speciality occupations. In ELSA, if participants had never worked, their HAIs were 19.8% (95% CI: 12.8–26.7%) lower than those in higher managerial and professional occupations. In CHARLS and JSTAR, few significant associations between occupation and HAI were found. Nonetheless, Chinese people who exclusively conducted unpaid agricultural work had 10.1% (95% CI: 6.4–13.9%) lower HAIs than those who were officials/managers/leaders or clerks/paid workers. In JSTAR, only participants with an unclassified occupation had significantly lower HAIs than those in the highest occupational positions at baseline. Father's occupation seemed to be a risk factor for healthy ageing in the HRS and ELSA, since more disadvantaged occupational positions were significantly associated with lower HAIs. No significant results were found in JSTAR. However, in CHARLS, participants whose fathers were clerks were healthier in later life than those whose fathers were managers ($P = 0.036$). Ex- or current smokers in the HRS and ELSA had lower HAIs than non-smokers. However, in CHARLS and JSTAR, ex- or current smokers had higher HAIs than non-smokers. In the four countries, alcohol consumers seemed to be healthier than non-drinkers.

Table 4-3 Coefficients, 95%CIs and P-values for associations between SEP/covariates and $\log_e$-transformed HAIs at baseline by country

Variables	HRS (N=10305) Coefficients (95%CIs)	P-values	ELSA (N=6590) Coefficients (95%CIs)	P-values	CHARLS (N=5930) Coefficients (95%CIs)	P-values	JSTAR (N=1935) Coefficients (95%CIs)	P-values
Age	-0.005 (-0.006 to -0.005)	<0.001	-0.006 (-0.007 to -0.006)	<0.001	-0.007 (-0.007 to -0.006)	<0.001	-0.005 (-0.006 to -0.004)	<0.001
Gender								
Male-Ref.								
Female	-0.036 (-0.043 to -0.030)	<0.001	-0.061 (-0.069 to -0.053)	<0.001	-0.102 (-0.112 to -0.092)	<0.001	-0.024 (-0.032 to -0.016)	<0.001
Ethnicity*								
1-Ref.								
2	-0.053 (-0.062 to -0.043)	<0.001	-0.031 (-0.061 to -0.002)	0.037	-0.041 (-0.063 to -0.018)	<0.001	-	-
3	-0.028 (-0.046 to -0.010)	0.002	-	-	-	-	-	-
Education								
First stage of tertiary edu. or above -Ref.								
Post-secondary non-tertiary edu.	-		-0.031 (-0.048 to -0.013)	0.001	-0.003 (-0.046 to 0.041)	0.907	-0.045 (-0.066 to -0.023)	<0.001
Upper secondary education	-0.043 (-0.050 to -0.035)	<0.001	-0.032 (-0.055 to -0.010)	0.005	0.001 (-0.046 to 0.048)	0.96	-0.021 (-0.034 to -0.007)	0.003
Lower secondary education	-0.102 (-0.111 to -0.092)	<0.001	-0.051 (-0.067 to -0.036)	<0.001	-0.050 (-0.084 to -0.015)	0.005	-0.052 (-0.066 to -0.039)	<0.001
Primary education or less	-0.137 (-0.150 to -0.124)	<0.001	-0.123 (-0.137 to -0.109)	<0.001	-0.157 (-0.191 to -0.123)	<0.001	-0.092 (-0.143 to -0.040)	<0.001
Others	-		-0.068 (-0.086 to -0.050)	<0.001	-		-	-
Income								
Highest-Ref.								
2nd	-0.029 (-0.038 to -0.019)	<0.001	-0.048 (-0.060 to -0.035)	<0.001	-0.040 (-0.056 to -0.023)	<0.001	-0.006 (-0.021 to 0.008)	0.393
3rd	-0.063 (-0.073 to -0.054)	<0.001	-0.105 (-0.117 to -0.092)	<0.001	-0.071 (-0.087 to -0.055)	<0.001	-0.014 (-0.029 to 0.000)	0.056
4th	-0.090 (-0.100 to -0.081)	<0.001	-0.088 (-0.101 to -0.076)	<0.001	-0.106 (-0.122 to -0.090)	<0.001	-0.025 (-0.040 to -0.010)	0.001
Lowest	-0.147 (-0.156 to -0.137)	<0.001	-0.089 (-0.102 to -0.077)	<0.001	-0.121 (-0.138 to -0.104)	<0.001	-0.049 (-0.064 to -0.034)	<0.001
Wealth								
Highest-Ref.								
2nd	-0.020 (-0.029 to -0.010)	<0.001	-0.037 (-0.049 to -0.025)	<0.001	-0.016 (-0.035 to 0.002)	0.077	0.000 (-0.013 to 0.013)	0.972
3rd	-0.042 (-0.052 to -0.033)	<0.001	-0.067 (-0.079 to -0.055)	<0.001	-0.037 (-0.055 to -0.019)	<0.001	-0.011 (-0.025 to 0.003)	0.116
4th	-0.086 (-0.095 to -0.077)	<0.001	-0.104 (-0.116 to -0.092)	<0.001	-0.076 (-0.093 to -0.059)	<0.001	-0.017 (-0.029 to -0.004)	0.009
Lowest	-0.133 (-0.143 to -0.124)	<0.001	-0.153 (-0.166 to -0.141)	<0.001	-0.072 (-0.092 to -0.052)	<0.001	-0.043 (-0.056 to -0.030)	<0.001
Occupation**								
1-Ref.								
2	-0.020 (-0.037 to -0.003)	0.02	-0.049 (-0.066 to -0.032)	<0.001	-0.012 (-0.063 to 0.039)	0.650	-0.011 (-0.030 to 0.007)	0.229
3	-0.042 (-0.061 to -0.022)	<0.001	-0.085 (-0.103 to -0.067)	<0.001	-0.059 (-0.106 to -0.013)	0.013	-0.013 (-0.030 to 0.004)	0.133

Variables	HRS (N=10305) Coefficients (95%CIs)	P-values	ELSA (N=6590) Coefficients (95%CIs)	P-values	CHARLS (N=5930) Coefficients (95%CIs)	P-values	JSTAR (N=1935) Coefficients (95%CIs)	P-values
4	-0.031 (-0.064 to 0.002)	0.064	-0.066 (-0.086 to -0.047)	<0.001	-0.101 (-0.142 to 0.061)	<0.001	-0.025 (-0.103 to 0.053)	0.524
5	-0.037 (-0.064 to -0.010)	0.008	-0.096 (-0.115 to -0.078)	<0.001	-0.101 (-0.139 to 0.064)	<0.001	-0.052 (-0.068 to -0.036)	<0.001
6	-0.035 (-0.058 to -0.013)	0.002	-0.114 (-0.131 to -0.097)	<0.001	-	-	-	-
7	-0.042 (-0.130 to 0.045)	0.341	-0.135 (-0.153 to -0.118)	<0.001	-	-	-	-
8	-0.108 (-0.120 to -0.095)	<0.001	-0.198 (-0.267 to -0.128)	<0.001	-	-	-	-
9	-0.038 (-0.078 to 0.002)	0.06		-	-	-	-	-
10	-0.307 (-0.339 to -0.276)	<0.001		-	-	-	-	-
11	-0.123 (-0.138 to -0.108)	<0.001		-	-	-	-	-
Marital status								
Married or partnered-Ref.								
Separated, divorced or single	-0.032 (-0.042 to -0.023)	<0.001	-0.023 (-0.035 to -0.010)	0.001	-0.037 (-0.071 to -0.002)	0.04	-0.045 (-0.065 to -0.026)	<0.001
Widowed	-0.060 (-0.067 to -0.053)	<0.001	-0.073 (-0.083 to -0.064)	<0.001	-0.070 (-0.083 to -0.057)	<0.001	-0.037 (-0.049 to -0.025)	<0.001
Father's occupation***								
1-Ref.								
2	0.001 (-0.013 to 0.015)	0.912	-0.024 (-0.042 to -0.005)	0.013	0.034 (-0.012 to 0.080)	0.148	-0.006 (-0.018 to 0.006)	0.323
3	-0.048 (-0.067 to -0.029)	<0.001	-0.044 (-0.059 to -0.029)	<0.001	0.049 (-0.011 to 0.108)	0.109	-0.007 (-0.041 to 0.026)	0.662
4	-0.048 (-0.059 to -0.037)	<0.001	-0.045 (-0.069 to -0.021)	<0.001	0.048 (0.003 to 0.093)	0.036	-0.011 (-0.029 to 0.006)	0.206
5	-0.017 (-0.029 to -0.005)	0.005	-0.063 (-0.082 to -0.043)	<0.001	-0.025 (-0.059 to 0.009)	0.145	-	-
6	-0.026 (-0.038 to -0.014)	<0.001	-0.057 (-0.072 to -0.041)	<0.001	0.031 (-0.015 to 0.078)	0.187	-	-
7	0.007 (-0.032 to 0.045)	0.729	-0.045 (-0.093 to 0.002)	0.059	-0.029 (-0.083 to 0.025)	0.296	-	-
8	-	-	-0.062 (-0.089 to -0.034)	<0.001	-	-	-	-
Self-rated health in childhood								
Excellent-Ref.								
Very good	-0.024 (-0.031 to -0.016)	<0.001	-0.028 (-0.043 to -0.013)	<0.001	-0.014 (-0.032 to 0.004)	0.128	-	-
Good	-0.042 (-0.050 to -0.033)	<0.001	-0.051 (-0.068 to -0.034)	<0.001	-0.026 (-0.045 to -0.007)	0.007	-	-
Fair	-0.067 (-0.083 to -0.052)	<0.001	-0.078 (-0.102 to -0.054)	<0.001	-0.026 (-0.046 to -0.006)	0.011	-	-
Poor	-0.090 (-0.117 to -0.064)	<0.001	-0.139 (-0.174 to -0.104)	<0.001	-0.067 (-0.091 to -0.042)	<0.001	-	-
Smoking status								
Never smoke-Ref.								
Ever smoked, now no smoke	-0.012 (-0.018 to -0.005)	<0.001	-0.013 (-0.022 to -0.004)	0.005	0.022 (0.007 to 0.038)	0.006	0.006 (-0.003 to 0.016)	0.207
Smoke	-0.005 (-0.015 to 0.006)	0.401	-0.021 (-0.034 to -0.008)	0.002	0.068 (0.057 to 0.079)	<0.001	0.019 (0.008 to 0.031)	0.001
Frequency of drinking****								
0-Ref.								

Variables	HRS (N=10305) Coefficients (95%CIs)	P-values	ELSA (N=6590) Coefficients (95%CIs)	P-values	CHARLS (N=5930) Coefficients (95%CIs)	P-values	JSTAR (N=1935) Coefficients (95%CIs)	P-values
1	0.055 (0.044 to 0.066)	<0.001	0.058 (0.046 to 0.070)	<0.001	0.049 (0.022 to 0.077)	<0.001	0.022 (0.009 to 0.036)	0.001
2	0.070 (0.055 to 0.085)	<0.001	0.081 (0.067 to 0.095)	<0.001	0.074 (0.047 to 0.102)	<0.001	0.022 (0.004 to 0.040)	0.018
3	0.068 (0.052 to 0.084)	<0.001	0.079 (0.063 to 0.095)	<0.001	0.094 (0.049 to 0.139)	<0.001	0.031 (0.019 to 0.043)	<0.001
4	0.076 (0.054 to 0.098)	<0.001	0.108 (0.088 to 0.129)	<0.001	0.081 (0.065 to 0.097)	<0.001	0.036 (0.026 to 0.047)	<0.001
5	0.069 (0.047 to 0.092)	<0.001	0.101 (0.077 to 0.124)	<0.001	-	-	-	-
6	0.076 (0.045 to 0.107)	<0.001	0.118 (0.093 to 0.143)	<0.001	-	-	-	-
7	0.066 (0.055 to 0.078)	<0.001	0.080 (0.069 to 0.092)	<0.001	-	-	-	-

* In HRS, 1=White/Caucasian 2=Black/African American 3=Others; In ELSA, 1=White 2=Non-white; In CHARLS, 1=Han 2=Minorities; No ethnicity variable in JSTAR

** In HRS, 1=Managerial and professional sociality occupation 2=Technical, sales and administrative support 3=Service occupations 4=Farming, forestry and fishing occupations 5=Precision production, craft and repair 6=Operators, fabricators and labours 7=Others 8=Retired 9=Unemployed 10=Disabled 11=Not in the labour force; In ELSA, 1=Higher managerial and professional employers 2=Lower managerial and professional employers 3=Intermediate employees 4=Small employers and own account workers 5=Lower supervisory, craft and related employees 6=Employees in semi-routine occupations 7=Employees in routine occupations 8=Never worked; In CHARLS, 1=Officials/managers/leaders or Clerks/paid workers 2=Self-employed workers 3=Unpaid family business 4=Others 5=Only agricultural work; In JSTAR, 1=Highest 2=Intermediate 3=Lowest 4=Others 5=Unclassifiable

*** In HRS, 1=Managerial and professional speciality occupation 2=Technical, sales and administrative support 3=Services occupation 4=Farming, forestry and fishing occupations 5=Precision productions, craft and repair occupations 6=Operators, fabricators and labours 7=Unclassifiable; In ELSA, 1=Manager, senior official, admin., cleric or secretarial 2=Own business, or skilled trade 3=Service-skilled non-manual 4=Service-skilled manual 5=Others 6=Retired 7=Unemployed, sick or disabled; In CHARLS, 1=Manager 2=Professional and technician 3=Clerk 4=Commercial and service worker 5=Agricultural, forestry, husbandry and others 6=Production and transportation workers 7=Others; In JSTAR, 1=Employed (including public employee), 2=Self-employed (including self-employed farmer) 3= Others 4= No work (including father passed away when participants was 15 years)

**** In HRS and ELSA, frequency of drinking = days of drinking per week (0=None 1=1 day 2=2 days 3=3 days 4=4 days 5=5 days 6=6 days 7=7 days); In CHARLS, frequency of drinking= times of drinking per month (0=non or less than once per month 1=one to several times per month 2=one to several times per week 3=most days of the week 4=every day of the week; In JSTAR, frequency of drinking= times of drinking per month (1=None 2=A few times in month 3=1-2 in a week 4=3-4 in a week 5=5-6 in a week 5=Every day)

4.4.2 Multilevel Models of HAI by SEP in Each Country

US

Table 4-4 to Table 4-7 present results for the relationship between socioeconomic indicators (education, income, wealth and occupation) and $\log_e$-transformed HAIs in the HRS. The coefficients (b) for interactions between socioeconomic indicators and age give the effects of SEP on rates of change in HAI from the age of 60 years. Here the multilevel models estimate average changes per year in the HAI after the age of 60 years.

In all minimally, partially and fully adjusted models, there were non-linear relationships between age and $\log_e$-transformed HAIs. Both linear and quadratic age terms were negative and (boundary) significant, indicating accelerating health declines with increased age. Both linear and quadratic cohort terms were also significant. At the same age, participants who had been born later were less healthy than those who had been born earlier. However, the rates of change in HAI became slower across cohorts.

In Table 4-4, in the minimally adjusted model, compared with those who had a first-stage tertiary education or more, participants with any lower levels of education had lower HAIs at 60 years ($P < 0.001$). For example, those who had a primary education or less had 14.9% (95% CI: 13.8–16.1%) lower HAIs at 60 years. After partial adjustment, the gap in HAI between the top and bottom levels of education became narrower (9.5%, 95% CI: 7.8–11.2%). In the fully adjusted model, the difference in HAI between the top and bottom levels of education fell to 5.8% (95% CI: 4.2–7.4%). The interactions between education and age were all significant in the three models. The coefficients were all negative values, meaning that with increased age, HAIs declined more quickly for participants with lower levels of education. However, the changes in the rates of decline were small. For example, with increased age, the rate of decline in HAI was only 0.4% (95% CI: 0.3–0.6%) quicker for those with the bottom level of education in the fully adjusted model.

In Table 4-5, in the minimally adjusted model, compared with those who were in the top quintile of income, participants in any lower income quintiles had lower HAIs at 60 years ($P < 0.001$). For example, those in the bottom quintile of income had 4.1% (95% CI: 3.7–4.5%) lower HAIs at 60 years. After partial adjustment, the gap in HAI between the top and bottom quintiles of income became narrower (3.1%, 95% CI: 2.5–3.8%). In the fully adjusted model, the difference in HAI between the top and bottom income quintiles fell to 1.1% (95% CI: 0.5–1.8%). Compared with those in the top income quintile, participants in the second and third income quintiles had no significantly lower HAIs at 60 years. All interactions between age and income were positive, indicating that the rates of decline in HAI became slower after the age of 60 years for those in lower income quintiles. However, the changes in rates of decline might not be obvious, since the coefficients for the interaction terms were nearly 0.

In Table 4-6, in the minimally adjusted model, compared with those in the top wealth quintile, participants in any lower wealth quintiles had lower HAIs at 60 years ($P < 0.001$). For example, participants in the bottom wealth quintile had 6.8% (95% CI: 6.3–7.3%) lower HAIs at 60 years than those in the top wealth quintile. After partial adjustment, the gap in HAI between the top and bottom wealth quintiles became narrower (4.6%, 95% CI: 3.8–5.4%). In the fully adjusted model, the difference in HAI between the highest and lowest wealth quintiles fell to 2.8% (95% CI: 2.0–3.6%). Participants who were in the second wealth quintile had no significantly lower HAIs at 60 years. No significant interactions were found between wealth and age, suggesting that the rates of decline of HAI by different wealth quintiles after 60 years were similar with increased age.

In Table 4-7, the occupational gradient in healthy ageing among employed participants was unclear in both the minimally and partially adjusted models. However, in the fully adjusted model, participants in service occupations had 2.2% (95% CI: 0.3–4.1%) higher HAIs at 60 years than managers and professionals. The interactions between age and service occupation were also significant across models, suggesting that after the age of 60 years, the rates of decline of HAI for those in service occupations became 0.2% (95% CI: 0.0–0.4%) slower with increased age. For unemployed participants at the age of 60 years – including those who were retired, unemployed or disabled and were not in the labour force – their HAIs were all significantly lower than for those in managerial and professional occupations in the minimally adjusted model. However, after I controlled for covariates, retired and disabled participants alone had HAIs at 60 years that were 1.7% (95% CI: 0.7–2.7%) and 4.7% (95% CI: 2.5–6.9%) lower than those in managerial and professional positions after full adjustment. The interactions between disability and age were significant in the three models. The values of interacting coefficients were positive, indicating slower rates of decline in HAI with increased age after 60 years.

In terms of random effects, the coefficients for variance of HAI at occasional level were very small at around 0.08^2 (0.0064), with 73% of the unexplained variance in the fully adjusted models by education, income, wealth and occupation, attributable to unobserved individual factors, respectively.

Table 4-4 Results of minimally, partially and fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in HRS

	Minimally adjusted model*		**Partially adjusted model***		**Fully adjusted model***	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.013 (-0.014 to -0.012)	<0.001	-0.013 (-0.014 to -0.012)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age²	-0.00009 (-0.0002 to -0.00002)	0.017	-0.00008 (-0.0002 to -0.00001)	0.026	-0.00009 (-0.0002 to -0.00001)	0.028
Cohort	-0.009 (-0.009 to -0.008)	<0.001	-0.009 (-0.009 to -0.008)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
Cohort²	0.0007 (0.0006 to 0.0007)	<0.001	0.0007 (0.0006 to 0.0008)	<0.001	0.0006 (0.0006 to 0.0007)	<0.001
Education						
First stage of tertiary or more -Ref.						
Upper secondary education	-0.045 (-0.052 to -0.038)	<0.001	-0.039 (-0.049 to -0.030)	<0.001	-0.023 (-0.032 to -0.013)	<0.001
Lower secondary education	-0.107 (-0.116 to -0.099)	<0.001	-0.075 (-0.088 to -0.062)	<0.001	-0.049 (-0.061 to -0.036)	<0.001
Primary education or less	-0.149 (-0.161 to -0.138)	<0.001	-0.095 (-0.112 to -0.078)	<0.001	-0.058 (-0.074 to -0.042)	<0.001
Education*age						
Upper secondary education	-0.001 (-0.002 to 0.000)	0.015	-0.001 (-0.002 to 0.000)	0.016	-0.001 (-0.002 to 0.000)	0.007
Lower secondary education	-0.001 (-0.002 to 0.000)	0.003	-0.001 (-0.002 to -0.001)	0.001	-0.002 (-0.003 to -0.001)	<0.001
Primary education or less	-0.004 (-0.005 to -0.003)	<0.001	-0.004 (-0.005 to -0.003)	<0.001	-0.004 (-0.006 to -0.003)	<0.001
Intercept	4.366 (4.360 to 4.373)	<0.001	4.398 (4.387 to 4.408)	<0.001	4.422 (4.409 to 4.435)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.080 (0.080 to 0.081)	-	0.080 (0.080 to 0.081)	-	0.081 (0.080 to 0.081)	-
Level 2: intercept	0.408 (0.378 to 0.438)	-	0.138 (0.136 to 0.140)	-	0.131 (0.129 to 0.133)	-
Level 2: age	0.141 (0.139 to 0.144)	-	0.010 (0.009 to 0.010)	-	0.009 (0.009 to 0.010)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and education, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and education, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus income, wealth, occupation, smoking and drinking, and interactions between age and income, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-5 Results of minimally, partially and fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in HRS

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.015 (-0.015 to -0.014)	<0.001	-0.014 (-0.015 to -0.014)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.0001 (-0.0002 to -0.00002)	0.011	-0.00007 (-0.0002 to -0.00001)	0.023	-0.00009 (-0.0002 to -0.00001)	0.029
Cohort	-0.008 (-0.009 to -0.008)	<0.001	-0.008 (-0.009 to -0.008)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
$Cohort^2$	0.0007 (0.0006 to 0.0007)	<0.001	0.0007 (0.0006 to 0.0007)	<0.001	0.0006 (0.0006 to 0.0007)	<0.001
Income						
Ref- Highest						
2nd	-0.007 (-0.010 to -0.004)	<0.001	-0.008 (-0.013 to -0.004)	<0.001	-0.004 (-0.008 to 0.001)	0.093
3rd	-0.013 (-0.017 to -0.010)	<0.001	-0.013 (-0.018 to -0.008)	<0.001	-0.004 (-0.009 to 0.001)	0.101
4th	-0.024 (-0.028 to -0.021)	<0.001	-0.023 (-0.028 to -0.018)	<0.001	-0.010 (-0.015 to -0.004)	<0.001
Lowest	-0.041 (-0.045 to -0.037)	<0.001	-0.031 (-0.038 to -0.025)	<0.001	-0.011 (-0.018 to -0.005)	0.001
Income*age						
2nd	0.000 (0.000 to 0.001)	0.089	0.000 (0.000 to 0.001)	0.231	0.000 (0.000 to 0.001)	0.503
3rd	0.001 (0.001 to 0.001)	<0.001	0.001 (0.000 to 0.001)	0.001	0.001 (0.000 to 0.001)	0.011
4th	0.001 (0.000 to 0.001)	0.002	0.001 (0.000 to 0.001)	0.039	0.000 (0.000 to 0.001)	0.183
Lowest	0.001 (0.001 to 0.002)	<0.001	0.001 (0.000 to 0.001)	0.003	0.001 (0.000 to 0.001)	0.026
Intercept	4.329 (4.325 to 4.334)	<0.001	4.329 (4.325 to 4.334)	<0.001	4.426 (4.414 to 4.438)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.080 (0.080 to 0.081)	-	0.080 (0.080 to 0.081)	-	0.081 (0.080 to 0.081)	-
Level 2: intercept	0.143 (0.141 to 0.146)	-	0.140 (0.138 to 0.142)	-	0.132 (0.130 to 0.134)	-
Level 2: age	0.010 (0.010 to 0.010)	-	0.010 (0.010 to 0.010)	-	0.009 (0.009 to 0.010)	-

* Minimally adjusted model: age, age^2, cohort and $cohort^2$, and interactions between age and income, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and income, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, wealth, occupation, smoking and drinking, and interactions between age and education, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-6 Results of minimally, partially and fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in HRS

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.014 (-0.015 to -0.013)	<0.001	-0.014 (-0.015 to -0.013)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.00007 (-0.0001 to -0.00001)	0.059	-0.00007 (-0.0001 to 0.00001)	0.079	-0.00008 (-0.0002 to -0.00001)	0.032
Cohort	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
Cohort^2	0.0007 (0.0006 to 0.0007)	<0.001	0.0007 (0.0006 to 0.0007)	<0.001	0.0006 (0.0006 to 0.0007)	<0.001
Wealth						
Ref- Highest						
2nd	-0.010 (-0.013 to -0.006)	<0.001	-0.005 (-0.011 to 0.000)	0.042	-0.001 (-0.006 to 0.004)	0.747
3rd	-0.023 (-0.028 to -0.019)	<0.001	-0.017 (-0.023 to -0.011)	<0.001	-0.008 (-0.014 to -0.002)	0.009
4th	-0.041 (-0.045 to -0.036)	<0.001	-0.031 (-0.038 to -0.024)	<0.001	-0.017 (-0.024 to -0.010)	<0.001
Lowest	-0.068 (-0.073 to -0.063)	<0.001	-0.046 (-0.054 to -0.038)	<0.001	-0.028 (-0.036 to -0.020)	<0.001
Wealth*age						
2nd	0.000 (0.000 to 0.001)	0.569	0.000 (0.000 to 0.000)	0.898	0.000 (0.000 to 0.000)	0.929
3rd	0.000 (0.000 to 0.001)	0.060	0.000 (0.000 to 0.001)	0.260	0.000 (0.000 to 0.001)	0.306
4th	0.000 (0.000 to 0.001)	0.308	0.000 (-0.001 to 0.001)	0.889	0.000 (-0.001 to 0.000)	0.782
Lowest	0.000 (-0.001 to 0.000)	0.751	0.000 (-0.001 to 0.000)	0.115	-0.001 (-0.001 to 0.000)	0.122
Intercept	4.339 (4.334 to 4.344)	<0.001	4.389 (4.380 to 4.399)	<0.001	4.422 (4.410 to 4.434)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.081 (0.080 to 0.081)	-	0.081 (0.080 to 0.081)	-	0.081 (0.080 to 0.081)	-
Level 2: intercept	0.140 (0.138 to 0.143)	-	0.138 (0.136 to 0.140)	-	0.451 (0.420 to 0.481)	-
Level 2: age	0.010 (0.010 to 0.010)	-	0.010 (0.009 to 0.010)	-	0.132 (0.130 to 0.134)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and wealth, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and wealth, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, income, occupation, smoking and drinking, and interactions between age and education, age and income, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-7 Results of minimally, partially and fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in HRS

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.014 (-0.015 to -0.013)	<0.001	-0.014 (-0.015 to -0.013)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.0001 (-0.0002 to -0.00003)	0.004	-0.0001 (-0.0002 to -0.00003)	0.009	-0.00009 (-0.0002 to -0.00001)	0.029
Cohort	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
$Cohort^2$	0.0007 (0.0006 to 0.0007)	<0.001	0.0007 (0.0006 to 0.0007)	<0.001	0.0006 (0.0006 to 0.0007)	<0.001
Occupation						
Ref- Managerial and professional specialty occupation						
Technical, sales and administrative support	-0.004 (-0.015 to 0.007)	0.516	0.000 (-0.016 to 0.015)	0.981	0.004 (-0.011 to 0.020)	0.598
Service occupations	0.002 (-0.011 to 0.015)	0.751	0.013 (-0.006 to 0.032)	0.177	0.022 (0.003 to 0.041)	0.020
Farming, forestry and fishing occupations	-0.013 (-0.032 to 0.007)	0.198	-0.005 (-0.026 to 0.016)	0.627	0.001 (-0.019 to 0.022)	0.891
Precision production, craft, and repair occupations	-0.001 (-0.019 to 0.017)	0.898	0.009 (-0.010 to 0.029)	0.354	0.014 (-0.006 to 0.034)	0.161
Operators, fabricators and labours	-0.012 (-0.027 to 0.004)	0.143	-0.007 (-0.024 to 0.010)	0.447	0.002 (-0.015 to 0.018)	0.845
Others	-0.012 (-0.021 to -0.003)	0.007	-0.004 (-0.015 to 0.007)	0.479	0.002 (-0.009 to 0.013)	0.693
Retired	-0.036 (-0.044 to -0.028)	<0.001	-0.026 (-0.036 to -0.016)	<0.001	-0.017 (-0.027 to -0.007)	0.001
Unemployed	-0.017 (-0.032 to -0.002)	0.025	-0.012 (-0.030 to 0.007)	0.210	-0.001 (-0.020 to 0.017)	0.874
Disabled	-0.073 (-0.086 to -0.061)	<0.001	-0.060 (-0.082 to -0.038)	<0.001	-0.047 (-0.069 to -0.025)	<0.001
Not in the labour force	-0.030 (-0.039 to -0.021)	<0.001	0.011 (-0.017 to 0.040)	0.437	0.026 (-0.002 to 0.055)	0.073
Occupation*age						
Technical, sales and administrative support	0.001 (-0.001 to 0.002)	0.235	0.001 (-0.001 to 0.002)	0.240	0.001 (0.000 to 0.003)	0.141
Service occupations	0.002 (0.000 to 0.004)	0.048	0.002 (0.000 to 0.004)	0.055	0.002 (0.000 to 0.004)	0.031
Farming, forestry and fishing occupations	-0.001 (-0.003 to 0.002)	0.641	-0.001 (-0.003 to 0.002)	0.631	-0.001 (-0.003 to 0.002)	0.698
Precision production, craft, and repair occupations	0.000 (-0.002 to 0.003)	0.869	0.000 (-0.002 to 0.003)	0.780	0.001 (-0.002 to 0.003)	0.661
Operators, fabricators and labours	0.001 (-0.001 to 0.003)	0.421	0.001 (-0.001 to 0.003)	0.392	0.001 (-0.001 to 0.003)	0.211
Others	0.001 (0.000 to 0.002)	0.069	0.001 (0.000 to 0.002)	0.059	0.001 (0.000 to 0.003)	0.022
Retired	0.000 (-0.001 to 0.001)	0.459	0.000 (-0.001 to 0.001)	0.465	0.001 (0.000 to 0.002)	0.196
Unemployed	0.001 (-0.002 to 0.003)	0.488	0.001 (-0.001 to 0.003)	0.416	0.001 (-0.001 to 0.004)	0.277
Disabled	0.002 (0.000 to 0.004)	0.011	0.002 (0.000 to 0.004)	0.015	0.002 (0.001 to 0.004)	0.004

Not in the labour force	0.001 (0.000 to 0.002)	0.149	0.001 (0.000 to 0.002)	0.228	0.001 (0.000 to 0.002)	0.099
Intercept	4.342 (4.334 to 4.351)	<0.001	4.400 (4.388 to 4.413)	<0.001	4.421 (4.408 to 4.434)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.080 (0.080 to 0.081)	-	0.080 (0.080 to 0.081)	-	0.081 (0.080 to 0.081)	-
Level 2: intercept	0.146 (0.143 to 0.148)	-	0.140 (0.138 to 0.142)	-	0.132 (0.130 to 0.134)	-
Level 2: age	0.010 (0.010 to 0.010)	-	0.010 (0.010 to 0.010)	-	0.009 (0.009 to 0.010)	-

[*] Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and occupation, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and occupation, and age and marital status; fully adjusted model: Covariates and interactions in partially adjusted model plus education, income, wealth, smoking and drinking, and interactions between age and education, age and income, age and wealth, and age and smoking.

[**] b (95%CIs): linear regression coefficients with 95% confidence intervals.

England

Table 4-8 to Table 4-11 present the results for the relationship between socioeconomic indicators (education, income, wealth and occupation) and log_e-transformed HAIs in ELSA. The coefficients (b) for the interactions between socioeconomic indicators and age give the effects of SEP on rates of change in HAI from the age of 60 years. Here the multilevel models estimate average changes per year in HAI after the age of 60 years.

In all minimally, partially and fully adjusted models, there were non-linear relationships between age and log_e-transformed HAIs. Both linear and quadratic age terms were negative and statistically significant, indicating accelerating health declines with increased age. Both linear and quadratic cohort terms were also significant. At the same age, participants who had been born later were less healthy than those who had been born earlier. However, the rates of change in HAI became slower across cohorts.

In Table 4-8, in the minimally adjusted model, compared with those who had a first-stage tertiary education or more, participants with any lower levels of education had lower HAIs at 60 years. For example, those who had a primary education or less had 10.9% (95% CI: 9.6–12.3%) lower HAIs at 60 years than those who had a first-stage tertiary education or more. After partial adjustment, the gap in HAI between the top and bottom levels of education became narrower (9.2%, 95% CI: 7.4–11.0%). In the fully adjusted model, this gap fell to 5.8% (95% CI: 3.9–7.6%). However, after full adjustment, only those with the bottom level of education had significantly lower HAIs at 60 years (5.8%, 95% CI: 3.9–7.6%). The interactions between education and age were all non-significant across models, indicating that the rates of decline in HAI for participants at different levels of education were similar.

In Table 4-9, in the minimally adjusted model, compared with those who were in the top income quintile, participants in any lower income quintiles had significantly lower HAIs at 60 years. For example, those in the bottom income quintile had 0.7% (95% CI: 0.2–1.2%) lower HAIs at 60 years. After partial adjustment, participants in the lowest income quintile no longer had significantly lower HAIs than those in the top income quintile. In the fully adjusted model, the cross-sectional relationship between income and HAIs became non-significant. All coefficients for significant interactions between income and age were positive values, indicating that the rates of decline in HAI became slower after 60 years for those in lower income quintiles. But the changes in rates of decline were minimal, since the coefficients for the interacting terms were nearly 0.

In Table 4-10, in the minimally adjusted model, compared with those who were in the top wealth quintile, participants in any lower wealth quintiles had lower HAIs at the age of 60 years ($P < 0.001$). For example, those in the lowest wealth quintile had 6.9% (95% CI: 6.1–7.6%) lower HAIs at the age of 60 years. After partial adjustment, the 95% CI of the gap in HAI between the top and bottom wealth quintiles became wider (6.8%, 95% CI: 5.6–7.9%). In the fully adjusted model, this gap fell to 5.5% (95% CI: 4.3–6.6%). The coefficients for significant interactions between wealth and age were negative values, indicating that the rates of decline in HAI for participants in the second and third wealth quintiles became quicker after the age of 60 years. But the changes in rates of decline might not be obvious, since the coefficients for the interacting terms were nearly 0.

In Table 4-11, in the minimally adjusted model, the cross-sectional relationships between occupation and HAIs were all significant in both minimally and partially adjusted models. For example, employees in routine occupations had 8.3% (95% CI: 7.0–9.6%) lower HAIs than those who were higher managers and professionals in the minimally adjusted model. After partial adjustment, the gap in HAI between the two groups became 6.3% (95% CI: 4.7–7.9%). In the fully adjusted model, this gap fell to 3.4% (95% CI: 1.7–5.0%). In the fully adjusted model, at 60 years, only small employers and own-account workers, lower supervisory, craft and related employees, and employees in routine occupations had (boundary) significantly lower HAIs than higher managers and professionals. There were no significant interactions between age and occupation across models, indicating that after the age of 60 years, the rates of decline in HAI were similar for participants in all occupational positions.

In terms of random effects, the coefficients for variance of HAI at occasional level were very small at around 0.08^2 (0.0064), with 76% of the unexplained variance in the fully adjusted models by education, income, wealth and occupation attributable to unobserved individual factors, respectively.

Table 4-8 Results of minimally, partially and fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in ELSA

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.010 (-0.011 to -0.009)	<0.001	-0.010 (-0.011 to -0.009)	<0.001	-0.009 (-0.010 to -0.007)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.004 (-0.005 to -0.003)	<0.001	-0.004 (-0.005 to -0.003)	<0.001	-0.003 (-0.004 to -0.003)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001
Education						
Ref – First stage of tertiary edu. or above						
Post-secondary non-tertiary edu.	-0.028 (-0.045 to -0.011)	0.001	-0.014 (-0.035 to 0.008)	0.203	0.000 (-0.021 to 0.021)	0.991
Upper secondary education	-0.035 (-0.057 to -0.013)	0.001	-0.027 (-0.054 to 0.001)	0.057	-0.010 (-0.037 to 0.017)	0.458
Lower secondary education	-0.048 (-0.063 to -0.033)	<0.001	-0.039 (-0.058 to -0.020)	<0.001	-0.014 (-0.033 to 0.005)	0.147
Primary education or less	-0.109 (-0.123 to -0.096)	<0.001	-0.092 (-0.110 to -0.074)	<0.001	-0.058 (-0.076 to -0.039)	<0.001
Others	-0.067 (-0.084 to -0.050)	<0.001	-0.037 (-0.063 to -0.011)	0.006	-0.011 (-0.036 to 0.015)	0.409
Education*age						
Post-secondary non-tertiary edu.	0.000 (-0.001 to 0.002)	0.875	0.000 (-0.001 to 0.002)	0.742	0.000 (-0.001 to 0.002)	0.612
Upper secondary education	-0.001 (-0.002 to 0.001)	0.497	0.000 (-0.002 to 0.001)	0.592	0.000 (-0.002 to 0.002)	0.822
Lower secondary education	0.000 (-0.001 to 0.002)	0.471	0.001 (-0.001 to 0.002)	0.410	0.001 (-0.001 to 0.002)	0.293
Primary education or less	-0.001 (-0.002 to 0.000)	0.144	-0.001 (-0.002 to 0.001)	0.375	0.000 (-0.002 to 0.001)	0.664
Others	0.000 (-0.001 to 0.002)	0.608	0.001 (-0.001 to 0.002)	0.452	0.001 (-0.001 to 0.002)	0.358
Intercept	4.418 (4.405 to 4.431)	<0.001	4.476 (4.457 to 4.495)	<0.001	4.483 (4.463 to 4.503)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-
Level 2: intercept	0.146 (0.143 to 0.149)	-	0.140 (0.137 to 0.143)	-	0.135 (0.132 to 0.138)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.009 (0.008 to 0.009)	-	0.008 (0.008 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and education, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and education, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus income, wealth, occupation, smoking and drinking, and interactions between age and income, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-9 Results of minimally, partially and fully adjusted linear multilevel models for associations between income and HAI (loge-transformed) in ELSA

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.011 (-0.012 to -0.010)	<0.001	-0.010 (-0.011 to -0.009)	<0.001	-0.009 (-0.010 to -0.007)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0003)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.002)	<0.001	-0.003 (-0.004 to -0.002)	<0.001	-0.003 (-0.004 to -0.003)	<0.001
$Cohort^2$	0.0004 (0.0002 to 0.0005)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001
Income						
Ref- Highest						
2nd	-0.008 (-0.012 to -0.004)	<0.001	-0.007 (-0.012 to -0.001)	0.029	-0.003 (-0.009 to 0.003)	0.287
3rd	-0.012 (-0.017 to -0.008)	<0.001	-0.009 (-0.016 to -0.003)	0.005	-0.003 (-0.009 to 0.004)	0.427
4th	-0.009 (-0.014 to -0.004)	<0.001	-0.009 (-0.016 to -0.001)	0.018	0.001 (-0.006 to 0.008)	0.802
Lowest	-0.007 (-0.012 to -0.002)	0.009	-0.007 (-0.015 to 0.001)	0.094	0.004 (-0.004 to 0.012)	0.378
Income*age						
2nd	0.000 (0.000 to 0.001)	0.506	0.000 (0.000 to 0.001)	0.573	0.000 (0.000 to 0.001)	0.480
3rd	0.001 (0.000 to 0.002)	0.002	0.001 (0.000 to 0.002)	0.003	0.001 (0.000 to 0.002)	0.002
4th	0.001 (0.000 to 0.001)	0.053	0.001 (0.000 to 0.001)	0.076	0.001 (0.000 to 0.001)	0.092
Lowest	0.001 (0.000 to 0.001)	0.059	0.001 (0.000 to 0.001)	0.094	0.001 (0.000 to 0.001)	0.126
Intercept	4.354 (4.347 to 4.360)	<0.001	4.452 (4.436 to 4.468)	<0.001	4.481 (4.462 to 4.500)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-
Level 2: intercept	0.150 (0.147 to 0.153)	-	0.143 (0.140 to 0.146)	-	0.135 (0.132 to 0.138)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.009 (0.008 to 0.009)	-	0.008 (0.008 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and $cohort^2$, and interactions between age and income, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and income, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, wealth, occupation, smoking and drinking, and interactions between age and education, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-10 Results of minimally, partially and fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in ELSA

Main exposures	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.010 (-0.010 to -0.009)	<0.001	-0.009 (-0.010 to -0.008)	<0.001	-0.009 (-0.010 to -0.007)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.002)	<0.001	-0.003 (-0.004 to -0.002)	<0.001	-0.003 (-0.004 to -0.003)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001
Wealth						
Ref- Highest						
2nd	-0.013 (-0.017 to -0.008)	<0.001	-0.014 (-0.020 to -0.007)	<0.001	-0.011 (-0.017 to -0.004)	0.002
3rd	-0.026 (-0.031 to -0.020)	<0.001	-0.023 (-0.031 to -0.015)	<0.001	-0.017 (-0.025 to -0.009)	<0.001
4th	-0.043 (-0.049 to -0.037)	<0.001	-0.042 (-0.051 to -0.033)	<0.001	-0.033 (-0.042 to -0.024)	<0.001
Lowest	-0.069 (-0.076 to -0.061)	<0.001	-0.068 (-0.079 to -0.056)	<0.001	-0.055 (-0.066 to -0.043)	<0.001
Wealth*age						
2nd	0.000 (-0.001 to 0.000)	0.195	0.000 (-0.001 to 0.000)	0.199	-0.001 (-0.001 to 0.000)	0.059
3rd	0.000 (-0.001 to 0.000)	0.174	0.000 (-0.001 to 0.000)	0.189	-0.001 (-0.001 to 0.000)	0.043
4th	0.000 (-0.001 to 0.000)	0.366	0.000 (-0.001 to 0.000)	0.407	-0.001 (-0.001 to 0.000)	0.082
Lowest	0.000 (-0.001 to 0.001)	0.458	0.000 (-0.001 to 0.001)	0.646	-0.001 (-0.002 to 0.000)	0.183
Intercept	4.377 (4.370 to 4.384)	<0.001	4.460 (4.445 to 4.476)	<0.001	4.482 (4.463 to 4.501)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-
Level 2: intercept	0.145 (0.142 to 0.148)	-	0.139 (0.136 to 0.142)	-	0.135 (0.132 to 0.138)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.009 (0.008 to 0.009)	-	0.008 (0.008 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and wealth, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and wealth, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, income, occupation, smoking and drinking, and interactions between age and education, age and income, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-11 Results of minimally, partially and fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in ELSA

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.010 (-0.011 to -0.009)	<0.001	-0.009 (-0.011 to -0.008)	<0.001	-0.009 (-0.010 to -0.007)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0003)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.002)	<0.001	-0.003 (-0.004 to -0.002)	<0.001	-0.003 (-0.004 to -0.003)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001
Occupation						
Ref- Higher managerial and professional employers						
Lower managerial and professional employers	-0.026 (-0.036 to -0.015)	<0.001	-0.013 (-0.025 to -0.001)	0.039	-0.008 (-0.021 to 0.004)	0.180
Intermediate employees	-0.040 (-0.052 to -0.027)	<0.001	-0.021 (-0.039 to -0.002)	0.030	-0.011 (-0.029 to 0.008)	0.260
Small employers and own account workers	-0.042 (-0.054 to -0.029)	<0.001	-0.029 (-0.044 to -0.014)	<0.001	-0.015 (-0.030 to 0.000)	0.057
Lower supervisory, craft and related employees	-0.057 (-0.070 to -0.044)	<0.001	-0.041 (-0.056 to -0.026)	<0.001	-0.019 (-0.035 to -0.004)	0.014
Employees in semi-routine occupations	-0.065 (-0.076 to -0.053)	<0.001	-0.036 (-0.052 to -0.020)	<0.001	-0.010 (-0.027 to 0.006)	0.207
Employees in routine occupations	-0.083 (-0.096 to -0.070)	<0.001	-0.063 (-0.079 to -0.047)	<0.001	-0.034 (-0.050 to -0.017)	<0.001
Never worked	-0.078 (-0.101 to -0.055)	<0.001	-0.048 (-0.095 to -0.001)	0.047	-0.023 (-0.071 to 0.025)	0.342
Occupation*age						
Lower managerial and professional employers	0.000 (-0.001 to 0.001)	0.984	0.000 (-0.001 to 0.001)	0.972	0.000 (-0.001 to 0.001)	0.918
Intermediate employees	-0.001 (-0.002 to 0.001)	0.323	-0.001 (-0.002 to 0.001)	0.323	-0.001 (-0.002 to 0.001)	0.324
Small employers and own account workers	-0.001 (-0.002 to 0.001)	0.454	0.000 (-0.002 to 0.001)	0.673	0.000 (-0.002 to 0.001)	0.703
Lower supervisory, craft and related employees	-0.001 (-0.002 to 0.001)	0.279	-0.001 (-0.002 to 0.001)	0.453	-0.001 (-0.002 to 0.001)	0.489
Employees in semi-routine occupations	0.000 (-0.002 to 0.001)	0.662	0.000 (-0.001 to 0.001)	0.828	0.000 (-0.001 to 0.001)	0.945
Employees in routine occupations	-0.001 (-0.002 to 0.001)	0.237	-0.001 (-0.002 to 0.001)	0.416	-0.001 (-0.002 to 0.001)	0.460
Never worked	-0.002 (-0.005 to 0.001)	0.267	-0.002 (-0.004 to 0.001)	0.302	-0.002 (-0.005 to 0.001)	0.286
Intercept	4.395 (4.384 to 4.406)	<0.001	4.464 (4.447 to 4.482)	<0.001	4.479 (4.460 to 4.498)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-	0.076 (0.075 to 0.077)	-
Level 2: intercept	0.147 (0.144 to 0.150)	-	0.141 (0.138 to 0.144)	-	0.135 (0.132 to 0.138)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.009 (0.008 to 0.009)	-	0.008 (0.008 to 0.009)	-

[*] Minimally adjusted model: age, age^2, cohort and $cohort^2$, and interactions between age and occupation, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and occupation, and age and marital status; fully adjusted model: Covariates and interactions in partially adjusted model plus education, income, wealth, smoking and drinking, and interactions between age and education, age and income, age and wealth, and age and smoking.

[**] b (95%CIs): linear regression coefficients with 95% confidence intervals.

China

Table 4-12 to Table 4-15 present the relationships between socioeconomic indicators (education, income, wealth and occupation) and $\log_e$-transformed HAIs in CHARLS. The coefficients (b) for the interactions between socioeconomic indicators and age give the effects of SEP on rates of change in HAI from the age of 60 years. Here the multilevel models estimate average changes per year in HAI after the age of 60 years.

The linear relationships between age and $\log_e$-transformed HAIs were significant in the minimally and partially adjusted models. The coefficients of age were negative, suggesting declining health with increased age. In the fully adjusted model, the linear age term became non-significant (even after the quadratic age term was removed), indicating a weak linear effect of age on HAI. All quadratic age terms were statistically non-significant across models, indicating weak non-linear effects of age on HAI. However, both linear and quadratic cohort terms were significant. At the same age, participants who had been born later were less healthy than those who had been born earlier. But the rates of change in HAI became slower across cohorts.

In Table 4-12, in the minimally adjusted model, compared with those who had a first-stage tertiary education or more, only participants with a lower secondary or primary education or less had lower HAIs at 60 years ($P < 0.001$). For example, those with a primary education or less had 17.8% (95% CI: 14.6–20.9%) lower HAIs at 60 years. After partial adjustment, the gap in HAI between the top and bottom levels of education became 12.2% (95% CI: 8.6–15.9%). In the fully adjusted model, this gap fell to 10.8% (95% CI: 7.0–14.5%). All interactions between education and age were non-significant in the three models, indicating that the rates of decline in HAI after the age of 60 years for participants with different levels of education were similar.

In Table 4-13, in both the minimally and partially adjusted models, compared with those who were in the top income quintile, participants in any lower income quintiles had significantly lower HAIs at 60 years. For example, those in the lowest income quintile had 4.8% (95% CI: 3.7–5.9%) lower HAIs at 60 years. After partial adjustment, the 95% CI of the gap in HAI between the top and bottom income quintiles became wider (4.0%, 95% CI: 2.6–5.3%). However, after I controlled for all covariates, only participants in the lowest and fourth income quintiles had significantly lower HAIs at 60 years than those in the top income quintiles. In the fully adjusted model, the gap in HAI between the top and bottom income quintiles fell to 2.5% (95% CI: 1.1–3.9%). All interactions between income and age were non-significant across models, indicating that the rates of decline in HAI for different income quintiles after the age of 60 years were similar.

In Table 4-14, in the minimally adjusted model, compared with those who were in the top wealth quintile, participants in the fourth and lowest wealth quintiles had significantly lower HAIs at 60 years. For example, those in the lowest wealth quintile had 1.9% (95% CI: 0.8–3.1%) lower HAI at 60 years. However, after partial adjustment, only those in the fourth wealth quintile had significantly lower HAIs. In the fully adjusted model, the association between wealth and HAIs at 60 years became non-significant. All interactions between wealth and age were not significant across models, meaning that the rates of decline in HAI for different wealth quintiles after the age of 60 years were similar.

In Table 4-15, in the minimally adjusted model, compared with those who were officials/managers/leaders and clerks/paid workers, participants who conducted unpaid family business, other work and unpaid agricultural work had lower HAIs at 60 years. For example, the estimated HAIs for those in unpaid agricultural work were 4.3% (95% CI: 1.7–6.9%) lower at 60 years. After full adjustment, those who conducted unpaid family business, other work and unpaid agricultural work still had (boundary) significantly lower HAIs at 60 years than officials/managers/leaders and clerks/paid workers. The interactions between occupation and age were not significant in the three models.

In terms of random effects, the coefficients for variance of HAI at occasional level were very small at around 0.12^2 (0.0144), with 64% of the unexplained variance in the fully adjusted models by education, income, wealth and occupation attributable to unobserved individual factors, respectively.

Table 4-12 Results of minimally, partially and fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in CHARLS

	Minimally adjusted model*		**Partially adjusted model***		**Fully adjusted model***	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.012 (-0.017 to -0.007)	<0.001	-0.012 (-0.016 to -0.007)	<0.001	-0.013 (-0.039 to 0.013)	0.323
Age^2	0.0002 (-0.0001 to 0.0005)	0.278	0.0002 (-0.0001 to 0.0005)	0.256	0.0002 (-0.0001 to 0.0005)	0.277
Cohort	-0.008 (-0.010 to -0.007)	<0.001	-0.008 (-0.010 to -0.006)	<0.001	-0.008 (-0.010 to -0.006)	<0.001
Cohort^2	0.0007 (0.0003 to 0.001)	<0.001	0.0007 (0.0003 to 0.001)	<0.001	0.0008 (0.0004 to 0.001)	<0.001
Education						
Ref – First stage of tertiary edu. Or above						
Post-secondary non-tertiary edu.	-0.013 (-0.053 to 0.027)	0.537	-0.012 (-0.057 to 0.033)	0.600	-0.007 (-0.052 to 0.037)	0.749
Upper secondary education	-0.011 (-0.056 to 0.033)	0.612	-0.013 (-0.063 to 0.038)	0.626	-0.008 (-0.058 to 0.042)	0.753
Lower secondary education	-0.073 (-0.106 to -0.041)	<0.001	-0.057 (-0.094 to -0.021)	0.002	-0.046 (-0.083 to -0.009)	0.015
Primary education or less	-0.178 (-0.209 to -0.146)	<0.001	-0.122 (-0.159 to -0.086)	<0.001	-0.108 (-0.145 to -0.070)	<0.001
Education*age						
Post-secondary non-tertiary edu.	-0.002 (-0.008 to 0.004)	0.478	-0.002 (-0.008 to 0.004)	0.541	-0.002 (-0.008 to 0.004)	0.484
Upper secondary education	0.000 (-0.006 to 0.007)	0.922	0.001 (-0.006 to 0.007)	0.843	0.000 (-0.006 to 0.007)	0.893
Lower secondary education	-0.001 (-0.006 to 0.004)	0.656	-0.001 (-0.006 to 0.004)	0.708	-0.001 (-0.006 to 0.004)	0.659
Primary education or less	-0.003 (-0.008 to 0.001)	0.179	-0.003 (-0.007 to 0.002)	0.289	-0.003 (-0.007 to 0.002)	0.295
Intercept	4.412 (4.380 to 4.444)	<0.001	4.451 (4.400 to 4.501)	<0.001	4.429 (4.292 to 4.566)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-
Level 2: intercept	0.162 (0.158 to 0.166)	-	0.156 (0.152 to 0.160)	-	0.153 (0.149 to 0.157)	-
Level 2: age	0.006 (0.004 to 0.008)	-	0.005 (0.004 to 0.008)	-	0.005 (0.003 to 0.008)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and education, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and education, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus income, wealth, occupation, smoking and drinking, and interactions between age and income, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-13 Results of minimally, partially and fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in CHARLS

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.014 (-0.016 to -0.012)	<0.001	-0.013 (-0.015 to -0.011)	<0.001	-0.013 (-0.039 to 0.013)	0.329
Age^2	0.0002 (-0.0001 to 0.0005)	0.268	0.00002 (-0.0001 to 0.0005)	0.262	0.0002 (-0.0001 to 0.0005)	0.277
Cohort	-0.008 (-0.010 to -0.006)	<0.001	-0.008 (-0.010 to -0.006)	<0.001	-0.008 (-0.010 to -0.006)	<0.001
Cohort^2	0.0007 (0.0003 to 0.001)	0.001	0.0007 (0.0003 to 0.001)	<0.001	0.0008 (0.0004 to 0.001)	0.001
Income						
Ref- Highest						
2nd	-0.016 (-0.026 to -0.007)	0.001	-0.014 (-0.026 to -0.001)	0.030	-0.006 (-0.018 to 0.006)	0.346
3rd	-0.029 (-0.039 to -0.019)	<0.001	-0.019 (-0.032 to -0.006)	0.003	-0.008 (-0.021 to 0.005)	0.230
4th	-0.039 (-0.048 to -0.029)	<0.001	-0.032 (-0.045 to -0.019)	<0.001	-0.018 (-0.031 to -0.005)	0.007
Lowest	-0.048 (-0.059 to -0.037)	<0.001	-0.040 (-0.053 to -0.026)	<0.001	-0.025 (-0.039 to -0.011)	<0.001
Income*age						
2nd	0.000 (-0.002 to 0.001)	0.703	0.000 (-0.002 to 0.001)	0.800	0.000 (-0.002 to 0.002)	0.952
3rd	0.000 (-0.002 to 0.001)	0.646	0.000 (-0.002 to 0.001)	0.854	0.000 (-0.002 to 0.002)	0.827
4th	0.000 (-0.001 to 0.002)	0.849	0.000 (-0.001 to 0.002)	0.684	0.001 (-0.001 to 0.002)	0.422
Lowest	-0.001 (-0.003 to 0.001)	0.182	-0.001 (-0.003 to 0.001)	0.303	0.000 (-0.002 to 0.001)	0.652
Intercept	4.316 (4.307 to 4.325)	<0.001	4.386 (4.356 to 4.417)	<0.001	4.435 (4.300 to 4.570)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-
Level 2: intercept	0.169 (0.165 to 0.173)	-	0.158 (0.154 to 0.163)	-	0.153 (0.149 to 0.157)	-
Level 2: age	0.005 (0.003 to 0.008)	-	0.005 (0.003 to 0.008)	-	0.005 (0.003 to 0.008)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and income, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and income, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, wealth, occupation, smoking and drinking, and interactions between age and education, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-14 Results of minimally, partially and fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in CHARLS

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.014 (-0.016 to -0.011)	<0.001	-0.012 (-0.015 to -0.010)	<0.001	-0.013 (-0.039 to 0.013)	0.323
Age^2	0.0002 (-0.0001 to 0.0005)	0.254	0.0002 (-0.0001 to 0.0005)	0.256	0.0002 (-0.0002 to 0.0005)	0.295
Cohort	-0.008 (-0.010 to -0.006)	<0.001	-0.008 (-0.010 to -0.006)	<0.001	-0.008 (-0.010 to -0.006)	<0.001
Cohort^2	0.0006 (0.0003 to 0.001)	0.001	0.0007 (0.0003 to 0.001)	0.001	0.0008 (0.0004 to 0.001)	<0.001
Wealth						
Ref- Highest						
2nd	0.000 (-0.010 to 0.009)	0.953	-0.002 (-0.014 to 0.010)	0.764	0.001 (-0.011 to 0.013)	0.904
3rd	-0.007 (-0.017 to 0.002)	0.130	-0.005 (-0.017 to 0.007)	0.424	0.002 (-0.010 to 0.014)	0.758
4th	-0.018 (-0.028 to -0.009)	<0.001	-0.015 (-0.027 to -0.002)	0.019	-0.005 (-0.017 to 0.007)	0.420
Lowest	-0.019 (-0.031 to -0.008)	0.001	-0.013 (-0.027 to 0.002)	0.089	-0.005 (-0.019 to 0.010)	0.525
Wealth*age						
2nd	-0.001 (-0.003 to 0.000)	0.077	-0.001 (-0.003 to 0.000)	0.081	-0.001 (-0.003 to 0.000)	0.163
3rd	0.000 (-0.002 to 0.001)	0.609	0.000 (-0.002 to 0.001)	0.599	0.000 (-0.002 to 0.002)	0.887
4th	0.000 (-0.002 to 0.002)	0.873	0.000 (-0.002 to 0.002)	0.851	0.000 (-0.002 to 0.002)	0.826
Lowest	-0.001 (-0.003 to 0.001)	0.227	-0.001 (-0.003 to 0.001)	0.279	-0.001 (-0.003 to 0.002)	0.613
Intercept	4.298 (4.289 to 4.308)	<0.001	4.377 (4.346 to 4.408)	<0.001	4.441 (4.249 to 4.634)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-
Level 2: intercept	0.171 (0.167 to 0.176)	-	0.160 (0.156 to 0.164)	-	0.153 (0.149 to 0.158)	-
Level 2: age	0.005 (0.003 to 0.008)	-	0.005 (0.003 to 0.008)	-	0.005 (0.003 to 0.008)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and wealth, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and wealth, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, income, occupation, smoking and drinking, and interactions between age and education, age and income, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-15 Results of minimally, partially and fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in CHARLS

	Minimally adjusted model*		**Partially adjusted model***		**Fully adjusted model***	
Fixed effects	**b (95%CIs) ** **	**P-values**	**b (95%CIs) ** **	**P-values**	**b (95%CIs) ** **	**P-values**
Age	-0.012 (-0.017 to -0.007)	<0.001	-0.011 (-0.016 to -0.006)	<0.001	-0.008 (-0.015 to -0.002)	0.013
Age^2	0.0002 (-0.0002 to 0.0005)	0.302	0.0002 (-0.0001 to 0.0005)	0.271	0.0002 (-0.0002 to 0.0005)	0.284
Cohort	-0.008 (-0.010 to -0.006)	<0.001	-0.008 (-0.009 to -0.006)	<0.001	-0.008 (-0.010 to -0.006)	<0.001
Cohort^2	0.0006 (0.0002 to 0.001)	0.003	0.0006 (0.0002 to 0.001)	0.001	0.0008 (0.0004 to 0.001)	<0.001
Occupation						
Ref- Officials/managers/leaders or clerks/paid workers						
Self-employed workers	-0.017 (-0.052 to 0.017)	0.328	-0.016 (-0.052 to 0.021)	0.407	0.019 (-0.056 to 0.017)	0.299
Unpaid family business	-0.034 (-0.064 to -0.005)	0.024	-0.028 (-0.062 to 0.006)	0.102	-0.031 (-0.065 to 0.003)	0.072
Others	-0.045 (-0.072 to -0.019)	0.001	-0.036 (-0.065 to -0.007)	0.015	-0.015 (-0.066 to -0.008)	0.013
Only agricultural work	-0.043 (-0.069 to -0.017)	0.001	-0.032 (-0.060 to -0.004)	0.023	-0.029 (-0.057 to -0.001)	0.041
Occupation*age						
Self-employed workers	-0.0008 (-0.007 to 0.006)	0.815	-0.0008 (-0.007 to 0.005)	0.792	-0.0008 (-0.007 to 0.005)	0.801
Unpaid family business	-0.001 (-0.007 to 0.004)	0.648	-0.001 (-0.007 to 0.004)	0.603	-0.002 (-0.007 to 0.004)	0.579
Others	-0.002 (-0.007 to 0.003)	0.406	-0.002 (-0.007 to 0.003)	0.360	-0.002 (-0.007 to 0.003)	0.374
Only agricultural work	-0.002 (-0.007 to 0.003)	0.460	-0.002 (-0.007 to 0.003)	0.356	-0.003 (-0.007 to 0.002)	0.288
Intercept	4.331 (4.305 to 4.358)	<0.001	4.403 (4.363 to 4.442)	<0.001	4.458 (4.409 to 4.507)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-	0.116 (0.114 to 0.118)	-
Level 2: intercept	0.172 (0.168 to 0.176)	-	0.161 (0.157 to 0.165)	-	0.153 (0.149 to 0.158)	-
Level 2: age	0.005 (0.003 to 0.008)	-	0.005 (0.003 to 0.008)	-	0.005 (0.004 to 0.008)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and occupation, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status, father's occupation and self-rated health in childhood, and interactions between gender and occupation, and age and marital status; fully adjusted model: Covariates and interactions in partially adjusted model plus education, income, wealth, smoking and drinking, and interactions between age and education, age and income, age and wealth, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Japan

Table 4-16 to Table 4-19 present the relationships between socioeconomic indicators (education, income, wealth and occupation) and $\log_e$-transformed HAIs in JSTAR. The coefficients (b) for the interactions between socioeconomic indicators and age give the effects of SEP on rates of change in HAI from the age of 60 years. Here the multilevel models estimate average changes per year in HAI after the age of 60 years.

In all minimally, partially and fully adjusted models, there were non-linear relationships between age and $\log_e$-transformed HAIs. The coefficients for the quadratic age terms were negative, indicating that the rates of decline in health accelerated with increased age. Similarly, there were non-linear relationships between cohort and $\log_e$-transformed HAIs in all models. It seemed that at the same age, participants who had been born later were less healthy than those who had been born earlier. Also, the rates of decline in HAI increased across cohorts.

In Table 4-16, in the minimally adjusted model, compared with those who had a first-stage tertiary education or more, participants with any lower education had significantly lower HAIs at 60 years. For example, those who had a primary education or less had 8.8% (95% CI: 2.4–15.3%) lower HAIs at baseline. However, after partial or full adjustment, only those with a lower secondary education had significantly lower HAIs at 60 years. All interactions between education and age were non-significant in the three models, indicating that the rates of decline in HAI for participants with different levels of education were similar.

In Table 4-17, in both the minimally and partially adjusted models, compared with those who had the highest level of income, participants with the second, fourth and lowest levels of income had significantly lower HAIs at 60 years. For example, those with the lowest level of income had 1.5% (95% CI: 0.7–2.4%) lower HAIs at 60 years. After partial adjustment, the 95% CI of the gap in HAI between the highest and lowest income quintiles became wider (1.6%, 95% CI: 0.4–2.8%). However, after I controlled for all covariates, the cross-sectional relationship between income and HAIs was no longer significant. All interactions between income and age were non-significant in the three models, indicating that the rates of decline in HAI for different income quintiles were similar after the age of 60 years.

In Table 4-18, in the minimally adjusted model, compared with those who were in the top wealth quintile, participants in the fourth and the lowest wealth quintiles had lower HAIs at 60 years. For example, those in the lowest wealth quintile had 1.4% (95% CI: 0.6–2.3%) lower HAIs at 60 years. However, in both the partial and fully adjusted models, only individuals in the lowest wealth quintile had (boundary) significantly lower HAIs at 60 years. As with income, all interactions between wealth and age were non-significant in all models, meaning that after the age of 60 years, the rates of decline in HAI for different wealth quintiles were similar.

In Table 4-19, there were no clear occupational gradients in HAI at 60 years in any model. Only those in unclassifiable occupations had 2.3% (95% CI: 0.9–3.8%) lower HAIs at 60 years compared with those in the most advantaged occupational group in the fully adjusted model. All interactions between occupation and age were non-significant in the three models.

In terms of random effects, the coefficients for variance of HAI at occasional level were very small at around 0.05^2 (0.0025), with 71% of the unexplained variance in the fully adjusted models by education, income, wealth and occupation attributable to unobserved individual factors, respectively.

Table 4-16 Results of minimally, partially and fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in JSTAR

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.005 (-0.008 to -0.002)	0.003	-0.005 (-0.008 to -0.002)	0.001	-0.002 (-0.006 to 0.002)	0.273
Age^2	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.0008 (-0.003 to 0.001)	0.511	-0.0007 (-0.003 to 0.002)	0.550	-0.0009 (-0.003 to 0.001)	0.425
Cohort^2	-0.0009 (-0.002 to -0.0002)	0.007	-0.0009 (-0.002 to -0.0002)	0.010	-0.001 (-0.002 to -0.0003)	0.004
Education						
Ref – First stage of tertiary edu. or above						
Post-secondary non-tertiary edu.	-0.032 (-0.054 to -0.010)	0.005	-0.031 (-0.070 to 0.008)	0.117	-0.033 (-0.071 to 0.005)	0.085
Upper secondary education	-0.017 (-0.031 to -0.002)	0.022	-0.016 (-0.034 to 0.001)	0.065	-0.017 (-0.034 to 0.001)	0.058
Lower secondary education	-0.044 (-0.058 to -0.030)	<0.001	-0.047 (-0.065 to -0.029)	<0.001	-0.047 (-0.064 to -0.029)	<0.001
Primary education or less	-0.088 (-0.153 to -0.024)	0.007	-0.027 (-0.100 to 0.046)	0.464	-0.021 (-0.092 to 0.051)	0.569
Education*age						
Post-secondary non-tertiary edu.	0.001 (-0.003 to 0.005)	0.734	0.001 (-0.003 to 0.005)	0.725	0.001 (-0.003 to 0.005)	0.682
Upper secondary education	0.000 (-0.003 to 0.003)	0.960	0.000 (-0.003 to 0.003)	0.968	0.000 (-0.002 to 0.003)	0.886
Lower secondary education	-0.001 (-0.003 to 0.002)	0.586	-0.001 (-0.003 to 0.002)	0.560	-0.001 (-0.004 to 0.002)	0.421
Primary education or less	-0.001 (-0.012 to 0.009)	0.807	0.000 (-0.010 to 0.011)	0.944	-0.001 (-0.012 to 0.009)	0.805
Intercept	4.471 (4.457 to 4.485)	<0.001	4.481 (4.464 to 4.497)	<0.001	4.486 (4.465 to 4.508)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.050 (0.048 to 0.052)	-	0.050 (0.048 to 0.052)	-	0.049 (0.047 to 0.051)	-
Level 2: intercept	0.080 (0.076 to 0.083)	-	0.078 (0.075 to 0.082)	-	0.076 (0.072 to 0.079)	-
Level 2: age	0.008 (0.007 to 0.010)	-	0.008 (0.007 to 0.010)	-	0.008 (0.007 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and education, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status and father's occupation, and interactions between gender and education, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus income, wealth, occupation, smoking and drinking, and interactions between age and income, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-17 Results of minimally, partially and fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in JSTAR

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.004 (-0.007 to -0.002)	<0.001	-0.005 (-0.007 to -0.002)	<0.001	-0.002 (-0.006 to 0.002)	0.265
Age^2	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.00002 (-0.002 to 0.002)	0.987	-0.00002 (-0.002 to 0.002)	0.985	-0.001 (-0.003 to 0.001)	0.406
Cohort^2	-0.0009 (-0.002 to -0.0003)	0.006	-0.0009 (-0.002 to -0.0002)	0.008	-0.001 (-0.002 to -0.0003)	0.004
Income						
Ref- Highest						
2nd	-0.007 (-0.014 to 0.000)	0.047	-0.010 (-0.019 to -0.001)	0.039	-0.008 (-0.017 to 0.001)	0.094
3rd	-0.004 (-0.011 to 0.004)	0.334	-0.003 (-0.012 to 0.007)	0.559	0.001 (-0.009 to 0.011)	0.826
4th	-0.012 (-0.019 to -0.004)	0.002	-0.014 (-0.024 to -0.003)	0.010	-0.009 (-0.020 to 0.001)	0.081
Lowest	-0.015 (-0.024 to -0.007)	<0.001	-0.016 (-0.028 to -0.004)	0.010	-0.007 (-0.019 to 0.005)	0.250
Income*age						
2nd	-0.001 (-0.003 to 0.001)	0.187	-0.001 (-0.003 to 0.001)	0.189	-0.001 (-0.003 to 0.000)	0.167
3rd	0.000 (-0.002 to 0.001)	0.631	0.000 (-0.002 to 0.001)	0.580	0.000 (-0.002 to 0.001)	0.572
4th	0.000 (-0.002 to 0.001)	0.717	0.000 (-0.002 to 0.001)	0.635	0.000 (-0.002 to 0.001)	0.714
Lowest	-0.001 (-0.003 to 0.000)	0.129	-0.002 (-0.003 to 0.000)	0.081	-0.002 (-0.003 to 0.000)	0.077
Intercept	4.450 (4.442 to 4.458)	<0.001	4.464 (4.452 to 4.477)	<0.001	4.483 (4.463 to 4.504)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.049 (0.047 to 0.051)	-	0.049 (0.047 to 0.051)	-	0.049 (0.047 to 0.051)	-
Level 2: intercept	0.081 (0.077 to 0.084)	-	0.079 (0.076 to 0.083)	-	0.076 (0.073 to 0.080)	-
Level 2: age	0.008 (0.007 to 0.010)	-	0.008 (0.007 to 0.010)	-	0.008 (0.007 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and income, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status and father's occupation, and interactions between gender and income, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, wealth, occupation, smoking and drinking, and interactions between age and education, age and wealth, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-18 Results of minimally, partially and fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in JSTAR

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**	**b (95%CIs) ****	**P-values**
Age	-0.006 (-0.008 to -0.003)	<0.001	-0.006 (-0.009 to -0.004)	<0.001	-0.002 (-0.006 to 0.002)	0.269
Age^2	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.0001 (-0.002 to 0.002)	0.933	-0.00008 (-0.002 to 0.002)	0.945	-0.0009 (-0.003 to 0.001)	0.416
Cohort^2	-0.0009 (-0.002 to -0.0002)	0.008	-0.0009 (-0.002 to -0.0002)	0.010	-0.001 (-0.002 to -0.0003)	0.004
Wealth						
Ref- Highest						
2nd	-0.001 (-0.008 to 0.007)	0.827	-0.001 (-0.012 to 0.010)	0.848	0.001 (-0.010 to 0.012)	0.839
3rd	-0.002 (-0.010 to 0.006)	0.686	-0.005 (-0.017 to 0.006)	0.349	-0.003 (-0.014 to 0.009)	0.643
4th	-0.011 (-0.018 to -0.003)	0.008	-0.010 (-0.021 to 0.002)	0.090	-0.006 (-0.017 to 0.006)	0.328
Lowest	-0.014 (-0.023 to -0.006)	0.001	-0.016 (-0.028 to -0.003)	0.016	-0.012 (-0.025 to 0.000)	0.052
Wealth*age						
2nd	0.000 (-0.001 to 0.002)	0.710	0.000 (-0.001 to 0.002)	0.740	0.000 (-0.002 to 0.002)	0.775
3rd	0.001 (-0.001 to 0.002)	0.506	0.001 (-0.001 to 0.003)	0.461	0.001 (-0.001 to 0.003)	0.370
4th	0.001 (-0.001 to 0.003)	0.503	0.001 (-0.001 to 0.003)	0.500	0.001 (-0.001 to 0.003)	0.450
Lowest	0.002 (0.000 to 0.004)	0.081	0.002 (0.000 to 0.004)	0.096	0.002 (0.000 to 0.004)	0.070
Intercept	4.448 (4.440 to 4.456)	<0.001	4.463 (4.450 to 4.476)	<0.001	4.484 (4.463 to 4.505)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.050 (0.048 to 0.052)	-	0.050 (0.048 to 0.052)	-	0.049 (0.047 to 0.051)	-
Level 2: intercept	0.080 (0.077 to 0.084)	-	0.079 (0.076 to 0.083)	-	0.076 (0.073 to 0.080)	-
Level 2: age	0.008 (0.007 to 0.010)	-	0.008 (0.007 to 0.010)	-	0.008 (0.007 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and wealth, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status and father's occupation, and interactions between gender and wealth, and age and marital status; fully adjusted model: covariates and interactions in partially adjusted model plus education, income, occupation, smoking and drinking, and interactions between age and education, age and income, age and occupation, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

Table 4-19 Results of minimally, partially and fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in JSTAR

	Minimally adjusted model*		Partially adjusted model*		Fully adjusted model*	
Fixed effects	**b (95%CIs) ** **	**P-values**	**b (95%CIs) ** **	**P-values**	**b (95%CIs) ** **	**P-values**
Age	-0.003 (-0.006 to 0.001)	0.113	-0.003 (-0.006 to 0.000)	0.076	-0.002 (-0.006 to 0.002)	0.308
Age^2	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.0003 (-0.002 to 0.002)	0.822	-0.0002 (-0.002 to 0.002)	0.842	-0.0009 (-0.003 to 0.001)	0.434
Cohort^2	-0.0009 (-0.002 to -0.0002)	0.007	-0.0009 (-0.002 to -0.0002)	0.009	-0.001 (-0.002 to -0.0003)	0.003
Occupation						
Ref- Highest						
Intermediate	-0.005 (-0.018 to 0.009)	0.513	-0.001 (-0.018 to 0.015)	0.896	0.000 (-0.016 to 0.016)	0.994
Lowest	-0.002 (-0.014 to 0.011)	0.786	-0.001 (-0.015 to 0.014)	0.939	0.004 (-0.010 to 0.019)	0.561
Others	-0.007 (-0.036 to 0.023)	0.653	0.000 (-0.034 to 0.033)	0.981	0.004 (-0.030 to 0.037)	0.837
Unclassifiable	-0.027 (-0.039 to -0.015)	<0.001	-0.028 (-0.042 to -0.013)	<0.001	-0.023 (-0.038 to -0.009)	0.001
Occupation*age						
Intermediate	-0.002 (-0.005 to 0.001)	0.149	-0.002 (-0.005 to 0.001)	0.130	-0.002 (-0.005 to 0.001)	0.224
Lowest	0.000 (-0.003 to 0.002)	0.743	-0.001 (-0.003 to 0.002)	0.669	0.000 (-0.003 to 0.003)	0.909
Others	-0.001 (-0.008 to 0.007)	0.843	-0.001 (-0.008 to 0.007)	0.886	0.000 (-0.008 to 0.007)	0.917
Unclassifiable	-0.002 (-0.005 to 0.000)	0.078	-0.003 (-0.005 to 0.000)	0.054	-0.002 (-0.005 to 0.001)	0.130
Intercept	4.460 (4.448 to 4.473)	<0.001	4.473 (4.456 to 4.489)	<0.001	4.484 (4.463 to 4.505)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.050 (0.048 to 0.052)	-	0.050 (0.048 to 0.052)	-	0.049 (0.047 to 0.051)	-
Level 2: intercept	0.079 (0.075 to 0.082)	-	0.079 (0.075 to 0.082)	-	0.076 (0.073 to 0.080)	-
Level 2: age	0.008 (0.007 to 0.009)	-	0.008 (0.007 to 0.009)	-	0.008 (0.007 to 0.009)	-

* Minimally adjusted model: age, age^2, cohort and cohort^2, and interactions between age and occupation, and age and cohort; partially adjusted model: covariates and interactions in minimally adjusted model plus gender, ethnicity, marital status and father's occupation, and interactions between gender and occupation, and age and marital status; fully adjusted model: Covariates and interactions in partially adjusted model plus education, income, wealth, smoking and drinking, and interactions between age and education, age and income, age and wealth, and age and smoking.

** b (95%CIs): linear regression coefficients with 95% confidence intervals.

4.4.3 Trajectories of HAI by Socioeconomic Predictors in Each Country

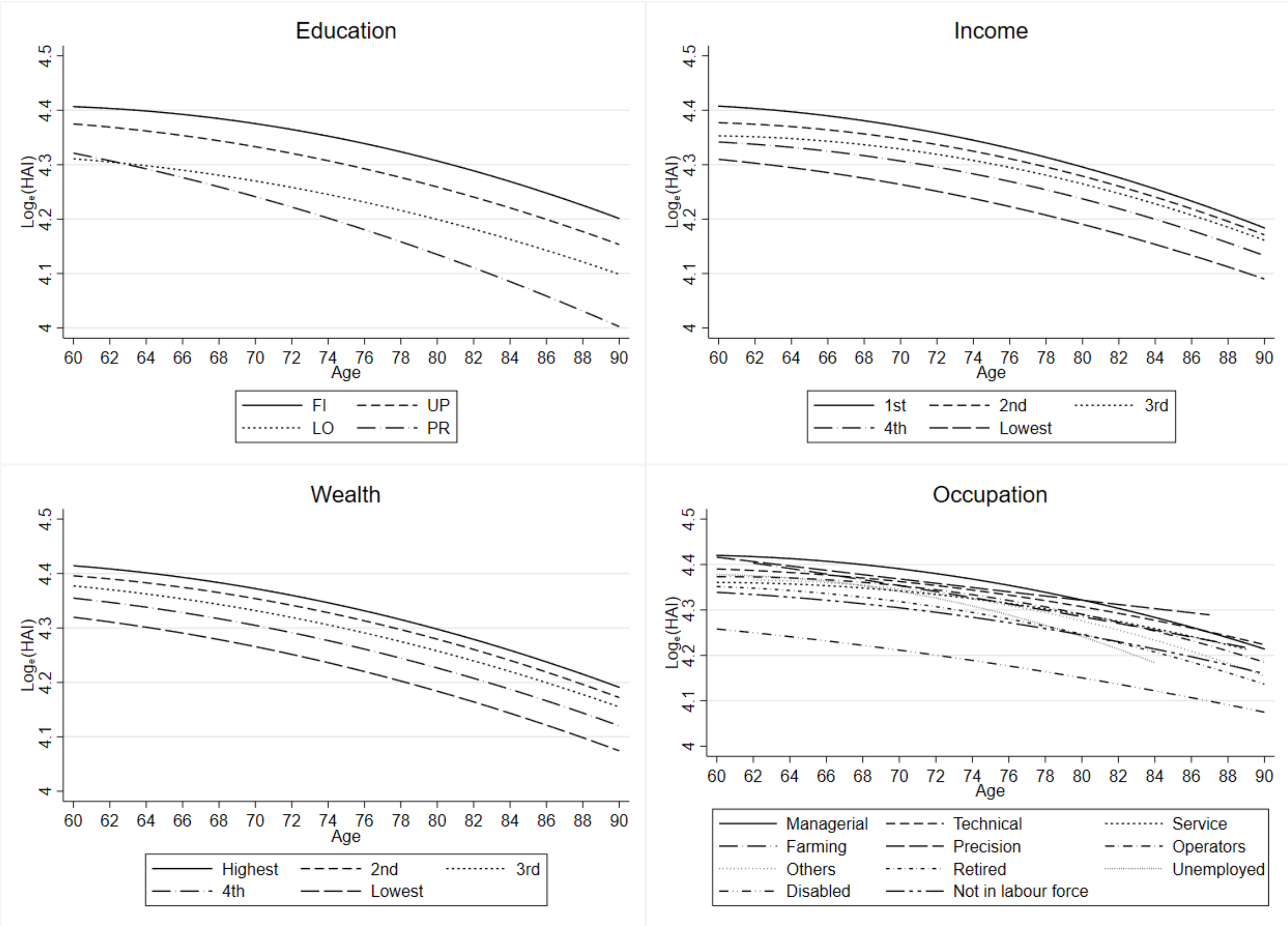
US

The trajectories of healthy ageing by education, income, wealth and occupation in the HRS are shown in Figure 4-2, respectively, based on the results of the fully adjusted multilevel models in Table 4-4 to Table 4-7. Generally, the trajectories decline with increased age. Individuals in advantaged SEPs have better health profiles in each year after the age of 60.

In Figure 4-2, the education, income and wealth gradients in healthy ageing are clear after the age of 60 years. Due to a non-significant interaction between wealth and age, with increased age all trajectories by wealth show a similar acceleration of decline of healthy ageing. The interaction between age and income is not strong, so all the trajectories by income take similar shapes. The trajectory for primary education or less declines much faster than any other educational trajectory, as the interaction between age and education for those with a primary education or less is strongly significant.

The interaction between age and occupation is weak, so most occupational trajectories decline at similar rates. The trajectory for disabled participants is distinctly lower than any other trajectory, suggesting that disabled persons have the worst health profile during the whole of later life. The trajectories for persons who are retired and for those who are not in the labour market remain similar to each other, but both indicate significantly lower levels of healthy ageing in later life. The trajectories in the middle are for persons who are still employed or temporarily unemployed (i.e. those who have just quit their last job and are looking for a new one). They aggregate together, especially before the age of 80 years. After 80 years, it seems that the health profiles of unemployed persons become worse than those who are retired or not in the labour force; however, those in precision production, craft and repair occupations age better than those in managerial and professional specialty occupations. But the 95% CIs of these trajectories might become very wide, especially at very late ages. Therefore, it is still unclear whether trajectories eventually merge at the end. But in general, individuals who are employed are healthier than those who are not employed after the age of 60 years.

Figure 4-2 Predicted trajectories of HAI by socioeconomic indicators in HRS



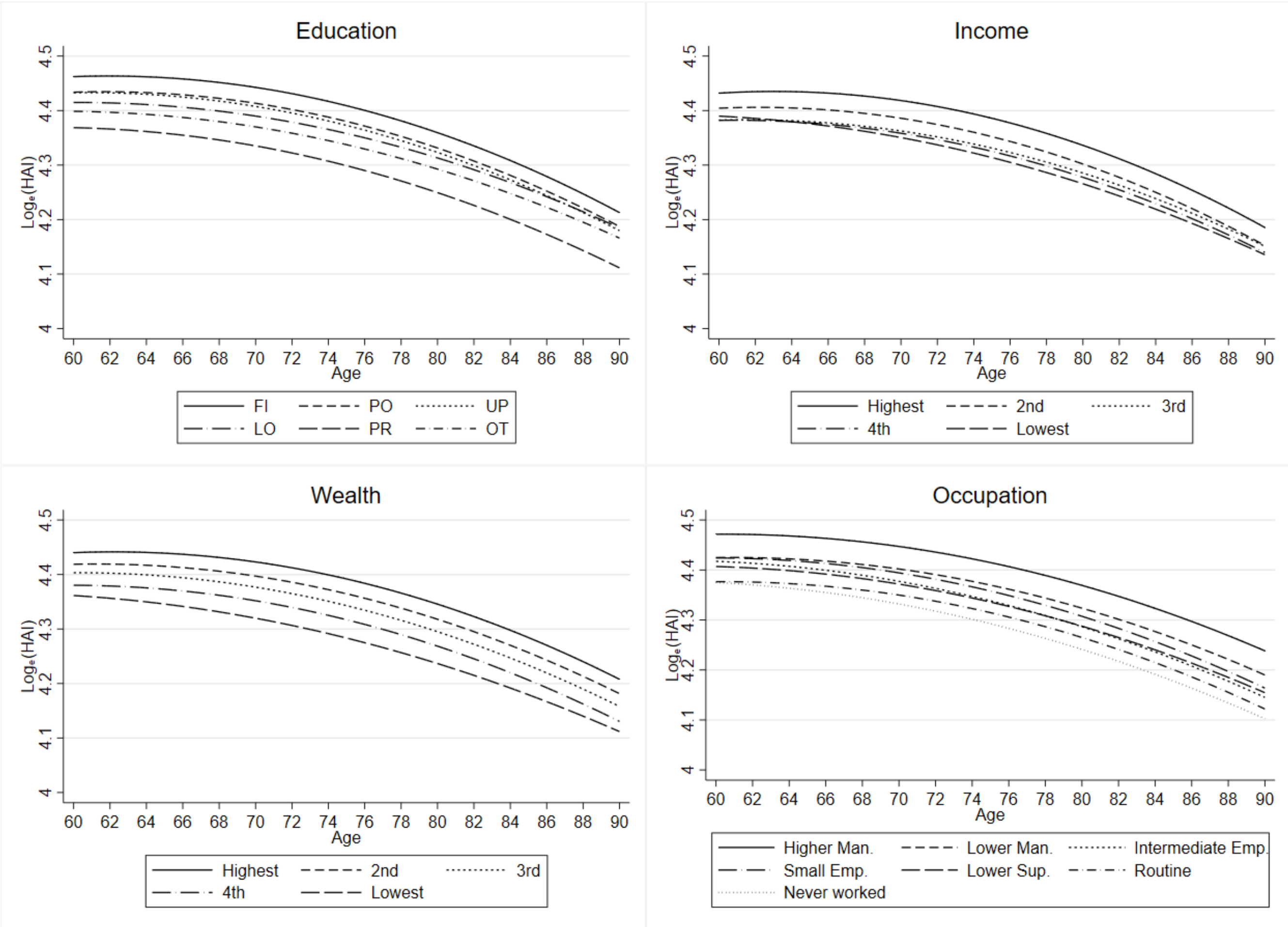
England

The trajectories of healthy ageing by education, income, wealth and occupation in ELSA are shown in Figure 4-3, based on the results of the fully adjusted multilevel models in Table 4-8 to Table 4-11. Generally, the trajectories decline with increased age. Individuals in advantaged SEPs have better health profiles in each year after the age of 60.

In Figure 4-3, due to the non-significant interactions between education and occupation and age, all educational and occupational trajectories decline at similar rates. The trajectory for primary education or less is much lower than that for the first-stage tertiary education or more. The trajectories for participants who are not in higher managerial or professional occupations are lower than those in higher managerial and professional occupations; they all have worse health profiles after the age of 60 years.

The interactions between age and wealth and income are not strong. All the trajectories for different wealth and income quintiles decline at similar rates. However, the wealth gradient in healthy ageing is very clear during the whole of later life. The trajectories by income are similar to each other, especially for participants at the third, fourth and lowest levels of income.

Figure 4-3 Predicted trajectories of HAI by socioeconomic indicators in ELSA



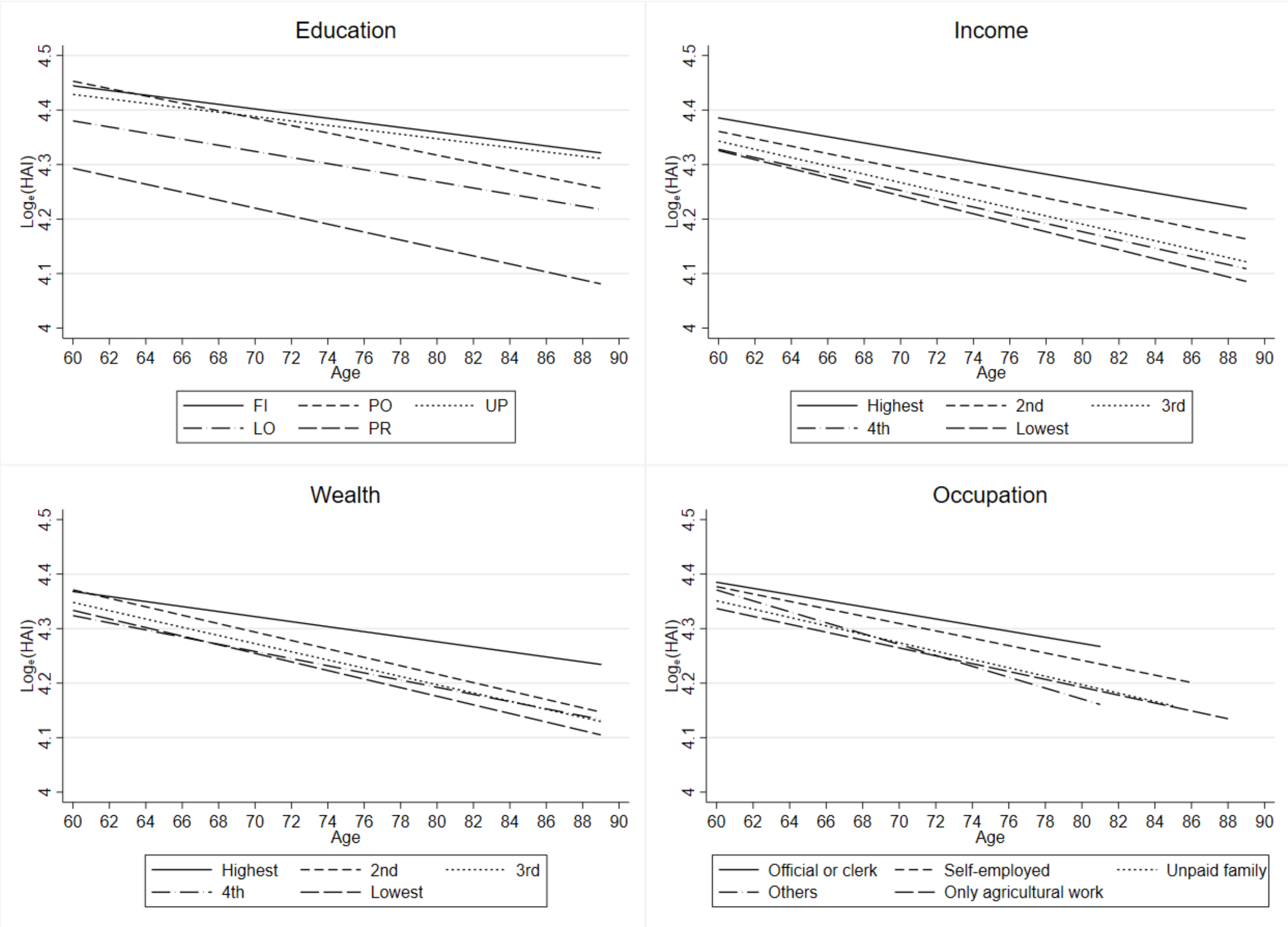
China

Trajectories of healthy ageing by education, income, wealth and occupation in CHARLS are shown in Figure 4-4, based on the results of the fully adjusted multilevel models in Table 4-12 to Table 4-15. Unlike the trajectories in the HRS and ELSA, the trajectories in CHARLS do not present non-linear effects, as the quadratic age terms are not statistically significant. Generally, individuals in the most advantaged SEPs have the best health profiles in later life. Even though the interaction between age and each socioeconomic indicator is not significant, it seems that the trajectories for those in lower SEPs decline faster than the trajectory for persons in the most advantaged SEP, especially in very old age. But the 95% CIs of the trajectories might be very wide in later ages, due to the small sample size of very old participants and the limited numbers of waves in CHARLS. Therefore, it is still unclear whether all the trajectories eventually aggregate together.

In Figure 4-4, there is a clear gradient in healthy ageing by categories of education and income. The gap in healthy ageing between the top and bottom or second-bottom levels of education is large over the entire age range. Compared with educational gaps in healthy ageing, gaps in healthy ageing by different income quintiles are smaller after the age of 60 years, especially for persons at the third, fourth and lowest levels of income.

It seems that individuals at the lower levels of wealth age worse in later life. But the wealth gradient in healthy ageing is not obvious, especially for persons at the third, fourth and lowest levels of wealth. The trajectories for persons in other work, unpaid family business and only agricultural work remain lower than the trajectories for officials/clerks and self-employed persons. It seems that participants who have paid and stable jobs are healthier than those in unpaid and unstable work after the age of 60 years.

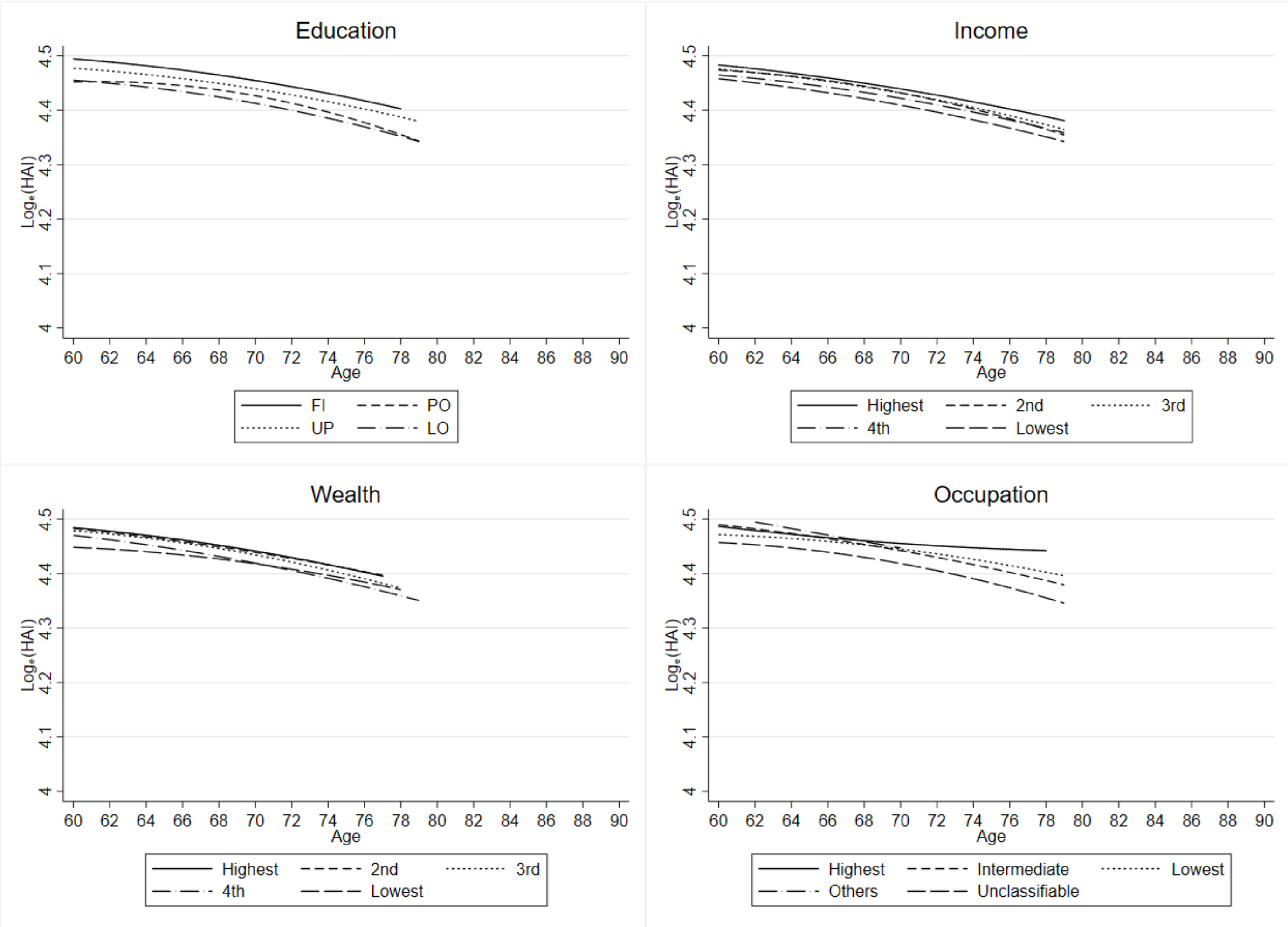
Figure 4-4 Predicted trajectories of HAI by socioeconomic indicators in CHARLS



Japan

The trajectories of healthy ageing by education, income, wealth and occupation in JSTAR are shown in Figure 4-5, respectively, based on the results of the fully adjusted multilevel models in Table 4-16 to Table 4-19. In Figure 4-5, compared with trajectories in other countries, the trajectories in JSTAR are flatter. Generally, individuals in the most advantaged SEPs have the best health profiles in each year after the age of 60. The gaps in healthy ageing by different levels of socioeconomic indicator are much smaller than in any other country. Due to the non-significant interactions between age and each socioeconomic indicator, the trajectories by education, income and wealth decline at similar rates. The trajectory for the most advantaged occupation seems to decline more slowly than any other occupational trajectory. But the 95% CI of the top occupational trajectory becomes very wide, especially at very old ages, due to the small sample size of very old participants and the limited waves in JSTAR.

Figure 4-5 Predicted trajectories of HAI by socioeconomic indicators in JSTAR



4.4.4 Comparisons of Socioeconomic Inequalities Across Countries

The linear coefficients of education, income and wealth in Table 4-20 to Table 4-22 present the SII at 60 years: the proportions of average change in HAI at 60 years if individuals had moved from the most to the least advantaged socioeconomic groups in the four countries. The linear coefficients of interactions between education/income/wealth and age present the trends of SII thereafter: the gap in average HAI changes after 60 years between the most and the least advantaged socioeconomic groups. All multilevel models shown below are fully adjusted.

In Table 4-20, the relationships between educational rank scores and HAIs at 60 years are significant in the four countries. The educational rank score represents a hierarchical ranking of each educational category (from the highest to lowest groups) based on a series of values (0-1) assigned to different categories, depending on the proportion of the population in each category. If individuals move from the highest to the lowest education group, the HAIs change greatly at 60 years in each country. For example, in CHARLS, moving from the highest to the lowest education group is associated with a 13.9% (95% CI: 11.4–16.3%) decrease in HAI at 60 years. Only in the HRS and CHARLS are the interactions between education rank scores and age negative and significant, meaning that with increased age, the gaps in average HAI between the highest and lowest education groups become larger.

In Table 4-21, the relationship between income rank scores and HAIs at 60 years is only significant in the HRS and CHARLS. The income rank score represents a hierarchical ranking of each income category (from the highest to lowest groups) based on a series of values (0-1) assigned to different categories, depending on the proportion of the population in each category. If individuals move from the top to the bottom income group, the HAIs change less at 60 years compared with the average changes for education rank scores. For example, in the HRS, moving from the top to the bottom income group is associated with a 1.4% (95% CI: 0.7–2.2%) decrease in HAI at 60 years. Only in the HRS and ELSA are the interactions between income rank scores and age (boundary) significant. The coefficient is positive but small in ELSA, suggesting that with increased age, the gaps in average HAI between the top and bottom income groups might become narrower.

In Table 4-22, the relationship between wealth rank scores and HAI at 60 years is significant in the HRS, ELSA and JSTAR. The wealth rank score represents a hierarchical ranking of each wealth category (from the highest to lowest groups) based on a series of values (0-1) assigned to different categories, depending on the proportion of the population in each category. If individuals move from the top to the bottom wealth group, the HAIs change more greatly at 60 years in ELSA than in the HRS or JSTAR. In ELSA, moving from the top to the bottom wealth group is associated with a 6.2% (95% CI: 4.9–7.5%) decrease in HAI at 60 years. The interactions between wealth rank scores and age are (boundary) significant in the HRS and JSTAR only. The coefficient is negative but very small in the HRS, suggesting that with increased age, the gaps in average HAI between the top and bottom wealth groups might not become larger.

Table 4-20 Results of fully adjusted linear multilevel models* for associations between educational rank scores and HAI (log_e-transformed) across countries

Main exposures	HRS		ELSA		CHARLS		JSTAR	
Fixed effects	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**
Age	-0.012 (-0.013 to -0.010)	<0.001	-0.008 (-0.010 to -0.007)	<0.001	-0.014 (-0.039 to 0.012)	0.295	-0.002 (-0.006 to 0.002)	0.259
Age^2	-0.0001 (-0.0002 to -0.00001)	0.027	-0.0003(-0.0004 to -0.0002)	<0.001	0.0002(-0.0002 to 0.0005)	0.317	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.008 (-0.009 to -0.008)	<0.001	-0.003 (-0.004 to -0.003)	<0.001	-0.008 (-0.010 to -0.006)	<0.001	-0.001 (-0.003 to.0.001)	0.418
Cohort^2	0.0006 (0.0006 to 0.0007)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0007 (0.0003 to 0.001)	<0.001	-0.001 (-0.002 to -0.0003)	0.005
Education	-0.067 (-0.082 to -0.052)	<0.001	-0.082 (-0.104 to -0.060)	<0.001	-0.139 (-0.163 to -0.114)	<0.001	-0.061 (-0.082 to -0.039)	<0.001
Education*age	-0.004 (-0.005 to -0.002)	<0.001	-0.0001 (-0.002 to 0.001)	0.340	-0.003 (-0.006 to -0.0001)	0.044	-0.002 (-0.005 to 0.0005)	0.102
Intercept	4.440 (4.426 to 4.453)	<0.001	4.511 (4.492 to 4.530)	<0.001	4.415 (4.283 to 4.547)	<0.001	4.484 (4.463 to 4.505)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.081 (0.080 to 0.081)	-	0.076 (0.075 to 0.077)	-	0.116 (0.114 to 0.118)	-	0.050 (0.048 to 0.052)	-
Level 2: intercept	0.132 (0.130 to 0.134)	-	0.136 (0.134 to 0.139)	-	0.153 (0.149 to 0.158)	-	0.076 (0.073 to 0.080)	-
Level 2: age	0.010 (0.009 to 0.010)	-	0.009 (0.008 to 0.009)	-	0.005 (0.004 to 0.008)	-	0.008 (0.007 to 0.009)	-

* Each model was adjusted for age, age^2, cohort, cohort^2, gender, ethnicity, self-rated health in childhood (unavailable in JSTAR), father's occupation, marital status, income rank score, wealth rank score, occupation, smoking and drinking.

Table 4-21 Results of fully adjusted linear multilevel models[*] for associations between income rank scores and HAI (log_e-transformed) across countries

	HRS		ELSA		CHARLS		JSTAR	
Fixed effects	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**
Age	-0.012 (-0.013 to -0.010)	<0.001	-0.008 (-0.010 to -0.007)	<0.001	-0.014 (-0.039 to 0.012)	0.297	-0.002 (-0.006 to 0.002)	0.247
Age²	-0.0001 (-0.0002 to -0.00001)	0.028	-0.0003 (-0.0004 to -0.0002)	<0.001	0.0002 (-0.0002 to 0.0005)	0.320	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.008 (-0.009 to -0.008)	<0.001	-0.003 (-0.004 to -0.003)	<0.001	-0.008 (-0.010 to -0.006)	<0.001	-0.001 (-0.003 to 0.001)	0.403
Cohort²	0.0006 (0.0006 to 0.0007)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0007 (0.0003 to 0.001)	<0.001	-0.001 (-0.002 to -0.0003)	0.005
Income	-0.014 (-0.022 to -0.007)	<0.001	0.005 (-0.004 to 0.014)	0.296	-0.032 (-0.048 to -0.017)	<0.001	-0.009 (-0.022 to 0.005)	0.207
Income*age	0.00006 (-0.00004 to 0.001)	0.065	0.001 (0.0001 to 0.002)	0.027	-0.0001 (-0.002 to 0.002)	0.950	-0.001 (-0.003 to 0.001)	0.273
Intercept	4.452 (4.439 to 4.465)	<0.001	4.509 (4.490 to 4.528)	<0.001	4.422 (4.290 to 4.553)	<0.001	4.480 (4.459 to 4.501)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.081 (0.080 to 0.081)	-	0.076 (0.075 to 0.077)	-	0.116 (0.114 to 0.118)	-	0.050 (0.048 to 0.052)	-
Lever 2:intercept	0.132 (0.130 to 0.135)	-	0.137 (0.134 to 0.139)	-	0.153 (0.149 to 0.158)	-	0.076 (0.073 to 0.080)	-
Level 2: age	0.010 (0.009 to 0.010)	-	0.009 (0.008 to 0.009)	-	0.005 (0.004 to 0.008)	-	0.008 (0.007 to 0.009)	-

[*] Each model was adjusted for age, age², cohort, cohort², gender, ethnicity, self-rated health in childhood (unavailable in JSTAR), father's occupation, marital status, educational rank score, wealth rank score, occupation, smoking and drinking.

Table 4-22 Results of fully adjusted linear multilevel models[*] for associations between wealth rank scores and HAI (log_e-transformed) across countries

	HRS		ELSA		CHARLS		JSTAR	
Fixed effects	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**	**b (95%CIs)**	**P-values**
Age	-0.012 (-0.013 to -0.010)	<0.001	-0.008 (-0.010 to -0.007)	<0.001	-0.014 (-0.039 to 0.012)	0.298	-0.002 (-0.006 to 0.002)	0.245
Age²	-0.0001 (-0.009 to -0.008)	0.028	-0.0003 (-0.0004 to -0.0002)	<0.001	0.0002 (-0.0002 to 0.0005)	0.334	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.008 (-0.009 to -0.008)	<0.001	-0.003 (-0.004 to -0.003)	<0.001	-0.008 (-0.010 to -0.006)	<0.001	-0.001 (-0.003 to 0.001)	0.405
Cohort²	0.0006 (0.0006 to 0.0007)	<0.001	0.0003 (0.0002 to 0.0004)	<0.001	0.0007 (0.0003 to 0.001)	<0.001	-0.001 (-0.002 to -0.0003)	0.005
Wealth	-0.033 (-0.043 to -0.024)	<0.001	-0.062 (-0.075 to -0.049)	<0.001	-0.007 (-0.023 to 0.009)	0.378	-0.015 (-0.030 to -0.001)	0.037
Wealth*age	-0.0007 (-0.001 to -0.0001)	<0.001	-0.001 (-0.002 to 0.0002)	0.108	0.000004 (-0.002 to 0.002)	0.997	0.002 (-0.0004 to 0.005)	0.096
Intercept	4.433 (4.420 to 4.446)	<0.001	4.507 (4.488 to 4.526)	<0.001	4.421 (4.289 to 4.552)	<0.001	4.481 (4.460 to 4.501)	<0.001
Random effects	**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**		**S.D. (95%CIs)**	
Level 1: residual	0.081 (0.080 to 0.081)	-	0.076 (0.075 to 0.077)	-	0.116 (0.114 to 0.118)	-	0.050 (0.048 to 0.052)	-
Level 2: intercept	0.132 (0.130 to 0.134)	-	0.137 (0.134 to 0.140)	-	0.153 (0.149 to 0.158)	-	0.076 (0.073 to 0.080)	-
Level 2: age	0.010 (0.009 to 0.010)	-	0.009 (0.008 to 0.009)	-	0.005 (0.004 to 0.008)	-	0.008 (0.007 to 0.009)	-

[*] Each model was adjusted for age, age², cohort, cohort², gender, ethnicity, self-rated health in childhood (unavailable in JSTAR), father's occupation, marital status, educational rank score, income rank score, occupation, smoking and drinking.

Figure 4-6 shows the SIIs for education, income and wealth at 60 years in the four countries, to compare the magnitude of healthy ageing inequalities by education, income and wealth within and across countries.

The SIIs for education were large in the four countries. Moving from the highest to the lowest education groups was associated with a 6.7% (95% CI: 5.2–8.2%), 8.2% (95% CI: 6.0–10.4%), 13.9% (95% CI: 11.4–16.3%) and 6.1% (95% CI 3.9–8.2%) decrease in average HAIs at 60 years in the HRS, ELSA, CHARLS and JSTAR respectively. Due to the negatively significant interactions between age and education in the HRS and CHARLS (Table 4-20), with increased age the gaps in the average HAIs between the highest and lowest education groups become larger. But the 95% CIs of the SII also become wider.

The healthy ageing gap at 60 years between the top and bottom income groups was smaller than that between the highest and lowest education groups in each country. Moving from the top to the bottom income quintile was associated with a 1.4% (95% CI: 0.7–2.2%) and 3.2% (95% CI: 1.7–4.8%) decrease in average HAIs at 60 years in the HRS and CHARLS respectively. Due to boundary or non-significant interactions between age and income in the HRS, CHARLS and JSTAR (Table 4-21), the gaps in the average HAI between the highest and lowest income groups might not obviously change with increased age. The relationships between income rank scores and HAIs in ELSA and JSTAR were not significant (Table 4-21). Therefore, the healthy ageing gap between the top and bottom income levels in ELSA and JSTAR was unclear.

Moving from the highest to the lowest wealth levels was associated with a 3.3% (95% CI: 2.4–4.3%), 6.2% (95% CI: 4.9–7.5%) and 1.5% (95% CI: 0.1–3.0%) decrease in average HAIs at 60 years in the HRS, ELSA and JSTAR respectively. In the HRS, due to the negatively significant interaction between age and wealth (Table 4-22), with increased age the healthy ageing gap between the top and bottom wealth levels becomes larger, but the 95% CIs of the SII also become wider.

Education was the most influential indicator of healthy ageing in later life in the four countries. Wealth was the second most influential indicator in the HRS, ELSA and JSTAR. Compared with education and wealth, income was a less influential predictor of inequalities in healthy ageing in the HRS. Moreover, income was not an influential indicator of healthy ageing among participants in ELSA and JSTAR. In CHARLS, income was the second most influential predictor of healthy ageing inequalities, but wealth was not an influential indicator among Chinese participants.

To compare across countries, educational inequalities in healthy ageing in CHARLS were distinctly larger than any other socioeconomic inequality in healthy ageing in the four countries. The inequalities continuously increased with increased age in CHARLS. Compared with wealth inequalities in healthy ageing in the HRS and JSTAR, the wealth inequalities in ELSA were larger. The magnitude of socioeconomic inequalities in healthy ageing was great in CHARLS but relatively small in JSTAR.

Figure 4-6 SIIs for HAI by education, income and wealth at 60 years across countries

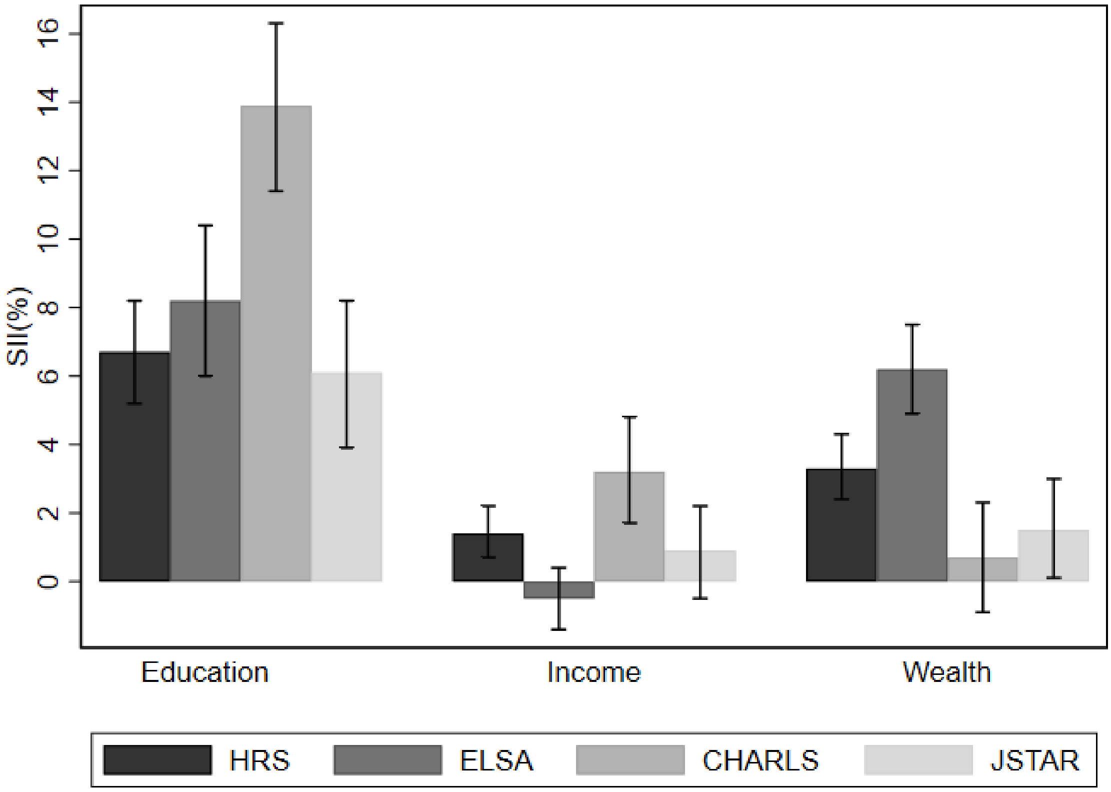
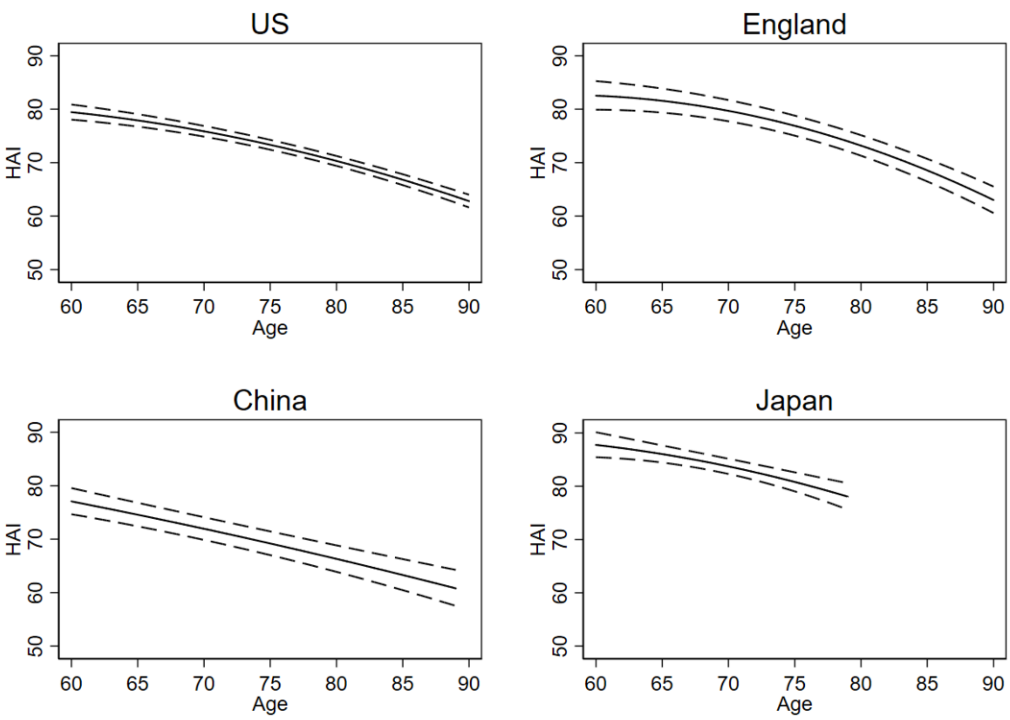


Figure 4-7 shows the predicted trajectories of healthy ageing by age, based on fully adjusted models in the four countries. The gradient in healthy ageing across countries is clear. Japanese participants are healthier after 60 years than participants in any other country. Chinese participants have the worst health profiles in each year after the age of 60. English and American participants' healthy ageing ranks second and third respectively. However, the four trajectories might aggregate in very old age. The rates of decline in healthy ageing accelerate with increased age in the HRS, ELSA and JSTAR. However, in CHARLS, the slope does not change across ages, due to the non-significant non-linear effect of age, suggesting a constant rate of decline in HAI across ages after 60 years.

Figure 4-7 Predicted trajectories of HAI by age and country



4.4.5 Results of Sensitivity Analyses

Table A 3 to Table A 19 in the appendix present the results of the sensitivity analyses. In the HRS, ELSA and CHARLS, after the variable of self-rated health in childhood was excluded as a covariate, multilevel results based on fully adjusted models (Table A 4 to Table A 15) were all similar to the original results (Table 4-4 to Table 4-15). This suggested that including or excluding the variable for self-rated health in childhood for multilevel analyses in the HRS, ELSA and CHARLS did not obviously change the original results. Therefore, comparisons of socioeconomic inequalities in healthy ageing based on imputed data across countries would not be biased due to the unavailability of the variable for self-rated health in childhood in JSTAR.

However, the results were different between imputed and complete case analyses in each country based on fully adjusted models. In the HRS, compared with imputed results, the interaction between age and wealth in complete case analyses became significant for those in the lowest wealth quintile (Table A 6). In complete case analyses in ELSA, the interaction between age and income only became significant for those in the lowest income quintile (Table A 9). English participants in the second wealth quintile did not have significantly lower HAIs at the age of 60 years, but the interaction effect between wealth and age became stronger (Table A 10). Moreover, the cross-sectional relationship between occupation and $\log_e$-transformed HAIs became non-significant in ELSA (Table A 11). In CHARLS, the cohort effect on HAIs became linear in the complete case analyses. Unlike the imputed results, the cross-sectional relationships between education, income and occupation and $\log_e$-transformed HAIs were non-significant in CHARLS (Table A 12, Table A 13 and Table A 14); the association between wealth and $\log_e$-transformed HAIs became significant for persons in the third, fourth and lowest wealth quintiles at 60 years (Table A 14). In JSTAR, unlike the imputed results, persons in the lowest income quintile had significantly lower HAIs at 60 years in the complete case analyses (Table A 17). The interaction between age and income also became significant for those in the third and lowest income quintiles (Table A 17). Moreover, in the complete case analyses, the cross-sectional relationship between wealth and $\log_e$-transformed HAIs became significantly strong for persons in the fourth and lowest wealth quintiles (Table A 18).

In the HRS, ELSA, CHARLS and JSTAR, 8281 of 13790, 3456 of 7225, 1039 of 7385 and 1209 of 2169 participants respectively were included for the complete case analyses. Table A 3 presents the baseline sample characteristics for the complete case analyses. Compared with the baseline imputed sample in Table 4-2, participants in Table A 3 in the four countries tended to be younger and have higher HAIs. The complete case analyses excluded more participants in middle income quintiles in the HRS, in lower income quintiles in ELSA and JSTAR, and in higher income quintiles in CHARLS. More participants in lower wealth quintiles in the HRS and ELSA, in higher wealth quintiles in CHARLS, and in middle and bottom wealth quintiles in JSTAR were also excluded. Moreover, the complete case analyses excluded more American participants who were in work, English participants who were in less advantaged occupational positions, Chinese participants who conducted unpaid family business and other work, and Japanese participants who were in mediate positions at baseline. Furthermore, compared with the baseline imputed sample in Table 4-2, the complete case analyses included greater percentages of current smokers and frequent alcohol consumers in the four countries.

Therefore, the large missingness of data in the complete case analyses might result in less representative samples, especially for data analyses in ELSA, CHARLS and JSTAR. Compared with the imputed case analyses, the true associations between SEP and HAIs may be underestimated in the complete case analyses in each country.

4.5 Discussion

4.5.1 Summary of Results

The univariate analyses indicated that the covariates were all significantly associated with HAIs at baseline. For each longitudinal relationship between SEP and HAIs, after adjustment for different covariates, the results changed across models, suggesting the existence of confounding and potential mediating effects on the main exposure-outcome relationships.

There were non-linear effects of age and cohort on healthy ageing in the HRS, ELSA and JSTAR. In CHARLS, only the non-linear cohort effect on healthy ageing was statistically significant. HAIs declined with increased age. Participants in more recent birth cohorts had lower average HAIs than their predecessors at the same age in the four countries. A longitudinal relationship between SEP and HAIs existed in each country.

Generally, compared with JSTAR, the socioeconomic inequalities in healthy ageing in the HRS, ELSA and CHARLS were more evident. The trajectories of healthy ageing in different categories of socioeconomic indicator might decline at different rates. The 95% CIs of trajectories might become very wide at very late ages, especially in CHARLS and JSTAR. It is still unclear whether the trajectories will merge at the end of later life.

Japanese, English, American and Chinese participants' healthy ageing in later life ranked first, second, third and last respectively. Education was the most influential indicator of healthy ageing in later life in the four countries. Wealth was the second most influential indicator in the HRS and ELSA. Compared with education and wealth, income was a less influential predictor of inequalities in healthy ageing in the HRS. Moreover, income was not an influential indicator of healthy ageing among participants in ELSA and JSTAR. In CHARLS, income was the second most influential predictor of healthy ageing inequalities, but wealth was not an influential indicator among Chinese participants. In JSTAR, wealth was an influential predictor of healthy ageing inequalities, but it was less influential than education.

If we compare across countries, the education inequality in healthy ageing in CHARLS was distinctly larger than any other socioeconomic inequality in healthy ageing in the four countries. This education inequality continuously increased with increased age in CHARLS. Compared with the wealth inequalities in healthy ageing in the HRS and JSTAR, the wealth inequality in ELSA was larger. The magnitude of socioeconomic inequalities in healthy ageing was relatively small in JSTAR.

4.5.2 Confounding and Mediating Effects on the SEP-HAI Relationship

The minimally adjusted models included age, age^2, cohort, $cohort^2$, and interactions between age and main exposure, and age and cohort. The partially adjusted models added personal characteristics including gender, ethnicity, marital status, childhood SEP (father's occupation) and self-rated health in childhood, as well as interactions between gender and the main exposure, and age and marital status. The fully adjusted model added other socioeconomic indicators and health behaviours (smoking and drinking), as well as interactions between age and other socioeconomic indicators, and age and smoking (Table 4-1).

The univariate analyses found that gender, ethnicity, marital status, father's occupation and self-rated health in childhood were significantly associated with HAIs at baseline. Compared with results in the minimally adjusted models, the stepwise effect of SEP on healthy ageing in the partially adjusted models became less strong, and the socioeconomic gradient in healthy ageing was also narrower in the four countries. I concluded that gender, ethnicity, marital status, father's occupation and self-rated health in childhood explain part of the SEP inequalities in healthy ageing in each country. However, in all the partially adjusted models, SEP was still a strong predictor of inequalities in healthy ageing. The magnitude of significance did not change distinctly between the minimally and partially adjusted models. Therefore, the analysis identified gender, ethnicity, marital status, father's occupation and self-rated health in childhood as confounders for the SEP-HAI association.

The WHO active ageing framework identified these five factors as important determinants of healthy ageing [264]. Many previous studies have also found the five factors to have close connections with SEP. For example, American women's poverty rates are substantially above men's poverty rates [265]. Another US study indicated that Mexican immigrants had lower levels of schooling and income than any other Hispanic groups, black people and white people; Hispanic households had 10% less overall wealth than white families in 2004, and the gap has become wider in recent years [266]. Additionally, high divorce risks were found among spouses with little formal education and in manual occupations [267]. Being continuously married buffered mortality risks among men with low incomes [268]. Moreover, family background, such as parental occupation or education, plays an important role in children's inheritance of social class [269]. Furthermore, the "health selection hypothesis" indicates that better health in childhood helps one to move up the class hierarchy, while worse health in childhood leads to social mobility from high to low levels in adulthood [270].

The main exposure-outcome relationship is more likely to become non- or boundary significant after adjustment for mediators [204]. In several fully adjusted models, after adjustment for other socioeconomic indicators, health behaviours and relevant interactions (Table 4-1), the relationships between SEP and HAI were obviously attenuated, suggesting the existence of potential mediating effects. For example, in ELSA, the relationships between education, income and occupation and HAIs became very weak or non-significant in the fully adjusted model. In CHARLS, after full adjustment, there was no significant relationship between wealth and healthy ageing; Chinese participants in medium income quintiles no longer had lower HAIs than those in the top income quintile. In JSTAR, the effect of wealth on healthy ageing became boundary significant; there was no longer any evident income inequality in healthy ageing. Some SEP-HAI relationships in the fully adjusted models might be partially or completely mediated by potential mediators such as other socioeconomic indicators, smoking or drinking.

However, it is not always clear whether a variable is a confounder or a mediator; the distinction between the two might be different across study samples [199]. Therefore, in Chapter 5, for the longitudinal relationship between education and HAIs in each country, the mediating effect is assessed using path analysis to provide estimates of the magnitude and significance of the hypothesised connections between socioeconomic indicators, smoking, drinking and HAIs.

4.5.3 Age Versus Cohort Effects on Healthy Ageing

The effect of age is the effect of the accumulation of physiological changes and social experiences on health outcomes during the biological ageing process [271]. Physiological changes – such as the loss of bone density, the functional decline of organs, and the reduction of muscle mass and strength in the human body – are caused by a gradual accumulation of molecular and cellular damage during the biological ageing process, contributing to a general decline in individual capacity and an increased risk of multi-morbidity. The accumulation with increased age of social experiences such as a loss of close relationships or shifts in social roles and capabilities (e.g. changes in work patterns) will influence individuals' available options and choices regarding health behaviours, in turn shaping individuals' physical and mental capacities, and ultimately contributing to their biological responses. The cohort effect is the effect on health outcomes of a unique exposure (or the sum of all unique exposures) that one birth cohort experience as they move across time [271]. For example, childhood experiences such as quality of education, nutritional intake and socioeconomic circumstances will have long-lasting impacts on persons' functional health [272, 273]. In my analysis, the age and cohort effects on healthy ageing were denoted by varying HAIs across chronological ages and birth cohort groups respectively.

The effect of age on healthy ageing was statistically significant among American and English participants across models. For Chinese and Japanese participants, the effects of age on healthy ageing seemed not to be strong. One potential reason is the limited number of waves in CHARLS and JSTAR for multilevel analyses. Chinese and Japanese participants tended to be younger and to have narrower age ranges than American and English participants. However, the trajectories of healthy ageing in CHARLS and JSTAR still presented declining trends with increased age. Older participants tended to have lower HAIs than younger participants in the four countries, which is similar to changes in remaining life expectancy by age: older individuals tend to have less remaining life expectancy than younger individuals.

Among American, English and Japanese participants, the rates of decline in HAI accelerated with increased age, but this acceleration was slow. One important reason might be the increased life expectancy for the general population in the US, UK and Japan. There has been a long-term upward trend in life expectancy at birth (total years) in the US, UK and Japan. For example, between 1960 to 2015, life expectancy increased from 69 to 78 years in the US, from 71 to 81 years in the UK, and from 67 to 83 years in Japan [226]. Improvements in these three countries in the prevention and control of major infectious diseases, as well as in housing, hygiene, medical care and nutritional intake, have not only contributed to the increase in life expectancy, but have also slowed the acceleration of rates of decline in healthy ageing by age [274]. It is still unclear whether the pattern of rates of decline in healthy ageing by age among the Chinese ageing population is similar to those in other countries, due to the non-significant quadratic age terms. However, life expectancy in China has also increased sharply during the past decades, from 44 years in 1960 to 76 years in 2015 [226]. More empirical research is needed to assess the non-linear age effect on healthy ageing among the Chinese ageing population.

The cohort effect on healthy ageing was statistically significant among American, English and Chinese participants across models. The cohort effect seemed not to be strong among Japanese participants, but the quadratic cohort terms were still significant across models, indicating variations of HAI across birth cohort groups. Lower HAIs were observed in later cohorts compared with earlier cohorts at the same age after 60 years, even though the rates of decline by cohort did not accelerate in the HRS, ELSA and CHARLS. These findings were in line with some other studies of the ageing populations in the US, UK, China and Japan. A study based on the HRS found that participants from more recent cohorts had higher average levels of frailty than their predecessors at the same age [275]. Another study based on ELSA also examined the cohort-specific trajectories of frailty and reported higher levels of frailty in later cohorts [276]. A meta-analysis of the prevalence of dementia in mainland China, Hong Kong and Taiwan found no significant variations across cohorts among older adults, but suggested a potential increasing pattern of prevalence from less to more recent birth cohorts among individuals over 70 years [277]. Another Chinese study reported that individuals in more recent cohorts had higher age-specific mean BMIs than individuals from older cohorts given similar environmental exposures, suggesting that there might be greater obesity rates among younger generations [278]. In Japan, researchers found that the suicide mortality rate increased in male birth cohorts after 1926 [279]. Another study reported that Japanese people who were born in 1934 had significantly smaller changes in height between the ages of nine and 15 than did those born in 1894; those who were born in 1934 did not reach the expected average height until the age of 20 [280]. Additionally, an increased incidence of breast cancer was found among younger Japanese female cohorts [281].

Cohort differences in healthy ageing might reflect a real deterioration in older adults' health in the four countries over time, even though people's life expectancy on average has significantly improved during the past decades. From a lifecourse perspective, some researchers refer to the "accumulation of risk model" [180], proposing that the increase in the prevalence of unhealthy lifestyle behaviours among younger generations might have a cumulative effect over the lifecourse, contributing to worse health in later life [276, 278].

Moreover, different earlier-life experiences and social circumstances in childhood might also contribute to disparities in health outcomes in later life. In my multilevel analysis, the participants had been born in 1896–1945 in the US, 1908–1943 in England, 1910–1953 in China, and 1932–1947 in Japan. The Great Depression started in 1929 and lasted until 1941, and it had devastating effects on the economy in many countries, including the US, UK, China and Japan [282]. The effects of the Great Depression lasted until the start of World War II (1939–1945) [282]. In my analysis, the participants who had been born during the Great Depression and World War II were the later-born cohorts. According to the "critical period " lifecourse theory, disadvantaged social circumstances and poor maternal nutrition during pregnancy during the Great Depression and World War II might have contributed to impaired foetal growth and hence to subsequent adverse health outcomes in later life [180]. Researchers in Japan have found that people who were born in 1934, and who should have reached puberty during the final years of World War II's devastating aftermath, show obvious stunting among both women and men [280].

Therefore, these later-born cohorts' health might be worse in later life than their older counterparts. This might also explain why my analysis found significant birth-cohort effects on healthy ageing among Chinese participants, rather than significant chronological age effects: adverse social circumstances during the war and post-war period might have contributed to severe heath impairments for later-born cohorts, which might be more evident than age effects among the Chinese ageing population. Additionally, cohort differences in healthy ageing may also be due to growing health gaps between socially advantaged and disadvantaged groups among younger generations [283]. The most socially disadvantaged individuals in younger cohorts might have worse health than their older counterparts who were the most socially disadvantaged individuals at the same ages [284]. Therefore, average HAIs among younger generations have fallen below those of older generations at the same ages.

4.5.4 Socioeconomic Inequalities in Healthy Ageing in the US

Educational and Wealth Inequalities in Healthy Ageing

Education was an influential socioeconomic indicator of healthy ageing among American participants. The trajectory for those with a primary education or less declined significantly faster than any other education trajectory. In the US, education has been widely used as a measure of social status, since it is regarded as way to raise one's rank in society [137, 142]. Education-related differences in mortality and life expectancy have widened over the past 20–25 years in the US [285].

Wealth was another influential indicator of healthy ageing in the HRS. A previous study suggested that compared with education and income, wealth was the strongest predictor of mortality in the HRS [149]. One potential reason was that in the US, wealth brings the feeling of security. A sufficient accumulation of wealth can buffer one against sudden major health costs in a way that goes beyond income level [149]. Researchers have found that wealth inequality in the US has increased continuously since the 1980s.

The top 10% of people held at least 50% of the society's total wealth in the 20th century, and their share of wealth is even higher at present [286].

Many studies have already found strong associations between education and wealth and health outcomes in later life in the US. For example, several studies based on the HRS indicate that there are significantly negative education and wealth gradients in self-reported diseases [154], mortality [149], stroke [152, 287] and obesity [148]; the largest disparity in self-reported diseases exists between persons at the top and bottom levels of education [154]; and wealth is a predictor of stroke that is independent of income [287].

Is Income Inequality in Healthy Ageing Less Important?

The effect of income on healthy ageing was moderately strong at the age of 60 years, but it became weaker thereafter. It seemed that compared with education and wealth, income was a less influential indicator of healthy ageing among American participants.

In my analysis, 74.33% of American participants were not employed at the age of 60. Among these, 83.01% of individuals were retired (see Table 4-2). Income in the HRS was a combination of the individual's employment earnings (after tax), pension fees, public old age pension, capital income (a rise in the value of a capital asset (investment or real estate) that gives it a higher worth than the purchase price [288]) and other government transfers (see Chapter 2). For retired and other unemployed participants, pensions, capital income and other government transfers might be their main source of non-asset income. Researchers have found that even though American older adults are far more dependent on government transfers than younger people, public benefits for the elderly have been largely protected over the past decades, especially for older people on low incomes; compared with the working-age population, government transfers have been more equally distributed among the ageing population in the US [289]. Equally distributed government transfers might buffer the effect of income on inequalities in healthy ageing in the US.

However, one cannot deny that there is an effect of income on health inequalities among the American ageing population. My analysis found a significantly positive income gradient in healthy ageing in the HRS. For example, participants in the lowest income quintile had 1.1% lower HAIs than those in the top income quintile at 60 years. The trajectories of income also presented a clear income gradient in healthy ageing. One possible reason was that even though public pensions in the US have protected low-income older adults' benefits, the distribution of private pensions is still unequal. The 1983 Survey of Consumer Finances in the US found that private pensions increased annual income inequality by 21% among low-income workers [290]. Another study based on the HRS also found that low income is a more influential risk factor for mortality than low education [149].

Inequalities in capital income might be another contributor to income disparities in healthy ageing. However, as Piketty has pointed out, capital income is the most important source of income only for the very rich, such as those with the top 0.1% of incomes in the US [291]. Therefore, inequalities in capital income might not be observed among the general American ageing population.

Therefore, income inequality is as important as wealth and educational inequalities in healthy ageing in the US. Among Americans who are not employed, the impact of private pension inequalities on healthy ageing should be strongly noted.

Effects of Labour Force Non-participation on Healthy Ageing

The employed American participants were healthier than the retired and unemployed participants in later life. In the literature, the effects of labour force non-participation on older people's health in the US are diverse, due to different patterns of labour force non-participation. For example, a study in 1991 among the American ageing population reported that persons who had left the labour market from personal choice had higher levels of physical and psychological well-being than those whose labour force involvement was constrained by other factors [292]. Another study suggested that older individuals (approaching the age of 65) who continued to work, and retirees who regularly participated in physical activity, sustained more constant cerebral blood flow levels and scored better on cognitive testing than those who had become physically inactive after retirement [293]. Furthermore, different durations of labour force participation also affect individual health differently. For example, a US study found that older respondents who continued to work had lower depression scores than those who had retired; retirement had a positive influence on self-esteem but a negative influence on depression [294]. A UK/US comparative study indicated that individuals' health improved after a break from work among those who had poor self-reported health [295].

My analysis found a negative impact of retirement on healthy ageing. One potential reason is that some retirees might leave the labour market due to health problems rather than personal choice, and might become physically inactive due to poor health, which could negatively affect their physical and psychological health [292, 293]. Another potential reason is that some participants in the analysis were early retirees who had retired before the age of 65. In the US, 65 is the retirement age when persons can get full social security benefits [296]. An early retiree can only get reduced benefits, which might affect their living standards, healthcare access and well-being in later life.

My analysis found that disabled participants had 4.7% lower HAIs than managerial and professionals at the age of 60 years, after full adjustment. Moreover, the healthy ageing trajectory for disabled participants was significantly lower than any other trajectory. A US study reported that disabled and non-institutionalised American adults had the worst physical performance in work and independent living activities, which crucially affected their involvement in the labour market, making them financially and socially disadvantaged [297]. An official report in the US indicated that in 2015, 59.8% of adults aged 65 or over had at least one basic action difficulty or one complex activity limitation; even among those aged 18 and over, the percentage was 32.2% [298]. Disability and relevant labour force non-participation might negatively affect the operation of the labour market, placing increasing burdens on healthcare, and hindering the achievement of healthy ageing in the US.

Do Persons in Service Occupations Age Better?

Participants in service occupations had 2.2% higher HAIs than managerial and professionals at the age of 60 years, after full adjustment. In this research, participants in service occupations actually had different skill levels based on their different educational attainments. In the HRS, those who were in service occupations but had top levels of education were highly skilled persons such as police officers or detectives [299]. Table A 20 in the appendices shows the approach to deriving skill levels in the HRS, based on occupation and harmonised education variables [299, 300]. Among individuals in service occupations, 73.41% were at skill level 2 (a low-skill level, including e.g. cleaners, kitchen assistants or waiting staff [299]), while 4.97% and 14.07% were at skill levels 3 and 4 (high skill levels); however, among individuals with managerial and professional specialty occupations, 37.42% were also at skill level 2 (see Table A 21). Participants in highly skilled service occupations might age better, while participants in low-skilled managerial and professional specialty occupations might age worse. Therefore, compared with managerial and professional workers, participants in service occupations might not have significantly lower HAIs at the age of 60 years.

Few previous studies have considered the effect of skill levels on inequalities in health when they assess the effects of occupation on health. Kaplan and colleagues proposed that this unmeasured heterogeneity may affect the estimations of age-related trends in the main exposure-outcome associations [254]. Therefore, with increased age, participants in low-skilled service occupations might die earlier, leaving those in highly skilled service occupations behind. In that case, the effects of occupation on health inequalities at later ages might be reversed, since more socioeconomically advantaged individuals will remain in the service occupational group. This is also a survival selection bias. Two previous studies based on the HRS also found that a higher risk of mortality was associated with higher education; however, both acknowledged a selective survival bias: high-risk individuals were more likely to die earlier, and the survivors were a rather hardy group of people [149, 301].

More empirical analyses of the effects of skill levels on healthy ageing are needed. Unmeasured heterogeneity in the hierarchy caused by different skill levels within occupational exposures could be addressed in future research.

4.5.5 Socioeconomic Inequalities in Healthy Ageing in England

Educational and Wealth Inequalities in Healthy Ageing

My analysis found a clear and positive wealth gradient in healthy ageing. The wealth inequality in healthy ageing in ELSA was also greater than in any other country. Wealth is one of the most frequently used socioeconomic indicators among the ageing population in England. A previous study has suggested that total net non-pension household wealth is the most robust indicator of current SEP in ELSA, since it captures financial and other material resources at older ages the most accurately [173]. Several studies based on ELSA have also found that English people with less wealth are more likely to report worse health conditions [160] and higher rates of physical disability [159] and functional impairment [157] than those with more wealth.

Education is another frequently used socioeconomic indicator in epidemiological studies in England. Indeed, education was the most influential predictor of healthy ageing in ELSA. Previous research based on ELSA and another national ageing study in England found that lower educational attainment was related to poorer self-rated health [302, 303] and more functional limitations [159, 302] and diseases [302]. Some researchers have suggested that most older adults in Britain left school early without academic qualifications, meaning that the differentiations in the distribution of education are limited [303]. In my analyses, 47.8% of English participants had a primary education or less; only 9.0% of participants had a first-stage tertiary education or more. Therefore, after controls for all covariates, the educational variable might only allow the healthy ageing gap between the top and bottom levels of education to be distinguished.

Both education and wealth are influential indicators of healthy ageing, but wealth seems to be more robust in predicting inequalities among English older generations. More English people in younger generations have attained educational qualifications. More empirical study is needed to explore whether the education gradients in health outcomes are more pronounced among younger generations in England when they reach 60 years or older.

Is No Income Inequality in Healthy Ageing a Reliable Finding?

My analysis found a non-significant association between income and healthy ageing in ELSA, after full adjustment. As with the American participants, here the source of income for the English elderly was mainly pensions and other public benefits. A comparative study in the US, UK and Germany reported that the level of income inequality was substantially lower in the UK than in the US among older adults. However, the UK pension system is effective in preventing the "very bottom" but not "low to moderate" poverty; compared with the US and Germany, the average pension income of older people in the UK is distinctly lower [304]. Another UK study found worse self-reported health among older people on low incomes [303]. Some researchers nevertheless suggest that greater public pension entitlement is still important for reducing inequalities in unmet medical need among older adults in the UK [305].

Therefore, income inequalities in healthy ageing still exist in England, even though income is a less influential predictor in the analysis. The current pension system in the UK might protect persons on bottom-level incomes, but not those on "low or moderate" incomes. This might be an explanation why the income gradient in trajectories in the analysis was unclear among people with moderate and bottom levels of income, which limits the assessment of income inequalities in healthy ageing. Moreover, the low level of pension income in general might negatively affect the well-being of the entire ageing population and the achievement of healthy ageing in the UK.

Occupation Gradient in Healthy Ageing

After full adjustment, even though only small employers and own-account workers, lower supervisory, craft and related employees, and employees in routine occupations had significantly lower HAIs than higher managerial and professional workers at the age of 60 years, trajectories by occupation still presented a clear gradient in healthy ageing among English participants,

In 1982, *The Black Report* drew attention to the fact that during 1970–1971 individuals in occupational class V had been 2.5 times more likely to die before reaching retirement age than their professional counterparts in occupational class I [306]. Thereafter, many studies in the UK also found strong associations between occupation and health outcomes among the ageing population. For example, one study in 1997 suggested that individuals in lower occupational positions in the UK were more likely to have long-standing illnesses; men's unemployment also had adverse consequences for the health of their wives [307]. Another study based on ELSA reported that people in manual work had a higher risk of experiencing severe disability than their managerial and professional counterparts [159]. According to Weber's "life chances" theory, persons in disadvantaged occupational positions, especially in routine occupations, are subjected to worse working conditions, less autonomy, less job security, fewer prospects, no chance of promotion, and tight supervision: the occupation gradient is actually a gradient of security, opportunity and power [308].

Currently in the UK, there are increasing numbers of paid workers aged 60 years or older. Further increases have been expected since the state pension age rose. Occupation-related illnesses and accidents among older workers might gradually become a major public health concern. A literature review in 2012 found few studies in the UK concerning safety practices and health risks for workers aged 60 or more, but the existing studies suggested that accidents and injuries were more likely to be serious or fatal for older workers when they occurred [309]. Longitudinal studies of workers aged over 60 years in the UK are needed to assess the occupational gradient in health among them, and the effects of specific work patterns such as shift work or overtime on health among people in routine occupations.

My analyses also found relatively lower HAIs among those who had never worked. But the relationship was not strong in the partially adjusted model, and even became non-significant after controls for all covariates. Unlike the occupational categories in the HRS, which highlighted the disabled cases in the cohort, with ELSA it was unclear whether the participants who had never worked were all socially disadvantaged cases. The most advantaged persons might also be categorised as never working. They do not need to work for a living, since they own assets that yield enough to live on. However, if the persons who had never worked were mainly socially disadvantaged, a potential explanation for the non-significant result could be that there was a mediation effect in the occupation-healthy ageing relationship. The effect of never working on healthy ageing might be mediated by covariates such as income and wealth.

Additionally, participants' skill levels can also be derived from occupation and harmonised education variables in ELSA [299]. Table A 22 in the appendices shows a detailed approach to deriving skill levels in ELSA. People in managerial or professional occupations might still be at skill level 2 if their educational attainments are low; those in elementary occupations might well be at skill levels 3 and 4 if they have attained higher-education degrees. As with the HRS, future studies assessing the effects of skill levels on health outcomes among the English ageing population might be needed.

4.5.6 Socioeconomic Inequalities in Healthy Ageing in China

Great Educational Inequality in Healthy Ageing

Education was the most influential indicator of healthy ageing among Chinese participants. Educational inequalities in healthy ageing among the Chinese participants were distinctly larger than any other socioeconomic inequalities in healthy ageing in the four countries.

Previous studies found strong educational inequalities in health outcomes among the Chinese ageing population. For example, two studies based on CHARLS found that SEP was the predominant factor that accounted for rural disadvantage regarding depressive symptoms, where persons who were illiterate and low-educated had significantly higher levels of depression [164, 165]. Educational attainment makes people pay more attention to their health and engage in more preventative healthcare in

China [310]. However, and more importantly, education in China is a ladder to social success, especially among the older generations. China started making tremendous efforts to improve the quality of education only after the late 1950s; the major transformations of the educational system only started in the early 1980s [311]. Therefore, most Chinese participants born between 1910 and 1953 ended up illiterate or with an education at less than secondary-school level; few of them went to university for bachelor's or higher studies (see Table 4-2). However, enterprises and governments desperately needed highly educated "talent" to contribute to economic acceleration and capital accumulation in the late 20th century in China [311]. In this context, educational inequalities created significant income and occupational gaps, since persons with bachelor's degrees or more during that time quickly achieved upward social mobility, gaining higher incomes and occupational positions and greater asset accumulation [311]. From a lifecourse perspective, this is intragenerational mobility – a change from a disadvantaged SEP to an advantaged SEP within one's own lifecourse [183]. During this time, highly educated people might have had a healthier working life, a less deprived living environment, more positive social participation, and stronger economic and social security. Therefore, among the older generations, compared with those who did not even go to secondary school, people with bachelor's degrees or more in China were far more likely to achieve healthy ageing.

After 1977, China relaunched its National Higher Education Entrance Examination (known as "Gao Kao") to provide all students with an equal opportunity to get into university [312]. Thereafter, a large number of students, especially from rural China, attained bachelor's degrees or more, and achieved upward social mobility during adulthood. However, at the same time, the labour market has gradually become more competitive. Educational degrees for the younger generation have become less worthwhile than they were for their older counterparts in China. When the younger generations reach later ages, the education gradient in healthy ageing among them might be different from that of their older counterparts at the same age.

Pension Income Inequality in Healthy Ageing

My analysis found significant income inequality in healthy ageing among Chinese participants. Previous studies among the Chinese ageing population have also found evidence of income inequalities in health. A study based on CHARLS reported that lower levels of per capita expenditure were related to higher levels of depressive symptoms among middle-aged and older adults [166]. Another study suggested that income was the dominant risk factor for inequalities in healthcare utilisation among outpatients in both developed and developing provinces of China [167].

A study based on CHARLS suggested that pension income was an important socioeconomic predictor of health inequalities in China [164]. The retirement age in China is 60 years for males, 55 years for female civil servants and 50 years for female workers [313]. The overall state pension system includes three pension schemes: for urban workers, civil servants and residents (i.e. those who are not covered by the first two pension schemes in both rural and urban China). In my analysis, only 7.12% of Chinese participants were civil servants or paid workers who would be eligible for the first two types of pension. More than 56% of participants were in unpaid agricultural work and would be covered only by a rural residents' pension. There are disparities in benefit level among the three pension schemes. The International Labour Office has reported that in 2013, the ratio of average benefits in China was estimated at 50:25.5:1 for civil servants', workers' and residents' pensions respectively; more than 400 million people in China had no old age pension at all [314]. The huge gaps among pension schemes, and between pension receivers and non-receivers, greatly contribute to inequalities in living standards and in the utilisation of health services in China.

The Chinese government is now continuing the expansion of pensions, especially in rural areas. Further improvements in the equity of the pension system are also important for achieving healthy ageing. The regional disparity in pension income and its effects on healthy ageing also need to be evaluated, as the coverage and benefits of the pension scheme vary across regions due to different levels of economic development across provinces in China [314].

Is the Effect of Wealth on Healthy Ageing Less Important?

My analysis found that wealth was not an influential indicator of healthy ageing among Chinese participants. However, the China Household Finance Survey found that wealth inequality in China was much larger than income inequality among the general population [315]. Another investigation indicated that wealth inequality in China rose dramatically after 2002, especially in relation to property ownership [316]. However, compared with income inequality, evidence of wealth inequality in health at the individual level in China is scarce. To my knowledge, only one English publication has included wealth as a covariate. This study measured wealth by counting household luxury items and assessing housing quality; it found that more luxury items and better housing quality were associated with less depression among the rural Chinese ageing population [165].

However, a lack of evidence does not mean the non-existence of a strong association between wealth and health for the elderly. The China Family Panel Studies reported that 78.7% and 60.9% of household wealth consisted of housing assets in urban and rural China respectively in 2012 [317]. Property ownership affects the accumulation of individual wealth not only via asset values, but also via income earned from properties. The National Bureau of Statistics found that between 2013 and 2015, property income rose by 9.9%, while salary income increased by only 8.9% [318]. Inequalities in property ownership and property earnings among the ageing population in China might contribute to inequalities in healthy ageing.

The effect of wealth on healthy ageing might be no less important than the effect of other socioeconomic indicators on healthy ageing in China. More empirical research is needed to make refined measurements of individual wealth, and to explore the association between individual wealth and healthy ageing among Chinese older adults. However, some researchers believe that compared with developed countries, the achievement of high levels of population health in China might not require a generally high level of national wealth [319]. Social investments to eliminate illiteracy, improve the quality of education, protect farmers' benefits, provide universal primary healthcare services and meet basic living needs are more important for achieving healthy ageing in China [319].

Unpaid Farming Work and the "Left-Behind" Elderly

My analysis found that participants in paid and stable employment were healthier than those who were exclusively in unpaid farming work in later life. Compared with those in stable and paid jobs, Chinese farming workers are more likely to be exposed to risks such as excessive physical activity [320], injury from agricultural machinery [321], and toxic pesticides [322], which will negatively affect their health. More importantly, occupational inequalities have contributed to evident inequalities in pension incomes and property ownership, which have crucially affected people's living standards and healthcare utilisation in China [314].

The derived occupational variable in CHARLS captured information based on participants' major types of current employment (see Chapter 2 for details), indicating that participants who mainly conducted unpaid farming work after the age of 60 years were neither migrant workers who had moved to urban China and become industrial labourers, nor highly skilled farmers who were able to manage farmland and work for others to gain payment. Those in unpaid farming work in CHARLS are probably the "left-behind" elderly in China, who live in rural villages but whose children have left them and gone to work in cities as migrant workers [323]. These persons are more vulnerable to physical and cognitive impairment, psychological problems and social isolation: a few studies have assessed the health status of the "left-behind" elderly in China, reporting that they are more likely to suffer from serious falls [324], chronic digestive diseases [325] and depression [326].

In China, the agricultural share of total employment declined from 70.5% in 1978 to 29.5% in 2014, implying that around 317 million rural labourers have found jobs in the industrial and service sectors. However, the population share of households with only elderly people at home has increased, from 3.46% in 2003 to 6.21% in 2011 in rural China [327]. Government evidence has shown that in 2015, 23.3% of the elderly in rural China were categorised as "left behind" elderly [328]. The increasing numbers of "left-behind" elderly might enlarge the gap in healthy ageing between urban and rural China, due to inequalities in pension incomes, primary healthcare services, and vulnerability to adverse physical and mental impairments.

Moreover, currently in China, some of the "left-behind" elderly continue to work on farmland to support themselves, while others mainly rely on their children for financial support in old age [329]. A previous study based on CHARLS found that rural participants who received high levels of financial support from their adult children were less likely to be depressed than those who received no financial support from their children [165]. Therefore, rather than comparing unpaid farming workers with other occupational groups for health inequalities, it might also be important to assess inequalities in health within the "left-behind" group, for example by finding out whether financial support from children or governmental support helps the "left-behind" elderly to achieve healthy ageing in China.

4.5.7 Has Japan Achieved Equity in Healthy Ageing?

In JSTAR, only participants with a lower secondary education had significantly lower HAIs at the age of 60 years than participants with the top level of education. Compared with the trajectories in other countries, the trajectories of healthy ageing were flatter in Japan, and the gaps between the top and bottom trajectories were narrower. The magnitude of healthy ageing inequalities in Japan was relatively small.

Japan's achievement in promoting good health is well known. Before the Meiji restoration (the period between 1868 and 1889, when industrialisation and urbanisation developed in Japan), health and welfare in Japan were as good as in contemporary Europe and early industrial Japan [280]. During the first half of the 20th century, life expectancy in Japan fell behind western Europe, as the government invested heavily in the military but little in public health technologies such as hospitals and sanatoriums, modern sewer systems or piped water [330]. However, after 1946, general individual health in Japan improved quickly, even though half of Japanese residents still had no access to piped water and sanitation in the mid-1990s [331, 332]. Since 1986, Japan has ranked first in the world for women's life expectancy in childbirth [214].

From the perspective of social determinants of health, researchers have different explanations for Japan's general health gains. Some propose that low-cost health services in Japan during the past decades have maintained people's health and increased social equity among the general population [214]. Others believe that Japanese society became more economically egalitarian after the Allied occupation of Japan (1945–1952) [333]. Japanese people focused on productive outcomes, and on societal rather than market or individual opportunities, which had profound health effects among the general population [332]. In terms of income equality, a few researchers have suggested that compared with many other developed countries, Japan has a higher tax threshold for people in higher occupational positions such as CEOs and managers. However, the wage ratios between managers and entry-level workers are much lower, which has significantly promoted occupational equity with regard to health [334]. By 1970, the income ratio between the top and bottom income quintiles had decreased to 4.3:1 in Japan, while in the same year the ratio was 7.1:1 in the US [335].

However, some recent studies do indicate that health inequalities still exist among the ageing population in Japan. For example, a previous study found that older people with lower levels of education had a higher risk of experiencing early mortality than people with higher levels of education [336]; richer participants were more likely to use dental care services than poorer participants, even though the latter needed more dental treatment [169]. Another study also reported that Japanese individuals with lower household incomes and in more disadvantaged occupational positions tended to have poorer self-rated health [337]. Moreover, socioeconomic inequalities in life expectancy and mortality increased continuously between 1995 and 2000 [338]. My analysis only included 1935 Japanese participants aged between 60 and 79 years. This limited sample size and narrow age range might bias the assessment of socioeconomic inequalities in healthy ageing for a general ageing population.

Moreover, my analysis found no significant association between occupation and healthy ageing. The unrepresentative distribution of occupational variables in JSTAR might underestimate occupational inequality in healthy ageing, since 56.79% of participants were categorised as having unclassifiable occupations (see Table 4-2). A previous study in Japan found that between 1980 and 2010, the age-standardised mortality rates across all occupations decreased, and therefore absolute inequality in the mortality rate across occupations was reduced; but relative inequalities were widening between advantaged occupational groups such as managerial and administrative workers and disadvantaged occupational groups such as farmers and fishery and service workers, since the age-standardised mortality rates declined slowly among the disadvantaged occupational groups [339].

Japan’s achievement in promoting healthy ageing among the general population in a more equal society cannot be denied. However, relative inequalities in healthy ageing across SEPs still exist. More empirical evidence is needed regarding socioeconomic inequalities in healthy ageing in Japan, based on data with fewer missing values, less skewed distributions of variables and a wider age range.

4.5.8 Gaps in Healthy Ageing Across Countries

My analysis found that Japanese, English, American and Chinese participants’ healthy ageing in later life ranked first, second, third and last respectively. Chinese participants were less healthy than their counterparts in the US, UK and Japan. As a lower middle-income country, China has significantly lower life expectancy at birth in comparison with high-income Asian countries such as Japan [283]. The WHO in 2014 also indicated that people in the US, UK and Japan had higher life expectancy at 60 years than China [340]. This lag in achieving healthy ageing is affected by great health disparities in China. To judge from this project and previous studies, China's health equity challenges are truly daunting. Some researchers have decomposed world health inequality by employing height as a health indicator, finding that China's contribution to world health inequality was 19.80% [341]. With a great share of the world's population, China's achievement in healthy ageing is important for the achievement of health equity worldwide.

The US government spends more on healthcare than any other developed country. For example, in 2015 the per capita healthcare expenditure in the US was $9024 ($5817 more than the OECD average); in Japan and the UK, the amounts were $4152 and $3971 respectively [342]. However, the American population is still less healthy than the Japanese and English populations. There is a negative socioeconomic gradient in adverse health issues such as self-reported diseases [154], mortality [149], risk of stroke [152] and obesity [148]. The Commonwealth Fund in 2016 reported that 37% of adults in the US did not see a doctor or failed to fill a prescription because of high costs; compared with other developed countries, adults in the US are sicker and more economically disadvantaged [343]. The socially produced inequalities in health status in the US have made the achievement of healthy ageing more difficult than in the UK and Japan.

4.6 Limitations

Some limitations of my study need to be raised. First, to conduct comparisons across countries, the analysis only included common variables across countries for harmonisation. A limited number of socioeconomic indicators were included to assess inequalities in healthy ageing. Some country-specific socioeconomic indicators – such as deprivation scores in ELSA, financial support from children and health insurance in CHARLS, and consumption of food or goods in daily life in JSTAR – were not considered. Moreover, a few country-specific covariates have not been included for adjustment, such as hospital stays and doctor visits in the HRS, CHARLS and JSTAR, or mother's education in the HRS, ELSA and CHARLS. Such country-specific socioeconomic indicators and covariates might also explain variations in the relationship between SEP and healthy ageing in each country.

Second, the analysis provided limited information on participants' occupational positions. For example, in the HRS, occupational information was not available for participants who were not in work (unemployed, disabled, retired and not in the labour force) at baseline; four-digit occupation codes were not available for the four countries. The potential harmonisation of occupational variables across countries by applying the Standard International Classification of Occupations was not applicable, since four-digit occupation codes and full information on occupational positions would be required. Therefore, the analysis did not conduct a cross-country comparison of occupational inequalities in healthy ageing.

Third, a selective survival bias might exist in this research. The analysis only imputed missing values in the main exposures and covariates for responders in each wave. Non-responders and respondents without HAIs in each wave were excluded from the data analyses. Their exclusion from the analyses might have caused a selective survival bias, since non-responders and respondents without HAIs are more likely to have been in severe illness and then to have quit the cohort [254, 344]. Furthermore, the analysis excluded individuals aged less than 60 years at baseline. Therefore, the distributions of some covariates among respondents might be altered and the variation in risk factors might also be reduced due to survival selection, leading to biased estimations for the main exposure-outcome association [254].

Finally, my analyses only predicted HAIs and drew trajectories of healthy ageing at an average level. Trajectories for individuals are not presented. Variations across individuals might exist.

4.7 Conclusions

In conclusion, Japanese, English, American and Chinese participants' healthy ageing ranked first, second, third and last respectively. A positive socioeconomic gradient in healthy ageing existed in all countries. The rates of decline of healthy ageing accelerated with increased age in the US, England and Japan. Lower levels of healthy ageing in later-born cohorts were found, reflecting a real deterioration in older adults' health over time in the four countries.

Japan's achievement in promoting healthy ageing among the general population in a more equal society cannot be denied. On the other hand, China's health equity challenges are truly daunting. Education has become a universally influential socioeconomic indicator of healthy ageing among the ageing population after the age of 60 years in the four countries, indicating that this early-life socioeconomic factor may affect individuals' healthy ageing later in the lifecourse. It seems that for developed countries including the US, England and Japan, wealth is more influential than income in predicting healthy ageing inequalities; while for a developing country such as China, income is more influential than wealth in predicting healthy ageing inequalities among the ageing population.

Labour force non-participation (e.g. retirement or disability) had negative effects on healthy ageing in the US. Chinese people in paid and stable work were healthier than those in unpaid farming work in later life. Particular attention needs to be paid to older people who are poor and marginalised, such as disabled older workers, early retirees and the "left-behind" elderly who live in deprived areas.

This research provided a unique opportunity to conduct a multinational comparison of socioeconomic impacts on healthy ageing. The identification of the most influential socioeconomic indicators of healthy ageing in each country will be instructive for exploring universal and country-specific public health practices to support healthy ageing in both Western and Asian countries. The HAI can be applied as a preliminary screening of healthy agers after 60 years of age in the four countries.

This chapter has assessed socioeconomic inequalities in healthy ageing within and across countries. In the next chapter, on the longitudinal relationship between education and HAIs in each country, the mediating effect is assessed using path analysis to provide estimates of the magnitude and significance of hypothesised connections between socioeconomic indicators, smoking, drinking and HAIs.

Chapter 5 Mediators Between Education and Healthy Ageing

5.1 Introduction

In Chapter 4, I found that in several fully adjusted models, after adjustments for occupation, income, wealth, health behaviours and relevant interactions, the relationships between education and HAIs were evidently attenuated, suggesting the potential existence of mediating effects in the association between education and healthy ageing. Covariates including occupation, income, wealth, smoking and drinking might partially or fully mediate the relationship between education and HAIs. Therefore, in this chapter, I apply path analysis to investigate the potential mediation of the relationship between education and healthy ageing.

5.2 Aim and Hypothesised Conceptual Framework

This chapter aims to assess the mediating effects of occupation, income, wealth, smoking and drinking in the relationship between education and healthy ageing in the HRS, ELSA, CHARLS and JSTAR. Specifically, I outline a conceptual framework for pathways from education to healthy ageing, and I calculate the total, direct and indirect effects of education, occupation, income and wealth on healthy ageing in the four countries.

In Chapter 1, I showed that socioeconomic factors including occupation, income and wealth, and health behaviours including smoking and drinking, could become mediators on the pathway from education and healthy ageing [186-198]. Therefore, my hypothesised conceptual framework for pathways between education and healthy ageing is applied to each country.

A conceptual framework showing all pathways from education to time-varying healthy ageing through time-varying mediators is very complex and difficult to visualise. Figure 5-1 presents a simplified version, without considering time-varying elements, of pathways from education to healthy ageing. Education (X_1) is the exogenous independent variable, and the HAI (X_7) is the outcome. Occupation (X_2), income (X_3), wealth (X_4), smoking (X_5) and drinking (X_6) are potential mediators. The hypotheses are: education, occupation, income, wealth, smoking and drinking all have direct effects on healthy ageing in each country; education, occupation, income and wealth also have indirect effects on healthy ageing through 29 different pathways. For example, education has an effect on healthy ageing through five mediators: occupation, income, wealth, smoking and drinking (see Table 5-1 for more details).

In the analysis, variables for potential mediators and HAI are time-varying. The effect of baseline education on healthy ageing in later life is therefore decomposed into direct and indirect effects through time-varying covariates and HAIs in the four countries. Including time-varying covariates and HAIs allows the mutual associations between repeatedly measured covariates and the associations between these covariates and HAIs to vary over time. Sample clustering within individuals is also considered, allowing for variations in pathway between individuals [345].

The correlations between income and wealth, and smoking and drinking, are allowed for. The direction of influence between income and wealth is difficult to estimate: one's income during adult life might be one's main source of wealth accumulation, but an individual who inherits sufficient wealth might not need a job to gain more income.

Figure 5-1 Hypothesised conceptual framework for pathways from education to healthy ageing

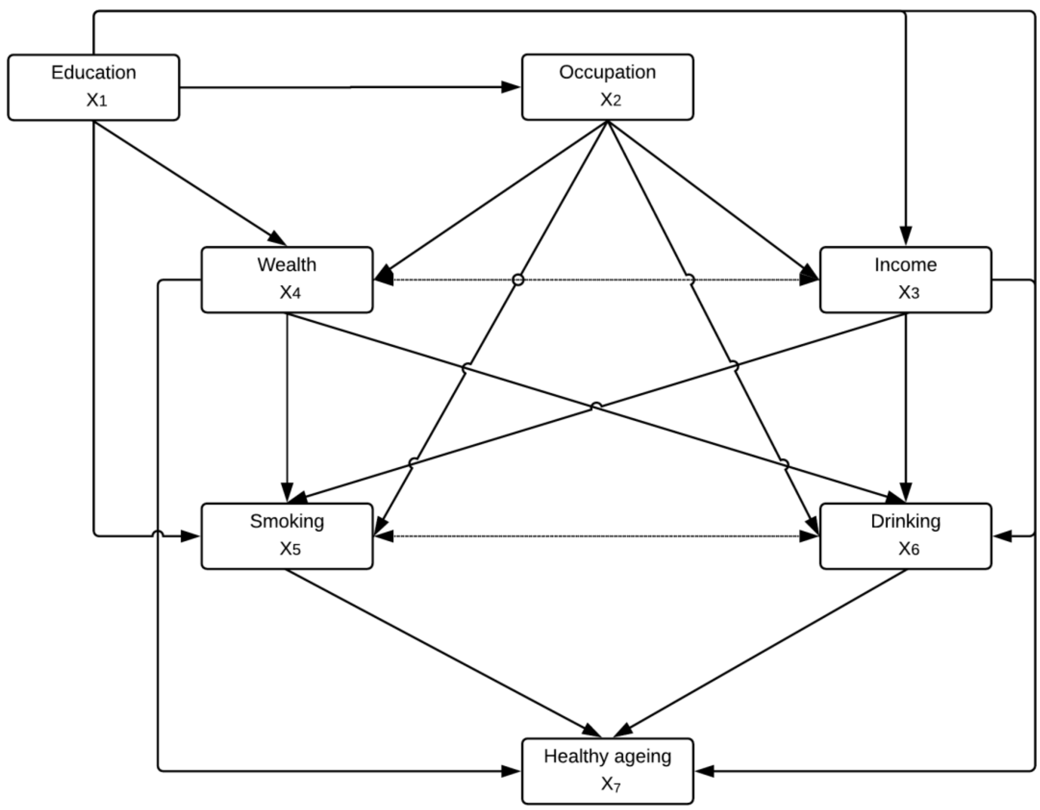


Table 5-1 Pathways from education to healthy ageing

Variables	Pathways
Education	Education→Occupation→Healthy ageing
	Education→Occupation→Income→Healthy ageing
	Education→Occupation→Income→Smoking→Healthy ageing
	Education→Occupation→Income→Drinking→Healthy ageing
	Education→Occupation→Wealth→Healthy ageing
	Education→Occupation→Wealth→Smoking→Healthy ageing
	Education→Occupation→Wealth→Drinking→Healthy ageing
	Education→Occupation→Smoking→Healthy ageing
	Education→Occupation→Drinking→Healthy ageing
	Education→Income→Healthy ageing
	Education→Income→Smoking→Healthy ageing
	Education→Income→Drinking→Healthy ageing
	Education→Wealth→Healthy ageing
	Education→Wealth→Smoking→Healthy ageing
	Education→Wealth→Drinking→Healthy ageing
	Education→Smoking→Healthy ageing
	Education→Drinking→Healthy ageing
Occupation	Occupation→Income→Healthy ageing
	Occupation→Income→Smoking→Healthy ageing
	Occupation→Income→Drinking→Healthy ageing
	Occupation→Wealth→Healthy ageing
	Occupation→Wealth→Smoking→Healthy ageing
	Occupation→Wealth→Drinking→Healthy ageing
	Occupation →Smoking→Healthy ageing
	Occupation →Drinking→Healthy ageing
Income	Income→Smoking→Healthy ageing
	Income→Drinking→Healthy ageing
Wealth	Wealth→Smoking→Healthy ageing
	Wealth→Drinking→Healthy ageing

5.3 Methods

5.3.1 Overall Study Design

There were 10305, 6590, 5930 and 1935 participants in the HRS, ELSA, CHARLS and JSTAR respectively. The sample size was the same as that used for the multiple imputation in each country (see Figure 2-1 for details of the sample selection). This data analysis also used the filled-in data derived by multiple imputation. However, different from the imputed datasets used in Chapter 4, the imputed datasets in Chapter 5 included records with missing values for the occupational variables. The FIML estimation method [241] was applied to deal with the missingness in occupational variables. See Section 2.5 in Chapter 2 for details.

Multi-group path analysis stratified by gender was used to calculate the mediating effects of occupation, income, wealth, smoking and drinking on healthy ageing. In this chapter, the term "effect" used to describe the path models does not imply causality, since the longitudinal studies of ageing in this research are observational, which is not sufficient for causal inference. Nevertheless, this practice is common in descriptions of path analysis results.

Education (time-invariant) was the exogenous variable which was not predicted by any other variables after controls for confounders in the path model. The endogenous mediating variables were occupation, income, wealth, smoking and drinking (time-varying), which mediated some part of the effect of antecedent variables on subsequent variables. The endogenous outcome was healthy ageing ($\log_e$(HAI), time-varying). Cohort, cohort^2, ethnicity, father's occupation and self-rated health in childhood (time-invariant) and age, age^2 and marital status (time-varying) were considered as confounders. Dummy variables were derived for ordinal and nominal categorical confounders. All analyses were stratified by gender, since the multilevel models in Chapter 4 found significant interactions between gender and SEP in the four countries.

The occupational variable NS-SEC in ELSA in the multilevel analysis in Chapter 4 was not an ordinal variable. A re-categorisation was conducted. A three-category NS-SEC was generated: "higher managerial, administrative and professional occupations", "intermediate occupations" and "routine and manual occupations" [346]. For the occupational variable in the HRS, a previous study has suggested that The 1980 U.S.

Census Occupation is categorised on the basis of education and income levels, and is similar to the ordinal classification of the British RGSC (without the armed forces) [233]. Therefore, the occupational variable in the HRS could be treated as an ordinal variable.

In ELSA, some participants' educational attainments were categorised as "other" if they had attained foreign degrees. English participants with the "other" educational classification in ELSA were reallocated into educational classifications based on their years of schooling [154]. Sixteen, 13, 11 and less than 11 years of schooling were respectively treated as equivalent to first-stage tertiary education or more, upper secondary education, lower secondary education, and primary education or less.

Finally, all occupational and educational variables were turned into ordinal categorical variables, in order to make them dependent variables in the path analysis [240].

5.3.2 Statistical Analyses

The path analysis estimated the extent to which the introduction of a mediator reduced or attenuated the direct effect of education on healthy ageing in the four countries. This approach models explanatory relationships between observed variables [347]. In order to use imputed data, the syntax *type=imputation* specified multiply imputed datasets and invoked pooling rules for conducting the path analysis. For the continuous dependent variable ($\log_e$(HAI)), linear regression models were used; for ordered categorical dependent variables (occupation, income, wealth, smoking and drinking), multivariate probit regression models were used [240]. With an ordinal mediator, it is assumed that there is a continuous latent variable underlying the ordinal variable whose observed categorical data arises through a threshold step function; there is a normal probability distribution underlying the ordinal variable [348].

Direct, indirect and total effects were calculated with 95% CIs. Direct effects were the effects of education, occupation, income, wealth, smoking and drinking on healthy ageing; indirect effects were the effects of education, occupation, income and wealth on healthy ageing operating through mediators; the total effect was the sum of the direct and indirect effects. The magnitude of mediating effects was quantified by standardised regression coefficients. Coefficients were standardised using the variances of the continuous latent variables. They are interpreted as the percentage of average change in HAI brought about by a one-unit change in the standard deviation of an independent variable. In this analysis, exogenous and endogenous variables were recoded to take the same direction as the $\log_e$(HAI): higher values for education, occupation, income and wealth, and for smoking and drinking, indicate higher SEPs and healthier behaviours respectively. A positive coefficient between an independent variable and $\log_e$(HAI) suggests a positive effect of that independent variable on healthy ageing.

The assumptions were that all relations are linear and additive; only endogenous outcomes have error terms to represent unexplained variance; error terms are not correlated to any other variables; there are no direct effects between income and wealth, or smoking and drinking, but they are correlated. The comparative fit index (CFI) and the root mean square error of approximation (RMSEA) were used to test the goodness of fit of the model. CFI ≥ 0.95 and RMSEA ≤ 0.05 suggested a well-fitting model [349].

A sensitivity analysis was conducted to check whether results estimated by FIML based on incomplete data were comparable with results based on augmented data using multiple imputation. In each augmented dataset using multiple imputation, the original categories of occupation had been used to impute the missing values. For example, unclassifiable occupational categories such as "others", "retired", "unemployed", "disabled" and "not in the labour force" in the HRS were all kept and imputed. Therefore, the imputed occupational variable in each augmented dataset was still nominal rather than ordered. In order to carry out the sensitivity analysis, I decided to keep the original categories of occupation in each incomplete dataset. Instead of recoding unclassifiable occupational categories into missing values to generate an ordinal occupational variable, I derived dummy variables for occupation for a nominal categorical occupational variable. Occupation then could not be used directly as a dependent variable in the path analysis to calculate the indirect effect of education on healthy ageing via occupation. Instead, a new path model was built where only income, wealth, smoking and drinking were used as mediators, while dummy occupational variables were employed as confounders. This path model was estimated for both imputed data using multiple imputation and incomplete data using FIML. The path models were all stratified by gender. Figure A 2 in the appendices illustrates the hypothesised conceptual model used for the sensitivity analysis, and is followed by tables comparing results based on the two datasets in the four countries (Table A 23 to Table A 38).

All analyses were performed using Mplus 7.4 [240], and $P < 0.05$ was considered statistically significant.

5.4 Results

5.4.1 Sample Characteristics at Baseline

Participants’ baseline characteristics in the four countries are presented in Table 5-2. Chinese and Japanese participants tended to be younger than American and English participants. The geometric mean HAI at baseline was 75.65, 78.40, 73.76 and 85.22 in the HRS, ELSA, CHARLS and JSTAR respectively. Japanese participants seemed to be healthier than participants in any other country. There were more females in the HRS, ELSA and JSTAR, but more males in CHARLS. The majority of participants were white in the HRS and ELSA, and Han in CHARLS. Participants mainly had an upper secondary education in the HRS, a primary education or less in ELSA and CHARLS, and an upper or lower secondary education in JSTAR. In the HRS, more than 50% of participants had more advantaged occupations, while in CHARLS participants mainly did farming work, and in JSTAR most were in the lowest or medium occupational positions. In the HRS, ELSA, CHARLS and JSTAR, 39.51%, 35.84%, 20.61% and 17.00% of participants respectively had no spouse. American fathers had mainly been in disadvantaged occupational positions (more than 70%), and Chinese fathers had mainly been in agricultural work (78.30%), when their children were teenagers. However, in ELSA, fathers’ occupational positions had mainly been at intermediate levels (around 70%). There were no specific classifications of occupational position in JSTAR, but participants’ fathers had mainly been employed (28.44%) or self-employed (52.82%). Compared with American and English participants, a greater proportion of Chinese participants reported poor or fair health in childhood. In the HRS and ELSA the majority of participants were ex-smokers, while in CHARLS and JSTAR most were non-smokers. However, compared with the HRS and ELSA, CHARLS and JSTAR had a greater proportion of current smokers. Participants were mainly non-drinkers in all countries. However, there were greater proportions of participants who consumed alcohol every day in CHARLS and JSTAR.

Table 5-2 Sample characteristics at baseline by country

Variables	HRS (N=10305)	ELSA (N=6590)	CHARLS (N=5930)	JSTAR (N=1935)
HAI (Mean)	75.45	78.40	73.76	85.22
Age (Mean)	72	71	68	67
Gender (%)				
Male	41.24	45.42	51.74	48.01
Female	58.76	54.58	48.26	51.99
Ethnicity* (%)				
1	84.70	98.03	93.14	-
2	12.29	1.97	6.86	-
3	3.02			-
Education (%)				
Primary education or less	7.26	51.21	54.70	0.62
Lower secondary education	18.12	20.93	37.67	43.47
Upper secondary education	53.45	5.16	2.26	40.21
Post-secondary non-tertiary	-	12.19	3.24	4.87
First stage of tertiary or more	21.18	10.51	2.12	10.83
Income (%)				
Lowest	19.13	18.87	18.63	19.97
2nd	21.25	19.68	19.71	19.69
3rd	21.38	20.17	20.36	20.26
4th	20.10	20.54	20.30	20.40
Highest	18.15	20.73	21.01	19.69
Wealth (%)				
Lowest	19.10	18.59	19.02	19.84
2nd	19.65	19.65	20.28	23.22
3rd	20.37	20.52	20.10	17.00
4th	20.54	20.57	19.98	20.11
Highest	20.34	20.66	20.62	19.84
Occupation (%)**				
1	11.53	35.16	93.32	52.43
2	7.17	36.62	1.45	31.26
3	4.55	28.22	2.47	16.31
4	17.86	-	2.76	-
5	28.83	-	-	-
6	30.05	-	-	-
7	-	-	-	-
Marital status (%)				
Married or partnered	60.49	64.16	79.39	83.00
Separated, divorced or single	11.94	11.75	2.19	4.60
Widowed	27.57	24.10	18.41	12.40
Father's occupation* (%)**				
1	13.39	9.47	4.69	28.44
2	11.32	9.89	3.88	52.82
3	4.38	35.93	1.71	2.92
4	27.81	4.26	4.00	15.82
5	21.52	8.35	79.06	-
6	21.81	28.48	3.64	-
7	0.77	0.82	3.01	-
8	-	2.80	-	-
Self-rated health in childhood (%)				
Poor	1.46	3.86	7.56	-
Fair	4.71	8.81	17.69	-
Good	18.71	22.86	27.82	-
Very good	26.12	35.03	36.75	-
Excellent	48.99	29.44	10.18	-
Smoking status (%)				
Smoke	10.34	14.22	30.88	17.41
Ever smoked, now no smoke	47.36	50.88	12.58	26.83

Variables	HRS (N=10305)	ELSA (N=6590)	CHARLS (N=5930)	JSTAR (N=1935)
Never smoke	42.30	34.90	56.54	55.77
Frequency of drinking** (%)**				
1	7.90	17.96	12.48	22.60
2	0.98	2.70	0.95	15.80
3	1.90	3.21	3.09	5.95
4	1.94	4.17	3.02	12.00
5	3.86	7.53	80.46	43.65
6	4.51	11.50	-	-
7	8.43	17.70	-	-
8	70.48	35.24	-	-

[*] In HRS, 1=White/Caucasian 2=Black/African American 3=Others; In ELSA, 1=White 2=Non-white; In CHARLS, 1=Han 2=Minorities; No ethnicity variable in JSTAR

[**] In HRS, 1=Operators, fabricators and labours, 2=Precision production, craft and repair, 3=Farming, forestry and fishing occupations, 4=Service occupations, 5=Technical, sales and administrative support, 6=Managerial and professional sociality occupation; In ELSA, 1=Higher managerial, administrative and professional occupations, 2=Intermediate occupations, 3= Routine and manual occupations; In CHARLS, 1=Only agricultural work, 2=Unpaid family business, 3=Self-employed workers, 4=Officials/managers/leaders or Clerks/paid workers; In JSTAR, 1=Lowest, 2=Intermediate, 3=Highest

[***] In HRS, 1=Managerial and professional speciality occupation 2=Technical, sales and administrative support 3=Services occupation 4=Farming, forestry and fishing occupations 5=Precision productions, craft and repair occupations 6=Operators, fabricators and labours 7=Unclassifiable; In ELSA, 1=Professional or technical 2=Manager, senior official, admin., cleric or secretarial 3=Own business, or skilled trade 4=Service-skilled non-manual 5=Service-skilled manual 6=Others 7=Retired 8=Unemployed, sick or disabled; In CHARLS, 1=Manager 2=Professional and technician 3=Clerk 4=Commercial and service worker 5=Agricultural, forestry, husbandry and others 6=Production and transportation workers 7=Others; In JSTAR, 1=Employed (including public employee), 2=Self-employed (including self-employed farmer) 3= Others 4= No work (including father passed away when participants was 15 years)

[****] In HRS and ELSA, frequency of drinking = days of drinking per week (1=7 days 2=6 days 3=5 days 4=4 days 5=3 days 6=2 days 7=1 day 8=None); In CHARLS, frequency of drinking= times of drinking per month (1=every day of the week 2=most days of the week 3=one to several times per week 4=one to several times per month 5=non or less than once per month; In JSTAR, frequency of drinking= times of drinking per month (1=every day 2= 3-4 times in a week 3= 1-2 times in a week 4=a few times in one month 5=none)

5.4.2 Path Model for the HRS

Table 5-3 (men) and Table 5-4 (women) present standardised regression coefficients with 95% CIs for total, direct and indirect effects by gender in the HRS. The CFI and RMSEA values were 0.904 and 0.047 (95% CI: 0.045–0.049) respectively, indicating that the path model for American participants was well fitted.

For men, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 3.1% (95% CI: 2.7–3.5%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.019 (0.012–0.027). Education had (boundary) significant and positive effects on HAI through simple pathways via income, wealth, smoking and drinking, as well as through complex pathways including via occupation and wealth, and via wealth and drinking (Figure 5-2). The effect of education on HAI was not fully mediated, since the direct effect of education was still positive and significant (0.012, 95% CI: 0.003–0.021).

For women, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 3.1% (95% CI: 2.7–3.5%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.018 (0.010–0.026). Education had (boundary) significant and positive effects on HAI through simple pathways via income, wealth and drinking, as well as through complex pathways via occupation and smoking, via income and drinking, via wealth and smoking, and via wealth and drinking (**Figure *5-2***). The effect of education on HAI was not fully mediated, since the direct effect of education was still positive and significant (0.013, 95% CI: 0.004–0.022).

For both men and women, the total effects of occupation on HAI were non-significant. Both income and wealth still had positive and significant total effects on HAI, but they were not fully mediated.

Only direct effects of smoking and drinking were estimated. Smoking less and drinking less had positive and negative effects on HAI respectively. One standard-deviation increase in smoking (which means smoking less) was associated with a 0.9% (95% CI: 0.4–1.3%) and 1.9% (95% CI: 1.4–2.4%) increase in HAI among men and women respectively; one standard-deviation increase in drinking (which means drinking less) resulted in a 2.3% (95% CI: 1.9–2.8%) and 3.3% (95% CI: 2.7–3.8%) decrease in HAI among men and women respectively.

The correlations between income and wealth, and smoking and drinking, were 0.432 (95% CI: 0.406–0.458) and 0.181 (95% CI: 0.140–0.222) respectively among men, and 0.427 (95% CI: 0.406–0.448) and 0.267 (95% CI: 0.228–0.3.7) respectively among women, indicating moderate or weak correlations.

Table 5-3 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among men in HRS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.031 (0.027 to 0.035)	$X_1 \rightarrow X_7$	0.012 (0.003 to 0.021)	0.019 (0.012 to 0.027)	$X_1 \rightarrow X_2 \rightarrow X_7$	0.001 (-0.007 to 0.009)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_7$	0.004 (0.002 to 0.006)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.007 (0.005 to 0.009)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.001 to 0.002)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.003 (0.001 to 0.004)
Occupation X_2	0.005 (-0.009 to 0.018)	$X_2 \rightarrow X_7$	0.002 (-0.011 to 0.016)	0.002 (-0.001 to 0.006)	$X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.002 (0.000 to 0.003)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.002 to 0.002)
Income X_3*	0.010 (0.006 to 0.013)	$X_3 \rightarrow X_7$	0.008 (0.005 to 0.012)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.023 (0.019 to 0.026)	$X_4 \rightarrow X_7$	0.018 (0.014 to 0.022)	0.005 (0.003 to 0.006)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.004 (0.003 to 0.005)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.009 (0.004 to 0.013)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.023 (-0.028 to -0.019)	-	-	-

* The correlation between income and wealth is 0.432 (0.406 to 0.458); ** the correlation between smoking and drinking is 0.181 (0.140 to 0.222).

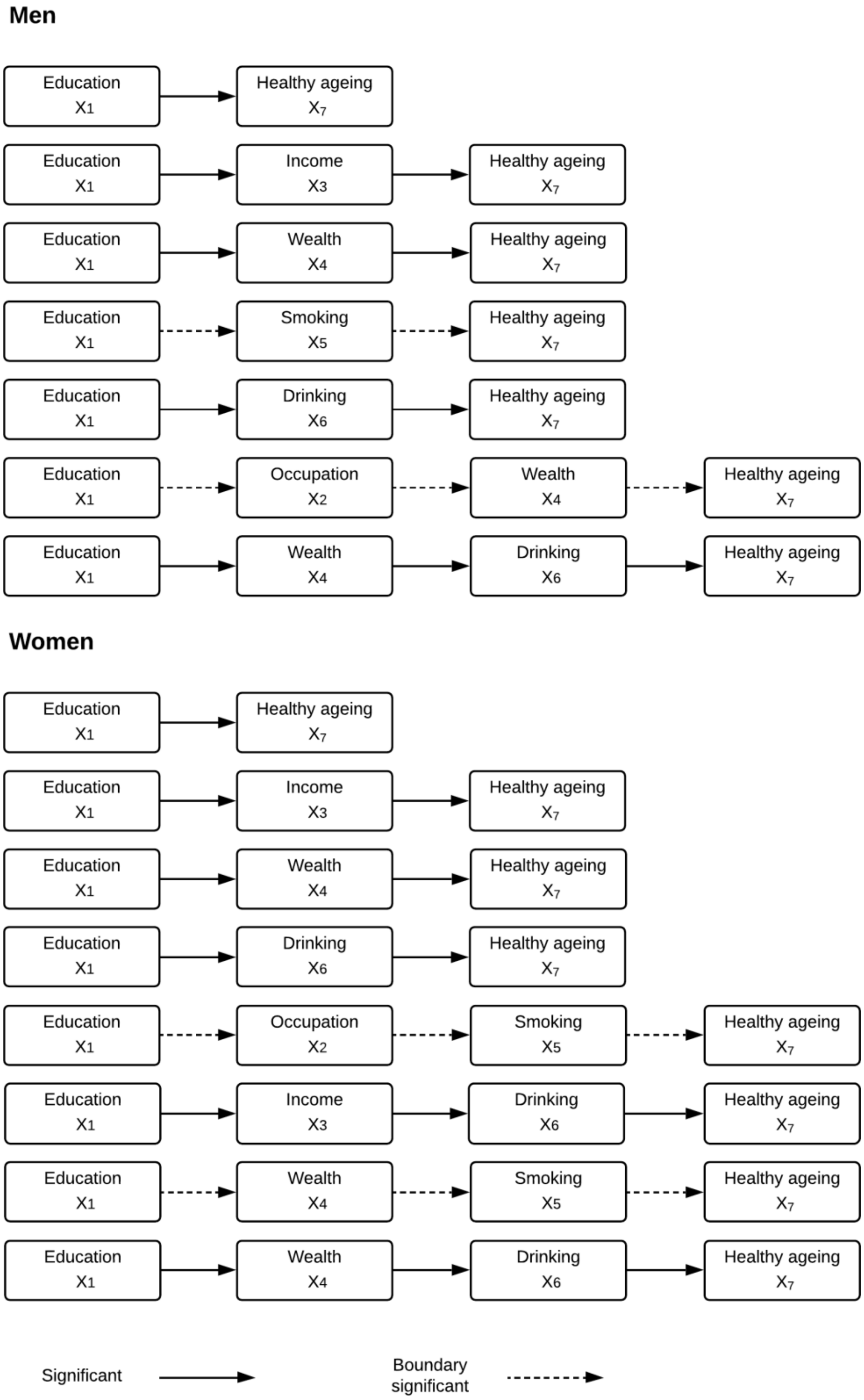
*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table 5-4 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among women in HRS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.031 (0.027 to 0.035)	$X_1 \rightarrow X_7$	0.013 (0.004 to 0.022)	0.018 (0.010 to 0.026)	$X_1 \rightarrow X_2 \rightarrow X_7$	-0.006 (-0.014 to 0.003)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
					$X_1 \rightarrow X_3 \rightarrow X_7$	0.006 (0.004 to 0.007)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.008 (0.007 to 0.010)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.002 (0.002 to 0.003)
					$X_1 \rightarrow X_5 \rightarrow X_7$	-0.001 (-0.002 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.004 (0.002 to 0.006)
Occupation X_2	-0.006 (-0.021 to 0.009)	$X_2 \rightarrow X_7$	-0.010 (-0.025 to 0.005)	0.005 (0.000 to 0.009)	$X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.000 (-0.001 to 0.002)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.002 (0.000 to 0.004)
					$X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.002 to 0.004)
Income X_3*	0.014 (0.011 to 0.018)	$X_3 \rightarrow X_7$	0.012 (0.009 to 0.016)	0.002 (0.000 to 0.003)	$X_3 \rightarrow X_5 \rightarrow X_7$	-0.001 (-0.001 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.003)
Wealth X_4*	0.028 (0.024 to 0.032)	$X_4 \rightarrow X_7$	0.020 (0.017 to 0.024)	0.008 (0.006 to 0.009)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.001 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.006 (0.004 to 0.007)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.019 (0.014 to 0.024)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.033 (-0.038 to -0.027)	-	-	-

* The correlation between income and wealth is 0.427 (0.406 to 0.448); ** the correlation between smoking and drinking is 0.267 (0.228 to 0.307).
*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Figure 5-2 (Boundary) significant pathways from education to HAI by gender in HRS



5.4.3 Path Model for ELSA

Table 5-5 (men) and Table 5-6 (women) present standardised regression coefficients with 95% CIs for total, direct and indirect effects by gender in ELSA. The CFI and RMSEA values were 0.916 and 0.046 (95% CI: 0.043–0.048) respectively, indicating that the path model for English participants was well fitted.

For men, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 3.1% (95% CI: 2.5–3.7%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.010 (0.006–0.014). Education had (boundary) significant effects on HAI through simple pathways via income, wealth, smoking and drinking, as well as through complex pathways via occupation and income, via occupation and wealth, and via wealth and smoking (**Figure *5-3***). The effect of education on HAI was not fully mediated, since the direct effect of education was still positive and significant (0.021, 95% CI: 0.014–0.028).

For women, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 2.6% (95% CI: 2.0–3.3%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.015 (0.008–0.021). Education had (boundary) significant effects on HAI through simple pathways via income, wealth and drinking, as well as through complex pathways via occupation and income, via occupation and wealth, and via wealth and drinking (**Figure *5-3***). The effect of education on HAI was not fully mediated, since the direct effect of education was still positive and significant (0.012, 95% CI: 0.002–0.022).

The total effect of occupation on HAI was non-significant among men and boundary significant among women. For both men and women, the coefficients for the effects of education and occupation on HAI through income were negative. Lower income tended to be correlated with healthier ageing. The total effects of wealth on HAI were positive and significant among men and women, but they were not fully mediated.

Only direct effects of smoking and drinking were estimated. Smoking less and drinking less had positive and negative effects on healthy ageing respectively. One standard-deviation increase in smoking (which means smoking less) was associated with a 1.3% (95% CI: 0.7–2.0%) and 1.8% (95% CI: 1.2–2.4%) increase in HAI among men and women respectively; one standard-deviation increase in drinking (which means drinking less) resulted in a 1.3% (95% CI: 0.8–1.8%) and 2.2% (95% CI: 1.6–2.8%) decrease in HAI among men and women respectively.

The correlations between income and wealth, and smoking and drinking, were 0.330 (95% CI: 0.295–0.366) and 0.091 (95% CI: 0.039–0.142) respectively among men, and 0.274 (95% CI: 0.241–0.308) and 0.135 (95% CI: 0.085–0.184) respectively among women, indicating a moderate or weak correlation.

Table 5-5 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among men in ELSA

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.031 (0.025 to 0.037)	$X_1 \rightarrow X_7$	0.021 (0.014 to 0.028)	0.010 (0.006 to 0.014)	$X_1 \rightarrow X_2 \rightarrow X_7$	-0.003 (-0.006 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	-0.001 (-0.001 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.005 (0.003 to 0.007)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_7$	-0.002 (-0.004 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.006 (0.004 to 0.008)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Occupation X_2	0.005 (-0.003 to 0.012)	$X_2 \rightarrow X_7$	-0.005 (-0.012 to 0.002)	0.009 (0.007 to 0.012)	$X_2 \rightarrow X_3 \rightarrow X_7$	-0.001 (-0.002 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.008 (0.006 to 0.011)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.001)
Income X_3*	-0.005 (-0.010 to 0.001)	$X_3 \rightarrow X_7$	-0.006 (-0.012 to -0.001)	0.002 (0.001 to 0.003)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.027 (0.021 to 0.033)	$X_4 \rightarrow X_7$	0.024 (0.018 to 0.030)	0.003 (0.002 to 0.004)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.001 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.013 (0.007 to 0.020)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.013 (-0.018 to -0.008)	-	-	-

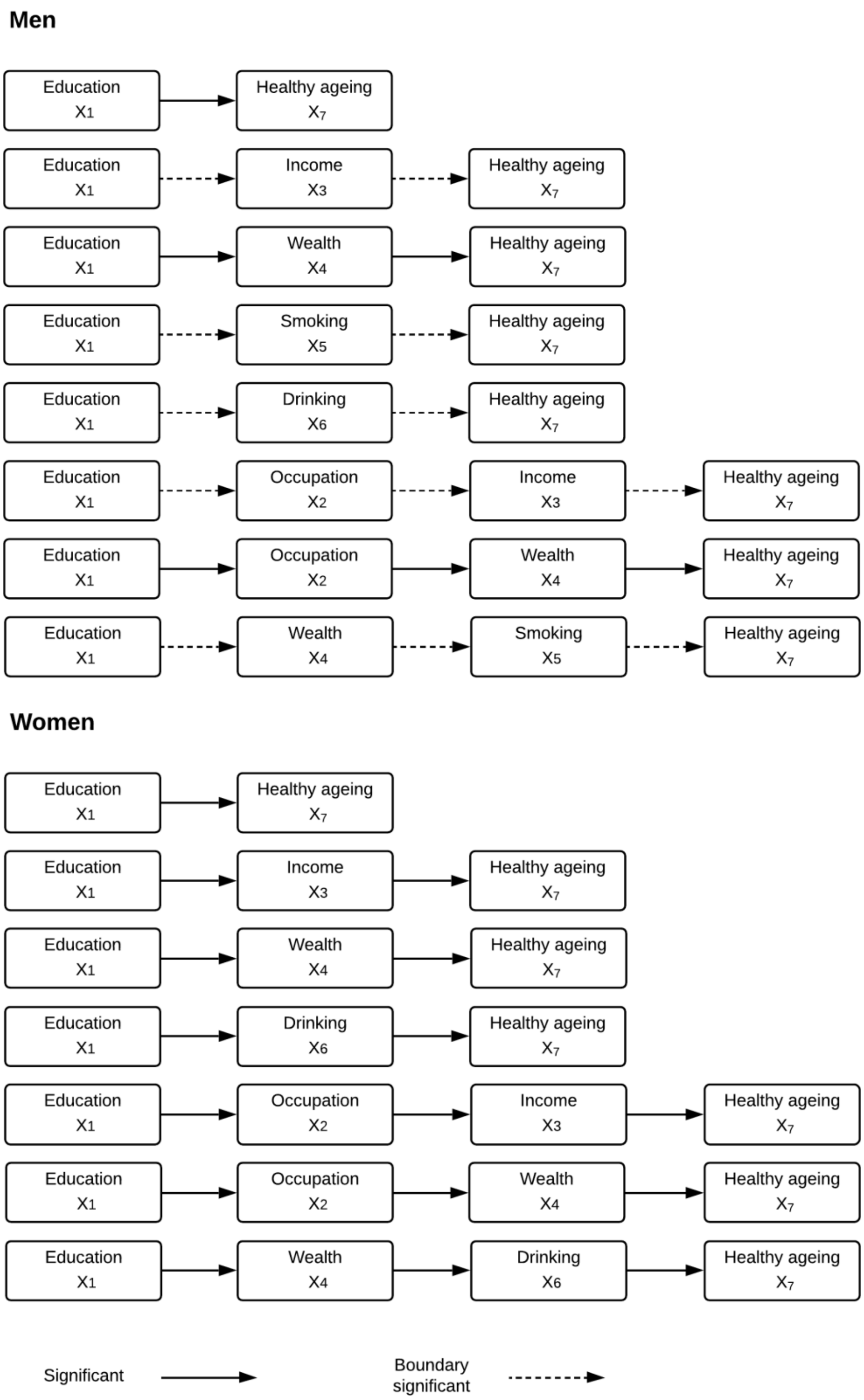
* The correlation between income and wealth is 0.330 (0.295 to 0.366); ** the correlation between smoking and drinking is 0.091 (0.039 to 0.142).
*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table 5-6 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among women in ELSA

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.026 (0.020 to 0.033)	$X_1 \rightarrow X_7$	0.012 (0.002 to 0.022)	0.015 (0.008 to 0.021)	$X_1 \rightarrow X_2 \rightarrow X_7$	0.003 (-0.003 to 0.009)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	-0.002 (-0.003 to -0.001)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.004 (0.002 to 0.006)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_3 \rightarrow X_7$	-0.006 (-0.008 to -0.004)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.008 (0.006 to 0.011)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.001 to 0.002)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (-0.001 to 0.003)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.003 (0.001 to 0.005)
Occupation X_2	0.008 (0.000 to 0.017)	$X_2 \rightarrow X_7$	0.004 (-0.004 to 0.012)	0.005 (0.002 to 0.007)	$X_2 \rightarrow X_3 \rightarrow X_7$	-0.003 (-0.004 to -0.002)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.005 (0.003 to 0.007)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.003)
Income X_3*	-0.020 (-0.025 to -0.014)	$X_3 \rightarrow X_7$	-0.020 (-0.026 to -0.015)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.037 (0.031 to 0.042)	$X_4 \rightarrow X_7$	0.031 (0.025 to 0.037)	0.006 (0.004 to 0.008)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.000 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.004 (0.003 to 0.006)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.018 (0.012 to 0.024)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.022 (-0.028 to -0.016)	-	-	-

* The correlation between income and wealth is 0.274 (0.241 to 0.308); ** the correlation between smoking and drinking is 0.135 (0.085 to 0.184).
*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Figure 5-3 (Boundary) significant pathways from education to HAI by gender in ELSA



5.4.4 Path Model for CHARLS

Table 5-7 (men) and Table 5-8 (women) present standardised regression coefficients with 95% CIs for total, direct and indirect effects by gender in CHARLS. The CFI and RMSEA values were 0.966 and 0.023 (95% CI: 0.017–0.030) respectively, indicating that the path model for Chinese participants was well fitted.

For men, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 4.1% (95% CI: 3.3–4.8%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.008 (0.004–0.011). Education had boundary significant effects on HAI through income (0.003, 95% CI: - 0.001–0.008) and wealth (0.003, 95% CI: 0.000–0.006) (**Figure *5-4***). The effect of education on HAI was not fully mediated, since the direct effect of education was still positive and significant (0.033, 95% CI: 0.025–0.041).

For women, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 9.1% (95% CI: 6.1–12.2%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.029 (0.017–0.041). Education had (boundary) significant effects on HAI through wealth (0.015, 95% CI: 0.005–0.025) and smoking (0.005, 95% CI: 0.000–0.010) (**Figure *5-4***). The effect of education on HAI was not fully mediated, since the direct effect of education was still positive and significant (0.062, 95% CI: 0.033–0.091).

The total effect of occupation on HAI was boundary significant among men and non-significant among women. The total effects of wealth on HAI were significant among both men and women, but neither smoking nor drinking mediated the effects of wealth on HAI.

Only direct effects of smoking and drinking were estimated. For men, one standard-deviation increase in drinking (which means drinking less) was associated with a 1.8% (95% CI: 0.9–2.6%) decrease in HAI, indicating a negative effect of drinking less on healthy ageing. However, smoking did not have a significant direct effect on HAI. For women, one standard-deviation increase in smoking (which means smoking less) was associated with a 1.8% (95% CI: 0.3–3.3%) increase in HAI, indicating a positive effect of smoking less. However, drinking less did not have a significant direct effect on HAI.

The correlations between income and wealth, and smoking and drinking, were 0.397 (95% CI: 0.335–0.458) and 0.234 (95% CI: 0.168–0.301) respectively among men, and 0.507 (95% CI: 0.455–0.559) and 0.145 (95% CI: 0.027–0.261) respectively among women, indicating a moderate or weak correlation.

Table 5-7 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among men in CHARLS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.041 (0.033 to 0.048)	$X_1 \rightarrow X_7$	0.033 (0.025 to 0.041)	0.008 (0.004 to 0.011)	$X_1 \rightarrow X_2 \rightarrow X_7$	0.001 (-0.001 to 0.003)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_7$	0.003 (-0.001 to 0.008)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.003 (0.000 to 0.006)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Occupation X_2	0.015 (0.000 to 0.030)	$X_2 \rightarrow X_7$	0.013 (-0.003 to 0.029)	0.002 (-0.001 to 0.006)	$X_2 \rightarrow X_3 \rightarrow X_7$	0.002 (0.000 to 0.004)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
Income X_3*	0.008 (-0.001 to 0.017)	$X_3 \rightarrow X_7$	0.008 (-0.001 to 0.016)	0.000 (-0.001 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.002)
Wealth X_4*	0.011 (0.001 to 0.021)	$X_4 \rightarrow X_7$	0.011 (0.000 to 0.021)	0.000 (-0.002 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.000 (-0.009 to 0.010)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.018 (-0.026 to -0.009)	-	-	-

* The correlation between income and wealth is 0.397 (0.335 to 0.458); ** the correlation between smoking and drinking is 0.234 (0.168 to 0.301).

*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

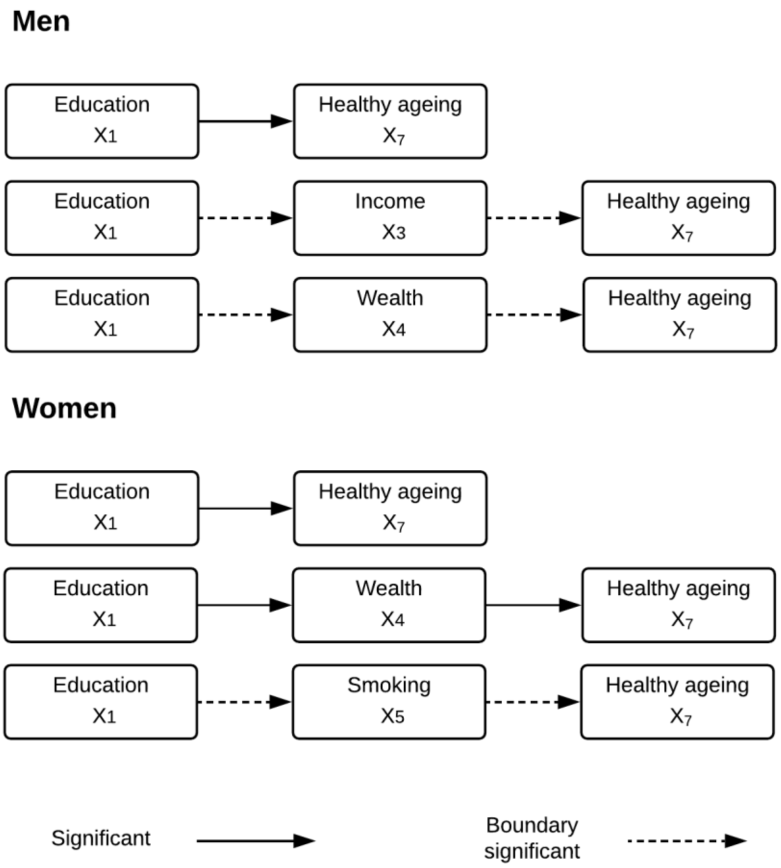
Table 5-8 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among women in CHARLS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.091 (0.061 to 0.122)	$X_1 \rightarrow X_7$	0.062 (0.033 to 0.091)	0.029 (0.017 to 0.041)	$X_1 \rightarrow X_2 \rightarrow X_7$	0.001 (-0.001 to 0.003)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_7$	0.005 (-0.004 to 0.015)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.015 (0.005 to 0.025)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.005 (0.000 to 0.010)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.002 (-0.001 to 0.006)
Occupation X_2	0.062 (-0.002 to 0.125)	$X_2 \rightarrow X_7$	0.041 (-0.020 to 0.102)	0.020 (0.002 to 0.038)	$X_2 \rightarrow X_3 \rightarrow X_7$	0.003 (-0.002 to 0.008)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.009 (0.000 to 0.018)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.007 (-0.006 to 0.020)
					$X_2 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.005 to 0.006)
Income X_3*	0.009 (-0.004 to 0.021)	$X_3 \rightarrow X_7$	0.007 (-0.005 to 0.020)	0.001 (-0.001 to 0.004)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.002)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.003)
Wealth X_4*	0.023 (0.008 to 0.039)	$X_4 \rightarrow X_7$	0.024 (0.008 to 0.040)	0.000 (-0.003 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.002 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	-0.001 (-0.002 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.018 (0.003 to 0.033)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.014 (-0.030 to 0.001)	-	-	-

* The correlation between income and wealth is 0.507 (0.455 to 0.559); ** the correlation between smoking and drinking is 0.145 (0.027 to 0.264).

*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Figure 5-4 (Boundary) significant pathways from education to HAI by gender in CHARLS



5.4.5 Path Model for JSTAR

Table 5-9 (men) and Table 5-10 (women) present standardised regression coefficients with 95% CIs for total, direct and indirect effects by gender in JSTAR. **Figure *5-5*** lists (boundary) significant pathways from education to HAI by gender in JSTAR. The CFI and RMSEA values were 0.960 and 0.033 (95% CI: 0.022–0.045) respectively, indicating that the path model for Japanese participants was well fitted.

For men, the total effect of education on healthy ageing was positive and significant: one standard-deviation increase in education was associated with a 1.7% (95% CI: 1.0–2.4%) increase in HAI. The coefficient for the total indirect effect of education on healthy ageing was 0.015 (0.007–0.023). The effect of education on HAI was fully mediated. There was a (boundary) significant effect of education on healthy ageing through occupation or wealth (**Figure *5-5***).

For women, the total effect of education on HAI was non-significant. Neither the direct nor the indirect effect of education on HAI was significant.

The total effect of occupation was only significant among men. The direct effect of occupation on HAI was significant, but the effect of occupation on HAI was not mediated by other variables. For both men and women, the total effects of wealth on HAI were significant, but neither smoking nor drinking mediated the effects of wealth on HAI.

Only direct effects of smoking and drinking were estimated. Only drinking had a significant direct effect on HAI among both men and women. However, drinking less had a negative effect on healthy ageing: for men and women, one standard-deviation increase in drinking (which means drinking less) was associated with a 1.5% (95% CI: 0.5–2.4%) and 1.0% (95% CI: 0.0–2.0%) decrease in HAI respectively.

The correlations between income and wealth, and smoking and drinking, were 0.197 (95% CI: 0.120–0.273) and 0.076 (95% CI: - 0.017–0.168) respectively among men, and 0.171 (95% CI: 0.069–0.273) and 0.300 (95% CI: 0.143–0.457) respectively among women, indicating weak or moderate correlations.

Table 5-9 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among men in JSTAR

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.017 (0.010 to 0.024)	$X_1 \rightarrow X_7$	0.002 (-0.009 to 0.013)	0.015 (0.007 to 0.023)	$X_1 \rightarrow X_2 \rightarrow X_7$	0.011 (0.003 to 0.020)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	-0.001 (-0.002 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.002 (0.000 to 0.004)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.002 (-0.001 to 0.004)
Occupation X_2	0.022 (0.009 to 0.036)	$X_2 \rightarrow X_7$	0.022 (0.007 to 0.037)	0.000 (-0.003 to 0.004)	$X_2 \rightarrow X_3 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_6 \rightarrow X_7$	-0.002 (-0.005 to 0.001)
Income X_3*	0.005 (-0.001 to 0.010)	$X_3 \rightarrow X_7$	0.004 (-0.002 to 0.010)	0.001 (-0.001 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
Wealth X_4*	0.012 (0.002 to 0.021)	$X_4 \rightarrow X_7$	0.011 (0.001 to 0.020)	0.001 (-0.001 to 0.003)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.002 (-0.008 to 0.011)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.015 (-0.024 to -0.005)	-	-	-

* The correlation between income and wealth is 0.197 (0.120 to 0.273); ** the correlation between smoking and drinking is 0.076 (-0.017 to 0.168).

*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

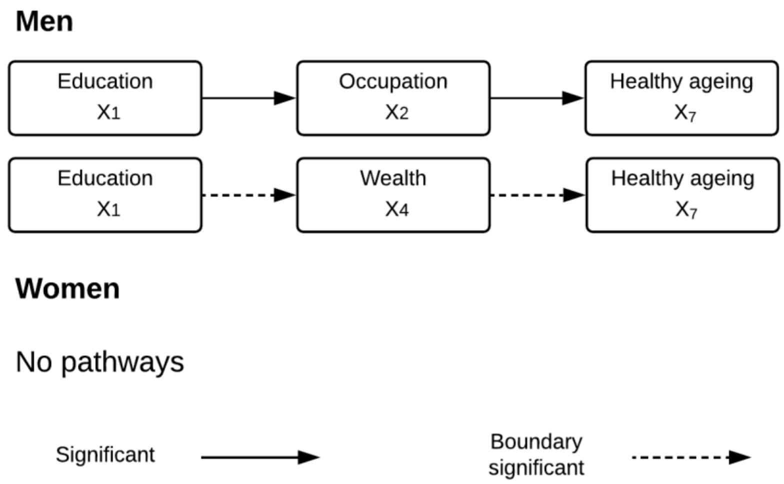
Table 5-10 Standardised regression coefficients with 95%CIs for total, direct and indirect effects among women in JSTAR

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.003 (-0.004 to 0.010)	$X_1 \rightarrow X_7$	0.000 (-0.014 to 0.013)	0.003 (-0.007 to 0.014)	$X_1 \rightarrow X_2 \rightarrow X_7$	0.000 (-0.012 to 0.012)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_7$	0.001 (0.000 to 0.003)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_2 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.001 (-0.001 to 0.003)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.003)
Occupation X_2	0.002 (-0.021 to 0.026)	$X_2 \rightarrow X_7$	0.001 (-0.026 to 0.027)	0.002 (-0.003 to 0.006)	$X_2 \rightarrow X_3 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_4 \rightarrow X_7$	0.003 (0.000 to 0.005)
					$X_2 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_2 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_2 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.002 to 0.002)
					$X_2 \rightarrow X_6 \rightarrow X_7$	-0.001 (-0.003 to 0.001)
Income X_3*	0.000 (-0.005 to 0.005)	$X_3 \rightarrow X_7$	0.001 (-0.005 to 0.006)	-0.001 (-0.002 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	-0.001 (-0.002 to 0.001)
Wealth X_4*	0.011 (0.003 to 0.019)	$X_4 \rightarrow X_7$	0.010 (0.002 to 0.019)	0.001 (-0.002 to 0.004)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.002 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.001 (-0.014 to 0.016)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.010 (-0.020 to 0.000)	-	-	-

* The correlation between income and wealth is 0.171 (0.069 to 0.273); ** the correlation between smoking and drinking is 0.300 (0.143 to 0.457).

*** X_1: Education; X_2: Occupation; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Figure 5-5 (Boundary) significant pathways from education to HAI by gender in JSTAR



5.4.6 Results of Sensitivity Analyses

Table A 23 to Table A 38 compare results estimated by FIML on incomplete data with results based on multiple imputation data in the four countries. In each country, among both men and women, the results based on the two datasets were very similar to each other, suggesting a good comparability between the two methods for dealing with missing data. Applying either multiple imputation or FIML to deal with missing data for the main analyses in this chapter would yield very similar results for mediating effects in the relationship between education and healthy ageing. Therefore, even though I re-categorised several occupational and educational variables, used imputed data with missingness in occupational variables to conduct path analyses, and applied FIML to handle missing values, the results in this chapter are still able to accurately quantify the hypothesised mediating effects for the longitudinal relationships between SEP and HAIs reported in Chapter 4.

5.5 Discussion

5.5.1 Summary of Results

The path models for the four countries were all well fitted. The total effects of education on healthy ageing were significantly positive among both men and women in the US, England and China, and among men in Japan. But there was no support for a significant effect of education on healthy ageing among Japanese females. As expected, there were complex pathways from education to healthy ageing in the four countries, but compared with China and Japan, a greater number of pathways from education to healthy ageing were found in the US and England. In the US, England and China, there were partial mediations of the relationship between education and healthy ageing among both men and women; in Japan, there was full mediation of the relationship between education and healthy ageing among men.

5.5.2 Mediators in the Relationship Between Education and Healthy Ageing

Wealth

Wealth was a universal mediator on the pathway from education to healthy ageing among both men and women in the US, England and China, and among men in Japan. Wealth comprised the sum of the net values of primary and secondary residences and other property after paying all debts; business, non-housing financial wealth; physical assets; and more (see Chapter 2).

Lynch and Kaplan suggest that more accumulated wealth is an indicator of social success, and can be predicted by a higher level of education [139]. For the ageing population, wealth reflects an accumulation of income and other materials during the lifecourse, and is more influential for describing and explaining health inequalities in older age [350]. In the US in 2013, the median net worth of a household headed by someone with a degree beyond a bachelor's was $689100; however, a household headed by someone without a high-school diploma had a median net worth of only $37766; the gap between the least- and most-educated families widened dramatically between 1998 and 2013 [351]. In the UK from 2006 to 2008, the median net worth per adult was £450000 in a family if the household head had qualifications at degree level or above at age 55–64; the value was only £75000 if the household head had no educational or vocational qualifications at the same age [352]. Similarly, in China in 2010, households with all illiterate members had a net worth of ¥138000 on average; however, if a household member had a college education or above, the net worth on average reached ¥626000 [353].

Nevertheless wealth only partially mediated the effect of education on healthy ageing in each country. The accumulation of wealth might rely on sources other than education. For example, the same study from the US reported that from 1989 to 2013, the percentage receiving or expecting an inheritance among highly educated families was higher than that among lower-educated families, since educated parents might produce both educated offspring and wealth that could be passed down [351]. Moreover, as an early-life socioeconomic indicator, education might not affect the accumulation of wealth in later life as strongly. The educational inequality in wealth might become smaller. For example, the same study from the UK applied a median regression adjusted for age, gender, education and relevant interactions, and found that after the age of 65 years, the gap in the median net wealth per adult between highly and low-educated families gradually became narrower with the increase in age [352].

Therefore, wealth is a universal and partial mediator on the pathway from education to healthy ageing in the four countries. Future studies could focus more on refining the measures of wealth during the lifecourse, such as family inheritance, property ownership or the amount of savings in later life, to identify their specific mediating effects on the pathway from education to healthy ageing from a lifecourse perspective.

Income

The effect of education on healthy ageing was partially mediated by income among men and women in the HRS, and among women in ELSA. It is generally accepted that higher education leads to better jobs and higher incomes during adulthood, which may enable people to afford sufficient medical care, healthy food, and the time and expense of regular physical activities [139]. However, to my knowledge, research on the relationship between education and later-life earnings is limited across countries. One study explored differences in lifetime earnings by education in the US, finding that higher education contributed to greater earnings at each stage of the work career and over a lifetime, but the effect of education on earnings in later life was not strong [354]. Another study among Norwegian males reported that additional schooling produced a steeper age-earnings profile, suggesting that more education was associated with significantly higher earnings at each age stage between the ages of 17 and 62 years [355].

In the HRS, among both men and women, the effect of education on healthy ageing through income was positive. However, among women in ELSA, the effect of education on healthy ageing via income was negative (Table 5-6). Researchers have found that in the UK, divorced women lose out on substantial sums of money and other assets in retirement, and have to continue working to attain enough later-life earnings, which may contribute to worse health [356, 357]. Therefore, a higher income may be closely correlated with less healthy ageing among English female participants.

Occupation

In JSTAR, among men, the effect of education on healthy ageing was fully mediated mainly by occupation. Previous publications on the mediating effect of occupation are scarce in Asian countries. One study tested the pathway from disadvantaged socioeconomic status to dementia in Japan, indicating that lower education was still a strong predictor of dementia risk after adjustment for employment history [358]. A study in Korea reported that the effect of education on mortality risk was more dominant than the effect of occupation [359]. It seems from the literature that occupation has a weak mediating effect on the relationship between education and health and mortality among the ageing population in developed Asian countries, which is different from my findings. The reason might be that in the path analysis, a large proportion of unclassifiable occupations in JSTAR caused bias.

Researchers have argued that unlike in the US, where the higher-education market is mainly driven by labour market demand, the higher-education market in Japan has weak connections with labour market demand, since occupational wages are heavily dependent on seniority, regardless of employees' educational background or field of study [360]. In this social context, the educational market in Japan cannot be shaped by the labour market, which weakens the connection between education and occupation. Another interesting phenomenon is that in Japan, employees are highly educated in general, even among blue-collar workers, since they like to keep learning new skills after schooling in order to improve themselves [361]. Higher education might not be related to more advantaged occupations. Occupation might not be an influential or generally used indicator of social status in Japanese society.

In ELSA, the effect of education on healthy ageing was mediated through pathways such as via occupation and wealth, or via occupation and income, among both men and women. Much evidence in Western countries has demonstrated this pathway: higher education brings a higher occupational position, which contributes to a higher income and more accumulated wealth [139]. A study among British civil servants found that pre-existing health and social positions such as occupation and wealth greatly accounted for the association between personal income and depression [362]. A study in the US also reported an interaction between occupation and wealth, suggesting that the negative impact of occupation on physical activity in retirement was exacerbated by a lack of wealth [363]. In 2013, around three million employees (8% of the total population) were in relative income poverty in the UK [364]. Occupational inequality in income and wealth is a feature of UK society.

Health Behaviours

Drinking was a partial mediator in the relationship between education and healthy ageing among men and women in the HRS, and among women in ELSA. Smoking mediated the effect of education on healthy ageing among women in CHARLS, but the mediating effect was boundary significant. Moreover, neither smoking nor drinking were mediators among men in ELSA and CHARLS, or among men and women in JSTAR.

The estimated contribution of health behaviours to educational inequalities in health has been shown to vary across countries. For example, a study in the US found that well-educated individuals were less likely to smoke but more likely to drink moderately, which were both associated with good health; but smoking and drinking, together with other behaviours, explained less than 10% of the educational inequality in health [365]. Another study in the US suggested that behaviours such as smoking and drinking accounted for over 40% of the effect of education on mortality risk [366]. A study of the ageing population based on ELSA and the Survey of Health, Ageing and Retirement in Europe (SHARE) indicated that the mediating effect of health behaviours measured by smoking, drinking, exercising and BMI accounted for 23–45% of the effect of education on subjective health, and that the mediating effect of health behaviours was stronger among men than women [367]. A study among the elderly Chinese suggested that participants with a higher education achieved higher scores in health literacy, were less likely to have risky behaviours such as smoking and harmful drinking, and reported better subjective health than those who were poorly educated [368]. Moreover, a Japanese study found that a higher education was associated with less smoking but more drinking, and the educational gradient in smoking was greater among women [369].

A path via wealth and drink also mediated the effect of education on healthy ageing among both men and women in the HRS, and among women in ELSA. Less wealth might bring financial stress and lower life control, which both contribute to unhealthy behaviours [370]. A study from the Netherlands found a similar psychosocial pathway from education to smoking, indicating that stressors including financial stress and suboptimal physical health, and resources including perceived life control and social support, partially mediated the relationship between education and smoking [371].

However, except for women in CHARLS, drinking had a positive effect on healthy ageing in the four countries. According to the WHO, no amount of alcohol consumption is beneficial for health, especially cardiovascular diseases [372]. One potential reason for my finding of a positive effect of drinking may be selection bias: non-drinkers and participants with a lower propensity to drink might have had poor health and stopped harmful drinking before they entered the cohort.

In summary, the results concerning the mediating effect of health behaviours are mixed in the literature. In the path analysis, support for the mediating effects of drinking and smoking was very limited. The positive effect of drinking on healthy ageing is doubtful.

A psychosocial pathway might exist between education and health behaviours. In terms of smoking, more evidence is needed, especially on the mediating effect of smoking among the Chinese and Japanese ageing population, since most Chinese and Japanese participants in the current sample were non-smokers (see Table 5-2). However, another investigation showed that the prevalence of smoking among men in the two countries was more than 50%, and the prevalence of smoking among women has been increasing during the past decade [373]. The mediating effect of smoking might be biased in the path analysis due to the unrepresentative proportion of current smokers.

5.5.3 Direct Effects of Socioeconomic Indicators on Healthy Ageing

Education

Education had a direct association with healthy ageing among both men and women in the HRS, ELSA and CHARLS. Previous studies have not achieved a consensus on the causal effect of education on health. Many studies argue that the indirect effect of education on health operating through health behaviours is stronger than its direct effect. For example, a randomised control trial conducted in the UK on socioeconomic differences in cancer screening demonstrated that education affected health through changes in health beliefs and behaviours [374]. A study based on two national surveys in the US also found that education enhanced health indirectly and dominantly through encouraging healthy behaviours [375]. Moreover, a study from Taiwan found no direct effect of education on mortality; instead, health status and behaviours, and social relationships, fully mediated the effect of education on mortality [376].

There are nonetheless a few studies that find a direct effect of education on health outcomes. For example, a natural experiment based on the UK Biobank demonstrated that the raising of the minimum school leaving age in 1972 reduced the risk of diabetes and premature mortality [377]. Another natural experiment in China suggested that the introduction of nine years’ compulsory schooling in 1986 had a direct impact on subjective health, underweight and cognition [378]. Moreover, a twin study in the US showed that among monozygotic twins, more years of schooling were associated with better self-rated health; however, the indirect effect of schooling operating via heath behaviours was very weak [379].

Reverse causation might be the main challenge for asserting causality from education to health. For example, children with higher IQs and better health in childhood are able to achieve higher educational attainments and look after themselves better at later ages [270, 380]. In my research, participants' self-rated health in childhood has been controlled for to take account of reverse causation, but some other early-life health measures might still be needed, as residual confounding could still be an issue.

Wealth

Wealth had a direct effect on healthy ageing among both men and women in the four countries. Higher levels of wealth were correlated with healthier ageing. A positive association between wealth and older people's health has repeatedly been found in many countries. For example, a study based on the HRS, ELSA and SHARE indicated a positive association between individual wealth and health [381]. A study based on CHARLS, JSTAR and the Korean Longitudinal Study of Aging also reported that wealth had negative impacts on depression in the three countries [382].

However, in terms of the causality between wealth and health, researchers hold different opinions. For example, a causality test based on the HRS found no evidence of a causal effect from household wealth to the health of either spouse [383]. Another causal study in the US also found that changes in wealth did not lead to health changes among the elderly aged 70 years or more [384]. Deaton has argued that a positive statistical relationship between wealth and life expectancy does not imply causality; the promotion of technical knowledge in medicine and public health may be what has led to the health improvement [385]. Indeed, Anand and Ravallion's cross-country study found that among developing countries, improved public health spending accounted for more variance than poverty alleviation in explaining the increase in life expectancy [386]. Similarly, Schweiger has suggested that providing a universal primary healthcare service is more important than increasing national wealth among developing countries [319]. In the path analysis, the direct effects of wealth on healthy ageing in China were only boundary significant among men and relatively weak among women, indicating that improving primary healthcare and basic living standards in China may be more important than increasing national wealth in order to achieve healthy ageing.

However, Marmot proposes that within a country, socioeconomically disadvantaged groups are less likely to gain benefits from advanced medical and public health services [387]. The editors of the *British Medical Journal* agree with Marmot's view, and even suggest that taking measures to distribute wealth as equally as possible might be the best way to improve health in a society [388]. Baker agrees that socioeconomic inequalities have great impacts on population health within a country, but he also suggests that maximising inputs into public health spending might help to minimise inequalities in health [389].

Developed countries including the US, UK and Japan have spent more than the OECD average level on healthcare expenditures, providing low-cost or free primary healthcare for the population for more than 60 years [342]. In 2011, China also successfully achieved universal health insurance coverage [390]. However, sufficient evidence of health disparities between the rich and poor still exists in the four countries [148, 157, 159, 203, 337]. Despite mixed opinions about the causal effect of wealth on health, reducing wealth inequalities by eliminating poverty among socioeconomically disadvantaged groups could still be an effective way of improving population health in both developing and developed countries.

Income

In terms of income, the path analysis found mixed results across countries. The direct effects of income on healthy ageing were significant among both men and women in the HRS: a higher income was correlated with healthier ageing. In ELSA, among both men and women, the direct effect of income on healthy ageing was also significant, but higher income was correlated with less healthy ageing; the total effect of income on healthy ageing was non-significant. In CHARLS, the direct effect of income was boundary significant among men, but non-significant among women. No significant direct effect of income on healthy ageing was found in JSTAR.

The incomes of participants aged 60 years or older were mainly from pension and social security benefits (see Chapter 2). Opinions vary in previous studies regarding the causal impacts of pension income and social security benefits on health outcomes among older adults. For example, a natural experiment based on the HRS assessed the impacts on mental health of changes in the Social Security Law in 1972, finding that female participants with higher social security benefits tended to have better mental health [391]. However, another natural experiment based on the same policy change in the US found that individuals who had been born in the last half of 1916 and who received more pension benefit had significantly higher mortality rates than those who had been born in the first half of 1917 and received less pension benefit; this was explained by the younger cohort having more part-time work and being less socially isolated [392]. To my knowledge, only limited studies in the UK have explored the causal effects of pension income and social security benefits on health outcomes among the British ageing population. One study used lottery winnings as an exogenous variable to evaluate the causal effect of income on health in the UK, finding that positive income shocks had no significant impact on subjective health, but had a positive effect on mental health among both younger and older adults [393]. In China, a study assessed the impact of China's New Rural Pension Scheme (established in 2009 and expanded to all counties by 2012) on various health outcomes, suggesting that after the scheme was implemented, pension recipients had significant improvements in physical health, cognitive function and psychological well-being [394]. However, especially among older generations, spousal income also positively determined Chinese women's economic well-being [395]. Therefore, Chinese women with lower pension benefits might not be financially constrained or less healthy in later life.

The main empirical challenge in assessing causality from income to health among the elderly is timing. One's current pension income might depend on one's cumulative work history and past income level. Therefore, the correlation between current income and health might be driven by older people's previous salaries. A study based on SHARE reported that for older adults aged 50 years or more, their past income had a permanent effect on their subjective health status in later life [396]. In China, older women's health status might even be determined by their partners' early-life earnings, since women with fewer years of employment and lower earnings receive similar pension benefits to those with more years of employment among older generations [397].

However, information on participants' and spouses' incomes and health in adulthood before they entered the cohort studies was unclear in the four countries. Therefore results might be biased, especially in ELSA and JSTAR, where the effect of income on healthy ageing was negative and non-significant respectively. Further evidence is needed to consider participants' earnings and health at different stages of life and to assess their effects on health in later life.

Occupation

Occupation had a direct effect on healthy ageing only among men in JSTAR. More disadvantaged occupational positions were correlated with less healthy ageing. In Japan, the impact of occupation on health has gradually become a popular research topic since World War II, since Japanese workers have faced a range of occupational hazards due to rapid industrialisation and economic development [398].

However, some findings for the occupational gradient in health outcomes and mortality in Japan have contradicted previous literature. For example, a cohort study among Japanese workers aged 65 or younger found that men in blue-collar jobs had a higher all-cause mortality risk than those in white-collar jobs, but non-managerial women showed a lower cardiovascular mortality risk than managerial women [399]. Another study in Japan also showed that male managers and professionals and female general workers were more susceptible to job stress, but the impacts of occupation on cardiovascular reactivity were non-significant among both men and women [400]. Moreover, a study suggested that female workers in higher positions were at greater risk of poorer psychological health due to their high level of effort-reward imbalance [401]. It seems that Japanese people in more advantaged occupations suffer more from work stress, which might negatively affect their physical and mental health. Some researchers even argue that the increased job demands and more stressful work environments of management and professional workers in Japan may have eliminated or even reversed the occupational inequality in health that existed before [402].

In JSTAR, 1132 of 1935 participants were workers without classifiable occupations, and were recoded as missing in the path analysis. Even though FIML estimation was applied to deal with the missingness, bias in the impact of occupation on healthy ageing caused by limited occupational information might still exist, especially if the missingness is not at random. Further, the direct effects of occupation on healthy ageing in the HRS, ELSA and CHARLS were non-significant. Similarly to JSTAR, a large number of HRS participants (8172 of 10305) had no identifiable occupations, since they had already left the labour market when they entered the cohort study, and their last known occupations were not asked. Further studies based on datasets with less missingness for occupation are needed to explore the causal effect of prior occupation on healthy ageing, and to evaluate whether occupational inequalities in health outcomes, especially in mental disorders, have been reversed among developed countries.

5.6 Limitations

Some limitations of my study must be raised. First, in order for me to conduct the path analysis, unclassifiable occupations in the four countries were recoded as missing. The mediating effect of occupation in the relationship between education and healthy ageing might be less precise because of this. FIML was applied to deal with missing values. Some researchers believe that FIML is superior to multiple imputation, as it correctly estimates the standard errors [403]. The sensitivity analysis confirmed that the results based on incomplete data generated by FIML were comparable with the results based on augmented data using multiple imputation. Recoding unclassifiable occupations might not have significantly affected the main results.

Second, due to the limited socioeconomic and behavioural variables that were used in the path analysis, some unexplained mediating effects might exist in the four countries. For example, as with the longitudinal studies in Chapter 4, some country-specific socioeconomic indicators – such as deprivation scores in ELSA, health insurance in CHARLS, and consumption of food or goods in daily life in JSTAR – were not included in the path analysis. However, they might mediate the effects of education on healthy ageing. Moreover, health behaviours such as physical activity and dietary intake might also be mediators in the relationship between education and healthy ageing, since sufficient evidence in the literature review has demonstrated their close connections with SEP [367, 378] and healthy ageing [73, 131].

Third, regarding the path analysis, the assumptions that relationships are linear and additive, variables are measured without error, and residuals are not correlated with variables in the model are difficult to uphold in social science [404]. Moreover, a small sample (as in JSTAR) might prevent the variance-covariance structure of the sample from matching the variance-covariance structure of the population [404].

Finally, the path analysis is based on observational data, which is not sufficient for a causality inference. In social epidemiology, even though the importance of the social determinants of health has been generally emphasised in many studies, it is still difficult to explore the causality of social influences on health outcomes. One reason is that social factors are often attributes of individuals. Manipulating social factors for humans in an experimental setting is unethical and implausible. For example, in a randomised trial of a social intervention to evaluate the effect of income supplementation, participants in the control group might find ways to supplement their income outside of the randomised programme [405]. Some researchers have applied twin studies to detect social causation, since twin samples have identical genes, and very similar family and environmental backgrounds when they are growing up [379, 406]. Policy interventions are also conducted as natural experiments to find the impacts of social determinants on health. However, at present, publications based on policy interventions in social epidemiology are limited in the literature. The reason is that social epidemiologists have not played a major role in many social interventions conducted by governments and international organisations, such as housing relocation and poverty reduction; little health data have been collected to evaluate social impacts on health outcomes, even though these social changes are likely to have impacts on human health [407].

5.7 Conclusion

In conclusion, education and healthy ageing were linked through partial mediation via complex pathways. Compared with China and Japan, a greater number of pathways from education to healthy ageing were found in the US and England. An effect of education on healthy ageing mediated by a path via wealth and drinking was found in both the US and England. There were still significant and strong direct effects of education on healthy ageing in the US, England and China, indicating that the path analysis did not identify all the mediators in the relationship between education and healthy ageing in the three countries.

Wealth was a partial and gender-invariant mediator in the association between education and healthy ageing in the US, England and China. Future studies could focus more on refining measures of wealth during the lifecourse, such as family inheritance, property income and ownership, the amount of savings in later life, and pension incomes, to identify their mediating effects on the relationship between education and healthy ageing from a lifecourse perspective. The effect of education on healthy ageing was partially mediated by income among men and women in the US, and among women in England. Occupation almost fully mediated the effect of education on healthy ageing among men in Japan, which went against findings from previous studies. Further evidence is needed based on studies with less missing data for occupation. Drinking was a universal and partial mediator among both men and women in the US, and among women in England. However, drinking’s positive effect on healthy ageing was doubtful. Smoking was not a mediator in any of the four countries. More evidence is needed, especially in China and Japan, since the prevalence of smoking in the two countries is high, especially among men.

Chapter 6 Overall Discussion

This PhD project has achieved the goal of comparing socioeconomic impacts on healthy ageing after 60 years in the US, England, China and Japan, based on evidence from four national longitudinal studies of ageing.

A comprehensive literature review of theories, domains and measurements of healthy ageing in epidemiological studies was conducted. Based on this review, the HAI, a multidimensional and quantitative measurement of healthy ageing at the individual level, was developed to measure healthy ageing in a comprehensive way. The reliability and validity of the HAI were also checked to ensure they reached an acceptable level. The longitudinal relationships between SEP and healthy ageing after 60 years of age in the four countries were assessed to compare socioeconomic gradients in healthy ageing, and to identify the most influential socioeconomic indicators of healthy ageing within and across countries. Trajectories of healthy ageing after the age of 60 years by socioeconomic indicators were also predicted in the four countries. Finally, full and partial mediators of the effect of education on healthy ageing were identified in each country.

6.1 Key Findings

6.1.1 Socioeconomic Inequalities in Healthy Ageing

Within Countries

Within countries, results for the longitudinal relationships between SEP and healthy ageing after the age of 60 years suggested that participants in disadvantaged SEPs (with lower levels of education, income and wealth, and in disadvantaged occupational positions) generally had lower levels of healthy ageing than those in advantaged SEPs (with higher levels of education, income and wealth, and in advantaged occupational positions) in each country. Therefore, the first hypothesis was accepted (see Section 1.8).

The analysis for the US found that retirement was not beneficial for achieving healthy ageing in later life. This might be due to early retirement or involuntary retirement caused by health problems. Furthermore, the “left-behind” elderly’s healthy ageing in rural China should be noted. The increasing number of “left-behind” elderly might enlarge the gap in healthy ageing between urban and rural China, due to inequalities in pension income, primary healthcare services, and vulnerability to adverse physical and mental impairments.

Across Countries

I also hypothesised that education was an influential predictor of inequalities in healthy ageing in the US, but not an influential predictor in China (see Section 1.8). The comparative analysis identified education as a universally influential socioeconomic predictor of healthy ageing among the ageing population in the four countries, indicating that this early-life socioeconomic factor can affect individuals' healthy ageing later in the lifecourse. Especially in China, educational inequalities in healthy ageing were evident, and indeed were greater than any other socioeconomic inequalities across countries. Therefore the hypothesis for the US was accepted, but the hypothesis for China was rejected. Although previous studies have not achieved a consensus on the causal effect of education on health, the results of this project support the opinion that education is likely to be an independent predictor of healthy ageing among the ageing population across all countries. The positive effects of improving education on healthy ageing should not be neglected.

Compared with other countries, the socioeconomic inequality in healthy ageing was smaller in Japan. However, the socioeconomic inequality in healthy ageing in China is daunting. Japanese, English and American participants achieved better healthy ageing after the age of 60 years on average than Chinese participants. Therefore, the third hypothesis was accepted (see Section 1.8).

The comparative analysis also indicated that among the high-income countries, compared with participants from Japan and England, participants from the US had worse healthy ageing profiles. Moreover, the socioeconomic inequalities in healthy ageing in England were still larger than in Japan, even though England has been covered by a free national health service.

Furthermore, among the developed countries of the US, England and Japan, wealth was more influential than income in predicting healthy ageing inequalities. In England, the wealth inequality in healthy ageing was greater than in any other country. However, in the developing country of China, wealth was less influential than income in predicting healthy ageing inequalities among the ageing population. Future studies could focus more on refining measures of wealth during the lifecourse, such as family inheritance, property ownership, or the amount of savings in later life. Evidence for the relationship between pension incomes/later-life earnings and healthy ageing is also needed.

6.1.2 Mediation of the Relationship Between Education and Healthy Ageing

For the potential mediation of the relationship between education and healthy ageing, the hypothesis was that socioeconomic factors including occupation, income and wealth, and health behaviours including smoking and drinking, are mediators on the pathway from education to healthy ageing (see Section 1.8). Indeed, the path analysis found that education and healthy ageing were linked through partial mediation via complex pathways in the four countries. However, not all covariates were mediators, and results were diverse across countries. Wealth was a partial and gender-invariant mediator for the association between education and healthy ageing in the US, England and China. Income and drinking were partial and gender-invariant mediators in the US only. Smoking was not a mediator in any of the four countries. Further, a common path via wealth and drinking to healthy ageing was found in the US and England. Therefore, this hypothesis can only be partially accepted.

My path analysis did not identify all the mediators in the relationship between education and healthy ageing. Compared with China and Japan, a greater number of pathways from education to healthy ageing were found in the US and England. More evidence is needed to explore the indirect effect of education on healthy ageing operating through other social and biological factors in the four countries, especially in China and Japan.

6.1.3 Healthy Ageing Profiles

This research predicted trajectories of healthy ageing after the age of 60 years in order to visualise older people's healthy ageing trends in the four countries. With an increase in age, all participants' healthy ageing gradually declined. However, this research found lower levels of healthy ageing in later-born cohorts compared with their earlier-born counterparts at the same age, reflecting a real deterioration in older adults' health over time in the four countries. Participants in the later-born cohorts in this project had been born during the Great Depression and World War II. Adverse social circumstances during that era might have contributed to severe health impairments for the later-born cohorts. More importantly, growing socioeconomic inequalities among younger generations might also have led to worse healthy ageing for those who were socially disadvantaged compared with their older counterparts at the same age.

6.2 Strengths and Limitations

Strengths

This research will contribute to knowledge about the measurement of healthy ageing and the assessment of socioeconomic impacts on healthy ageing in both Western and Asian countries. The main strengths are as follows.

First, even though a consistent definition of healthy ageing has not been achieved in the literature, this research provides sufficient and strong theoretical justifications for developing a robust measurement of healthy ageing. A comprehensive literature review was conducted based on 50 studies of healthy ageing among 23 countries and regions, to summarise the essential theories of healthy ageing and to recommend domains and measures to assess healthy ageing. The well-known theories that define healthy ageing were introduced and discussed, from the biological perspective (healthy biological ageing theory) to the psychosocial (Rowe and Kahn's three standards of successful ageing), social-environmental (the WHO 2012 active ageing model, and the WHO 2015 healthy ageing model) and resilience (Baltes and Baltes's SOC theory). Unlike previous studies, which have mainly referred to one theory for the measurement of healthy ageing, my HAI was developed to include both biological and psychosocial components of healthy ageing, and to consider social opportunities and resilience, thus measuring healthy ageing in a comprehensive way. This HAI may be a useful contribution to help academics worldwide to identify study samples' healthy ageing profiles.

Second, this research has not only assessed socioeconomic inequalities in healthy ageing in each country, but also fills a research gap by comparing socioeconomic inequalities in healthy ageing among Asian, European and North American countries. The US, UK, China and Japan are the four top economies in the world, and they are currently experiencing evident demographic transitions. The four countries need a healthy ageing population to transform the challenges of ageing into productivity, and to permit older people to make contributions to society. The use of four national longitudinal studies of ageing, with around 25000 representative older adults, has provided a unique opportunity to conduct a Western-Asian comparison of healthy ageing, which to my knowledge has never been done before. Information on trajectories of healthy ageing, influential socioeconomic predictors of healthy ageing, and conceptual frameworks for the path from education to healthy ageing in the four countries will be instructive for exploring universal and country-specific public health practices to support healthy ageing in both Western and Asian countries.

Third, the harmonisation of common variables in the four countries was conducted to make results comparable across countries. Harmonising common variables allows the same statistical analyses to be conducted across datasets. More importantly, this research provides strategies to solve challenges in the harmonisation of epidemiological data. One challenge was that there were missing values in the harmonised variables in specific waves. This research applied growth curve models with age, age^2, gender and waves to predict unobserved values of grip strength and self-reported life satisfaction in those waves in ELSA. The variables of the delayed word recall test and an item of ADLs (some difficulty in dressing) in wave 3 of JSTAR were also predicted using mean values of the first two waves. Another challenge is heterogeneity in categories of variables with similar questions and tests across studies. These variables were defined with similar concepts, but they had notable differences in measures and categories. For example, the ranges of CES-D scores were different between the US and England (0–8) and China and Japan (0–30). The approach of converting continuous variables into ordinal categorical variables by organising values into quintiles in each country was applied. Nevertheless, the harmonisation of occupational positions across countries was unachievable, due to the different social and cultural contexts. I explored a potential harmonisation of occupational positions by using information on education and occupational codes to derive skill levels (1–4, the lowest to highest skill levels), making occupational positions comparable across countries. However, the derivation of skill levels in my research is still preliminary (see Table A 20 to Table A 22 for details of the method), since occupational codes in CHARLS and JSTAR were unavailable, and in the HRS and ELSA only semi-masked codes were provided, due to the strong confidentiality of these datasets. But future users from internal survey teams of the HRS and ELSA could apply this approach appropriately.

Finally, advanced statistics were employed appropriately in this research. The two-fold FCS algorithm was applied to deal with missing data in main exposures and covariates. Unlike basic imputation by chain equation modelling, the two-fold FCS algorithm is able to specify an entry and exit time for each participant; automatically consider interactions between age and other variables; and impute non-responding items only, but not non-responders, in each wave. Multilevel modelling was used to assess the longitudinal relationships between SEPs and HAIs. The advantage of applying a multilevel approach is that the methodology is capable of handling attrition and wave non-response, unequal time spacing, and the inclusion of time-varying covariates that are either continuous or discrete measures. Unlike previous studies, which have mainly estimated the SII by using a one-level regression equation without adjustment [263], the SII in this research was calculated based on a multilevel regression equation with full adjustment. Confounding and random effects were taken into account. This multilevel approach allows the prediction of the SII at 60 years and of changing rates of SII after 60 years. A path analysis was employed to test a conceptual framework for a path from education to healthy ageing from a lifecourse perspective, and to explain how covariates mediated the effect of education on healthy ageing in each country. Moreover, the path analysis enabled the decomposition of relationships by showing direct and indirect effects of independent variables on healthy ageing with 95% CIs.

Limitations

Limitations of this research have been discussed in detail in Chapters 3, 4 and 5. In summary, my research has three main limitations in general.

The first main limitation is the difference in sample sizes and follow-up times across countries. There were more than 10000 participants from the US, but fewer than 7000, 6000 and 2000 participants from England, China and Japan respectively. This research included US data from 2004 to 2014 (11 years) and English data from 2002 to 2015 (14 years), while Chinese data were only available from 2011 to 2015 (five years) and Japanese data from 2007 to 2011 (five years). The data from the US and England had stronger statistical power for conducting longitudinal analyses than the data from China and Japan, due to the larger sample sizes and longer follow-up durations. For the longitudinal relationship between SEP and healthy ageing, and the mediating effects in the relationship between education and healthy ageing, the HRS and ELSA samples had a higher probability of avoiding type I and II errors than the CHARLS and JSTAR samples. Results from CHARLS and JSTAR might be unreliable, and some of them might contradict the literature. For example, this research found that the rates of decline in healthy ageing with increased age did not change among Chinese participants, but accelerated among participants from the other countries; and socioeconomic inequalities in healthy ageing among Japanese participants were distinctly smaller than in any other country. Moreover, no significant effect of occupation on healthy ageing was found among Japanese participants; however, occupation almost fully mediated the effect of education on healthy ageing among Japanese male participants, which contradicts the literature.

Another main limitation is the missing data in this research. The baseline response rates in ELSA and JSTAR were less than 70%. In the follow-up waves, the response rates for participants aged more than 60 years gradually decreased. Participants who were older, female, unmarried, from an ethnic minority and socially disadvantaged background, and had unhealthy behaviours were more likely to drop out during the follow-up. Some health indicators such as grip strength, self-reported life satisfaction and participation in social activities contained large numbers of missing values, resulting in fewer participants with valid HAIs in each country. When I conducted the data analyses, participants without valid HAIs at baseline were all excluded. The research also only imputed item non-response for main exposures and covariates in each wave. Missing HAIs and non-responders' information in each wave were not imputed. Moreover, this research excluded individuals aged less than 60 years at baseline. Distributions of some covariates among respondents might be altered and variation in risk factors might also be reduced due to survival selection, as some higher-risk individuals might have been selected out of the population at an earlier age, and survivors might have other environmental and genetic characteristics that prevent or slow down the progression of diseases, leading to biased estimations for the main exposure-outcome associations. Therefore, missing data might cause selection bias: the statistical results in general might underestimate the association between SEP and healthy ageing among older adults aged 60 years or more.

Additionally, unclassifiable information on occupational variables was also a significant issue for my research. For example, in the HRS, occupational information was not available for around 80% of participants at baseline, since they were not in work (i.e. were unemployed, disabled, retired or not in the labour force) when they entered the cohort; in JSTAR, around 59% of participants also had unclassifiable occupations. The occupational inequalities in healthy ageing, as well as the mediating effects of occupation in the relationship between education and healthy ageing, might be quite unreliable in this research due to the large number of unclassifiable occupational positions in these two countries.

The disadvantages of conducting data harmonisation constitute the third main limitation of this research. The same variables across countries must be chosen for data harmonisation, resulting in the exclusion of country-specific main exposures, covariates and health indicators. However, some country-specific socioeconomic factors and covariates – such as Index of Multiple Deprivation scores in England, financial support from children in China, and home ownership in Japan – might explain more variation in socioeconomic inequalities in healthy ageing, and might be identified as mediators in the relationship between education and healthy ageing in specific countries. Similarly, some country-specific health indicators – such as frequency of doctor visits in the US, help with family work in Japan, and caring for grandchildren in China – might be able to capture more characteristics of healthy ageing in different social and cultural contexts. Moreover, disaggregating individual incomes into pension/unearned income and earned income, and total household wealth into property ownership, inheritance, salary accumulation and others, and assessing their respective associations with healthy ageing might be instructive for a more nuanced understanding of income and wealth inequalities in healthy ageing. This may be especially relevant to England and China, since income and wealth inequalities in healthy ageing were non-significant among English and Chinese participants respectively, contradicting the literature.

Moreover, data harmonisation might produce artificial effects on variables, resulting in type I or type II errors in the analysis. For example, continuous income and wealth variables were organised into quintiles in order to be comparable across countries in this research. However, the quintiles were estimated using the current sampling error, which is a variation in the number or representativeness of the responding sample. The current sampling error was estimated from a subset of the population in each country, and might not be representative of the whole ageing population, especially of participants in CHARLS and JSTAR, who had nearly 30% missing data in baseline wealth and income respectively. Another example is that different cut-points in missing health indicators were set across countries in order to retain more than 70% of participants with valid HAIs in each country (e.g. participants whose numbers of missing indicators were ≤ 6 and ≤ 4 were selected to calculate the HAIs in the HRS and ELSA respectively). Different cut-point settings might alter the distribution of healthy ageing among the 70% of participants differently across countries: for example, more unhealthy participants may have been excluded in one country but retained in another country.

Even though the HAI's acceptable validity and reliability have been confirmed, the HAI might not reflect all participants' healthy ageing profiles accurately in the four countries.

6.3 Policy Implications

Although the limitations outlined above might decrease the power of this research, nevertheless its policy implications cannot be denied.

First, this research attempts to shift traditional stereotypes of "old age" by providing convincing theoretical and methodological guidelines for the development of well-suited assessments of healthy ageing in the area of public health. This might be useful for policymakers to capture key elements of healthy ageing when they are developing ageing policies in social, economic and civic affairs, and to optimise opportunities for older people's health, social participation and security.

Ageing should not be equivalent to frailty and disease alone. Older people are able to make crucial contributions to society. For example, in the US, more than 20% of new entrepreneurs were aged 55–64 years in 2011–2012; the number of successful entrepreneurs aged 50 years or older was twice that of successful entrepreneurs under 25 [408]. In Japan, as early as 1976, among people aged 65 or more, 43% of males and 15% of females were still employed; older people who work longer have high levels of life satisfaction in general [409]. The social response should be to see the phenomenon of ageing as an opportunity for personal fulfilment, economic growth and social contribution.

The WHO holds a similar opinion, suggesting that one of the main current challenges for the development of policy on ageing is outdated stereotypes such as the idea that older people are frail, out of touch, burdensome or dependent. These stereotypes have limited the ways that problems are conceptualised and the capacities of policymakers to seize innovative opportunities to solve ageing issues [2]. Rather than steering older people towards predetermined social roles, the achievement of healthy ageing to empower older people to make their own choices should become a new expectation for policymaking.

Second, this research has provided quantitative evidence of socioeconomic inequalities in healthy ageing within and across countries. An improved understanding of the determinants of healthy ageing is an important public health goal. The identification in each country of the most influential socioeconomic predictors of healthy ageing, and of the mediators in the effect of education on healthy ageing, is instructive for exploring universal and country-specific public health practices to support healthy ageing in both Western and Asian countries.

This research has found that education is a universal socioeconomic predictor of healthy ageing in the four countries, indicating that this early-life socioeconomic factor can affect individuals' healthy ageing later in the lifecourse. Educational inequality in earlier life has a critical bearing on status and well-being in old age, since illiteracy and low education usually lead to the exclusion and impoverishment of older people. Opportunities for education and lifelong learning are key factors in the social environment that enhance health, independence and productivity in older age [172]. At the global level, progress in eliminating illiteracy among the general population is evident [410]. However, in China there is still a large proportion of illiterate citizens among older people. The number of illiterate elderly people was 24.6 million in 2015 in China, accounting for around 15% of the world's illiterate elderly; between 1990 and 2015, the number of illiterate elderly people in China declined at only a moderate rate [411]. In my research, educational inequality in healthy ageing among the Chinese ageing population was greater than any other socioeconomic inequality in healthy ageing in the four countries. Policy responses that offer literacy programmes to improve education among children and adults in early life, and that provide opportunities for lifelong learning among the ageing population, might promote the achievement of healthy ageing in later life.

Evident wealth inequalities in healthy ageing were found among the ageing populations in the US, England and Japan, suggesting that health inequality by financial hardship among the elderly currently remains a challenge in developed countries. More societal responses are needed to ensure that poor people are as able to achieve healthy ageing as wealthy people in later life. On the one hand, policy recommendations in terms of maintaining and improving pension schemes for the current ageing population should be considered, especially for the poor elderly, since pensions are vital for providing a decent income in later life [289, 290]. For example, the UK government has simplified the state pension system, implementing a single-tier pension to deliver a simple and fair state pension that provides clarity and confidence to better support saving for retirement [412]. The US government has also broadened the coverage of private pension systems among working-class people by setting up defined contribution plans (where employers voluntarily establish a complementary occupational pension plan for their employees) to encourage private pension savings [413]. On the other hand, from a lifecourse perspective, policy interventions should be conducted to help younger generations accumulate and manage their personal and housing wealth during adulthood, since younger people who have been socioeconomically disadvantaged during their adult lives will be more likely to carry this disadvantage through to old age [133, 134].

This research found no significant wealth inequality in healthy ageing among the Chinese ageing population, but more data on personal wealth need to be collected in China. Results showing a significant income inequality in healthy ageing among the ageing population in China still suggest underlying challenges to the achievement of healthy ageing. Previous evidence has shown the increasing inequality in pension incomes among civil servants, industrial workers and general residents, and great inequality in pension benefits across provinces [314]. One study also indicated great inequality in property incomes among the general population [318]. Although some researchers argue that improving national wealth is not important for a developing country such as China, and that China should focus more on basic living needs [319], policy reforms in China still need to pay attention to resolving the huge benefits gaps by different levels of wealth and income, since people in socioeconomically disadvantaged groups are less likely to receive benefits even for basic living needs [387].

This research found that labour force non-participation (e.g. retirement or disability) had negative effects on healthy ageing in the US. Previous evidence has shown that early retirement [296] or involuntary retirement through illness [292, 293] might have adverse effects on health outcomes in later life. Therefore, societal responses in the US could focus more on protecting and improving benefits for persons with disadvantaged patterns of labour force non-participation, such as early retirees, or retirees with illness or disability. Especially nowadays, countries including the US, UK, China and Japan are all raising the state pension age to encourage old-age labour market participation, due to the decline of the replacement rate. Older people who are unable to continue to work in later age (e.g. workers with manual or physically demanding jobs) may be more socioeconomically disadvantaged compared with their healthy counterparts, since they will have no later-life earnings from work, and will receive a lower state pension due to early retirement. Policies to raise the state pension age in every country should consider disparities in occupations, life expectancy and social class among the ageing population. Moreover, reasonable adjustments in the workplace for people with disabilities or health conditions might encourage and maintain the labour force participation of disabled people and decrease the rate of unemployment due to disability, which may be beneficial for disabled people to maximise their healthy ageing in later life [414].

The health conditions of the "left-behind" elderly in rural China also need to be noted. This research found a low level of healthy ageing among this group. Government evidence has shown that in 2015, 23.3% of the elderly in rural China were categorised as "left-behind" elderly [328]. The increasing number of "left-behind" elderly might enlarge the gap in healthy ageing between rural and urban China. Improvements to the healthcare infrastructure and social support for this socially disadvantaged group in rural areas are needed to decrease inequalities in pension income, primary healthcare services, and vulnerability to adverse physical and mental impairments within the ageing population.

In summary, this research provides sufficient theoretical justifications and quantitative evidence for policymaking in relation to the issue of socioeconomic inequalities in healthy ageing in the US, England, China and Japan. The achievement of healthy ageing in both Western and Asian countries will require cooperation among different sectors. Societal responses should support intergenerational solidarity and include specific targets to reduce socioeconomic inequities among different subgroups within the ageing population. Additionally, particular attention needs to be paid to older people who are poor and marginalised, such as disabled older workers, and the "left-behind" elderly who live in deprived areas.

6.4 Future Directions for Research

This research has implications for several future directions in relation to healthy ageing.

First, in terms of measuring healthy ageing, this research does not claim to have established a "correct" measure of healthy ageing, but seeks to encourage other researchers to focus more on theoretical justifications when measuring healthy ageing, thereby creating rigorous approaches to measure healthy ageing from both biological and social perspectives.

Further improvements to the HAI are needed. For example, some country-specific indicators might be included to improve the index. In order to compare healthy ageing across countries, this research only selected health indicators which were available for the four countries. However, some country-specific indicators – such as frequency of doctor visits in the HRS, help with household work in JSTAR, or caring for grandchildren in CHARLS – might be able to capture more characteristics of healthy ageing in different social and cultural contexts. The literature review conducted in this thesis also found that previous studies' abilities to distinguish inequalities in healthy ageing among different healthy ageing models were similar, implying that the development of a single worldwide metric of healthy ageing may be unnecessary.

Another improvement could be to apply a weighted calculation of HAI, thus improving the robustness of this measure. This research calculated the HAI by summing all health scores and then dividing the total score by the number of indicators. This might not provide interpretable information about health for participants with intermediate HAI scores, since an intermediate score could have been obtained in many ways. For example, some participants attained higher scores on physical capabilities but lower scores on psychological well-being, while others did the opposite. Therefore, understanding the relationships between health indicators and observations is very important, since participants with the same HAIs might fall into different clustering groups. Currently, researchers in the field of machine learning are working on visualising a series of variables in a dataset in order to discover unknown subgroups across different variables; this is known as unsupervised learning [415]. In this setting, researchers could try to cluster participants based on health indicators, in order to identify distinct groups of participants. For example, participants might be clustered with respect to good physical capabilities but adverse mental health. Then the hierarchical clustering algorithm would rank all the health indicators for each clustering group on the basis of the pairwise inter-cluster dissimilarities. Eventually a weighted calculation of HAI could be achieved based on the coefficients for ranking. This advanced technique could be applied appropriately in the future to measure healthy ageing multidimensionally and precisely in epidemiological studies by visualising observations with measurements on a set of features.

Second, the current analysis has not identified all the mediators in the relationship between education and healthy ageing. Future studies could test the indirect effect of education on healthy ageing operating through other socioeconomic and behavioural factors. For example, country-specific measures of SEP – such as Index of Multiple

Deprivation scores in ELSA, financial support from children in CHARLS, and home ownership in JSTAR – and health behavioural measures such as dietary intake and physical exercise could be considered, as they are important social determinants of healthy ageing in the literature. Moreover, more evidence is needed on the mediating effects of occupation in Japan, and the mediating effects of smoking and drinking especially in Japan and China. Future studies could also use more refined measures of wealth during the lifecourse, such as family inheritance, property ownership or the amount of savings in later life, to identify their specific mediating effects on the pathway from education to healthy ageing from a lifecourse perspective. Moreover, in my analysis, income inequality in healthy ageing was non-significant among English participants, and the mediating effects of income in the relationship between education and healthy ageing were mixed across countries. The robustness of the income measure needs to be improved. Income could be split into salary income and pension income. More evidence is needed on the effect of pension incomes or later-life earnings on healthy ageing. Currently, many countries including the US, UK, China and Japan are raising or planning to raise the state pension age. Inequalities in later-life earnings and pension income might grow if governments raise the state pension age without considering disparities in occupation, life expectancy and social class among the ageing population, which might contribute to great inequalities in healthy ageing.

Third, a comparison of inequalities in healthy ageing could be conducted on other dimensions. For example, future studies could further explore disparities in healthy ageing across generations. This research only visualised healthy ageing by predicting trajectories of healthy ageing with the increase of age. However, healthy ageing trajectories over different generations might clearly identify the cohort effects on changes in older adults' health. Additionally, comparing healthy ageing by skill levels across countries might potentially become a substitute for comparing healthy ageing by occupation. Providing specific occupational codes and educational information for each observation to derive the participant's skill level is necessary. However, it might be inapplicable in many longitudinal studies of ageing, due to the strong confidentiality of the data. Data users outside the survey teams might not be able to access specific occupational codes.

Last, the underlying relationships between healthy ageing and mortality could be explored across different countries in future studies. Questions could be answered such as whether older people with healthier ageing are more likely to experience mortality events later than those with less healthy ageing; which components of healthy ageing mainly protect the elderly from experiencing mortality events earlier across different countries; and how many years of healthy ageing the ageing population might achieve during longevity in each country, especially among women and people who are socially disadvantaged.

6.5 Conclusion

In conclusion, Japanese and English participants achieved healthier ageing than American and Chinese participants. A positive socioeconomic gradient in healthy ageing existed in all countries. Socioeconomic inequality in healthy ageing was relatively small in Japan. In China, inequality in healthy ageing, especially by education, is daunting.

Education was a universally influential socioeconomic predictor of healthy ageing, and is likely to be an independent predictor of healthy ageing among the ageing population across all countries. There were complex pathways from education to healthy ageing in the four countries. The positive effects of improving education on healthy ageing should not be neglected.

Wealth inequality in healthy ageing was greater in England than in any other country. Wealth was more influential than income in predicting inequalities in healthy ageing in the US, England and Japan, while income was more influential than wealth in China.

Labour force non-participation (e.g. retirement or disability) had negative effects on healthy ageing in the US. Chinese people in paid and stable work were healthier than those in unpaid farming work in later life. Particular attention needs to be paid to older people who are poor and marginalised, such as disabled older workers, early retirees and the "left-behind" elderly who live in deprived areas.

This project provides sufficient theoretical and methodological guidelines for the development of well-suited assessments of healthy ageing in the field of public health. These guidelines will be useful for policymakers to capture key elements of healthy ageing when they are developing ageing policies in social, economic and civic affairs, and optimising opportunities for older people's health, social participation and security. This project has also provided a unique opportunity to conduct a multinational comparison of socioeconomic impacts on healthy ageing between Western and Asian countries that has never done before. The identification of the most influential socioeconomic indicators of healthy ageing in each country is instructive for exploring universal and country-specific public health practices to support healthy ageing. To promote the achievement of healthy ageing, a series of societal responses is needed, such as providing opportunities for lifelong learning among the ageing population, encouraging pension savings among the poor elderly and working-class employees, considering disparities in occupation, life expectancy and social class among the ageing population when raising the state pension age, and improving the healthcare infrastructure and social support for the “left-behind” elderly.

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Appendices

Table A 1 Outline of Established Scales

Dimensions	Methods	Outline
Physical capabilities	Basic Activities of Daily Livings	Evaluates individuals' basic functioning, including self-care tasks, such as walking, dressing, bathing, eating, getting in or out of bed, and using the toilet [416].
	Instrumental Activities of Daily Livings	Evaluates individuals' capability to live independently in a community, including more advanced-level skills in all performance areas, such as using a telephone or computer, managing money, cooking, shopping and taking medication [416].
	WHO Global Physical Activity Questionnaire	A standardised tool to measure physical activity that enables comparisons across culturally diverse populations, collecting information on physical activity in three domains: employment, transport and discretionary time [417].
	WHO Disability Assessment Schedule version II	A generic assessment instrument for health and disability which covers six domains: cognition, mobility, self-care, getting along, life activities and participation [418].
	Office of Population Censuses and Surveys Disability Scales	Thirteen scales that can be summed to give disability dimension scores and a total score. The thirteen scales include items covering locomotor, reaching and stretching, dexterity, personal care, continence, seeing, hearing, communication, behaviour, intellectual function, consciousness, eating/drinking/digestion and disfigurement. [419].
Psychological well-being	Centre for Epidemiological Studies-Depression Scale	A self-reported depression scale for the general population, designed for measuring depressed mood, psychological symptoms, well-being and social desirability, which has become the workhorse of depression epidemiology since the 1970s [113].
	Geriatric Depressive Screening Scale	Thirty items for measuring depressive symptoms, specially designed for rating depression among the elderly, and used extensively in community, acute and long-term care settings since the 1980s [114].
	9-item Patient Health Questionnaire	A nine-item depression module from the full questionnaire to make criteria-based diagnoses of depressive disorders and grade the severity of depressive symptoms [420].
	World Mental Health Survey Initiative version of the WHO Composite International Diagnostic Interview	A screening module developed by WHO to detect mental disorders among the general population, including forty sections that focus on diagnoses, functioning, treatment, risk factors, socio-demographic correlates and methodological factors [421].
	Hospital Anxiety and Depression Scale	A self-reported scale for detecting depression and anxiety in the setting of an hospital medical outpatients clinic [422].
	Life Satisfaction Inventory	A self-reported questionnaire which tests general feelings of well-being among older people to identify "successful ageing", measuring five components of life satisfaction: zest, resolution and fortitude, congruence between desired and achieved goals, positive self-concept, and mood tone [423].

Dimensions	Methods	Outline
	WHO Quality of Life	A multidimensional instrument to measure quality of life in psychological and physical health, social relationships and the environment [424].
	Flanagan Quality of Life Scale	A fifteen-item instrument that measures five conceptual domains of quality of life: material and physical well-being, relationships with other people, social, community and civic activities, personal development and fulfilment, and recreation [425].
	General Health Questionnaire	A screening instrument for common mental disorders, which has frequently been used in busy clinical settings, as well in settings where patients need help to complete the questionnaire. It includes items such as anxiety and depression, social dysfunction and loss of confidence [426].
	Satisfaction with Life Scale	A self-reported scale designed for an overall judgement of individuals' life satisfaction [115].
	Kessler Psychological Distress Scale	A (ten- or six-question) screening scale of psychological distress for the redesigned US National Health Interview Survey, including items such as depressed mood, anhedonia, eating, sleeping, motor agitation, motor retardation, fatigue, worthless guilt, concentration, death, anxiety, worry, motor tension, hypersensitivity, vigilance and positive affect [427].
	Connor-Davidson Resilience Scale	A self-reported scale comprised of twenty-five items to measure resilience – an individual's ability to thrive despite adversity [428].
	University of California Loneliness Scale	A self-reported twenty-item scale to measure current loneliness and related emotional states [429].
	Tenacious Goal Pursuit and Flexible Goal Adjustment Scales	Self-reported instruments to assess individuals' dispositional tendency to use assimilative and accommodative coping strategies, regularly used in ageing research [430].
	Environmental Mastery Scale	An instrument to test whether an individual has a sense of mastery and competence in managing their environment, controls a complex array of external activities, makes efficient use of surrounding opportunities, or can choose or create a context suitable for their personal needs and values [431].
	Positive and Negative Affect Schedule	Two ten-item mood scales. Descriptors such as attentive, interested, alert, excited, enthusiastic, inspired, proud, determined, strong and active are included in the Positive Affect Scale; distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty, nervous and jittery are included in the Negative Affect Scale [432].
	Life Orientation Test-Revised	A revised version of LOT containing twelve items to measure optimism versus pessimism, four worded positively, four worded negatively and four fillers [433].
	Purpose in Life Test	An instrument designed to assess perceived meaning and life purpose, including items such as enthusiasm, excitement in living, presence of clear life goals, life being meaningful, newness of each day, wishing for more lives, activity after retirement, life goal completion, good things in life, life lived having been worthwhile, and more [434].
Cognitive functions	Mini Mental State Examination	A tool to measure cognitive impairment, consisting of seven categories: orientation to time, orientation to place, registration of three words, attention and calculation, recall of three words, language and visual construction [107].

Dimensions	Methods	Outline
	Wechsler Adult Intelligence Scale-Revised	A general test of intelligence, consisting of six verbal subtests (information, comprehension, arithmetic, digit span, similarities and vocabulary) and five performance subtests (picture arrangement, picture completion, block design, object assembly, digit symbol) [435].
	Montreal Cognitive Assessment Scale	A tool to screen patients who present with mild cognitive complaints and usually perform in the normal range on MMSE. It consists of eleven categories: orientation, drawing figures, processing speed, naming objects, memory, recall, attention, vigilance, repetition, verbal fluency and abstraction [436].
	Modified Telephone Interview for Cognitive Status	A modified version of TICS to assess cognitive status based on a telephone interview screening, which is modelled after MMSE and composed of orientation, memory, simple attention, working memory, and verbal episodic memory [437].
	Canadian Community Health Survey-Healthy Ageing Cognition Module	A module that includes four cognitive tests: immediate and delayed word recall, animal-naming and the Mental Alternation Test (a simple and practical cognitive assessment tool which involves the timed performance of a sequencing and category switching task [438]) [65].
	Japanese cognitive impairment standards	An instrument that assesses functional decline or cognitive impairment, and makes a screening judgement based on the opinions of a regular doctor [84].
	Alice Heim 4 Test of General Intelligence	A test to measure fluid intelligence, composed of sixty-five verbal and mathematical reasoning items of increasing difficulty [439].
	Subjective Cognitive Failures Questionnaire	A questionnaire measuring self-reported failures in perception, memory and motor function [440].
Social well-being	Lubben Social Network Scale	An instrument to assess social integration and screen for social isolation among older adults, including family and friend networks and interdependent social supports [441].
	Classic Circle-diagram	An instrument comprising three differently sized circles that individuals use to differentiate the importance of their social networks: circle one includes persons to whom one feels closest emotionally, while circle three includes persons to whom one feels least close, but who are important for other reasons [442].
	De Jong-Gierveld Loneliness Scale	A unidimensional loneliness scale, consisting of emotional and social subscales including items such as severe deprivation, abandonment, missing companionship, sociability and meaningful relationships [443].
	Oslo 3 Support Scale	A short questionnaire with questions about the number of close confidants, the sense of concern or interest from other people, and relationships with neighbours [444].
Nutritional intake	The Mediterranean Diet Score	A diet questionnaire that asks questions about the frequency of consumption (servings per month) in eleven food categories, including non-refined cereals, potatoes, fruits, vegetables, legumes, fish, red meat and products, poultry, and full-fat dairy products [445].
	Short Form Health Survey	A multipurpose short-form health survey with thirty-six questions, including both physical and mental health summary measures, as opposed to surveys that target a specific age, disease or treatment group. Sections are vitality, physical functioning, body pain, general health perceptions, physical role functioning, emotional role functioning, social role functioning and mental health [446].

Table A 2 A list of original and harmonised categories of variables

Variables	Original categories	Harmonised categories
Common variables		
Income in the last calendar year	Amount ($, £, CN¥ or JP¥)	0. Highest
		1. Higher
		2. Middle
		3. Lower
		4. Lowest
Wealth in the last calendar year	Amount ($, £, CN¥ or JP¥)	0. Highest
		1. Higher
		2. Middle
		3. Lower
		4. Lowest
Age	60 years or above	60 years or above
Gender	0. Male	0. Male
	1. Female	1. Female
Smoking status	0. Never smoke	0. Never smoke
	1. Ever smoke, now no smoke	1. Ever smoke, now no smoke
	2. Smoke	2. Smoke
HRS (2004-2014)		
Education	0. Law/M.D./Ph.D.	0. First-stage tertiary education or more
	1. Master of Arts or MBA	
	2. Bachelor of Arts (B.A.)	
	3. Associate of Arts (A.A.) or less than A.A.	
	4. High School Diploma (H.S.)or GED Award	1. Upper secondary education
	5. H.S. Diploma	
	6. General Educational Development (GED) Award	
	7. No Degree (between 7 and 13 years)	2. Lower secondary education
	8. No Degree (less than 7 years)	3. Primary education or less

	9. Others	. Two participants only, recoded as missingness
Occupation	0. Managerial specialty operators	0. Managerial and professional specialty occupation
	1. Professional specialty opera. /technical sup.	
	2. Sales	1. Technical, sales and administrative support
	3. Clerical/administration support	
	4. Service: private household/ clean/bldg.	2. Service occupations
	5. Service: protection	
	6. Service: food preparation	
	7. Health service	
	8. Personal service	
	9. Farming/forestry/fishing	3. Farming, forestry and fishing occupations
	10. Mechanics/repair	4. Precision production, craft, and repair occupations
	11. Construct trade/extractors	
	12. Precision production	
	13. Operators: machine	5. Operators, fabricators and labours
	14. Operators: transport, etc	
	15. Operators: handlers, etc	
	16. Member of armed forces	6. Others
	7. Retired	7. Retired
	8. Unemployed	8. Unemployed
	9. Disabled	9. Disabled
	10. Not in the labour force	10. Not in the labour force
Ethnicity	0. White/Caucasian	0. White/Caucasian
	1. Black/African American	1. Black/African American
	2. Others	2. Others
Marital status	0. Married	0. Married or partnered
	1. Partnered	
	2. Separated	1. Separated, divorced, single, etc
	3. Divorced	

	4. Married, spouse absent	
	5. Never married	
	6. Widowed	2. Widowed
Days of drinking per week	0. 0 days	0 days
	1. 1 days	1 days
	2. 2 days	2 days
	3. 3 days	3 days
	4. 4 days	4 days
	5. 5 days	5 days
	6. 6 days	6 days
	7. 7 days	7 days
Self-rated health in childhood	0. Excellent	0. Excellent
	1. Very good	1. Very good
	2. Good	2. Good
	3. Fair	3. Fair
	4. Poor	4. Poor
Father's occupation	0. Managerial and professional specialty occupation	0. Managerial and professional specialty occupation
	1. Technical, sales and administrative support	1. Technical, sales and administrative support
	2. Service occupations	2. Service occupations
	3. Farming, forestry and fishing occupations	3. Farming, forestry and fishing occupations
	4. Precision production, craft, and repair occupations	4. Precision production, craft, and repair occupations
	5. Operators, fabricators and labours	5. Operators, fabricators and labours
	6. Unclassifiable	6. Unclassifiable
ELSA (2002-2015)		
Education	0. NVQ4/NVQ5/Degree or equivalent	0. First-stage tertiary education or more
	1. Higher education below degree	1. Post-secondary non-tertiary education
	2. NVQ3/GCE A level equivalent	2. Upper secondary education
	3. NVQ2/GCE O level equivalent	3. Lower secondary education
	4. NVQ1/CSE other grade equivalent	

	5. Foreign/other	4. Others
	6. No qualification	5. Primary education or less
Occupation	0. Higher managerial occupations	0. Higher managerial and professional employers
	1. Higher professional occupations	
	2. Lower professional & higher technical occupations	1. Lower managerial and professional employers
	3. Lower managerial occupations	
	4. Intermediate	2. Intermediate employees
	5. Employers in small organisations	3. Small employers and own account workers
	6. Own account workers	
	7. Lower supervisory occupations	4. Lower supervisory, craft and related employees
	8. Lower technical occupations	
	9. Semi-routine occupations	5. Employees in semi-routine occupations
	10. Routine occupations	6. Employees in routine occupations
	11. Never worked	7. Never worked
Ethnicity	0. White	0. White
	1. Non-white	1. Non-white
Marital status	0. Married	0. Married or partnered
	1. Partnered	
	2. Separated	1. Separated, divorced, single, etc
	3.Divorced	
	4.Never married	
	5.Widowed	2. Widowed
Days of drinking per week	0. 0 days	0 days
	1. 1 days	1 days
	2. 2 days	2 days
	3. 3 days	3 days
	4. 4 days	4 days
	5. 5 days	5 days
	6. 6 days	6 days

	7. 7 days	7 days
Self-rated health in childhood	0. Excellent	0. Excellent
	1. Very good	1. Very good
	2. Good	2. Good
	3. Fair	3. Fair
	4. Poor	4. Poor
Father's occupation	0. Professional or technical	0. Professional or technical
	1. Manager or senior official	1. Manager, senior official, admin, cleric or secretarial
	2. Administrative, clerical or secretarial	
	3. Running his own business	2. Own business, or skilled trade
	4. Skilled trade	
	5. Caring, leisure, travel or personal service	3. Service-skilled non-manual
	6. Sales or customer service	
	7. Plant process or machine drivers or operation	4. Service-skilled manual
	8. Armed forces	5. Others
	9. Other jobs	
	10. Something else	
	11. Casual jobs	
	12. Retired	6. Retired
	13. Unemployed	7. Unemployed, sick or disabled
	14. Sick/disabled	
CHARLS (2011-2015)		
Education	0. Master's degree	0. First-stage tertiary education or more
	1. 4 years college/Bachelor's degree	
	2. 2/3 years college/Associate degree	
	3. Vocational school	1. Post-secondary non-tertiary education
	4. High school	2. Upper secondary education
	5. Middle school	3. Lower secondary education
	6. Elementary school	

	7. Sishu	4. Primary education or less
	8. Did not finish primary school but capable of reading	
	9. No formal education illiterate	
Occupation	Employed - Officials/managers/leaders or Clerks/paid workers	0. Officials/managers/leaders or Clerks/paid workers
	Self-employed workers	1. Self-employed workers
	Unpaid family business	2. Unpaid family business
	Employed – others	3. Others
	No paid/self-employed work, no unpaid family business, only doing household agricultural work	4. Only agricultural work (no paid jobs, self-employed activities or unpaid family business work)
Ethnicity	0. Han	0. Han
	1. Minorities	1. Minorities
Marital status	0. Married	0. Married or partnered
	1. Partnered	
	2. Separated	1. Separated, divorced, single, etc
	3. Divorced	
	4. Never married	
	5. Widowed	2. Widowed
Days of drinking per week	0. None	0. None
	1. Once per month	1. One to several times per month
	2. 2-3 days per month	
	3. Once per week	2. One to several times per week
	4. 2-3 days per week	
	5. 4-6 days per week	3. Most days of the week
	6. Daily	4. Once/twice/more than twice per day
	7. Twice per day	
	8. More than twice per day	
Self-rated health in childhood	0. Excellent	0. Excellent
	1. Very good	1. Very good

	2. Good	2. Good
	3. Fair	3. Fair
	4. Poor	4. Poor
Father's occupation	0. Manager	0. Manager
	1. Professional and technician	1. Professional and technician
	2. Clerk	2. Clerk
	3. Commercial and service worker	3. Commercial and service worker
	4. Agricultural, forestry, husbandry and others	4. Agricultural, forestry, husbandry and others
	5. Production and transportation workers	5. Production and transportation workers
	6. Cannot be specified	6. Others
JSTAR (2006-2011)		
Education	0. Graduate school (Ph.D.)	0. First-stage tertiary education or more
	1. Graduate school (MA)	
	2. University	
	3. Junior college	
	4. Vocational school	1. Post-secondary non tertiary education
	5. High school	2. Upper secondary education
	6. Elementary/middle school	3. Lower secondary education
	7. Less than elementary/middle school	4. Primary education or less
Occupation	0. Specialist and technical workers	0. Highest
	1. Administrative and managerial workers	
	2. Clerical workers	1. Intermediate
	3. Sales workers	
	4. Security workers	
	5. Service workers	2. Lowest
	6. Agriculture, forestry and fishery workers	
	7. Transport and communication workers	
	8. Production process and related workers	
	9. Workers not classifiable by occupation	3. Others

	10. Not working*	4. Unclassifiable
Ethnicity	-	-
Marital status	0. Married	0. Married or partnered
	1. Divorced	1. Separated, divorced, single, etc
	2. Never married	
	4. Widowed	2. Widowed
Frequency of drinking	0. Not at all	0. None
	1. A few times in month	1. A few times in month
	2. 1-2 in a week	2. 1-2 in a week
	3. 3-4 in a week	3. 3-4 in a week
	4. 5-6 in a week	4. 5-6 in a week
	5. Every day	5. Every day
Self-rated health in childhood	-	-
Father's occupation	0. Employed (including public employee)	0. Employed (including public employee)
	1. Executive of company or organization	
	2. Self-employed (including self-employed farmer)	1. Self-employed (including self-employed farmer)
	3. Assisted a self-employed person	2. Others
	4. Worked at home	
	5. Other (specify)	
	6. Did not work	3. No work (including father passed away when participants was 15 years)
	7. Not applicable (already passed away when respondent was	

* Information on labour force status among these participants are not available in the dataset.

Figure A 1 The distribution of HAI at each wave in each study

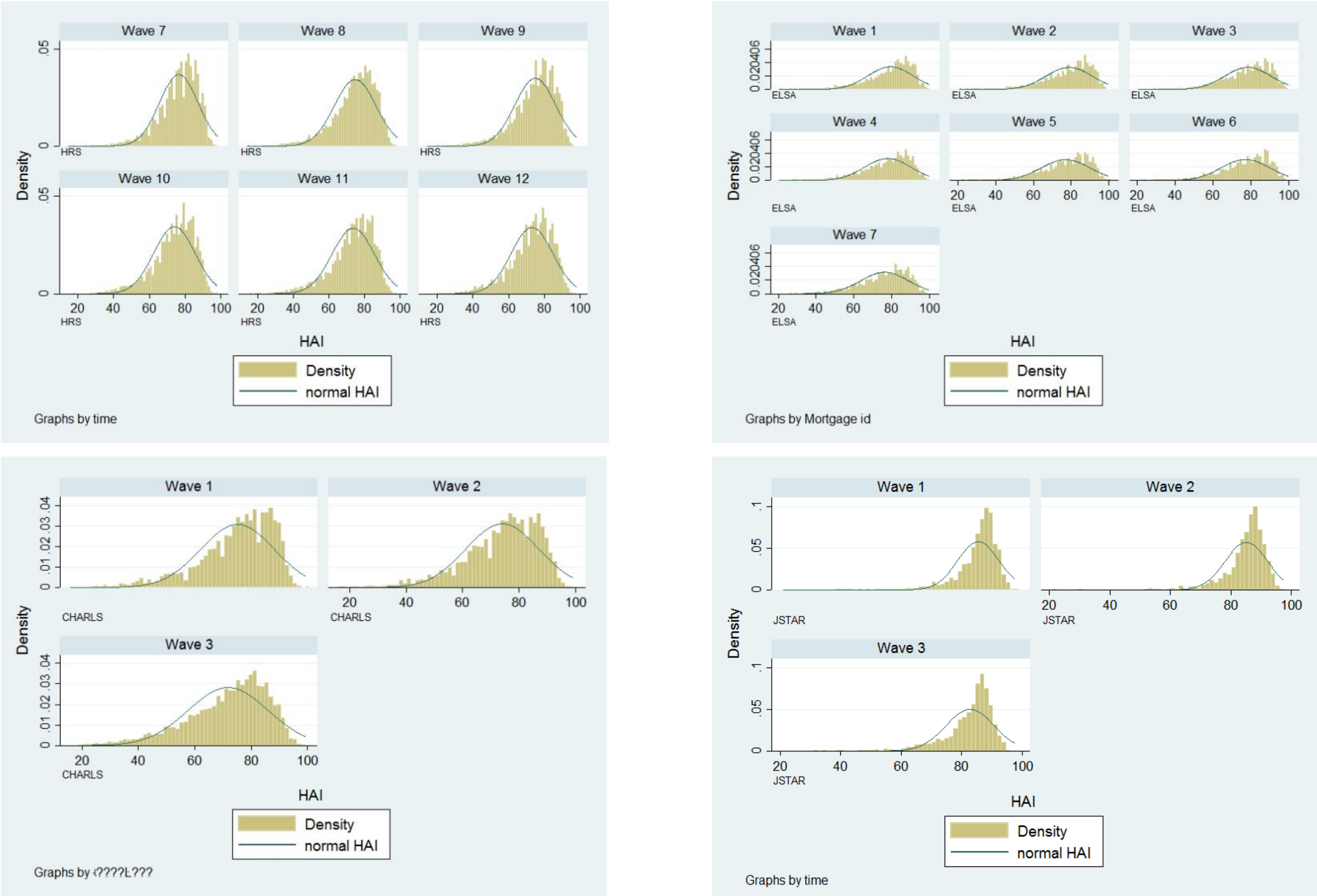

Table A 3 Baseline characteristics for complete case analyses by country

Variables	HRS (N=8281)	ELSA (N=3456)	CHARLS (N=1039)	JSTAR (N=1209)
HAI (Mean)	76.75	81.27	77.18	86.11
Age (Mean)	74	70	66	67
Gender (%)				
Male	43.03	44.56	63.91	51.28
Female	56.97	55.44	36.09	48.72
Ethnicity* (%)				
1	87.26	98.78	94.32	-
2	10.11	1.22	5.68	-
3	2.63			-
Education (%)				
First stage of tertiary or more	22.12	11.78	0.10	10.84
Post-secondary non-tertiary	-	13.14	1.15	5.29
Upper secondary education	53.99	5.06	1.25	39.29
Lower secondary education	17.51	20.72	40.52	43.92
Primary education or less	6.38	38.22	56.98	0.66
Others	-	11.08	-	-
Income (%)				
Highest	18.96	24.31	8.57	19.11
2nd	20.63	21.47	17.04	21.26
3rd	21.58	20.08	26.76	20.76
4th	20.83	18.32	27.24	19.85
Lowest	18.01	15.83	20.40	19.02
Wealth (%)				
Highest	21.64	24.48	9.91	19.27
2nd	21.29	21.90	17.61	20.26
3rd	20.76	21.15	24.64	17.95
4th	19.08	17.85	27.62	24.57
Lowest	17.23	14.61	20.21	17.95
Occupation (%)**				
1	6.48	9.20	2.89	7.36
2	6.05	23.09	3.75	12.74
3	3.48	14.84	0.87	24.32
4	0.99	10.47	0.67	-
5	1.57	11.66	91.82	55.58
6	2.26	16.87	-	-
7	0.01	13.86	-	-
8	67.52	-	-	-
9	0.59	-	-	-
10	0.98	-	-	-
11	10.07	-	-	-
Marital status (%)				
Married or partnered-Ref.	61.03	64.70	79.40	83.95
Separated, divorced or single	11.36	12.33	3.27	4.63
Widowed	27.61	22.97	17.32	11.41
Father's occupation* (%)**				
1	13.39	10.85	3.95	28.95
2	11.25	10.88	1.92	52.36
3	4.41	35.01	1.15	2.81
4	27.86	4.40	1.92	15.88
5	21.47	8.56	86.04	-
6	20.84	26.85	2.12	-
7	0.77	0.87	2.89	-
8	-	2.58	-	-
Self-rated health in childhood (%)				
Excellent	49.99	29.77	9.34	-
Very good	25.96	34.92	33.88	-

Variables	HRS (N=8281)	ELSA (N=3456)	CHARLS (N=1039)	JSTAR (N=1209)
Good	18.29	22.54	27.14	-
Fair	4.42	8.83	23.29	-
Poor	1.33	3.94	6.35	-
Smoking status (%)				
Never smoke	42.31	37.21	47.64	55.25
Ever smoked, now no smoke	47.58	49.86	11.55	27.38
Smoke	10.11	12.93	40.81	17.37
Frequency of drinking[****] (%)				
0	69.56	32.44	71.90	42.60
1	8.73	17.59	4.72	11.25
2	4.38	12.09	3.85	5.62
3	4.05	7.96	1.83	17.37
4	2.14	4.98	17.71	23.16
5	1.88	3.65	-	-
6	1.06	3.33	-	-
7	8.20	17.97	-	-

[*] In HRS, 1=White/Caucasian 2=Black/African American 3=Others; In ELSA, 1=White 2=Non-white; In CHARLS, 1=Han 2=Minorities; No ethnicity variable in JSTAR

[**] In HRS, 1=Managerial and professional sociality occupation 2=Technical, sales and administrative support 3=Service occupations 4=Farming, forestry and fishing occupations 5=Precision production, craft and repair 6=Operators, fabricators and labours 7=Others 8=Retired 9=Unemployed 10=Disabled 11=Not in the labour force; In ELSA, 1=Higher managerial and professional employers 2=Lower managerial and professional employers 3=Intermediate employees 4=Small employers and own account workers 5=Lower supervisory, craft and related employees 6=Employees in semi-routine occupations 7=Employees in routine occupations 8=Never worked; In CHARLS, 1=Officials/managers/leaders or Clerks/paid workers 2=Self-employed workers 3=Unpaid family business 4=Others 5=Only agricultural work; In JSTAR, 1=Highest 2=Intermediate 3=Lowest 4=Others 5=Unclassifiable
[***] In HRS, 1=Managerial and professional speciality occupation 2=Technical, sales and administrative support 3=Services occupation 4=Farming, forestry and fishing occupations 5=Precision productions, craft and repair occupations 6=Operators, fabricators and labours 7=Unclassifiable; In ELSA, 1=Professional or technical 2=Manager, senior official, admin., cleric or secretarial 3=Own business, or skilled trade 4=Service-skilled non-manual 5=Service-skilled manual 6=Others 7=Retired 8=Unemployed, sick or disabled; In CHARLS, 1=Manager 2=Professional and technician 3=Clerk 4=Commercial and service worker 5=Agricultural, forestry, husbandry and others 6=Production and transportation workers 7=Others; In JSTAR, 1=Employed (including public employee), 2=Self-employed (including self-employed farmer) 3= Others 4= No work (including father passed away when participants was 15 years)
[****] In HRS and ELSA, frequency of drinking = days of drinking per week (0=None 1=1 day 2=2 days 3=3 days 4=4 days 5=5 days 6=6 days 7=7 days); In CHARLS, frequency of drinking= times of drinking per month (0=non or less than once per month 1=one to several times per month 2=one to several times per week 3=most days of the week 4=every day of the week; In JSTAR, frequency of drinking= times of drinking per month (1=None 2=A few times in month 3=1-2 in a week 4=3-4 in a week 5=5-6 in a week 5=Every day)

Table A 4 Results of fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in HRS

	Imputed case analysis (N=10305)		Complete case analysis (N=8281)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.013 (-0.014 to -0.012)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.00009 (-0.0002 to -0.00001)	0.029	-0.0001 (-0.0002 to -0.00001)	0.023
Cohort	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.008 to -0.007)	<0.001
Cohort^2	0.0006 (0.0006 to 0.0007)	<0.001	0.0006 (0.0006 to 0.0007)	<0.001
Education				
First-stage tertiary education or more -Ref.				
Upper secondary education	-0.024 (-0.034 to -0.015)	<0.001	-0.022 (-0.032 to -0.012)	<0.001
Lower secondary education	-0.053 (-0.066 to -0.041)	<0.001	-0.049 (-0.063 to -0.036)	<0.001
Primary education or less	-0.064 (-0.081 to -0.048)	<0.001	-0.054 (-0.072 to -0.036)	<0.001
Education*age				
Upper secondary education	-0.001 (-0.002 to -0.0003)	0.007	-0.001 (-0.001 to 0.000)	0.052
Lower secondary education	-0.002 (-0.003 to -0.0007)	<0.001	-0.001 (-0.002 to 0.000)	0.005
Primary education or less	-0.004 (-0.006 to -0.003)	<0.001	-0.004 (-0.006 to -0.003)	<0.001
Intercept	4.414 (4.402 to 4.427)	<0.001	4.421 (4.408 to 4.435)	<0.001
Random effects				
Level 1: residual	0.081 (0.080 to 0.081)	-	0.006 (0.006 to 0.006)	-
Level 2: intercept	0.447 (0.416 to 0.477)	-	0.017 (0.016 to 0.017)	-
Level 2: age	0.132 (0.130 to 0.134)	-	0.00009 (0.00008 to 0.00009)	-

Table A 5 Results of fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in HRS

	Imputed case analysis (N=10305)		Complete case analysis (N=8281)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.012 (-0.014 to -0.011)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.00009 (-0.0002 to -0.00001)	0.029	-0.0001 (-0.0002 to -0.00001)	0.024
Cohort	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
Cohort^2	0.0006 (0.0006 to 0.0007)	<0.001	0.0006 (0.0006 to 0.0007)	<0.001
Income				
Ref- Highest				
2nd	-0.004 (-0.008 to 0.0005)	0.084	-0.003 (-0.007 to 0.002)	0.249
3rd	-0.004 (-0.009 to 0.0006)	0.087	-0.005 (-0.010 to 0.001)	0.083
4th	-0.010 (-0.016 to -0.005)	<0.001	-0.009 (-0.015 to -0.003)	0.002
Lowest	-0.012 (-0.019 to -0.005)	0.001	-0.013 (-0.020 to -0.005)	0.001
Income*age				
2nd	0.0002 (-0.0003 to 0.0006)	0.467	0.0002 (-0.0003 to 0.0007)	0.429
3rd	0.0006 (0.0002 to 0.001)	0.010	0.001 (0.000 to 0.001)	0.050
4th	0.0004 (-0.0001 to 0.0009)	0.161	0.0003 (-0.0003 to 0.001)	0.301
Lowest	0.0007 (0.0001 to 0.001)	0.020	0.001 (-0.0001 to 0.001)	0.111
Intercept	4.418 (4.406 to 4.430)	<0.001	4.425 (4.412 to 4.438)	<0.001
Random effects				
Level 1: residual	0.081 (0.080 to 0.081)	-	0.006 (0.006 to 0.006)	-
Level 2: intercept	0.132 (0.130 to 0.134)	-	0.017 (0.016 to 0.017)	-
Level 2: age	0.010 (0.010 to 0.010)	-	0.00009 (0.00008 to 0.0001)	-

Table A 6 Results of fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in HRS

	Imputed case analysis (N=10305)		Complete case analysis (N=8281)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.013 (-0.014 to -0.011)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.0001 (-0.0002 to -0.00001)	0.032	-0.0001 (-0.0002 to -0.00001)	0.024
Cohort	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
Cohort^2	0.0006 (0.0006 to 0.0007)	<0.001	0.0006 (0.0005 to 0.0007)	<0.001
Wealth				
Ref- Highest				
2nd	-0.001 (-0.006 to 0.004)	0.693	-0.002 (-0.007 to 0.004)	0.531
3rd	-0.009 (-0.015 to -0.002)	0.006	-0.010 (-0.016 to -0.003)	0.005
4th	-0.018 (-0.025 to -0.011)	<0.001	-0.022 (-0.029 to -0.014)	<0.001
Lowest	-0.028 (-0.037 to -0.020)	<0.001	-0.036 (-0.045 to -0.027)	<0.001
Wealth*age				
2nd	0.000 (0.000 to 0.000)	0.959	0.000 (-0.001 to 0.000)	0.458
3rd	0.000 (0.000 to 0.001)	0.269	0.000 (0.000 to 0.001)	0.695
4th	0.000 (-0.001 to 0.001)	0.866	0.000 (-0.001 to 0.001)	0.867
Lowest	0.000 (-0.001 to 0.000)	0.159	-0.001 (-0.001 to 0.000)	0.033
Intercept	4.414 (4.402 to 4.426)	<0.001	4.415 (4.402 to 4.428)	<0.001
Random effects				
Level 1: residual	0.081 (0.080 to 0.081)	-	0.006 (0.006 to 0.006)	-
Level 2: intercept	0.132 (0.130 to 0.134)	-	0.017 (0.016 to 0.017)	-
Level 2: age	0.010 (0.010 to 0.010)	-	0.00009 (0.00008 to 0.0001)	-

Table A 7 Results of fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in HRS

	Imputed case analysis (N=10305)		Complete case analysis (N=8281)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.013 (-0.014 to -0.011)	<0.001	-0.012 (-0.014 to -0.011)	<0.001
Age^2	-0.0001 (-0.0002 to -0.00001)	0.029	-0.0001 (-0.0002 to -0.00001)	0.024
Cohort	-0.008 (-0.009 to -0.007)	<0.001	-0.008 (-0.009 to -0.007)	<0.001
Cohort^2	0.0006 (0.0006 to 0.0007)	<0.001	0.0006 (0.0005 to 0.0007)	<0.001
Occupation				
Ref- Managerial and professional speciality				
Technical, sales and administrative support	0.004 (-0.011 to 0.020)	0.600	0.007 (-0.009 to 0.024)	0.392
Service occupations	0.022 (0.003 to 0.041)	0.022	0.031 (0.010 to 0.052)	0.004
Farming, forestry and fishing occupations	0.001 (-0.020 to 0.021)	0.951	-0.004 (-0.025 to 0.018)	0.743
Precision production, craft, and repair occupations	0.014 (-0.006 to 0.033)	0.176	0.017 (-0.004 to 0.039)	0.106
Operators, fabricators and labours	0.002 (-0.015 to 0.019)	0.825	0.001 (-0.018 to 0.020)	0.939
Others	0.002 (-0.009 to 0.013)	0.704	-0.003 (-0.015 to 0.009)	0.617
Retired	-0.017 (-0.027 to -0.007)	0.001	-0.019 (-0.030 to -0.008)	<0.001
Unemployed	-0.001 (-0.020 to 0.017)	0.872	-0.002 (-0.022 to 0.019)	0.871
Disabled	-0.046 (-0.069 to -0.024)	<0.001	-0.033 (-0.058 to -0.008)	0.010
Not in the labour force	0.025 (-0.003 to 0.054)	0.084	0.029 (-0.003 to 0.061)	0.072
Occupation*age				
Technical, sales and administrative support	0.001 (0.000 to 0.003)	0.128	0.001 (0.000 to 0.003)	0.163
Service occupations	0.002 (0.000 to 0.004)	0.029	0.002 (0.000 to 0.004)	0.018
Farming, forestry and fishing occupations	-0.001 (-0.003 to 0.002)	0.693	-0.001 (-0.004 to 0.002)	0.613
Precision production, craft, and repair occupations	0.001 (-0.002 to 0.003)	0.662	0.000 (-0.002 to 0.003)	0.798
Operators, fabricators and labours	0.001 (-0.001 to 0.003)	0.210	0.001 (-0.001 to 0.003)	0.387
Others	0.001 (0.000 to 0.003)	0.021	0.002 (0.000 to 0.003)	0.033
Retired	0.001 (0.000 to 0.002)	0.180	0.001 (-0.001 to 0.002)	0.268
Unemployed	0.001 (-0.001 to 0.004)	0.279	0.001 (-0.002 to 0.004)	0.439

Disabled	0.002 (0.001 to 0.004)	0.004	0.003 (0.001 to 0.005)	0.004
Not in the labour force	0.001 (0.000 to 0.002)	0.092	0.001 (0.000 to 0.002)	0.138
Intercept	4.413 (4.400 to 4.426)	<0.001	4.413 (4.399 to 4.427)	<0.001
Random effects				
Level 1: residual	0.081 (0.080 to 0.081)	-	0.006 (0.006 to 0.006)	-
Level 2: intercept	0.132 (0.130 to 0.134)	-	0.017 (0.016 to 0.017)	-
Level 2: age	0.010 (0.009 to 0.010)	-	0.00009 (0.00008 to 0.0001)	-

Table A 8 Results of fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in ELSA

	Imputed case analysis (N=6590)		Complete case analysis (N=3456)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.009 (-0.010 to -0.007)	<0.001	-0.007 (-0.008 to -0.005)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.003)	<0.001	-0.003 (-0.004 to -0.002)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0002 (0.00002 to 0.00003)	0.027
Education				
Ref – First-stage tertiary education or more				
Post-secondary non-tertiary education	-0.001 (-0.022 to 0.020)	0.914	-0.002 (-0.025 to 0.021)	0.843
Upper secondary education	-0.013 (-0.040 to 0.014)	0.357	-0.017 (-0.048 to 0.015)	0.298
Lower secondary education	-0.017 (-0.036 to 0.002)	0.087	-0.015 (-0.037 to 0.007)	0.177
Primary education or less	-0.059 (-0.077 to -0.040)	<0.001	-0.050 (-0.071 to -0.028)	<0.001
Others	-0.012 (-0.037 to 0.014)	0.377	-0.004 (-0.034 to 0.026)	0.780
Education*age				
Post-secondary non-tertiary education	0.000 (-0.001 to 0.002)	0.623	0.001 (-0.001 to 0.003)	0.242
Upper secondary education	0.000 (-0.002 to 0.002)	0.831	-0.0005 (-0.003 to 0.002)	0.652
Lower secondary education	0.001 (-0.001 to 0.002)	0.290	0.0006 (-0.0009 to 0.002)	0.391
Primary education or less	0.000 (-0.002 to 0.001)	0.652	0.000 (-0.001 to 0.002)	0.537
Others	0.001 (-0.001 to 0.002)	0.346	0.001 (-0.001 to 0.003)	0.318
Intercept	4.466 (4.447 to 4.486)	<0.001	4.494 (4.472 to 4.516)	<0.001
Random effects				
Level 1: residual	0.076 (0.075 to 0.077)	-	0.004 (0.004 to 0.005)	-
Level 2: intercept	0.138 (0.135 to 0.141)	-	0.015 (0.015 to 0.016)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.000 (0.000 to 0.000)	-

Table A 9 Results of fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in ELSA

	Imputed case analysis (N=6590)		Complete case analysis (N=3456)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.009 (-0.010 to -0.007)	<0.001	-0.007 (-0.008 to -0.005)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.003)	<0.001	-0.003 (-0.004 to -0.002)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0002 (0.00002 to 0.0003)	0.024
Income				
Ref- Highest				
2nd	-0.003 (-0.009 to 0.002)	0.251	-0.003 (-0.010 to 0.003)	0.331
3rd	-0.003 (-0.010 to 0.004)	0.383	-0.004 (-0.012 to 0.003)	0.278
4th	0.001 (-0.007 to 0.008)	0.879	-0.004 (-0.013 to 0.004)	0.324
Lowest	0.003 (-0.005 to 0.011)	0.421	0.001 (-0.009 to 0.011)	0.822
Income*age				
2nd	0.000 (0.000 to 0.001)	0.444	0.000 (0.000 to 0.001)	0.621
3rd	0.001 (0.000 to 0.002)	0.002	0.001 (0.000 to 0.001)	0.468
4th	0.001 (0.000 to 0.001)	0.080	0.000 (-0.001 to 0.001)	0.746
Lowest	0.001 (0.000 to 0.001)	0.107	0.001 (0.000 to 0.002)	0.019
Intercept	4.465 (4.447 to 4.483)	<0.001	4.495 (4.474 to 4.516)	<0.001
Random effects				
Level 1: residual	0.076 (0.075 to 0.077)	-	0.004 (0.004 to 0.005)	-
Level 2: intercept	0.138 (0.135 to 0.141)	-	0.015 (0.015 to 0.016)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.000 (0.000 to 0.000)	-

Table A 10 Results of fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in ELSA

	Imputed case analysis (N=6590)		Complete case analysis (N=3456)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.009 (-0.010 to -0.007)	<0.001	-0.007 (-0.008 to -0.005)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.003)	<0.001	-0.003 (-0.004 to -0.002)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0002 (0.00002 to 0.0003)	0.026
Wealth				
Ref- Highest				
2nd	-0.011 (-0.018 to -0.004)	0.001	-0.006 (-0.013 to 0.002)	0.136
3rd	-0.018 (-0.026 to -0.010)	<0.001	-0.015 (-0.024 to -0.006)	<0.001
4th	-0.034 (-0.043 to -0.025)	<0.001	-0.032 (-0.043 to -0.022)	<0.001
Lowest	-0.055 (-0.067 to -0.044)	<0.001	-0.048 (-0.062 to -0.034)	<0.001
Wealth*age				
2nd	-0.001 (-0.001 to 0.000)	0.066	-0.001 (-0.002 to 0.000)	0.018
3rd	-0.001 (-0.001 to 0.000)	0.046	-0.001 (-0.002 to 0.000)	0.047
4th	-0.001 (-0.001 to 0.000)	0.087	-0.001 (-0.002 to -0.0002)	0.013
Lowest	-0.001 (-0.002 to 0.000)	0.198	-0.001 (-0.002 to 0.0002)	0.099
Intercept	4.466 (4.448 to 4.484)	<0.001	4.494 (4.473 to 4.515)	<0.001
Random effects				
Level 1: residual	0.076 (0.075 to 0.077)	-	0.004 (0.004 to 0.005)	-
Level 2: intercept	0.138 (0.135 to 0.141)	-	0.015 (0.015 to 0.016)	-
Level 2: age	0.009 (0.008 to 0.009)	-	0.000 (0.000 to 0.000)	-

Table A 11 Results of fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in ELSA

	Imputed case analysis (N=6590)		Complete case analysis (N=3456)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.009 (-0.010 to -0.007)	<0.001	-0.007 (-0.008 to -0.005)	<0.001
Age^2	-0.0003 (-0.0004 to -0.0002)	<0.001	-0.0003 (-0.0004 to -0.0002)	<0.001
Cohort	-0.003 (-0.004 to -0.003)	<0.001	-0.003 (-0.004 to -0.002)	<0.001
Cohort^2	0.0003 (0.0002 to 0.0004)	<0.001	0.0002 (0.00002 to 0.0003)	0.025
Occupation				
Ref- Higher managerial and professional employers				
Lower managerial and professional employers	-0.009 (-0.021 to 0.003)	0.156	-0.006 (-0.024 to 0.011)	0.467
Intermediate employees	-0.011 (-0.029 to 0.008)	0.267	-0.005 (-0.030 to 0.019)	0.665
Small employers and own account workers	-0.015 (-0.030 to 0.000)	0.047	-0.005 (-0.024 to 0.014)	0.619
Lower supervisory, craft and related employees	-0.021 (-0.036 to -0.005)	0.009	-0.014 (-0.034 to 0.007)	0.192
Employees in semi-routine occupations	-0.013 (-0.029 to 0.004)	0.131	-0.008 (-0.029 to 0.013)	0.459
Employees in routine occupations	-0.036 (-0.052 to -0.019)	<0.001	-0.016 (-0.037 to 0.006)	0.153
Never worked	-0.026 (-0.074 to 0.022)	0.286	-0.034 (-0.128 to 0.061)	0.487
Occupation*age				
Lower managerial and professional employers	0.000 (-0.001 to 0.001)	0.965	0.000 (-0.002 to 0.001)	0.914
Intermediate employees	-0.001 (-0.002 to 0.001)	0.330	-0.001 (-0.002 to 0.001)	0.384
Small employers and own account workers	0.000 (-0.002 to 0.001)	0.708	-0.001 (-0.002 to 0.001)	0.796
Lower supervisory, craft and related employees	-0.001 (-0.002 to 0.001)	0.520	-0..0005 (-0.002 to 0.001)	0.564
Employees in semi-routine occupations	0.000 (-0.001 to 0.001)	0.956	-0.0004 (-0.002 to 0.001)	0.683
Employees in routine occupations	-0.001 (-0.002 to 0.001)	0.454	-0.001 (-0.003 to 0.001)	0.242
Never worked	-0.002 (-0.005 to 0.001)	0.294	-0.002 (-0.006 to 0.002)	0.450
Intercept	4.463 (4.444 to 4.481)	<0.001	4.492 (4.470 to 4.513)	<0.001
Random effects				
Level 1: residual	0.076 (0.075 to 0.077)	-	0.004 (0.004 to 0.005)	-
Level 2: intercept	0.138 (0.135 to 0.141)	-	0.015 (0.015 to 0.016)	-

Level 2: age	0.009 (0.008 to 0.009)	-	0.000 (0.000 to 0.000)	-

Table A 12 Results of fully adjusted linear multilevel models for associations between education and HAI (log$_e$-transformed) in CHARLS

	Imputed case analysis (N=5930)		Complete case analysis (N=1039)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.013 (-0.039 to 0.013)	0.328	-0.014 (-0.088 to 0.060)	0.718
Age^2	0.000 (0.000 to 0.001)	0.278	0.00002 (-0.001 to 0.001)	0.996
Cohort	-0.008 (-0.010 to -0.006)	<0.001	-0.009 (-0.015 to -0.003)	0.004
Cohort^2	0.0008 (0.0004 to 0.001)	<0.001	-0.0002 (-0.001 to 0.001)	0.786
Education				
Ref – First-stage tertiary education or more				
Post-secondary non-tertiary education	-0.008 (-0.052 to 0.037)	0.738	0.075 (-0.313 to 0.463)	0.706
Upper secondary education	-0.007 (-0.057 to 0.043)	0.782	0.058 (-0.344 to 0.460)	0.778
Lower secondary education	-0.046 (-0.083 to -0.009)	0.014	0.038 (-0.344 to 0.419)	0.846
Primary education or less	-0.108 (-0.146 to -0.071)	<0.001	0.003 (-0.379 to 0.385)	0.988
Education*age				
Post-secondary non-tertiary education	-0.002 (-0.008 to 0.004)	0.480	0.002 (-0.072 to 0.077)	0.955
Upper secondary education	0.000 (-0.006 to 0.007)	0.887	0.010 (-0.066 to 0.087)	0.795
Lower secondary education	-0.001 (-0.006 to 0.004)	0.651	0.008 (-0.066 to 0.081)	0.835
Primary education or less	-0.003 (-0.007 to 0.002)	0.296	0.008 (-0.066 to 0.081)	0.840
Intercept	4.416 (4.280 to 4.551)	<0.001	4.439 (4.050 to 4.829)	<0.001
Random effects				
Level 1: residual	0.116 (0.114 to 0.118)	-	0.011 (0.010 to 0.013)	-
Level 2: intercept	0.153 (0.149 to 0.158)	-	0.014 (0.012 to 0.016)	-
Level 2: age	0.005 (0.003 to 0.008)	-	0.000 (0.000 to 0.000)	-

Table A 13 Results of fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in CHARLS

	Imputed case analysis (N=5930)		**Complete case analysis (N=1039)**	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.013 (-0.039 to 0.013)	0.334	-0.014 (-0.087 to 0.060)	0.719
Age^2	0.000 (0.000 to 0.001)	0.278	0.000 (-0.001 to 0.001)	0.972
Cohort	-0.008 (-0.010 to -0.006)_	<0.001	-0.009 (-0.015 to -0.003)	0.004
Cohort^2	0.0008 (0.0004 to 0.001)	<0.001	0.000 (-0.001 to 0.001)	0.760
Income				
Ref- Highest				
2nd	-0.006 (-0.019 to 0.006)	0.332	-0.012 (-0.053 to 0.030)	0.584
3rd	-0.008 (-0.021 to 0.005)	0.214	-0.015 (-0.055 to 0.025)	0.468
4th	-0.018 (-0.032 to -0.005)	0.006	-0.026 (-0.067 to 0.015)	0.219
Lowest	-0.025 (-0.039 to -0.011)	<0.001	-0.036 (-0.079 to 0.007)	0.102
Income*age				
2nd	0.000 (-0.002 to 0.002)	0.956	-0.003 (-0.009 to 0.002)	0.253
3rd	0.000 (-0.002 to 0.002)	0.828	-0.004 (-0.009 to 0.002)	0.193
4th	0.001 (-0.001 to 0.002)	0.429	-0.002 (-0.007 to 0.004)	0.513
Lowest	0.000 (-0.002 to 0.001)	0.659	-0.005 (-0.010 to 0.001)	0.115
Intercept	4.422 (4.288 to 4.556)	<0.001	4.446 (4.057 to 4.835)	<0.001
Random effects				
Level 1: residual	0.116 (0.114 to 0.118)	-	0.011 (0.010 to 0.013)	-
Level 2: intercept	0.153 (0.149 to 0.158)	-	0.014 (0.012 to 0.016)	-
Level 2: age	0.005 (0.003 to 0.008)	-	0.000 (0.000 to 0.000)	-

Table A 14 Results of fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in CHARLS

	Imputed case analysis (N=5930)		Complete case analysis (N=1039)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.013 (-0.039 to 0.013)	0.328	-0.012 (-0.086 to 0.062)	0.747
Age^2	0.000 (0.000 to 0.001)	0.296	0.000 (-0.001 to 0.001)	0.967
Cohort	-0.008 (-0.010 to -0.006)	<0.001	-0.009 (-0.015 to -0.003)	0.004
Cohort^2	0.0008 (0.0004 to 0.001)	<0.001	0.000 (-0.001 to 0.001)	0.738
Wealth				
Ref- Highest				
2nd	0.001 (-0.011 to 0.013)	0.906	-0.030 (-0.071 to 0.011)	0.148
3rd	0.002 (-0.010 to 0.014)	0.773	-0.049 (-0.089 to -0.009)	0.017
4th	-0.005 (-0.017 to 0.007)	0.415	-0.043 (-0.083 to -0.003)	0.034
Lowest	-0.005 (-0.019 to 0.010)	0.524	-0.059 (-0.101 to -0.018)	0.005
Wealth*age				
2nd	-0.001 (-0.003 to 0.000)	0.166	0.003 (-0.003 to 0.008)	0.335
3rd	0.000 (-0.002 to 0.002)	0.897	0.000 (-0.006 to 0.005)	0.852
4th	0.000 (-0.002 to 0.002)	0.830	0.000 (-0.005 to 0.006)	0.870
Lowest	-0.001 (-0.003 to 0.002)	0.601	0.003 (-0.002 to 0.008)	0.284
Intercept	4.423 (4.288 to 4.557)	<0.001	4.455 (4.065 to 4.846)	<0.001
Random effects				
Level 1: residual	0.116 (0.114 to 0.118)	-	0.011 (0.010 to 0.013)	-
Level 2: intercept	0.153 (0.149 to 0.158)	-	0.014 (0.012 to 0.016)	-
Level 2: age	0.005 (0.003 to 0.008)	-	0.000 (0.000 to 0.000)	-

Table A 15 Results of fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in CHARLS

	Imputed case analysis (N=5930)		Complete case analysis (N=1039)	
	b (95%CIs)	**P-values**	**b (95%CIs)**	**P-values**
Fixed effects				
Age	-0.008 (-0.015 to -0.002)	0.014	-0.014 (-0.088 to 0.060)	0.711
Age^2	0.000 (0.000 to 0.001)	0.285	0.000 (-0.001 to 0.001)	0.973
Cohort	-0.008 (-0.010 to -0.006)	<0.001	-0.009 (-0.015 to -0.003)	0.003
Cohort^2	0.0008 (0.0004 to 0.001)	<0.001	0.000 (-0.001 to 0.001)	0.763
Occupation				
Ref- Officials/managers/leaders or clerks/paid workers				
Self-employed workers	-0.019 (-0.056 to 0.017)	0.306	-0.054 (-0.139 to 0.030)	0.204
Unpaid family business	-0.031 (-0.065 to 0.003)	0.077	0.047 (-0.076 to 0.170)	0.452
Others	-0.036 (-0.066 to -0.007)	0.014	0.029 (-0.065 to 0.123)	0.547
Only agricultural work	-0.029 (-0.057 to -0.001)	0.043	-0.032 (-0.101 to 0.037)	0.367
Occupation*age				
Self-employed workers	-0.001 (-0.007 to 0.005)	0.788	-0.003 (-0.016 to 0.010)	0.630
Unpaid family business	-0.002 (-0.007 to 0.004)	0.574	0.007 (-0.007 to 0.022)	0.335
Others	-0.002 (-0.007 to 0.003)	0.370	0.001 (-0.013 to 0.015)	0.931
Only agricultural work	-0.003 (-0.007 to 0.002)	0.283	0.001 (-0.009 to 0.011)	0.852
Intercept	4.446 (4.399 to 4.492)	<0.001	4.438 (4.047 to 4.829)	<0.001
Random effects				
Level 1: residual	0.116 (0.114 to 0.118)	-	0.011 (0.010 to 0.012)	-
Level 2: intercept	0.153 (0.149 to 0.158)	-	0.014 (0.012 to 0.016)	-
Level 2: age	0.005 (0.004 to 0.008)	-	0.000 (0.000 to 0.000)	-

Table A 16 Results of fully adjusted linear multilevel models for associations between education and HAI (log_e-transformed) in JSTAR

	Complete case analysis (N=1209)	
	b (95%CIs)	**P-values**
Fixed effects		
Age	0.001 (-0.005 to 0.006)	0.806
Age^2	-0.003 (-0.004 to -0.002)	<0.001
Cohort	0.0001 (-0.003 to 0.003)	0.973
Cohort^2	-0.003 (-0.004 to -0.001)	<0.001
Education		
Ref – First-stage tertiary education or more		
Post-secondary non-tertiary education	-0.042 (-0.082 to -0.001)	0.043
Upper secondary education	-0.019 (-0.039 to 0.001)	0.056
Lower secondary education	-0.045 (-0.064 to -0.025)	<0.001
Primary education or less	-0.018 (-0.093 to 0.057)	0.643
Education*age		
Post-secondary non-tertiary education	0.003 (-0.003 to 0.008)	0.293
Upper secondary education	-0.001 (-0.004 to 0.002)	0.614
Lower secondary education	-0.001 (-0.004 to 0.003)	0.656
Primary education or less	-0.008 (-0.022 to 0.005)	0.209
Intercept	4.496 (4.470 to 4.523)	<0.001
Random effects		
Level 1: residual	0.052 (0.049 to 0.055)	-
Level 2: intercept	0.069 (0.065 to 0.074)	-
Level 2: age	0.003 (0.001 to 0.011)	-

Table A 17 Results of fully adjusted linear multilevel models for associations between income and HAI (log_e-transformed) in JSTAR

	Complete case analysis (N=1209)	
	b (95%CIs)	**P-values**
Fixed effects		
Age	0.000 (-0.006 to 0.006)	0.943
Age^2	-0.003 (-0.004 to -0.002)	<0.001
Cohort	-0.0001 (-0.003 to 0.003)	0.975
Cohort^2	-0.003 (-0.004 to -0.001)	<0.001
Income		
Ref- Highest		
2nd	-0.005 (-0.020 to 0.009)	0.465
3rd	-0.015 (-0.030 to 0.001)	0.058
4th	-0.013 (-0.028 to 0.002)	0.098
Lowest	-0.031 (-0.048 to -0.013)	0.001
Income*age		
2nd	0.001 (-0.001 to 0.003)	0.435
3rd	0.002 (0.000 to 0.005)	0.047
4th	0.001 (-0.001 to 0.004)	0.216
Lowest	0.003 (0.000 to 0.006)	0.032
Intercept	4.498 (4.472 to 4.524)	<0.001
Random effects		
Level 1: residual	0.052 (0.049 to 0.055)	-
Level 2: intercept	0.070 (0.066 to 0.074)	-
Level 2: age	0.003 (0.001 to 0.011)	-

Table A 18 Results of fully adjusted linear multilevel models for associations between wealth and HAI (log_e-transformed) in JSTAR

	Complete case analysis (N=1209)	
	b (95%CIs)	**P-values**
Fixed effects		
Age	-0.006 (-0.008 to -0.003)	<0.001
Age^2	-0.001 (-0.002 to -0.001)	<0.001
Cohort	-0.0001 (-0.003 to 0.003)	0.951
Cohort^2	-0.003 (-0.004 to -0.001)	<0.001
Wealth		
Ref- Highest		
2nd	-0.001 (-0.008 to 0.007)	0.827
3rd	-0.002 (-0.010 to 0.006)	0.686
4th	-0.011 (-0.018 to -0.003)	0.008
Lowest	-0.014 (-0.023 to -0.006)	0.001
Wealth*age		
2nd	0.000 (-0.001 to 0.002)	0.710
3rd	0.001 (-0.001 to 0.002)	0.506
4th	0.001 (-0.001 to 0.003)	0.503
Lowest	0.002 (0.000 to 0.004)	0.081
Intercept	4.448 (4.440 to 4.456)	<0.001
Random effects		
Level 1: residual	0.050 (0.048 to 0.052)	-
Level 2: intercept	0.080 (0.077 to 0.084)	-
Level 2: age	0.008 (0.007 to 0.010)	-

Table A 19 Results of fully adjusted linear multilevel models for associations between occupation and HAI (log_e-transformed) in JSTAR

	Complete case analysis (N=1209)	
	b (95%CIs)	**P-values**
Fixed effects		
Age	0.001 (-0.005 to 0.007)	0.786
Age^2	-0.003 (-0.004 to -0.002)	<0.001
Cohort	0.0001 (-0.003 to 0.003)	0.948
Cohort^2	-0.003 (-0.004 to -0.001)	<0.001
Occupation		
Ref- Highest		
Intermediate	-0.004 (-0.026 to 0.019)	0.747
Lowest	0.005 (-0.015 to 0.026)	0.620
Others	-0.031 (-0.130 to 0.067)	0.534
Unclassifiable	-0.030 (-0.050 to -0.010)	0.004
Occupation*age		
Intermediate	-0.002 (-0.006 to 0.002)	0.369
Lowest	-0.001 (-0.005 to 0.003)	0.770
Others	-0.012 (-0.038 to 0.014)	0.365
Unclassifiable	-0.002 (-0.006 to 0.002)	0.256
Intercept	4.495 (4.469 to 4.522)	<0.001
Random effects		
Level 1: residual	0.052 (0.049 to 0.055)	-
Level 2: intercept	0.069 (0.065 to 0.074)	-
Level 2: age	0.003 (0.001 to 0.011)	-

Table A 20 An approach to deriving skill level by ISCED-97 and 1980 U.S. Census Occupation in HRS*

1980 U. S. Census Occupation	Major Group Codes	ISCED-97				
		PO	LO	UP	FI (Bachelor degree)	FI (Master degree or above)
1. Managerial speciality operation	1, 2, 3, 5	Skill 2	Skill 2	Skill 2	Skill 3	Skill 4
2. Professional specialty operation and technical support	1, 2, 3, 4, 6	Skill 2	Skill 2	Skill 2	Skill 3	Skill 4
3. Sales (representatives, cashier)	2, 3, 5, 7, 9	Skill 1	Skill 2	Skill 2	Skill 3	Skill 4
4. Clerical, administrative support (administration, receptionist)	1, 2, 3, 4, 9	Skill 1	Skill 2	Skill 2	Skill 3	Skill 4
5. Service: private household, cleaning and building services	3, 5, 7, 8, 9	Skill 1	Skill 2	Skill 2	Skill 3	Skill 3
6. Service: protection (policer officers, detective, firefighters)	5, 8	Skill 2	Skill 2	Skill 2	Skill 2	Skill 2
7. Service: food prep (supervisors, cooks, kitchen assistant, waitress)	3, 5, 7, 9	Skill 1	Skill 2	Skill 2	Skill 3	Skill 3
8. Health service (dental assistant., health aids, nursing aids)	2, 3	Skill 3	Skill 3	Skill 3	Skill 3	Skill 4
9. Personal service (supervisors, hairdresser, cleaner, pest control)	2, 3, 5, 7, 9	Skill 1	Skill 2	Skill 2	Skill 3	Skill 4
10.Farming, forestry and fishing (manager, workers)	2, 3, 6, 7	Skill 2	Skill 2	Skill 2	Skill 3	Skill 4
11. Mechanics and repair (supervisors, workers)	7	Skill 2	Skill 2	Skill 2	Skill 2	Skill 2
12. Construction trade and extractors (supervisors, workers)	7, 8, 3	Skill 2	Skill 2	Skill 2	Skill 3	Skill 3
13. Precision production (supervisors, workers)	3, 7, 8, 9	Skill 1	Skill 2	Skill 2	Skill 3	Skill 3
14. Operators machine, etc (workers)	3, 7, 8	Skill 2	Skill 2	Skill 2	Skill 3	Skill 3
15. Operators: transport, etc (supervisors and workers)	3, 4, 5, 7	Skill 1	Skill 2	Skill 2	Skill 3	Skill 3
16. Operators: handlers, etc (supervisors and helpers)	8, 9	Skill 1	Skill 2	Skill 2	Skill 2	Skill 2
17: Member of armed forces	7, 9	Skill 1	Skill 2	Skill 2	Skill 4	Skill 4

* The 1980 U.S. Census Occupation Codes were transferred to ISCO-88 version (*http://www.camsis.stir.ac.uk/occunits/distribution.html#Intro*). During this procedure the first character (for the classification of major groups) in ISCO-88 was highlighted. Then the differences of major groups between ISCO-88 and ISCO-08 were compared and marked, which was followed by transferring ISCO-88 to ISCO-08. Finally each respondent was arranged to different groups of skill levels according to the major groups of ISCED-97 and ISCO-08. However, the 1980 U.S. Census Occupation Codes was masked and only provided information on major groups of occupational positions (*http://hrsonline.isr.umich.edu/sitedocs/userg/dr-021.pdf*). The classification of skill levels may not be accurate for a few cases who had same codes of ISCO-88 but different codes of ISCO-08. It is difficult to allocate those respondents to different ISCO08 groups since the original variable did not provide detailed occupational classifications. Therefore those respondents' skill levels were recoded as missingness.

Table A 21 The distribution of occupation by skill levels at baseline in HRS

	Skill 4	Skill 3	Skill 2	Skill 1	Unclassifiable
Managerial and professional specialty occupation	616 (58.06)	48 (4.52)	397 (37.42)	0 (0.00)	0 (0.00)
Technical, sales and administrative support	188 (19.22)	48 (4.91)	727 (74.34)	15 (1.53)	0 (0.00)
Service occupations	29 (4.97)	82 (14.07)	428 (73.41)	44 (7.55)	0 (0.00)
Farming, forestry and fishing occupations	16 (9.94)	3 (1.86)	142 (88.20)	0 (0.00)	0 (0.00)
Precision production, craft, and repair occupations	0 (0.00)	20 (7.30)	247 (90.15)	7 (2.55)	0 (0.00)
Operators, fabricators and labours	0 (0.00)	24 (5.62)	384 (89.93)	19 (4.45)	0 (0.00)
Others	2 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Retired	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	8494 (100.00)
Unemployed	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	100 (100.00)
Disabled	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	252 (100.00)
Not in the labour force	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1385 (100.00)

Table A 22 An approach to deriving skill level by ISCED-97 and ISCO-08 in ELSA*

ISCO-08	**ISCED-97**				
	PR	LO	UP	PO	FI
1. Managers	Skill 2	Skill 2	Skill 2	Skill 3	Skill 4
2. Professionals	Skill 2	Skill 2	Skill 2	Skill 3	Skill 4
3. Technicians and associate professionals	Skill 1	Skill 2	Skill 2	Skill 3	Skill 4
4. Clerical support workers	Skill 1	Skill 2	Skill 2	Skill 3	Skill 4
5. Services and sales workers	Skill 1	Skill 2	Skill 2	Skill 3	Skill 3
6. Skilled agricultural, forestry and fishery workers	Skill 2	Skill 2	Skill 2	Skill 2	Skill 2
7. Craft and related trades workers	Skill 1	Skill 2	Skill 2	Skill 3	Skill 3
8. Plant and machine operators, and assemblers	Skill 3	Skill 3	Skill 3	Skill 3	Skill 4
9. Elementary occupations	Skill 1	Skill 2	Skill 2	Skill 3	Skill 4

* The transformation between SOC2000 and ISCO-88 was conducted firstly (*http://www.camsis.stir.ac.uk/occunits/distribution.html#Intro*).Then the major groups of ISCO-88 was transferred to that of ISCO-08. Finally each respondent was arranged into different skill level groups as shown above.

Figure A 2 A hypothesised conceptual framework for pathways between education and healthy ageing

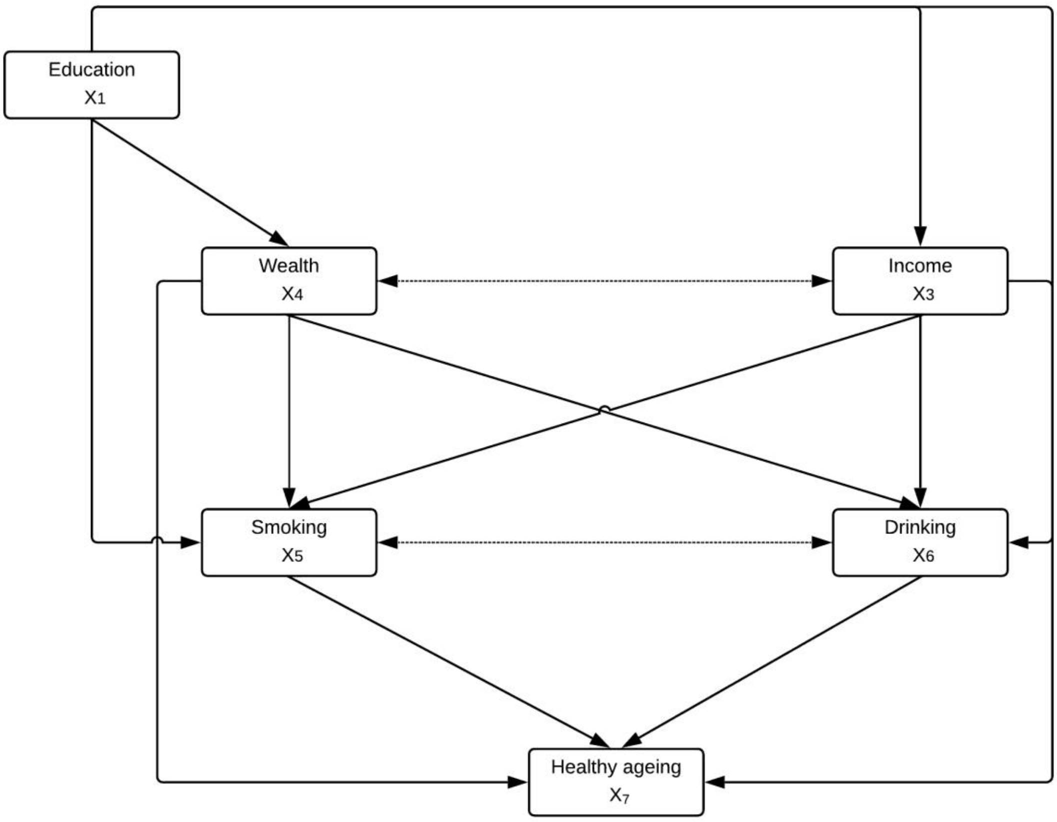

Table A 23 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among men in HRS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.028 (0.024 to 0.032)	$X_1 \rightarrow X_7$	0.012 (0.008 to 0.017)	0.015 (0.013 to 0.018)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.001 (0.000 to 0.003)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.008 (0.006 to 0.010)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.002)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.004)
Income X_3*	0.004 (0.000 to 0.008)	$X_3 \rightarrow X_7$	0.003 (-0.001 to 0.007)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.024 (0.021 to 0.028)	$X_4 \rightarrow X_7$	0.020 (0.016 to 0.024)	0.005 (0.003 to 0.006)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.004 (0.003 to 0.005)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.008 (0.003 to 0.013)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.023 (-0.027 to -0.019)	-	-	-

* The correlation between income and wealth is 0.437 (0.411 to 0.463); ** the correlation between smoking and drinking is 0.181 (0.140 to 0.222).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 24 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among men in HRS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.028 (0.024 to 0.032)	$X_1 \to X_7$	0.012 (0.008 to 0.017)	0.015 (0.013 to 0.018)	$X_1 \to X_3 \to X_7$	0.001 (0.000 to 0.003)
					$X_1 \to X_3 \to X_5 \to X_7$	0.000 (0.000 to 0.000)
					$X_1 \to X_3 \to X_6 \to X_7$	0.000 (0.000 to 0.001)
					$X_1 \to X_4 \to X_7$	0.008 (0.006 to 0.010)
					$X_1 \to X_4 \to X_5 \to X_7$	0.000 (0.000 to 0.001)
					$X_1 \to X_4 \to X_6 \to X_7$	0.002 (0.001 to 0.002)
					$X_1 \to X_5 \to X_7$	0.001 (0.000 to 0.002)
					$X_1 \to X_6 \to X_7$	0.002 (0.001 to 0.004)
Income X_3*	0.004 (0.000 to 0.008)	$X_3 \to X_7$	0.003 (-0.001 to 0.007)	0.001 (0.000 to 0.002)	$X_3 \to X_5 \to X_7$	0.000 (0.000 to 0.001)
					$X_3 \to X_6 \to X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.024 (0.021 to 0.028)	$X_4 \to X_7$	0.020 (0.016 to 0.024)	0.005 (0.003 to 0.006)	$X_4 \to X_5 \to X_7$	0.001 (0.000 to 0.002)
					$X_4 \to X_6 \to X_7$	0.004 (0.003 to 0.005)
Smoking X_5**	-	$X_5 \to X_7$	0.008 (0.003 to 0.013)	-	-	-
Drinking X_6**	-	$X_6 \to X_7$	-0.023 (-0.027 to -0.019)	-	-	-

* The correlation between income and wealth is 0.437 (0.411 to 0.463); ** the correlation between smoking and drinking is 0.181 (0.140 to 0.222).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 25 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among women in HRS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.029 (0.025 to 0.033)	$X_1 \rightarrow X_7$	0.008 (0.004 to 0.013)	0.020 (0.018 to 0.023)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.003 (0.002 to 0.005)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.009 (0.007 to 0.011)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.002 (0.002 to 0.003)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.004 (0.003 to 0.006)
Income X_3*	0.008 (0.005 to 0.012)	$X_3 \rightarrow X_7$	0.007 (0.004 to 0.011)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	-0.001 (-0.001 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.003)
Wealth X_4*	0.029 (0.026 to 0.033)	$X_4 \rightarrow X_7$	0.022 (0.018 to 0.026)	0.007 (0.006 to 0.009)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.001 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.006 (0.004 to 0.007)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.017 (0.012 to 0.021)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.031 (-0.036 to -0.026)	-	-	-

* The correlation between income and wealth is 0.434 (0.413 to 0.455); ** the correlation between smoking and drinking is 0.263 (0.225 to 0.301).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 26 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among women in HRS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.029 (0.025 to 0.033)	$X_1 \rightarrow X_7$	0.008 (0.004 to 0.013)	0.020 (0.018 to 0.023)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.003 (0.002 to 0.005)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.009 (0.007 to 0.011)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.002 (0.002 to 0.003)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.004 (0.003 to 0.006)
Income X_3*	0.008 (0.005 to 0.012)	$X_3 \rightarrow X_7$	0.007 (0.004 to 0.011)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	-0.001 (-0.001 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.003)
Wealth X_4*	0.029 (0.026 to 0.033)	$X_4 \rightarrow X_7$	0.022 (0.018 to 0.026)	0.007 (0.006 to 0.009)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.001 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.006 (0.004 to 0.007)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.017 (0.012 to 0.021)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.031 (-0.036 to -0.026)	-	-	-

* The correlation between income and wealth is 0.434 (0.413 to 0.455); ** the correlation between smoking and drinking is 0.263 (0.225 to 0.301).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 27 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among men in ELSA

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.022 (0.016 to 0.028)	$X_1 \rightarrow X_7$	0.014 (0.008 to 0.020)	0.011 (0.006 to 0.008)	$X_1 \rightarrow X_3 \rightarrow X_7$	-0.001 (-0.003 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.006 (0.004 to 0.008)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Income X_3*	-0.003 (-0.008 to 0.002)	$X_3 \rightarrow X_7$	-0.005 (-0.010 to 0.001)	0.002 (0.001 to 0.003)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.028 (0.022 to 0.033)	$X_4 \rightarrow X_7$	0.024 (0.019 to 0.030)	0.003 (0.002 to 0.005)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.001 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.013 (0.007 to 0.020)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.013 (-0.018 to -0.008)	-	-	-

* The correlation between income and wealth is 0.350 (0.315 to 0.385); ** the correlation between smoking and drinking is 0.087 (0.036 to 0.139).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 28 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among men in ELSA

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.024 (0.018 to 0.030)	$X_1 \rightarrow X_7$	0.016 (0.010 to 0.022)	0.008 (0.006 to 0.010)	$X_1 \rightarrow X_3 \rightarrow X_7$	-0.001 (-0.003 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.006 (0.004 to 0.008)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Income X_3*	-0.004 (-0.009 to 0.002)	$X_3 \rightarrow X_7$	-0.005 (-0.010 to 0.000)	0.001 (0.001 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.027 (0.021 to 0.033)	$X_4 \rightarrow X_7$	0.024 (0.018 to 0.030)	0.003 (0.002 to 0.005)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.002 (0.001 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.013 (0.007 to 0.019)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.012 (-0.018 to -0.007)	-	-	-

* The correlation between income and wealth is 0.351 (0.315 to 0.386); ** the correlation between smoking and drinking is 0.088 (0.036 to 0.140).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 29 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among women in ELSA

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.017 (0.011 to 0.024)	$X_1 \rightarrow X_7$	0.010 (0.004 to 0.017)	0.007 (0.004 to 0.010)	$X_1 \rightarrow X_3 \rightarrow X_7$	-0.005 (-0.006 to -0.003)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.008 (0.006 to 0.010)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.003)
Income X_3*	-0.018 (-0.023 to -0.012)	$X_3 \rightarrow X_7$	-0.019 (-0.024 to -0.014)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.036 (0.030 to 0.042)	$X_4 \rightarrow X_7$	0.030 (0.024 to 0.037)	0.005 (0.003 to 0.007)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.004 (0.002 to 0.005)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.016 (0.010 to 0.023)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.021 (-0.027 to -0.015)	-	-	-

* The correlation between income and wealth is 0.291 (0.259 to 0.322); ** the correlation between smoking and drinking is 0.126 (0.078 to 0.174).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 30 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among women in ELSA

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.018 (0.011 to 0.025)	$X_1 \rightarrow X_7$	0.010 (0.003 to 0.017)	0.008 (0.005 to 0.011)	$X_1 \rightarrow X_3 \rightarrow X_7$	-0.005 (-0.007 to -0.003)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.008 (0.006 to 0.010)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.001 (-0.001 to -0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.002 (0.001 to 0.004)
Income X_3*	-0.018 (-0.023 to -0.013)	$X_3 \rightarrow X_7$	-0.019 (-0.024 to -0.014)	0.001 (0.000 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Wealth X_4*	0.036 (0.030 to 0.042)	$X_4 \rightarrow X_7$	0.030 (0.024 to 0.037)	0.005 (0.003 to 0.007)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.004 (0.002 to 0.005)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.016 (0.010 to 0.023)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.021 (-0.027 to -0.015)	-	-	-

* The correlation between income and wealth is 0.287 (0.254 to 0.319); ** the correlation between smoking and drinking is 0.129 (0.080 to 0.177).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 31 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among men in CHARLS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.037 (0.028 to 0.046)	$X_1 \rightarrow X_7$	0.033 (0.024 to 0.042)	0.004 (0.001 to 0.007)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.004 (0.001 to 0.007)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.003 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Income X_3*	0.014 (0.006 to 0.023)	$X_3 \rightarrow X_7$	0.014 (0.006 to 0.023)	0.000 (-0.001 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Wealth X_4*	0.007 (-0.003 to 0.017)	$X_4 \rightarrow X_7$	0.007 (-0.004 to 0.017)	0.000 (-0.001 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	-0.002 (-0.011 to 0.008)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.009 (-0.017 to 0.000)	-	-	-

* The correlation between income and wealth is 0.207 (0.133 to 0.282); ** the correlation between smoking and drinking is 0.192 (0.104 to 0.280).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 32 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among men in CHARLS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.037 (0.028 to 0.046)	$X_1 \rightarrow X_7$	0.033 (0.024 to 0.043)	0.004 (0.001 to 0.007)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.003 (0.000 to 0.006)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.001 (0.000 to 0.003)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	-0.001 (-0.003 to 0.002)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Income X_3*	0.011 (0.002 to 0.019)	$X_3 \rightarrow X_7$	0.011 (0.002 to 0.019)	0.000 (-0.001 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.000)
Wealth X_4*	0.011 (0.002 to 0.020)	$X_4 \rightarrow X_7$	0.011 (0.001 to 0.020)	0.000 (-0.001 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.000)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	-0.002 (-0.012 to 0.007)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.009 (-0.017 to 0.000)	-	-	-

* The correlation between income and wealth is 0.263 (0.183 to 0.342); ** the correlation between smoking and drinking is 0.187 (0.099 to 0.276).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 33 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among women in CHARLS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.056 (0.025 to 0.087)	$X_1 \rightarrow X_7$	0.050 (0.017 to 0.082)	0.006 (-0.003 to 0.016)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.000 (-0.003 to 0.002)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.002 (-0.003 to 0.007)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.004 (-0.003 to 0.011)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.002 to 0.003)
Income X_3*	0.000 (-0.013 to 0.014)	$X_3 \rightarrow X_7$	-0.001 (-0.016 to 0.013)	0.002 (-0.001 to 0.004)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.001 (-0.001 to 0.003)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.001 (0.001 to 0.002)
Wealth X_4*	0.025 (0.010 to 0.041)	$X_4 \rightarrow X_7$	0.024 (0.008 to 0.040)	0.001 (-0.001 to 0.004)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (-0.001 to 0.003)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.002)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.015 (-0.005 to 0.034)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.007 (-0.024 to 0.011)	-	-	-

* The correlation between income and wealth is 0.345 (0.272 to 0.418); ** the correlation between smoking and drinking is 0.236 (0.069 to 0.404).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 34 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among women in CHARLS

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.058 (0.027 to 0.089)	$X_1 \rightarrow X_7$	0.053 (0.021 to 0.086)	0.005 (-0.004 to 0.014)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.001 (-0.001 to 0.002)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.001 (-0.003 to 0.005)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.004 (-0.003 to 0.011)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.003 to 0.002)
Income X_3*	0.004 (-0.009 to 0.017)	$X_3 \rightarrow X_7$	0.004 (-0.009 to 0.017)	0.000 (-0.001 to 0.002)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.001 (-0.001 to 0.002)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Wealth X_4*	0.021 (0.007 to 0.035)	$X_4 \rightarrow X_7$	0.019 (0.004 to 0.033)	0.002 (-0.002 to 0.006)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.001 (-0.001 to 0.004)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.003)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.013 (-0.006 to 0.032)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.008 (-0.025 to 0.010)	-	-	-

* The correlation between income and wealth is 0.366 (0.295 to 0.438); ** the correlation between smoking and drinking is 0.243 (0.080 to 0.407).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 35 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among men in JSTAR

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.019 (0.012 to 0.026)	$X_1 \rightarrow X_7$	0.015 (0.007 to 0.022)	0.004 (0.002 to 0.007)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.002 (0.000 to 0.004)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Income X_3*	0.006 (0.001 to 0.011)	$X_3 \rightarrow X_7$	0.006 (0.000 to 0.011)	0.000 (-0.001 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Wealth X_4*	0.014 (0.004 to 0.024)	$X_4 \rightarrow X_7$	0.013 (0.003 to 0.023)	0.001 (-0.001 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.002 (-0.008 to 0.011)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.010 (-0.018 to -0.001)	-	-	-

* The correlation between income and wealth is 0.207 (0.133 to 0.281); ** the correlation between smoking and drinking is 0.076 (-0.016 to 0.168).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 36 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among men in JSTAR

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.019 (0.012 to 0.026)	$X_1 \rightarrow X_7$	0.015 (0.008 to 0.023)	0.004 (0.002 to 0.006)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.001 (0.000 to 0.002)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.002 (0.000 to 0.004)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (0.000 to 0.002)
Income X_3*	0.005 (0.000 to 0.010)	$X_3 \rightarrow X_7$	0.005 (0.000 to 0.010)	0.000 (-0.001 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Wealth X_4*	0.011 (0.003 to 0.020)	$X_4 \rightarrow X_7$	0.011 (0.003 to 0.019)	0.001 (-0.001 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.002 (-0.007 to 0.011)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.010 (-0.018 to -0.001)	-	-	-

* The correlation between income and wealth is 0.189 (0.114 to 0.264); ** the correlation between smoking and drinking is 0.075 (-0.018 to 0.167).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 37 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on imputed data among women in JSTAR

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.003 (-0.004 to 0.011)	$X_1 \rightarrow X_7$	0.000 (-0.008 to 0.008)	0.003 (0.001 to 0.006)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.003 (0.001 to 0.004)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
Income X_3*	-0.001 (-0.005 to 0.004)	$X_3 \rightarrow X_7$	0.000 (-0.005 to 0.005)	-0.001 (-0.002 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_3 \rightarrow X_6 \rightarrow X_7$	-0.001 (-0.002 to 0.001)
Wealth X_4*	0.013 (0.007 to 0.018)	$X_4 \rightarrow X_7$	0.012 (0.006 to 0.018)	0.000 (-0.002 to 0.002)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.002 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.001 (-0.013 to 0.015)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.009 (-0.019 to 0.001)	-	-	-

* The correlation between income and wealth is 0.214 (0.123 to 0.304); ** the correlation between smoking and drinking is 0.288 (0.141 to 0.435).

*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI

Table A 38 Standardised regression coefficients with 95%CIs for total, direct and indirect effects based on FIML among women in JSTAR

Variables	Total Effects	Direct Effects		Total Indirect Effects	Indirect Effects	
Education X_1	0.003 (-0.004 to 0.011)	$X_1 \rightarrow X_7$	0.000 (-0.007 to 0.008)	0.003 (0.001 to 0.005)	$X_1 \rightarrow X_3 \rightarrow X_7$	0.000 (-0.001 to 0.001)
					$X_1 \rightarrow X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_3 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_7$	0.002 (0.000 to 0.004)
					$X_1 \rightarrow X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.000)
					$X_1 \rightarrow X_6 \rightarrow X_7$	0.001 (-0.001 to 0.002)
Income X_3*	0.000 (-0.005 to 0.005)	$X_3 \rightarrow X_7$	0.000 (-0.004 to 0.005)	-0.001 (-0.002 to 0.001)	$X_3 \rightarrow X_5 \rightarrow X_7$	0.000 (0.000 to 0.001)
					$X_3 \rightarrow X_6 \rightarrow X_7$	-0.001 (-0.002 to 0.001)
Wealth X_4*	0.011 (0.006 to 0.017)	$X_4 \rightarrow X_7$	0.011 (0.005 to 0.017)	0.000 (-0.002 to 0.003)	$X_4 \rightarrow X_5 \rightarrow X_7$	0.000 (-0.002 to 0.002)
					$X_4 \rightarrow X_6 \rightarrow X_7$	0.000 (-0.001 to 0.001)
Smoking X_5**	-	$X_5 \rightarrow X_7$	0.001 (-0.013 to 0.015)	-	-	-
Drinking X_6**	-	$X_6 \rightarrow X_7$	-0.009 (-0.019 to 0.002)	-	-	-

* The correlation between income and wealth is 0.199 (0.106 to 0.292); ** the correlation between smoking and drinking is 0.288 (0.141 to 0.434).
*** X_1: Education; X_3: Income; X_4: Wealth; X_5: Smoking; X_6: Drinking; X_7: HAI