The role of social relationships in explaining social inequalities in health in an ageing population – findings from the English Longitudinal Study of Ageing

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Thesis submitted for the degree of Doctor of Philosophy

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2023

Declaration of work

I, Nadia Khaliq confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

This work has been funded by the Medical Research Council (MRC) Doctoral Studentship.

Signature: [redacted] Date: 02/07/2023

Nadia Khaliq

Abstract

Introduction: Social inequalities in health are universally recognised as a significant public health problem. Whilst material and behavioural pathways between socioeconomic position and health have been studied extensively, few studies have explored the contribution of social relationships to social gradients in health.

Aim: To examine the mediating and moderating role of social relationships in the association between socioeconomic position, general health (self-rated health and blood pressure) and oral health (self-rated oral health, edentulousness and oral health-related quality of life) using data from English Longitudinal Study of Ageing (ELSA).

Methods: Four pieces of research make up the main body of this thesis. First, evidence was systematically reviewed from 69 studies that quantitatively assessed the role of social relationships in mediating (*n* = 42) or moderating (*n* = 33) health inequalities. Second, cross-sectional analyses using imputed data examined the role of loneliness, social isolation, and positive and negative social support in the attenuation of socioeconomic gradients in self-rated health (*n* = 8681) and systolic blood pressure (*n* = 6639) at wave 2, and in self-rated oral health, oral health-related quality of life and edentulousness at wave 3 (*n* = 8617). Third, structural equation modelling was implemented to explore the mediating role of social relationships in explaining wealth inequalities in self-rated health and systolic blood pressure using data from wave 2 to wave 6 (*n* = 12,723), and in self-rated oral health, oral health-related quality of life and edentulousness using data from wave 3 to wave 7 (*n* = 11,692). Finally, social relationships were assessed for their moderating role in associations between wealth and self-rated health and systolic blood pressure at waves 2, 4 and 6 (*n* = 12,594) and self-rated oral health, oral health-related quality of life and edentulousness at waves 3, 5 and 7 (*n* = 11,362) using random effects models.

Systematic review results: There was some evidence suggesting that social relationships partly explained social gradients in health, and that better social relationships buffered the negative effect of low socioeconomic position on health among adults.

Cross-sectional results: Overall, wealth remained a strong predictor of health after controlling for social relationship measures. Attenuation of social gradients were seen in four of the five health outcomes: self-rated health, systolic blood pressure, self-rated oral health, oral health-related quality of life and edentulousness. A social gradient in diastolic blood pressure was not evident. Of the four social relationship measures examined, loneliness, and social isolation made the greatest contribution to reducing the magnitude of the SEP-health association. Results from this cross-sectional analysis informed longitudinal mediation analyses and moderation analyses.

Mediation results: Loneliness and social isolation partially mediated associations between wealth and later self-rated health, self-rated oral health, and oral health-related quality of life. Bidirectional associations were observed between health (self-rated health, self-rated oral health, oral health-related quality of life, and edentulousness) and loneliness, as well as health and social isolation. Bidirectional associations between wealth and health were less consistent.

Moderation results: There was some evidence of an interaction between wealth and positive support for edentulousness only. However, the association between wealth and edentulousness appeared to be stronger (there was more inequality) among those reporting more positive support.

Conclusion: Wealth was strongly and consistently associated with better health throughout this study. There was some evidence that social relationships mediated associations between wealth and health outcomes, with loneliness and social isolation playing the most important role of the social relationship measures studied. Evidence for moderation was very limited, social relationships did not compensate for the effect of socioeconomic disadvantage on any of the outcomes studied except edentulousness. Policies and research should remain focused on socioeconomic position as a key structural determinant of health.

Impact Statement

Social inequalities in health are widely recognised as a major public health problem. Societies globally are also witnessing increasing ageing populations, with a sizeable proportion bearing the brunt of widening inequalities as society emerges from the Covid-19 pandemic. Health inequalities especially in the context of an ageing population are key in national policy, for example, *All Our Health* agenda (UK Government, 2022a), and the *Levelling Up* agenda (UK Government, 2022b). National policy in turn inform local authorities, clinical commissioning groups, and integrated health and social care systems and their partners to facilitate healthy ageing. Healthy ageing and social relationships are fundamental in international policy such as the United Nations Decade on Healthy Ageing (2021-2030). The UN Decade of Healthy Ageing agenda calls for joined-up action if we are to strive towards equity in longevity and extend healthy lives for all.

In this thesis, I first systematically reviewed the current evidence and have shown that overall, social relationships partly explained social gradients in health and buffered the negative effect of socioeconomic disadvantage on health. The review also highlighted several important gaps: the paucity of studies assessing the role of social relationships in explaining socioeconomic inequalities in oral health outcomes, a lack of longitudinal studies assessing these associations among older adults in the UK, and finally a lack of longitudinal studies using advanced statistical techniques such as structural equation modelling to assess mediation. This study observed that wealth was a strong predictor of poor health. There was some evidence for the mediating role of loneliness and social isolation in partly explaining socioeconomic inequalities in later health outcomes for older adults. Moreover, evidence for mediation was stronger for subjective rather than objective measures of health. Additionally, in the present study bidirectional associations were observed between health and social relationships, and wealth and health, although results were less consistent for the latter association. Interestingly, this study did not find evidence that social relationships buffer the negative effect of material disadvantage on health. Not only do these results add to the body of evidence surrounding health inequalities and support wealth as a structural determinant of health, but they can also enable us to better understand the role of social relationships in explaining socioeconomic inequalities among an ageing cohort. The results from this study support local and national policy, for example, social prescribing, to help foster health ageing.

Results from this thesis have been presented at the Society for Social Medicine and Population Health conference (University of Exeter, 2022), and the ESRC International Centre for Lifecourse Studies (UCL, London, 2022). The systematic review protocol paper in Chapter 3 has also been published in the Biomed Central Systematic Reviews Journal.

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Acronyms

AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
CAPI	Computer Assisted Personal Interviewing
CFI	Comparative Fit Index
CLPM	Cross-Lagged Panel Model
CSDH	Commission on Social Determinants of Health
CV	Cardiovascular
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
ELSA	English Longitudinal Study of Ageing
EMBASE	Excerpta Medica Database
FIML	Full Information Maximum Likelihood
HIC	High Income Countries
HSE	Health Survey for England
LMIC	Low- and Middle-income Countries
LR	Likelihood Ratio
MAR	Missing At Random
MASEM	Meta-Analytic Structural Equation Modelling
MCAR	Missing Completely At Random
MEDLINE	Medical Literature Analysis and Retrieval System Online
MeSH	Medical Subject Headings
MI	Multiple Imputation
MICE	Multiple Imputation by Chained Equation
ML	Maximum Likelihood
MLR	Robust Maximum Likelihood
MNAR	Missing Not AT Random
NICE	National Institute for Health and Care Excellence
NRES	National Research and Ethics Service
NS-SEC	The National Statistics Socio-economic Classification
OHRQoL	Oral Health-Related Quality of Life
OIDP	Oral Impacts on Daily Performance

ONS	Office of National Statistics
PRESS	Peer Review of Electronic Search Strategies
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PROSPERO	International Prospective Register of Systematic Reviews
PsycINFO	Psychological Information Database
RMSEA	Root Mean Square Error of Approximation
SABIC	Sample-Size Adjusted BIC
SBP	Systolic Blood Pressure
SEM	Structural Equation Modelling
SEP	Socioeconomic Position
SMFCS	Substantive Model Compatible Fully Conditional Specification
SN	Study Number
SRH	Self-rated health
SRMR	Standardised Root Mean Square Residual
SROH	Self-Rated Oral Health
TLI	Tucker-Lewis Index
UCLA	University of California, Los Angeles
UK	United Kingdom
UKDS	UK Data Service
USA	United States of America
WHO	World Health Organisation

Acknowledgements

I would like to begin by expressing my sincerest and heartfelt gratitude to my supervisors, Dr Anja Heilmann and Professor Anne McMunn for your invaluable guidance and mentorship from conception to completion of this PhD project. Without your continued support, kindness, and encouragement, especially during some very challenging and difficult personal circumstances, this project would not have been possible. I would also like to thank Professor Amanda Sacker, my thesis committee chair, for bringing a fresh perspective at pivotal points throughout this project – it has been an honour to have you as part of the team, to me you will be forever remembered as the 'SEM Queen.'

I would also like to thank my funders the MRC-Birkbeck Doctoral Training Programme for allowing me to embark upon a journey I never thought was possible: you made the dream a reality. Thank you to my friends from the Health of the Public MRC DTP Theme – you gave me hope, words of encouragement and practical support, especially in the early days of my PhD journey when we were all trying to find our feet.

Thank you to IEHC, EPH and DPH, I have felt part of a wider family, you gave me opportunities beyond research that I would never have gained elsewhere.

I would like to send my deepest gratitude to my dearest friends, Drs Alex Blokland, Egle Petrauskiene and Zainab Al-Assmi for being a source of great comfort especially when the going got tough, in each of you I have found a lifelong friendship, for that I am truly grateful.

My warmest gratitude goes to my parents, you have always believed in me, without you, nothing would be possible. Thank you to my siblings, nieces, and nephews, you have been a joy and light throughout life and especially during the last four years.

Finally, to my son, Ismail: you will forever be my joy and my love. You are my strength, and I, yours. Thank you.

List of publications

Nadia Khaliq, MSc, Anne McMunn, PhD, Carolina Machuca-Vargas, PhD, Anja Heilmann, PhD. Do social relationships mediate or moderate social inequalities in health? A systematic review protocol. Systematic Reviews 11, Article number: 91 (2022). https://doi.org/10.1186/s13643-022-01973-w

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   Nadia Khaliq developed the systematic review protocol and wrote the first and revised drafts under the supervision of Anja Heilmann and Anne McMunn who also contributed to the revision of the manuscript. Carolina Machuca-Vargas contributed to the development of the data extraction forms as the second reviewer

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   Anja Heilmann

   Date

   29/06/2023

Chapter 1. Introduction

Chapter summary: This first chapter presents the choice of topic for this thesis and the design of my PhD project. In this introductory section I provide an overview of social inequalities in health, the importance of addressing oral health as part of overall health among older adults, the relevance of social relationships for health and their role in explaining health inequalities. Finally, I map out the structure of this thesis.

Social inequalities in health are universally recognised as a significant public health problem (CSDH, 2008). The differences in health do not simply manifest themselves at the extreme ends of the social hierarchy – inequalities in health are socially graded (Marmot and Smith, 1997; Marmot, 2005; Sabbah *et al.*, 2007). The stark inequalities seen in oral health mirror those seen in general health (Sabbah *et al.*, 2007).

The last decade has witnessed a widening health inequalities gap in the United Kingdom despite the government's *Levelling Up* policy (UK Government, 2022b). Consequently, life expectancy has stalled, with the UK performing the worst among the G7 nations, barring the USA. Society is also witnessing a rapid trend towards an ageing population – over the next decade, 22% of the UK population will be 65 years and older. The deterioration in health for the most deprived, a sluggish life expectancy, and stagnating health improvement makes healthy later life less attainable for many. Improving the lives of older people is a key policy agenda as outlined in the United Nations Decade of Healthy Ageing (2021-2030). At the same time, improving health across society requires a recognition and understanding of the drivers of health inequalities. The WHO's conceptual framework on social determinants of health states that the conditions in which people are *born, grow, live, work and age* are pivotal in explaining health inequalities (Solar and Irwin, 2010). It is the influence of the socioeconomic and political upstream forces, i.e., the structural determinants, that shape inequalities in health (Solar and Irwin, 2010). The structural determinants of health have a cascading effect on the intermediary determinants, i.e., material, biological, behavioural, and psychosocial factors, consequently influencing equity in health and well-being. Social relationships are seen as cutting across the intermediary and structural determinants of health to impact health inequality (Solar and Irwin, 2010). Social relationships are unequivocally recognised as major contributors to health, well-being, and longevity, yet they are often overlooked as social determinants of healthy ageing. A plethora of studies have shown beyond doubt the link between poor social connections and poor health (Holt-Lunstad, Smith and Layton, 2010; Holt-Lunstad *et al.*, 2015; Valtorta, Kanaan, Gilbody, Ronzi, *et al.*, 2016; Leigh-Hunt *et al.*, 2017; Rico-Uribe *et al.*, 2018). Moreover, poor social relationships have been associated with premature mortality and are as harmful to health as classical risk factors, such as, smoking, obesity and physical inactivity (Holt-Lunstad, Smith and Layton, 2010).

The Global Burden of Disease study indicates that the continuation of ageing will present a considerable challenge for healthcare systems to ensure a healthy life across ageing societies (GBD 2019 Ageing Collaborators, 2022). Oral health is an integral part of overall health, and yet often remains siloed from the global health agenda. Yet, oral diseases are highly prevalent, currently affecting 3.5 billion people globally. Between 1990 and 2019, there was a 75% increase in the disability-adjusted life-years (DALYs) burden of oral diseases (Patel *et al.*, 2021; WHO, 2022b). Oral diseases remain a major public health concern and present a significant burden for the economy (WHO, 2022b). The UN action plan for healthy ageing, as detailed in *Decade of Healthy Ageing (2021–2030),* includes oral health as a key marker of overall health and well-being for older adults.

Given the impact of oral health on ageing and the prevalence of oral diseases, increasing our understanding of the role of social relationships in explaining the pathways between socioeconomic position and oral health is fundamental.

An overview of the doctoral thesis structure

This project begins by examining the public health significance of ageing, the theoretical underpinnings of social inequalities in health and social relationships, the associations between social relationships and health, and the rationale for the project (Chapter 2). Second, the aims, objectives, and hypotheses for this PhD are presented, followed by the theoretical models conceptualising the role of social relationships in mediating and moderating socioeconomic inequalities in health (Chapter 3). Third, I present a systematic review of the existing evidence that has quantitatively assessed the mediating and moderating role of social relationships in explaining socioeconomic inequalities in health (Chapter 4). I conclude the review by summarising the gaps in the current literature together with a rationale for the social relationship and health outcome measures used in this project. Chapter 5 introduces the data used in this project and details the methodology implemented for the quantitative data analyses. Cross-sectional analyses assessing associations between socioeconomic position, social relationships, and health outcomes at ELSA waves 2 and 3 are the focus of Chapter 6. Next, structural equation modelling is used to examine the mediating role of social relationships in longitudinal associations between socioeconomic position and health (Chapter 7). Chapter 8 assesses the moderating role of social relationships in explaining socioeconomic inequalities in health longitudinally using random effects modelling. Finally, the results of this thesis are discussed in the context of the existing literature, I summarise the strengths and limitations of this project, implications on policy and future research, before presenting concluding remarks (Chapter 9).

Chapter 2. Background

Chapter summary: This chapter begins by summarising the public health challenge of an ageing population. Secondly, it provides an overview of the WHO conceptual framework addressing social inequalities in health and how social relationships fit into this framework. Next, it gives an overview of the definitions and theoretical concepts of social relationships. The chapter then explores the links between social relationships and health and summarises the relevance of social relationships on health in later life. Finally, the chapter addresses the rationale for this doctoral project.

2.1 Health in an ageing population – the public health challenge

Societies globally are witnessing a rapid trend towards ageing populations. Older people account for 13.5% of the global population, and by 2050 it is estimated that over 2 billion people will be 60 years and above worldwide (WHO, 2021b, 2022a). By 2066, people aged 65 and above will account for 26% of the UK population, and those aged 85 years and above will make up 7% of the population (The Office of National Statistics, 2018). A key priority for healthy ageing, as outlined in the recent WHO baseline report on ageing, is to optimise the functional ability of older people (WHO, 2021b). Functional ability includes an individual's capacity to perform activities of daily living and to build and maintain social relationships.

Although many older people lead fulfilling lives, a healthy life does not extend at the same rate as lifespan for everybody. Older people suffering from chronic diseases and limiting physical and cognitive capacities face a prolonged period of declining health and quality of life (WHO, 2021b). The major cause of disease burden for people aged 60 and over are cardiovascular diseases, cancer, chronic respiratory diseases, musculoskeletal diseases, and neurological and mental disorders (Prince *et al.*, 2015; GBD 2019 Ageing Collaborators, 2022). When looking at disability globally, poor oral health including edentulousness, dental caries and chronic periodontal disease, is among the main drivers of functional decline among adults aged 70 years and above (Prince *et al.*, 2015; GBD 2019 Ageing Collaborators, 2022).

Societies are witnessing an increasing incidence and prevalence of multimorbidity, partly because of the rising ageing population, especially among those from more deprived backgrounds (NIHR Evidence, 2021). By 2035 almost 70% of older adults aged 65 years and over in England will have two or more chronic conditions, and those with at least four or more chronic conditions (complex multimorbidity) will increase to 17% (Kingston *et al.*, 2018). The increase in complex multimorbidity will lead to a rise in the burden on health care service provision in the UK – a currently over-stretched service and under crisis. Therefore, preventative strategies require addressing the structural and intermediate risk factors of poor health, especially among older people (Kingston *et al.*, 2018).

Social inequalities of health negatively impact an individual's experience of older age and are often the result of cumulative disadvantage over the life course. For some, this means poorer health, weaker social connections, poorer quality of life, and a shortened life. Developing strategies targeting older cohorts' experiences rely on understanding the interplay of social factors, such as, socioeconomic position, social relationships, and health in later life.

2.2 Social inequalities in oral and general health

Dahlgren and Whitehead (2006) state that social inequalities in health are *"systematic, unfair (therefore avoidable) and socially produced"* when combined, these three distinct facets turn differences in health to social inequalities in health. Health is recognised as a marker of how well society is flourishing socially and economically, and is closely linked to the conditions in which people live, work, grow and age, consequently resulting in unequal opportunities for people to lead healthy lives (Marmot, 2007; CSDH, 2008). The broader structural forces, i.e., the social determinants of health, influence and shape the differences seen in health across the population.

Socioeconomic position, a structural determinant of health, summarises an individual's position within the social hierarchy; it refers to their material and social resources (Solar and Irwin, 2010), and social disadvantage is associated with poor health (Marmot, Allen, Boyce, *et al.*, 2020).

The past decade has painted a bleak picture regarding associations between deprivation and life expectancy in the United Kingdom – people in the most deprived communities have a lower life expectancy than those in the least deprived areas (Marmot, Allen, Boyce, *et al.*, 2020). Although mortality rates for individuals in their 70's are decreasing, those aged 80 years and over have seen a continual increase in mortality rate beyond that which is attributable to winter-related mortality (Marmot, Allen, Boyce, *et al.*, 2020). Inequality in life expectancy is a foremost measure of a society's health status and level of health inequality. The early part of the 21st century saw significant improvements in life expectancy. However, since 2011, life expectancy has stalled for men and deteriorated for women in the most deprived communities (Marmot, Allen, Boyce, *et al.*, 2020) (Figure 2.1).

Geographical inequalities also exist; the divide in life expectancy between the North and South of England has risen continually since the mid-1990s, with deprivation playing a pivotal role (Kontopantelis *et al.*, 2018). For example, from 2010 to 2012 and from 2016 to 2018, Northeast England had the lowest life expectancy for men and women living in the most deprived areas (Marmot, Allen, Boyce, *et al.*, 2020). In contrast, life expectancy increased across all deciles of deprivation among those living in London (Marmot, Allen, Boyce, *et al.*, 2020).

Evidence not only demonstrates life expectancy tailing off since 2009/11 but a slowing down in the improvement of healthy life expectancy for men and women, i.e., a measure of how long an individual lives in good health. For example, in 2009/11, the percentage of life spent in poor health was 20% and 22.6% for men and women, respectively. By 2015/17, the percentage of life spent in poor health was 20.3% and 23.3% for men and women, respectively (Marmot, Allen, Boyce, *et al.*, 2020).

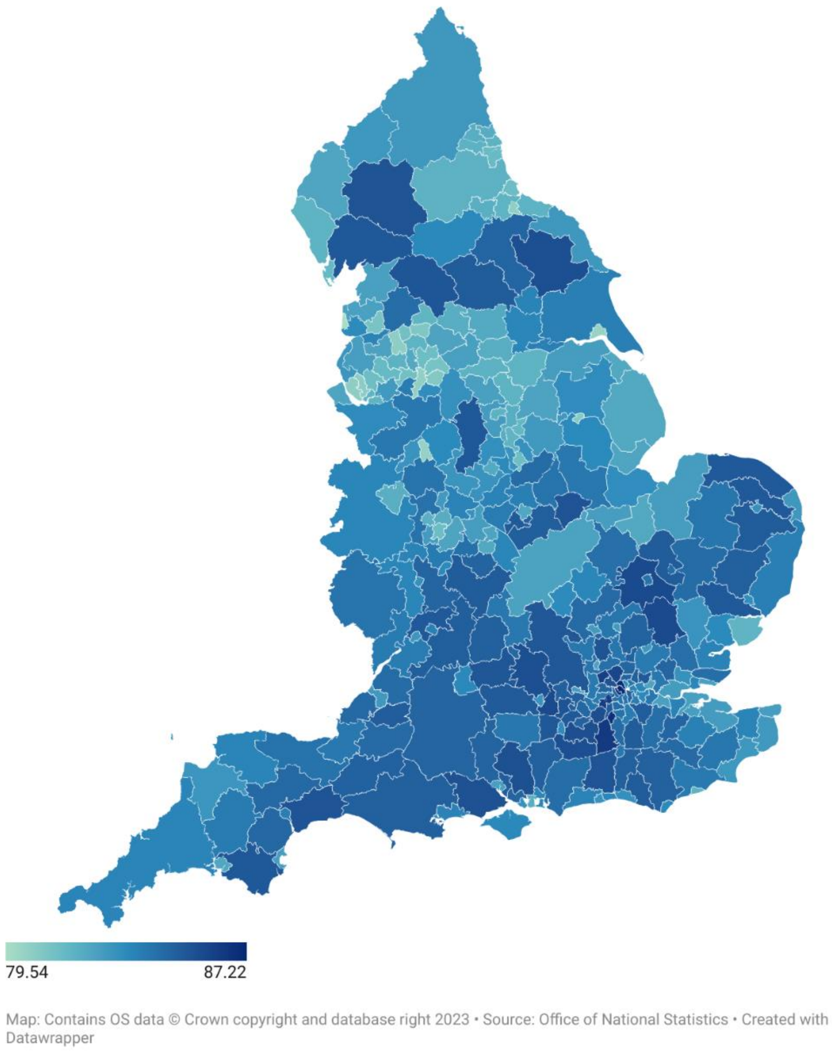

Figure 2.1 Life expectancy at birth (female) by local authority, 2017/19 (The Office of National Statistics, 2020)

In the UK, tackling health inequalities is an important national strategy. The publication of the white paper, *'Healthy Lives, Healthy People'* (Department of Health and Social Care 2010) in response to the *'Marmot Review'* (Marmot, 2010) led to fundamental legislative change in the Government's approach to tackling the broader structural determinants of health. The change in legislation led to the Health and Social Care Act (2012), mandating health bodies, including Public Health England (PHE), to reduce health inequalities (Public

Health England, 2017).[1] Furthermore, in 2022, the UK Government published its *Levelling Up* white paper which set out objectives to reduce the North-South divide in health inequalities (UK Government, 2022b). However, implementing successful public health strategies to tackle health inequalities requires a joined-up, cross-sector partnership – currently challenging in the face of a damaged political system (Hunter, Littlejohns and Weale, 2022).

More recently, the Covid-19 pandemic and the rising cost of living have put a spotlight on the disproportionate effect of the pandemic on stalling life expectancy in England and falling life expectancy for the poorest communities. Infection with SARS-CoV-2 and its variants has been higher among more impoverished communities, and was associated with higher hospitalisation rates and higher Covid-19-related mortality (Marmot, Allen, Goldblatt, *et al.*, 2020; Public Health England, 2020). The pandemic and cost-of-living crisis have seen a widening of the inequalities gap, but also reflect the failure of the Government to address stark pre-existing health inequalities (Marmot, Allen, Boyce, *et al.*, 2020; Marmot, Allen, Goldblatt, *et al.*, 2020; Munro, Allen and Marmot, 2023).

Social inequalities have been demonstrated for avoidable mortality and many different health outcomes in adults (Sommer *et al.*, 2015) and child health (Pillas *et al.*, 2014). Social patterning is also seen for oral diseases, and steep gradients are seen across all oral health conditions, for example, periodontal disease, dental caries, edentulism and oral cancer (Sabbah *et al.*, 2007; Conway *et al.*, 2008, 2021; Schwendicke *et al.*, 2015; Steele *et al.*, 2015; Watt *et al.*, 2015; Elani *et al.*, 2017; Vos *et al.*, 2017; Shen and Listl, 2018).

Differences in oral and general health are not randomly distributed; consistent patterns are seen throughout populations (Whitehead and Dahlgren, 2006) with a stepwise, linear social gradient in disease prevalence (Marmot *et al.*, 1991; CSDH, 2008; Solar and Irwin, 2010; Marmot, Allen, Boyce, *et al.*, 2020). Furthermore, the social gradients for general

[1]During the height of the Covid-19 pandemic, Public Health England was dismantled and replaced by the UK Health Security Agency and Office for Health Improvement and Disparities (OHID) in 2021. OHID aims to build on PHEs work for tackling the growing health inequalities and improving health outcomes across the population to reduce the burden of poor health on the health and social care systems.

and oral health are similar, indicating that pathways influencing these inequalities are also shared (Sabbah *et al.*, 2007).

The Commission on the Social Determinants of Health (CSDH) suggests that the socioeconomic and political processes at the societal level, i.e., the upstream forces, create a social stratification of society. This social stratification results in differential exposure and vulnerability to disease and impacts health via material circumstances, psychosocial factors, and biological and behavioural factors (intermediate determinants), giving rise to stark differences in health (Solar and Irwin, 2010). According to this conceptual framework, psychosocial factors include social relationships, with social cohesion and social capital seen as cutting across the structural and intermediary social determinants of health (Solar and Irwin, 2010) (Figure 2.2).

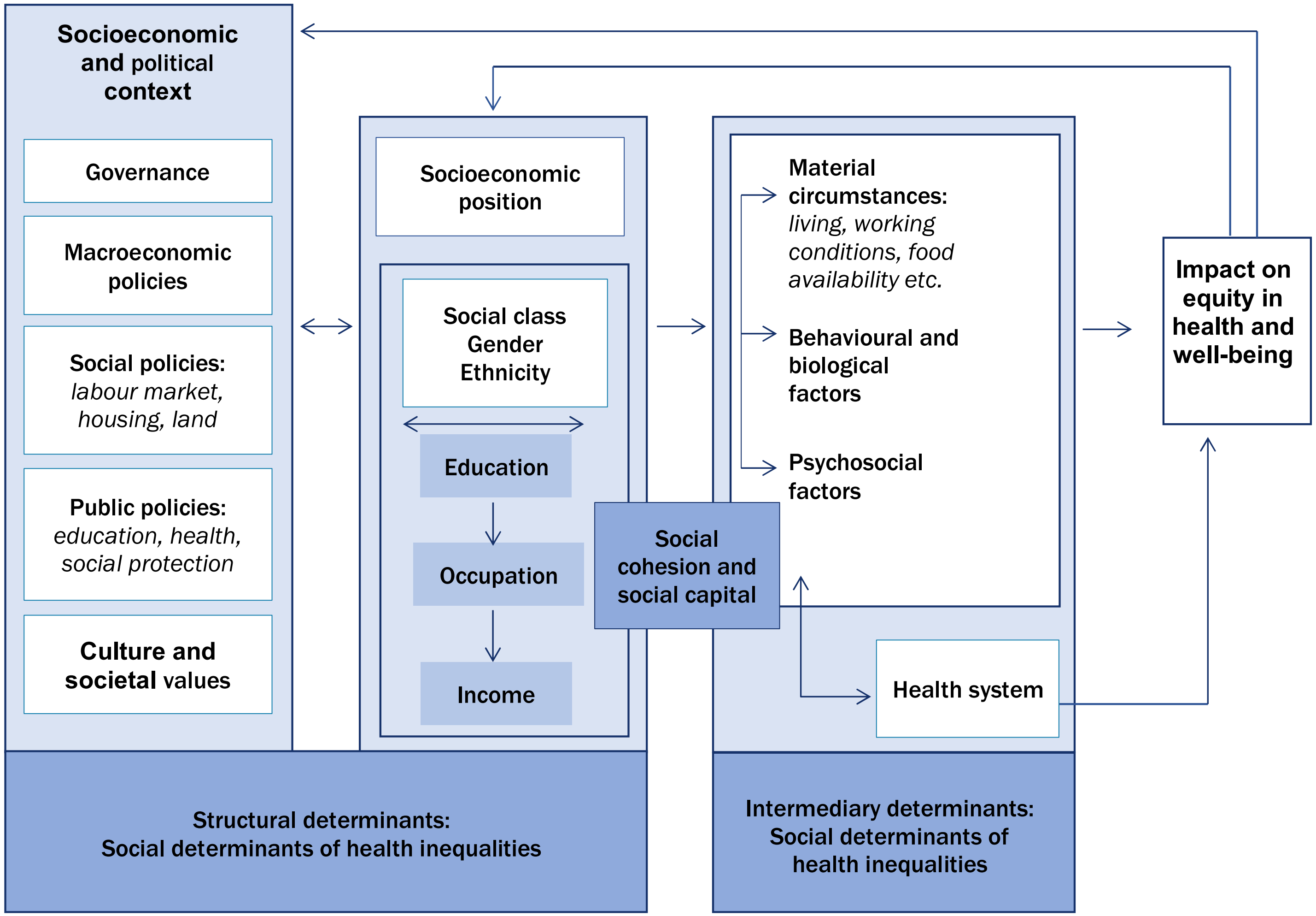

Figure 2.2 WHO Commission on the Social Determinants of Health (CSDH) conceptual framework (Solar and Irwin, 2010)

2.3 Social relationships and social inequalities in health

There is some evidence that the quality and quantity of social relationships are influenced by socioeconomic position (House, Landis, Karl and Umberson, 1988; Taylor and Seeman, 1999; Pinquart and Sorensen, 2001; Victor *et al.*, 2005; Weyers *et al.*, 2008; Holt-Lunstad, 2017; Macdonald et al., 2018; Röhr *et al.*, 2022). For example, in a meta-analysis of 131 cross-sectional studies, Pinquart and Sörensen (2001) found that low socioeconomic position was associated with higher levels of loneliness. Two UK-based longitudinal studies also reported significant associations between socioeconomic position and social relationships. In one study, higher education was protective against loneliness over time among older adults (Victor *et al.*, 2005). The second longitudinal study, conducted in the North-East of England, showed that the prevalence of loneliness and social isolation was highest among those with an annual household income of less than £10,000 (Macdonald *et al.*, 2018).

The Covid-19 pandemic has further highlighted the association between deprivation and poorer social connections and has brought their combined impact on health to the fore (Banerjee and Rai, 2020; Bu, Steptoe and Fancourt, 2020). Yet, despite the vast literature on the importance of social relationships for health, evidence regarding the role of social relationships in explaining health inequalities is limited, with contradictory results (House, Landis, Karl and Umberson, 1988; Taylor and Seeman, 1999). Considering this, two prominent frameworks attempt to disentangle the role of social relationships in explaining social inequalities in health.

The *Psychosocial Pathways Framework* builds on the CSDH conceptual model to delineate the role of social relationships in explaining social inequalities in health (Bell, 2017). The framework encompasses social support, social isolation, social networks, social cohesion, and social capital within broader psychosocial factors (Figure 2.3). The psychosocial pathways framework suggests that factors such as social isolation and low quality and quantity of social relationships are socially graded and, therefore, contribute to social inequalities in health (Bell, 2017). Moreover, the framework proposes that social relationships may partly mediate the association between socioeconomic position and health and well-being.

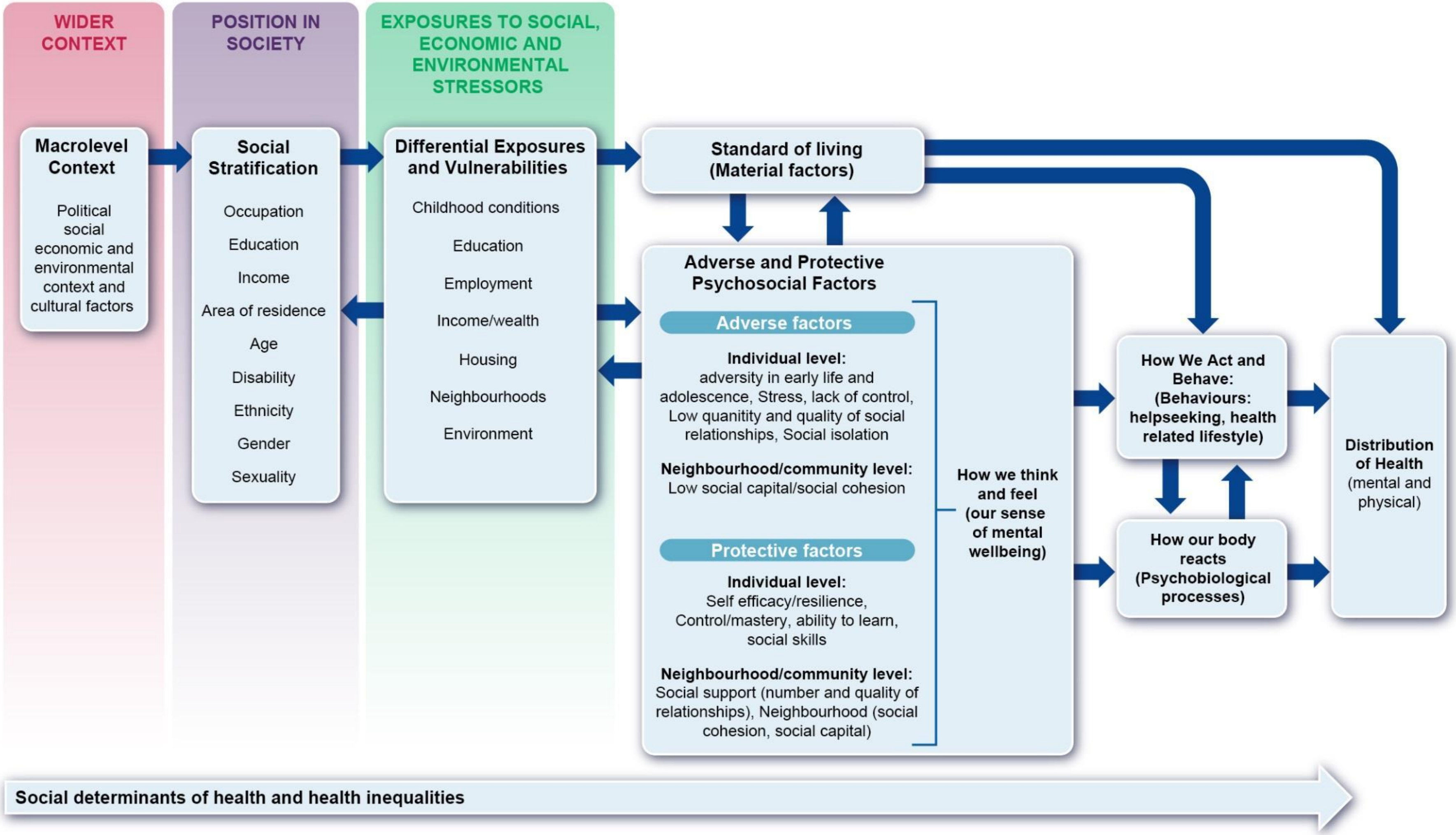

Figure 2.3 Psychosocial pathways framework (Bell, 2017)

The *social network model of health inequalities* framework scaffolds on the Dahlgren and Whitehead (2006) social determinants of health model and the Berkman and Glass (2000) social networks and health model (Klärner *et al.*, 2022). The social networks framework is presented as a causal model to help understand how social relationships are associated with social inequalities in health. It proposes that socioeconomic position has a cascading effect on the structural and functional aspects of the social network, which in turn impacts social network mechanisms, including social support and social integration. Consequently, these mechanisms will influence health inequalities via health behaviours and psychological and physiological factors (Figure 2.4). In other words, more disadvantaged individuals will have poorer social connections and fewer network resources, resulting in more pronounced adverse health effects (Klärner *et al.*, 2022).

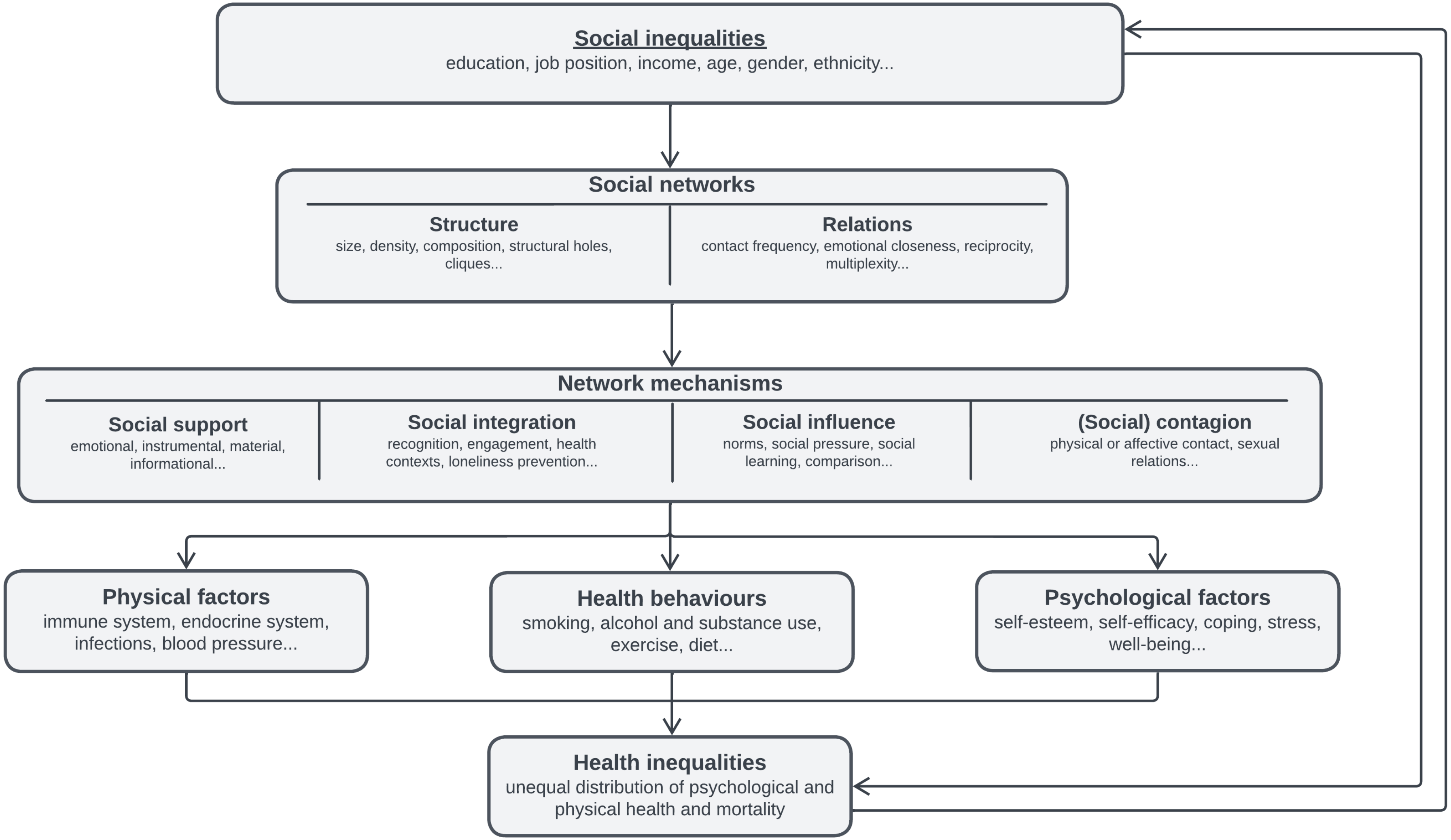

Figure 2.4 A social network model of health inequalities (adapted from Klärner et al., 2022)

Both models posit that health inequalities should not be viewed independently of the social environment. Secondly, they present social relationships as part of a broader mechanism, i.e., the psychosocial mechanism (Figure 2.3) or the social network mechanism (Figure 2.4) and as mediators in the association between socioeconomic position and health.

Although these frameworks do not present social relationships as moderating social inequalities in health, there is a large literature on the buffering effects of social support on health impacts of stress.

Additionally, studies have included social relationships as both mediators and moderators of the SEP-health association – these remain the focus of the systematic review in Chapter 4. However, to date, five reviews, including systematic reviews and literature and scoping reviews, have provided an overview of the literature examining the role of social relationships in explaining health inequalities. One review focused on the moderating role of social relationships in explaining socioeconomic inequalities (Carlson and Chamberlain, 2003), two reviews exclusively focused on the mediating role of social relationships in explaining socioeconomic inequalities (Moor, Spallek and Richter, 2017; Keim-Klärner *et al.*, 2023), and two reviews examined both the mediating and moderating role of social relationships in explaining socioeconomic inequalities in health (Uphoff *et al.*, 2013; Vyncke *et al.*, 2013). A systematic review of sixty studies looked exclusively at the moderating role of social capital in explaining social inequalities in health, and reported that social capital buffered the detrimental effect of low socioeconomic position on health (Uphoff *et al.*, 2013). In a literature review, two of the three included studies found evidence for social capital buffering the negative effect of neighbourhood deprivation on health and well-being in children (Vyncke *et al.*, 2013). A more recent scoping review also reported favourable social networks as buffering the ill-health effects of low socioeconomic position, and attenuated social inequalities in health (Keim-Klärner *et al.*, 2023). In the reviews that explored social relationships as mediating the SEP-health association, evidence for a mediating role of social relationships was not entirely consistent. In the most recent scoping review, seven of the nine included studies found social relationships attenuated the SEP-health association. In the second systematic review, eight of the eleven studies observed social relationships as mediating the association between material deprivation and health. However, disentangling social relationships as mediators of the SEP-health association was difficult as these were part of broader psychosocial factors that included factors such as coping efficacy and life events (Moor, Spallek and

Richter, 2017). In a literature review, only two of the six studies that examined the mediating role of social capital in explaining socioeconomic inequalities in health, found that social capital mediated the effect of neighbourhood deprivation on health and well-being in children (Vyncke *et al.*, 2013). Finally, in one systematic review of 19 qualitative and quantitative studies, no definitive conclusions were made regarding the overall contribution of social capital in explaining health inequalities (Carlson and Chamberlain, 2003).

2.4 Social inequalities in social relationships

Socioeconomic disadvantage is not only associated with poorer health but may also influence social relationships. As suggested in the CSDH conceptual model (Solar and Irwin, 2010), there is a complex relationship between the structural and intermediary determinants of health, taken together with the psychosocial model (Bell, 2017) and social network model (Klärner *et al.*, 2022), socioeconomic position is also seen to impact social relationships.

Research has suggested that socioeconomic position may shape the environments and influence the opportunities individuals have to establish and maintain social connections (Klärner *et al.*, 2022; Röhr *et al.*, 2022). Material deprivation may hinder individuals from participating within society or receiving adequate levels of social support by restricting access to diverse social networks and membership to certain organisations and societies (Klärner *et al.*, 2022; Röhr *et al.*, 2022). For example, in a cross-sectional study using data from the Survey of Health, Ageing and Retirement in Europe (SHARE), lower socioeconomic position was associated with lower levels of social participation and higher levels of loneliness among older individuals (Niedzwiedz *et al.*, 2016). In another cross-sectional study in Germany, middle-aged and older adults from more disadvantaged backgrounds reported lower levels of adequate social support (Weyers *et al.*, 2008). Similar findings have also been reported in a recent longitudinal study in Germany – not only was greater material disadvantage associated with a higher prevalence of social isolation, but this association was more pronounced among older individuals (Röhr *et al.*, 2022). Some research has also suggested an association with broader, state-level socioeconomic advantage and less favourable social relationships. Social security schemes, pensions, child benefit, parental leave and looking after those who are unemployed or retired are a few examples through which a state-level social safety net can help enhance self-esteem, resilience, mental health and maintain health and mobility to enable engagement with the wider society (Hansen and Slagsvold, 2016). For example, in recent a systematic review and meta-analysis across 113 countries, when disentangling patterns of association, greater welfare generosity appeared to be associated with a lower prevalence of loneliness in northern Europe compared to eastern Europe for all adults. Moreover, this association was more pronounced among older adults aged 60 year and above (Northern Europe pooled prevalence 5.2; 95% CI 4.2-6.5; Eastern Europe pooled prevalence 21.3; 95% CI 18.7-24.2) than among younger adults aged 30 to 59 years (Northern Europe pooled prevalence 2.7; 95% CI 2.4-3.0; Eastern Europe pooled prevalence 9.6; 95% CI 7.7-12.0) (Surkalim *et al.*, 2022).

It is also possible that the prevalence of social relationships may be vary according to different indicators of socioeconomic position prevalence. For example, in a systematic review by Pinquart and Sorenson (2001), not only was greater socioeconomic advantage associated with lower levels of loneliness among older people (r = -0.13; 95% CI -0.14, -0.12), but that the association was stronger between income and loneliness (r = -0.17; 95% CI -0.18, -0.15) than between education and loneliness (r = -0.08; 95% CI -0.09, -0.06).

Overall, research has shown that individuals, especially older people, may be more vulnerable to poorer social relationships due to several interconnected factors: socioeconomic position, health, and social relationships. These factors are likely to shape the opportunities people have for social participation and experiencing social relationships that are rewarding for health and well-being (Hansen and Slagsvold, 2016).

2.5 The importance of social relationships in an ageing population

Social relationships are essential for health and well-being in later life and are particularly salient in older people. For example, poorer social connections in older age are shown to be connected to premature mortality (Luo *et al.*, 2012; Schutter *et al.*, 2022), cardiovascular disease (Valtorta, Kanaan, Gilbody, Ronzi, *et al.*, 2016; Valtorta *et al.*, 2018), cognitive decline (Evans *et al.*, 2019; Lam *et al.*, 2021), and frailty (Davies *et al.*, 2021).

The prevalence of less favourable social relationships is also expected to increase with a growing ageing population. For example, in a systematic review and meta-analysis of thirty-one studies exploring the prevalence of loneliness in high-income countries, 1 in 4 older adults aged 60 years and over experienced loneliness some of the time. Furthermore, 1 in 12 people reported experiencing severe loneliness (Chawla *et al*., 2021). In 2018, 1.4 million older people in England reported often feeling lonely – a figure that is projected to increase to 2 million by 2025/26 (Age UK, 2018). Some studies have suggested a U-shaped curve of loneliness across the life course (Victor and Yang, 2012; Lasgaard, Friis and Shevlin, 2016; Luhmann and Hawkley, 2016), and yet other research suggests a non-linear relationship between loneliness and ageing (Hawkley *et al*., 2019; von Soest *et al*., 2020).

Less satisfactory social relationships, such as loneliness and social isolation among older people, are also a growing public health concern (WHO, 2021a). Organisations such as Age UK, Ageing Better, and the Campaign to End Loneliness have raised the importance of social connections for improving health and longevity, especially in later life. Moreover, The Jo Cox Commission and the UK appointing a Minister for Loneliness in 2018 have created the impetus to ensure social relationships are central in policymaking for older people. For example, *Travelling Companions' Pilot Programme* funded through the Tackling Loneliness with Transport Fund – a programme to improve older peoples' confidence in using local transport routes to connect them with their social network and access their local public services and amenities and the wider community (Age UK, 2023; Department for Digital Culture Media and Sport, 2023).

2.6 Defining social relationships

Social relationships refer to the relationship that exists between individuals. They are the recurring and reciprocal interactions between people (August and Rook, 2013; Valtorta *et al., 2016)*. Individuals are embedded in a broader network structure – families, neighbourhoods, communities, organisations or institutions – to form links with other individuals and groups (Kikuchi and Coleman, 2012). Social relationships extend from intimate ties with friends and family to wider societal ties and social integration (Ertel, Glymour and Berkman, 2009). Social interactions include a behavioural component, i.e., the degree of engagement in social activities and relationships, and a cognitive component, i.e., a sense of community and identification with one's social ties (Berkman *et al*., 2000).

Social relationships range from the individual level, for example, aspects such as social isolation, loneliness, and social support, to the community level, referring to measures such as social cohesion and social capital. Social relationships have also been shown to be associated with one another (Steptoe *et al*., 2004; Petersen *et al*., 2016).

Numerous terms exist referring to distinct aspects of social relationships, for example, social support, social network, social participation, loneliness, and social isolation. Often, terms such as social integration and social support are used interchangeably. However, conceptually they represent different approaches to understanding the influence of social relationships on health (Holt-Lunstad, 2015). No one definition of social relationships is more 'correct' than any other. For this thesis, social relationships will be an umbrella term for individuals' social ties with others, such as, but not limited to, social support, social networks, loneliness, and social participation.

2.7 Conceptualising and measuring social relationships

Conceptualising social relationships presents several important points that need consideration. First, the nomenclature of social relationships is highly varied, with no universal, agreed-upon definition. Second, there is considerable inconsistency in conceptualising social relationships. Third, evidence has shown that different aspects of social relationships affect health independently (Holt-Lunstad, 2017).

House and Kahn (1985) proposed that social relationships be distinguished through two dimensions: (1) structural and (2) functional aspects. Social support is seen as the functional dimension, with the social network as the structural dimension of social relationships. On the other hand, Holt-Lunstad (2015) suggests differentiating social relationships into three components: (1) level of integration within the social network, (2) received social support and (3) perceived social support. The latter two are concerned with the functional elements of social relationships, and the first is related to the structural component of social relationships. More recently, Valtorta *et al.* (2016) proposed a framework to classify measures of social relationships by the following two dimensions: (1) the structural or functional components of social relationships and (2) the degree of subjectivity asked of respondents. The degree of subjectivity relates to how individuals interpret social relationship questions. For example, when assessing one's satisfaction with the social network's quality and quantity, an individual may appraise social relations according to their expectations (Valtorta, Kanaan, Gilbody and Hanratty, 2016).

For this project, social relationships will be broadly thought of as having two dimensions: (1) structural and (2) functional. Structural social relationship measures refer to the quantitative part of social relationships, for example, marital status, social network size and social isolation. It includes the number and type of people interactions occur with, and the frequency and duration of the contact between individuals (Valtorta *et al.*, 2016). Functional measures refer to the qualitative aspect of social relationships, for example, social support and loneliness. It is related to the purpose and nature of relationships and the subjective assessment of the quality of one's social relationships (Valtorta *et al.*, 2016). Due to the issues with multidimensional constructs of social relationships, there are also numerous measurement tools and indices, for example, the UCLA Loneliness Scale (Russell, 1996), Berkman-Syme Social Network Index (Berkman and Breslow, 1983) and the Duke Social Support Index (Landerman *et al*., 1989). In this project, loneliness, a functional component of social relationships will be assessed using the *Revised UCLA Loneliness Scale* (Russell, 1996). Other functional and structural social relationships will be measured using scales developed and utilised by previous studies, for example, the social isolation scale utilised by Valtorta *et al*. (2018).

2.8 The influence of social relationships on health

The importance of social relationships for health and well-being is well-established (Holt-Lunstad, Smith and Layton, 2010; Berkman and Krishna, 2014).

The earliest empirical research linking social relationships to health was from the sociologist Emile Durkheim who initially linked social integration, social cohesion and mortality in his seminal work, *'Suicide'* (Durkheim, 1897). He stated that 'social facts' have a role to play in individual pathology, and showed that less socially integrated individuals were more likely to commit suicide than those who were more socially integrated (Durkheim, 1897; Berkman *et al.*, 2000).

In the mid-1970s, Cassel (1976) and Cob (1976), two influential epidemiologists, first suggested an association between social support and disease risk. Cobb's (1976) research posits social support as an essential resource in dealing with stressful life events, i.e., having a stress-buffering effect. Cassel (1976) focused on the link between social support to health via biological pathways. Following this, prominent evidence came from prospective cohort studies of mortality across developed countries (Cohen, 1988; House, Landis, Karl and Umberson, 1988; Berkman, 1995).

The evidence on associations between social relationships and health has expanded rapidly over the last two decades. This has led to several scoping reviews, systematic reviews, and meta-analyses to synthesise and provide an overview of the vast literature exploring links between social relationships, mortality, and morbidity. Where applicable, results from the reviews are summarised in the following sub-sections.

2.8.1 Social relationships and mortality

Studies consistently show that individuals with less satisfactory social relationships have an increased mortality risk compared to those with greater involvement in social relationships. For example, in a large meta-analysis of 148 studies, Holt-Lunstad *et al.* (2010) not only found that individuals with more satisfactory social relationships had a 50% increased likelihood of survival (HR: 1.50; 95% CI: 1.42-1.59) but also concluded that the influence of social relationships on mortality risk is comparable in magnitude to the impact of other well-known risk factors such as obesity and health-compromising behaviours. In a second meta-analysis, Holt-Lunstad *et al.* (2015) found social isolation and loneliness were associated with a 29% (HR: 1.29; 95% CI 1.06-1.56) and 26% (HR: 1.26; 95% CI 1.04-1.53) increased risk of mortality, respectively.

The association between loneliness and mortality risk has also been reported in two more recent systematic reviews: one was a systematic overview – a systematic review of systematic reviews, and the second was a meta-analysis of 32 studies. In the meta-analysis, loneliness was associated with a 44% (HR: 1.44; 95% CI 1.19-1.76) and 26% (HR: 1.26; 95% CI 1.07-1.48) higher risk of all-cause mortality among men and women, respectively (Rico-Uribe *et al.*, 2018). The systematic overview presented results from forty systematic reviews as a narrative synthesis. Significant associations were reported between less satisfactory levels of loneliness and social isolation and an increased risk of all-cause mortality. However, no sex differences in mortality risk were found (Leigh-Hunt et al., 2017).

Another meta-analysis of 95 studies investigated the risk of all-cause mortality using marital status (single versus married or cohabiting) as a social support and social network measure. Single people had a 24% higher risk of premature death than married or cohabiting individuals (HR: 1.24; 95% CI: 1.19-1.30) (Roelfs *et al.*, 2011). Another study examined the frequency of contact with family members, friends, and others (e.g., neighbours) on mortality risk. Those with lower levels of social contact frequency had a 1.13 (95% CI 1.09-1.17) higher risk of mortality than those with higher social contact frequency (Shor and Roelfs, 2015).

2.8.2 Social relationships and morbidity

Studies have also shown associations between social relationships and physical and mental health conditions, and biological markers. Overall, evidence links the low quantity or quality of social ties with various conditions, including the development and progression of cardiovascular disease, stroke, hypertension, inflammation, neurological outcomes, and depression.

In a meta-analysis of nineteen studies looking at the role of loneliness and social isolation on coronary heart disease (CHD) and stroke, less satisfactory social relationships were associated with a 1.29 (95% CI 1.04-1.59) higher risk of CHD and 1.32 (95% CI 1.04-1.68) higher risk of stroke (Valtorta, Kanaan, Gilbody, Ronzi, *et al.*, 2016).

More unsatisfactory social relationships and weaker social ties have also been linked to increased incidence of depression and poorer mental health (Stansfeld, Fuhrer and Shipley, 1998; Zhang and Hayward, 2006; Stafford *et al.*, 2011; Leigh-Hunt *et al.*, 2017; Sommerlad *et al.*, 2022), dementia, cognitive decline (Luanaigh and Lawlor, 2008; Cacioppo and Hawkley, 2009; Sampson, Bulpitt and Fletcher, 2009; Shankar *et al.*, 2013; Kuiper *et al.*, 2015, 2016; Donovan *et al.*, 2017; Evans *et al.*, 2019), psychophysiological outcomes (Brown, Gallagher and Creaven, 2018) and neurobiological outcomes (Lam *et al.*, 2021).

In a meta-analysis of fifty-one studies, lower levels of social isolation were associated with better cognitive function among older adults (*r*:0.054; 95% CI 0.04-0.07) (Evans *et al.*, 2019). In another systematic review of forty-one studies, higher levels of loneliness were associated with altered brain structure and function – included studies used various imaging techniques and brain tissues analyses, such as computer tomography (CT), structural magnetic resonance imaging (MRI), functional MRI (fMRI), and RNA analysis, to investigate grey and white brain matter, and activity responses in different brain regions (Lam *et al.*, 2021).

Less satisfactory relationships have also been associated with frailty. In a longitudinal study using data from the English Longitudinal Study of Ageing (ELSA), higher levels of loneliness and social isolation were associated with a higher frailty index score among people aged 50 years and above (Davies *et al.*, 2021).

Poorer social relationships are also shown to be associated with adverse oral health outcomes, such as higher rates of periodontal attachment loss (Sabbah *et al.*, 2011), a greater probability of dental caries (Tsakos *et al.*, 2013), fewer sound or filled teeth (Takeuchi *et al.*, 2013; Tsakos *et al.*, 2013; Koyama et al., 2016) and poorer subjective oral health among older adults (Tsakos *et al.*, 2013; Rouxel *et al.*, 2015). Low social support and social network ties are also associated with poorer oral health-related quality of life in adults with orofacial clefts (De Queiroz Herkrath *et al.*, 2018). Low social participation – namely, frequency of church attendance – was associated with a greater probability of gingival bleeding among adolescents (Tomazoni *et al.*, 2017).

To date, there is only one literature review that provides a narrative overview of the empirical evidence on the role of social relationships in explaining oral health inequalities. The literature included 95 studies that examined associations between social capital and various oral health outcomes such as, edentulousness, periodontal disease, dental caries, and dental pain. Social capital was positively associated with more favourable oral health outcomes such as lower rates of edentulousness, dental caries, periodontal disease and dental pain (Rouxel *et al.*, 2015).

2.8.3 The importance of different dimensions of social relationships on health

The literature on the link between social relationships and health is vast and consistent in showing that social relationships are essential for health. However, the relative importance of social relationships in predicting health and longevity may be influenced by the different aspects of social relationships being measured.

For example, two large meta-analyses found a more modest mortality risk than the systematic reviews discussed in Section 2.8.1. In a meta-analysis of ninety-one studies, a subgroup analysis of studies that excluded marital status as a measure of contact frequency reported an 11% increased mortality risk among those with lower contact frequency compared to those with greater levels of social contact (HR: 1.11; 95% CI 1.07-1.14) (Shor and Roelfs, 2015). In the second meta-analysis of thirty-six studies, loneliness was associated with a 10% higher mortality risk among older adults (HR: 1.10; 95% CI 1.06-1.14), and a larger social network was protective against premature mortality (HR: 0.96; 95% CI 0.93-0.99), although the effect size was small (Schutter *et al.*, 2022).

Another systematic found that low functional social support was significantly related to mortality risk (HR: 1.59; 95% CI 1.21-2.08), whereas structural support was not associated with mortality risk (HR: 1.12; 95% CI 0.98-1.29) (Barth, Schneider and von Känel, 2010).

Differences are also reported for associations between social relationships and morbidity. In a systematic overview, social isolation rather than loneliness was found to be associated with a higher risk of cardiovascular disease, with mixed evidence supporting associations between social isolation and hypertension. Very little evidence supported associations between loneliness, social isolation and other physical health outcomes (Leigh-Hunt *et al.*, 2017). In another systematic overview, social capital was found to be associated with better physical and mental health outcomes. However, the multi-dimensionality of social capital made it difficult to disentangle which component of social capital was more important for health (Ehsan *et al.*, 2019).

A recent narrative synthesis of 145 studies examined associations between social capital and multiple health conditions, including self-rated health, mortality, cardiovascular disease, obesity, and diabetes. 28% of studies reported a protective effect of social capital on poor health. However, 59% of studies reported mixed results, and 12% reported null effects (Rodgers *et al.*, 2019).

In a literature review examining the association between social capital and oral health, despite most studies reporting positive associations between social capital and better oral health outcomes, some notable differences were reported. Not all components of social capital were equally associated with oral health outcomes, for example, a larger network of friends was associated with lower levels of dental caries but not with edentulousness. Additionally, a larger network of friends rather than emotional social support was associated with less periodontal attachment loss (Rouxel *et al.*, 2015).

Another meta-analysis of forty-three longitudinal cohort studies investigated associations between social relationships and cognitive decline. Poorer functional (HR: 1.15; 95% CI 1.00-1.32) rather than structural social relationships (HR: 1.08; 95% CI 1.05-1.11) predicted a greater risk of cognitive decline among older adults (Kuiper *et al.*, 2016).

There were notable differences between three systematic reviews investigating the role of poor quality and low quantity of social ties in predicting inflammation. In a meta-analysis by Uchino *et al.* (2018), social support and social integration were taken as measures of social relationships. The meta-analysis reported a significant association between social support, social integration, and lower levels of inflammatory cytokines (*r*: -0.073; 95% CI -0.10, -0.05). However, another meta-analysis that focused on loneliness and social isolation found limited evidence to support associations between loneliness, social isolation, and inflammation. Of the inflammatory markers (CRP, fibrinogen, IL-6, IL-1RA and chemokine MCP-1) investigated, fully-adjusted analyses revealed that higher levels of loneliness were only associated with elevated levels of IL-6 (*r*: 0.07; 95% CI 0.02-0.12) and social isolation was only associated with elevated fibrinogen levels (*r*: 0.04; 95% CI: 0.01-0.07) (Smith *et al.*, 2020). The third systematic review also looked at the effect of loneliness on psychophysiological outcomes, such as neuroendocrine, cardiovascular, and immune responses and acute stressors. Overall, higher levels of loneliness were associated with exaggerated acute stress responses, higher blood pressure and inflammatory reactivity to acute stress. However, there was also some evidence in support of an effect in the opposite direction, i.e., higher levels of loneliness associated with blunted cardiac, cortisol, and immune responses (Brown, Gallagher and Creaven, 2018). It may be possible that loneliness operates through a mechanism that differs from other less favourable social relationship types, e.g., social isolation or poor social support (Hawkley and Cacioppo, 2003).

2.9 Pathways between social relationships and health

Durkheim's (1897) theory linking social integration, social cohesion, and suicide was one of three main theories underpinning empirical studies linking social relationships and health, and subsequently, the development of a framework to understand how social relationships influence health (Berkman *et al*., 2000). The two other theories were: social network theory, developed by two notable anthropologists, John Barnes (1954) and Elizabeth Bott (1957), linking the structure of social networks to individuals resource availability and how this shapes people's behaviour, and John Bowlby's (1969) seminal work that paved the way for life course analysis of social relationships in childhood to health in adulthood.

Social relationships are seen as being embedded within the broader cultural and social context. These cultural and social influences shape the nature of the social network structure and social ties to affect health mainly through three interrelated pathways: behavioural, psychological, and physiological (Berkman and Krishna, 2014) (See Figure 2.5). An individual's psychological state affects behaviours, and both behaviours and psychological states can manifest physiologically in measurable ways. Furthermore, to understand how social relationships are linked to health, researchers developed two models: (1) the stress-buffering model and (2) the main effects model (Cohen, 2004).

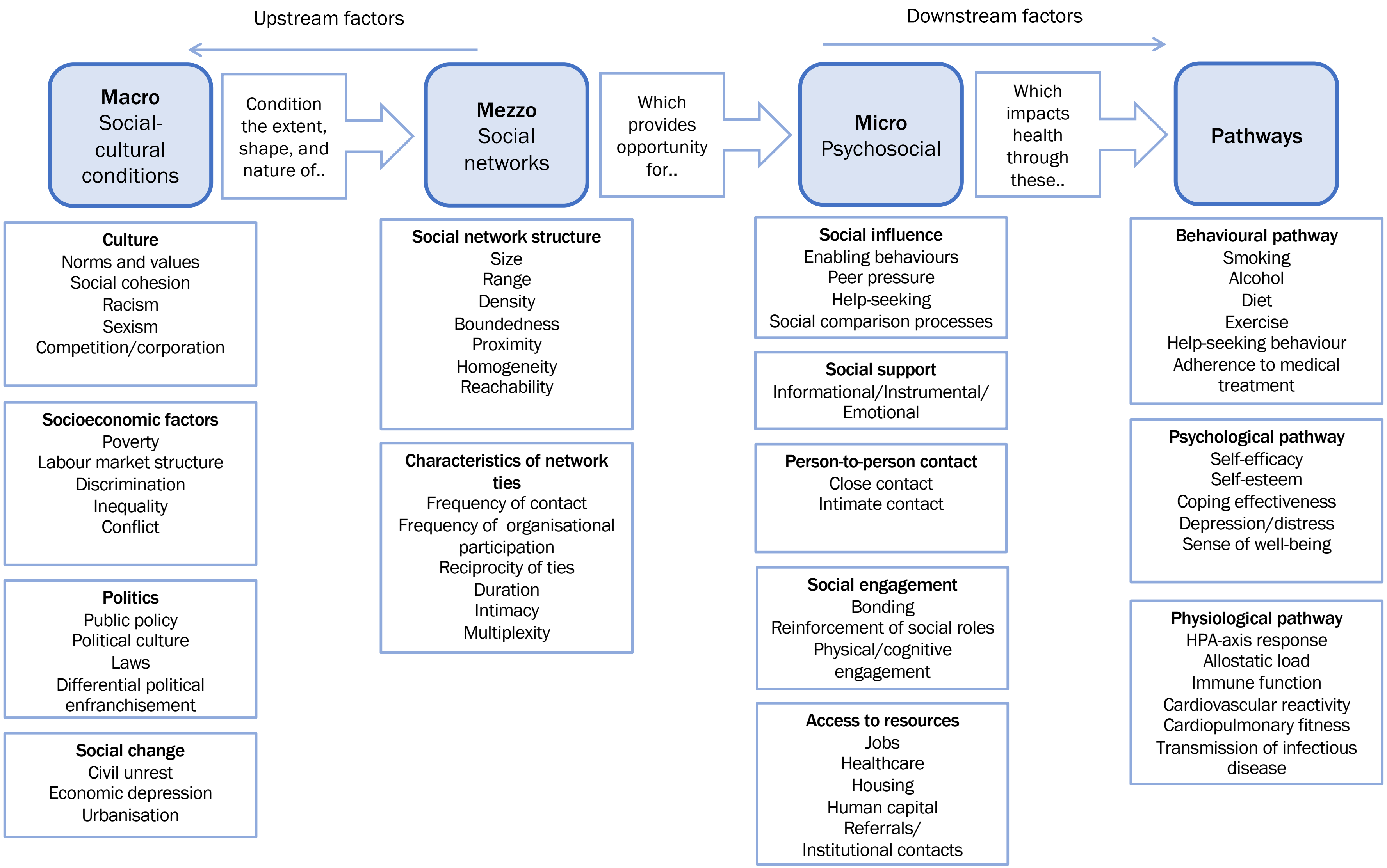

Figure 2.5 How the social network impacts health (adapted from Berkman and Krishna, 2014)

2.9.1 Behavioural pathway

Characteristics of the social environment, such as social networks and integration, regulate norms and values, which in turn influence health-related behaviours, such as the risk and attitudes towards tobacco use or alcohol consumption (Berkman and Krishna, 2014). For example, in the Framingham Heart Study: between 1971 and 2003, smoking cessation was seen as a collective phenomenon. Groups of participants became non-smokers, and smokers became increasingly marginalised in their social networks. The greater the degree of separation between those who smoked and those who did not smoke enabled smoking cessation to cascade through the network suggesting that smoking behaviour spreads through social ties (Christakis and Fowler, 2008). In a study by Watt *et al*. (2014), older Americans with a larger friendship network were more likely to be physically active, and those with less satisfactory social relationships were more likely to be engaged in smoking, heavy drinking, and less frequent dental visits.

2.9.2 Psychological pathway

Social relationships may affect health outcomes via their influence on cognitive states such as self-esteem or self-efficacy; or by directly impacting emotional well-being, mood and mental health (Berkman and Krishna, 2014). For example, in a Whitehall II study of British civil servants aged 35-55, poor social support was associated with greater psychiatric morbidity. Furthermore, confiding, emotional support and negative aspects of close relationships showed dose-response associations (Stansfeld, Fuhrer and Shipley, 1998). In a systematic overview, loneliness and social isolation were associated with several mental health outcomes, such as depression, anxiety and suicide ideation (Leigh-Hunt *et al.*, 2017).

2.9.3 Physiological pathway

Social relationships may influence health outcomes via physiological pathways such as the hypothalamic-pituitary-adrenal (HPA) axis, allostatic load, or cardiovascular and cardiopulmonary health (Berkman and Krishna, 2014). For example, several studies have found an association between less favourable social relationships and increased cortisol levels (Steptoe *et al.*, 2004; Stafford *et al.*, 2013; Brown, Gallagher and Creaven, 2018;

Iob, Kirschbaum and Steptoe, 2018). Another pathway may be the impact of less favourable social relationships, e.g., loneliness, inadequate social support or social isolation, on immune dysregulation (Brown, Gallagher and Creaven, 2018; Uchino *et al.*, 2018; Smith *et al.*, 2020). Moreover, research also shows that adverse social environments, such as loneliness, can impact cellular level changes, increasing the risk of cardiovascular disease, neurodegenerative diseases and some types of cancer (Cole *et al.*, 2007, 2011).

2.9.4 Stress-buffering model

Social relationships are seen as intervening between a stressful event, e.g., deprivation, bereavement, job loss, and its deleterious effect on health, i.e., they act as a buffer to adverse life events or stressful situations (Cohen and Wills, 1985; Cohen, 2004). Social support from an individual's social network can provide the resources to cope with the challenges of a stressful event. Stress-buffering is more effective when the social support matches the needs of the stressful event, such as emotional support availability for an uncontrollable stressful event (e.g., job loss) (Cutrona and Russell, 1990).

The stress-buffering model may operate through three interrelated pathways: behavioural, physiological, or psychological, to affect health. For example, an individual with little support may react to a stressful life event by being more negatively affected psychologically – through poorer mental health or depression – this may lead to engaging in harmful behaviours such as alcohol consumption and smoking, and these behaviours may, therefore, consequently manifest physiologically.

In a study of Mexican adults in the United States, high levels of social support buffered against life stress (Rodriguez *et al.*, 2019). In another study looking at older adults with dementia and their caregivers in Germany, social support moderated the association between stress and quality of life (Gellert *et al.*, 2018).

2.9.5 Main effects model

The main effect or direct model asserts that social relationships will affect health directly, irrespective of stressful events. This model suggests that structural and functional social relationships may influence normative health behaviours, access to resources and services and psychological well-being (Cohen and Wills, 1985; Cohen, 2004; Uchino, 2004; Thoits, 2011). Research suggests that the main effects pathway may operate via the social network to affect health to influence the regulation of self-esteem, self-mastery, self-worth, and a sense of belonging (Cohen, 2004). Emotional regulation may subsequently affect health through behavioural, psychological or physiological pathways (Berkman *et al.*, 2000; Cohen, 2004).

2.10 The rationale for the current project

Almost a quarter of the global disease burden is related to conditions affecting people aged 60 years and older, with ageing as a driver of chronic diseases that has profound societal costs (Prince *et al*., 2015). There is a wealth of literature linking poor quality and quantity of social relationships to adverse health implications, especially among older people. The evidence linking loneliness, social isolation and social support with poorer health suggests a considerable impact on individuals and society. In the UK, reducing social isolation and loneliness is a priority for public health and social care, therefore, understanding their role as mediators and moderators in the association between socioeconomic position and health is important.

Moreover, there is robust evidence on social inequalities in health: social gradients are well established, and the social determinants of health are widely recognised. While evidence has found that material, behavioural, physiological, and psychosocial pathways link socioeconomic position and health, few studies have explored the contribution of social relationships to social gradients in health. Therefore, advancing our understanding of the role of social relationship measures in explaining social inequalities in the health, especially among older adults, is paramount if we are to flatten the social gradient in health.

To date, there has been no comprehensive review of the literature on the role of social relationships in mediating or moderating health inequalities. Existing reviews have either been selective in the type of social relationship measure investigated (Carlson and Chamberlain, 2003; Uphoff *et al.*, 2013; Vyncke *et al.*, 2013), or presented a scoping review (Keim-Klärner *et al.*, 2023), or investigated social relationships as part of wider psychosocial measures (Moor, Spallek and Richter, 2017). Therefore, the first part of this project involved undertaking a comprehensive and systematic review of the empirical evidence to understand the mediating and moderating role of social relationships in the association between socioeconomic position and health.

Chapter 3. Aims, objectives and conceptual models

Chapter summary: This chapter outlines the aims, objectives, hypotheses, and conceptual models for the PhD thesis. This project focuses on four key aspects of social relationships: loneliness, social isolation, positive social support, and negative social support. The rationale for selecting these dimensions of social relationships is explained in Chapter 2. Five health outcomes have been selected for this project: self-rated health, blood pressure, self-rated oral health, oral health-related quality of life and edentulousness. The rationale for the health outcomes selected are presented in Chapter 4. This chapter also describes how social relationships fit in to the conceptual models to explain how they mediate and moderate social inequalities in health.

3.1 Aim

This PhD research aims to examine the mediating and moderating role of social relationships in the association between socioeconomic position and general health and oral health among a representative sample of UK older adults using data from the English Longitudinal Study of Ageing (ELSA).

3.2 Objectives and hypotheses

The following objectives will be addressed:

Objective 1: To systematically review and summarise the existing evidence for the mediating and moderating role of social relationships in the association between socioeconomic position and health.

Objective 1a: To assess the evidence for a mediating role of social relationships in the association between socioeconomic position and health.

Objective 1b: To assess the evidence for a moderating role of social relationships in the association between socioeconomic position and health.

Objective 2: To investigate the association between socioeconomic position and health outcomes among UK older adults.

Hypothesis for objective 2: There are stepwise, linear social gradients in general health and oral health among UK older adults.

Objective 3: To investigate the association between socioeconomic and social relationships.

Hypothesis for objective 3: Structural and functional measures of social relationships are socially patterned. The more advantaged an individual's socioeconomic position, the greater the number of social contacts and frequency of contact with their network structure; the more likely they are to be affiliated with a voluntary association; the lower the levels of social isolation and loneliness and the greater the levels of social support.

Objective 4: To examine cross-sectionally whether accounting for structural and functional aspects of social relationships attenuates social gradients in health outcomes.

Hypothesis for objective 4: Accounting for social relationships cross-sectionally will attenuate associations between socioeconomic position and health outcomes.

Objective 5: To examine longitudinally the extent to which structural and functional aspects of social relationships mediate associations between indicators of socioeconomic position and general and oral health outcomes.

Hypothesis for objective 5: Social relationships will mediate social inequalities in health longitudinally such that social relationships will be on the pathway between socio-economic position and general and oral health.

Objective 6: To examine effect modification to determine whether structural and functional aspects of social relationships buffer social gradients in general and oral health outcomes.

Hypothesis for objective 6: Social relationships will buffer social gradients in health such that the association between socioeconomic position and general and oral health will be weaker among those with more satisfactory social relationships.

3.3 Conceptual models for this research project

The systematic review and background chapters provide evidence for the links between social relationships, socioeconomic position, and health. To disentangle the association between socioeconomic position and health, the CSDH, psychosocial and social networks theoretical framework models presented in Chapter 2 (Section 2.3) have informed the conceptual models for this study.

The conceptual frameworks for this project exclusively explore the mediating and moderating role of social relationships in explaining socioeconomic inequalities in health. Socioeconomic position is a structural determinant of health inequality, and social relationships are seen as intervening the pathway between socioeconomic position and health. Therefore, socioeconomic position may also influence social relationships which in turn may affect health by mediating or moderating the association between socioeconomic position and health.

3.3.1 Conceptual model for social relationships mediating socioeconomic inequalities in health

Figure 3.1 illustrates that an individuals' socioeconomic position is hypothesised to affect general health and oral health outcomes partly through the functional and structural components of social relationships. Social relationships are hypothesised to intervene in the pathway between socioeconomic position and health (see pg. 140 for a detailed explanation).

Explaining the conceptual model from left to right, socioeconomic position (measured by wealth, educational level, and occupational status), is a structural determinant of health. Socioeconomic position not only defines an individual's position in society, but also influences vulnerability to disease. Associations also exist between the individual markers of socioeconomic position, although these associations were not tested empirically. The conceptual model illustrates that an individual's socioeconomic position is shaped by the broader, upstream political, social, and macroeconomic policies (see Chapter 2, Section 2.2).[2]

The model illustrates that socioeconomic position impacts health through a direct pathway as depicted by the solid arrows. The double headed solid arrows illustrate bidirectional associations between socioeconomic position and health. Greater socioeconomic advantage is hypothesised to be associated with a lower likelihood of poor health, similarly, poor health is hypothesised to be associated with a greater likelihood of socioeconomic disadvantage.

Moving to the middle of the model, direct pathways are hypothesised between socioeconomic position and social relationships (illustrated by the single-headed solid arrow). Better socioeconomic position is hypothesised as giving access to more satisfactory social relationships, i.e., greater positive social support, lower levels of negative support and loneliness, and feeling less social isolated. Conversely, greater socioeconomic disadvantage is hypothesised as being associated with poorer social relationships and will consequently have an adverse effect on health.

Moving from the middle of the model to the right-hand side: socioeconomic position is hypothesised to impact health indirectly via functional (negative and positive social support and loneliness) and structural (social isolation) social relationship measures (blue arrows). The solid double-headed arrows from social relationships to the health outcomes illustrate a bidirectional association between social relationships and health. Experiencing greater levels of loneliness, social isolation and negative social support and lower levels of positive social support are hypothesised to be associated with a greater likelihood of experiencing poor health. Similarly, poorer health is hypothesised to be associated with less favourable social relationships.

In both the direct and indirect pathways, low socioeconomic position is hypothesised to be associated with poor health.

[2]This pathway is depicted by the single-head grey arrow from the upstream factors to socioeconomic position – the dashed lines indicates that this pathway is beyond the scope of this PhD project and therefore, not investigated.

The conceptual model depicts alternative pathways that are not investigated as they are beyond the scope of this project. As described by the CSDH framework, socioeconomic position may also impact health via alternative pathways (see Chapter 2, Section 2.2) – these are illustrated by the grey box positioned between social relationships and health. Moreover, social relationships may affect health both directly and either through behavioural, physiological, or psychological pathways (see Chapter 2, Section 2.7), however, in this project these were not tested empirically. Since health behaviours, physiological factors and psychological factors are also potential mediators, and therefore on the causal pathway from socioeconomic position to health, including these as additional mediators or covariates would obscure the association being tested in this project: SEP → social relationships → health, and result in an over adjustment of the model.

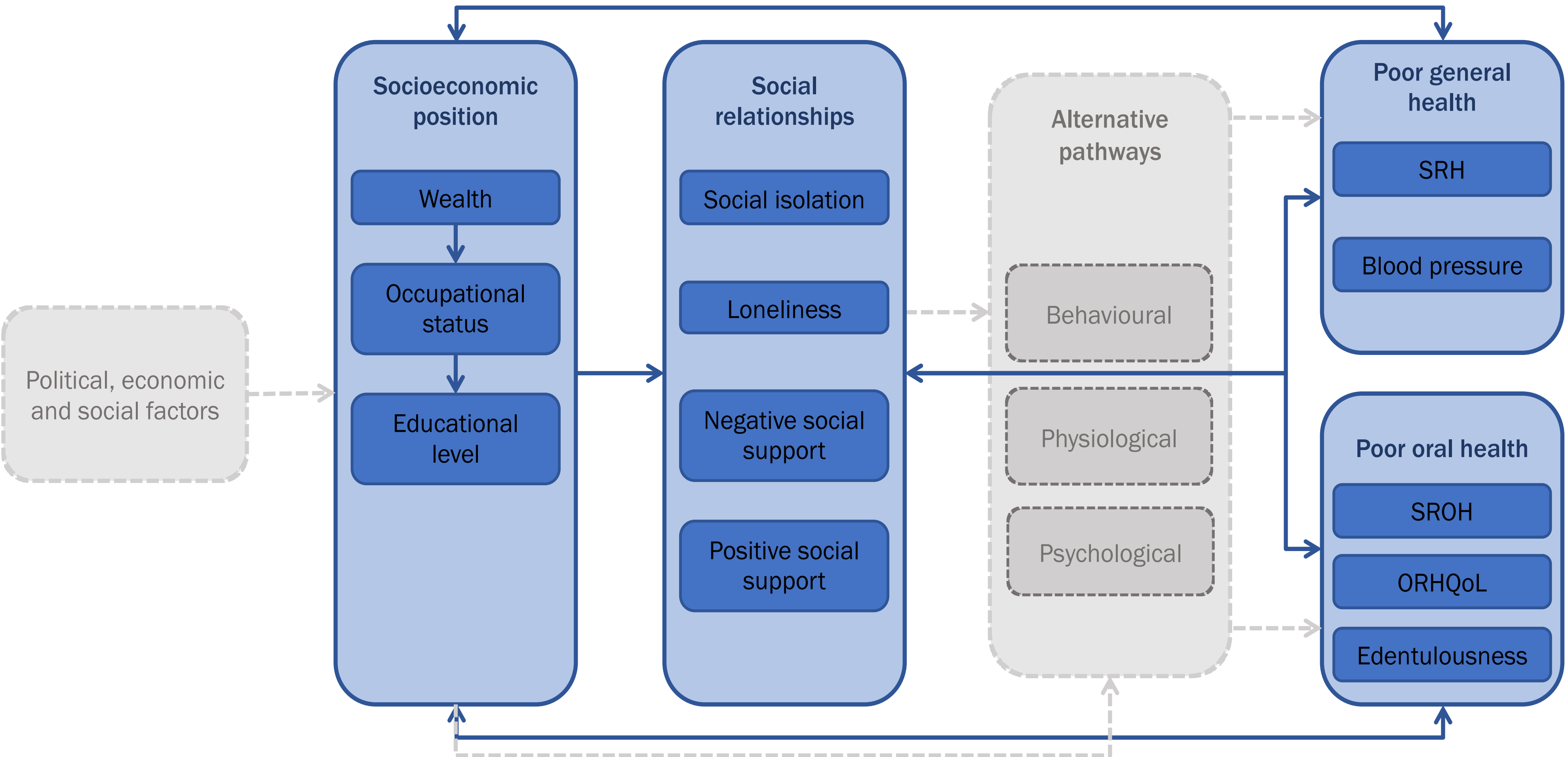

Figure 3.1 Conceptual model for thesis project: social relationships mediating socioeconomic inequalities in health

3.3.2 Conceptual model for social relationships moderating socioeconomic inequalities in health

Figure 3.2 illustrates that structural and functional social relationships may alter the strength of the association between socioeconomic position and health – social relationships may contribute to either enhance or diminish the effect of socioeconomic position on health (see pg. 145 for a detailed explanation)

In this model, low socioeconomic position, captured by the same indicators as in Figure 3.1, is hypothesised to be associated with poor health directly, as depicted by the dark solid arrows. However, unlike the mediation model whereby socioeconomic position indirectly affects health through social relationships, moderation implies that differing levels of social relationships will also differ in their contribution to either buffering or strengthening the negative effect of low socioeconomic position on poor health. This moderation effect is depicted by the blue arrows directly affecting the pathway from socioeconomic position to poor health.

Similar to the previous model in Figure 3.1, alternative pathways to poor health are also acknowledged, since testing these pathways is beyond the scope of this project they are depicted by grey dashed arrows.

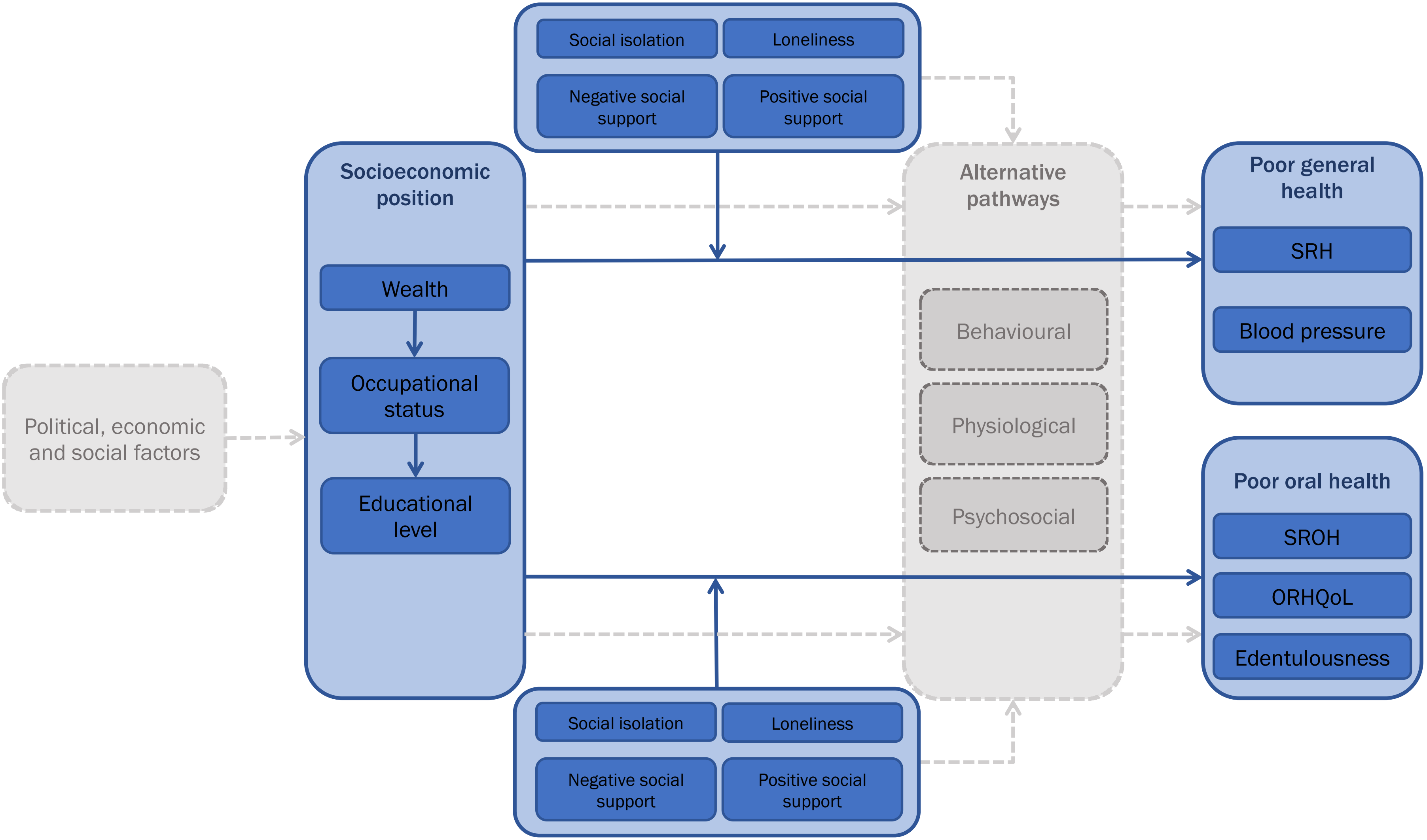

Figure 3.2 Conceptual model for thesis project: social relationships moderating socioeconomic inequalities in health

Chapter 4. Systematic Review

Chapter summary: To synthesise the existing evidence on whether social relationships mediate or moderate social inequalities in health, I systematically reviewed studies linking socioeconomic position, social relationships, and health. This chapter reports on the protocol implemented to conduct the systematic review, followed by a narrative synthesis presented separately for studies assessing the role of social relationships in mediating and moderating socioeconomic inequalities in health. Finally, I summarise the evidence in the discussion, discuss the strengths and limitations of the review and outline the gaps in the literature.

This systematic review's methods and results are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher, Liberati and Tetzlaff, 2009). This review's protocol was submitted for registration on PROSPERO (CRD42020181706) and published in Springer Nature Systematic Reviews Journal (Khaliq *et al.*, 2022).

4.1 Background

The rationale for undertaking this review has been outlined in the Chapter 2 (Section 2.10). To date, five reviews have been conducted on the role of social relationships in mediating or moderating health inequalities, however, these reviews have limitations and gaps remain. Existing reviews have focused on the role of social capital (Carlson and Chamberlain, 2003; Uphoff *et al.*, 2013; Vyncke *et al.*, 2013) or social relationships as part of wider psychosocial factors (Moor, Spallek and Richter, 2017). Carlson and Chamberlain (2003) and Vyncke *et al.* (2013) reviewed the role of social capital at the neighbourhood level in explaining social inequalities in health. Vyncke *et al.* (2013) limited the population group to children and adolescents. Carlson and Chamberlain (2003) focused on civic trust and social participation and could not make definitive conclusions regarding the overall contribution of social capital in explaining health inequalities. Similarly, Uphoff *et al.* (2013) only examined whether social capital moderate's socioeconomic inequalities in health. Moor *et al.*, (2017) focused on direct and indirect associations between socioeconomic position and self-rated health via three pathways: (1) psychosocial – this included social relationships but also had measures such stress, resilience and coping mechanisms, (2) behavioural and (3) material. Firstly, this systematic review limited health outcomes to one measure (self-rated health). Secondly, due to the overlap between socioeconomic position and material factors, distinguishing whether social relationships operate on the pathway from socioeconomic position to health was difficult. Thirdly, since social relationships were assessed as part of the wider psychosocial context, delineating their contribution to explaining social inequalities in health was also difficult. In a more recent review, social relationships were assessed for their contribution in mediating or moderating social inequalities in health (Keim-Klärner *et al.*, 2023). However, this was a scoping review, i.e., exploratory in nature, conducted to map qualitative and quantitative literature on social networks in explaining social inequalities in health.

The focus of this systematic review was to examine the link between social relationships and socioeconomic position and health. Strengths and limitations of the evidence are considered, and findings discussed in the context of previous reviews. It also identifies gaps in knowledge where further research is required. It is hoped that the findings will be useful for developing policies aiming to reduce social inequalities in health.

4.2 Aim

This systematic review aimed to assess and synthesize the evidence on the role of social relationships in the association between socioeconomic position and health. The main objectives were:

1. To assess the evidence for a mediating role of social relationships in the association between socioeconomic position and health
2. To assess the evidence for a moderating role of social relationships in the association between socioeconomic position and health

4.3 Methods

4.3.1 Study design

The review included any interventional (i.e., randomised, or non-randomised trials) or observational study (i.e., cross-sectional, cohort or case-control studies) that assessed the role of social relationships in mediating or moderating health inequalities. Studies needed to have quantified the contribution of social relationships to the association between socioeconomic position and health (for mediation) or presented interaction effects or stratified results for different levels of social relationships (for moderation).

Studies were included if they examined the mediating or moderating role of at least one indicator of social relationships in the association between socioeconomic position and health. The search included peer-reviewed articles, as well as grey literature (such as preprints and conference abstracts) available from the databases specified below. The only restrictions in terms of publication type were for review articles, opinion pieces and theoretical articles, which were excluded.

Studies were excluded if they only included socioeconomic position as a covariate rather than the exposure variable.

4.3.2 Participants

Individuals from any population group and of all ages were included – there were no age restrictions or cut-offs for including or excluding studies in this review. Individuals with any physical or mental health condition were also included.

4.3.3 Outcomes

An earlier scoping search revealed that there were not many studies that have examined the mediating and moderating role of social relationships in explaining social inequalities in health. As such, this review includes studies that cover a wide range of subjective or objective measures of mental and physical health when assessing health inequalities. Outcome measures include, but were not limited to, mortality, coronary heart disease, stroke, immune response, self-rated health, health-related quality of life, depression, cognitive decline, and measures of oral health. Studies were not excluded based on the type of outcome measure used.

4.3.4 Exposures

The exposures of interest were socioeconomic position and social relationships. The review focuses on the combined impact of these exposures, i.e., only studies that explored whether social relationships mediated or moderated the association between socioeconomic position and health have been included.

Socioeconomic position summarises an individual's position within the social hierarchy and refers to their material and social resources. Studies were not excluded based on the type of the socioeconomic variable used. Any measure of socioeconomic position was included such as occupational status, educational level, income, or household wealth; as well as proxy measures such as housing tenure or car ownership.

There is no universally agreed-upon definition of what constitutes social relationships; therefore, the search strategy intentionally included terms that refer to the degree of connection individuals have with others. These included, but were not limited to, social connectedness, social support, social networks, engagement, sociability, social attachments, social capital, and social integration—keeping the definition of social relationships broad permitted identifying studies that differentiated between structural and functional aspects of social relationships. Studies were not excluded based on the type, reliability and validity of the social relationship measure used.

4.3.5 Search strategy

An electronic search was carried out to identify all relevant studies from the following databases: MEDLINE, Embase Classic + Embase and PsycINFO (using the Ovid platform). No date restrictions were applied to the search strategy. Studies were included from database inception to 15th March 2023, published in any language, to identify all relevant studies.

Search terms included terms relating to social relationships, socioeconomic position, and health inequalities. Specific health outcomes were not included in the search strategy, as any health outcome was considered (Appendix 1).

Various tools such as Boolean operators, truncation and proximity indicators were used to ensure a comprehensive search that identified all relevant articles (Appendix 2). The search strategy was developed by me and Jacqueline Smith (Science Librarian, UCL), and peer reviewed by Jacqueline Smith, Katie Abranson and Dr Debora Marletta (UCL Library Services) using the Peer Review of Electronic Search Strategies (PRESS) checklist (McGowan, Sampson and Lefebvre, 2010). Reference lists of all relevant full-text papers were screened to retrieve additional articles not identified through the database search. The study selection process is summarised in a PRISMA flowchart (Moher, Liberati, Tetzlaff, 2009) (Figure 4.1).

4.3.6 Study selection

All relevant articles retrieved from the database searches were stored in the reference manager, Mendeley (Foeckler, Henning and Reichelt, 2008). After the removal of duplicates, articles were exported to Rayyan QCRI (Ouzzani *et al.*, 2016) for screening. The UCL findit@UCL linking service was used to retrieve the full texts of these articles. Rayyan QCRI (Ouzzani *et al.*, 2016) was used by two reviewers (Nadia Khaliq and Dr Carolina Machuca-Vargas) to independently (i.e., blind to the other reviewers' decisions) screen titles, abstracts and full-text reviews for eligibility, and carry out data extraction, and assessment of bias. Any remaining unresolved disputes following this process went through a tie-break decision from an external reviewer not involved in the review process (Dr Anja Heilmann).

4.3.7 Data extraction

Data extraction for this review was developed and piloted using a sample of eligible studies. The piloting process ensured reliability in the interpretation and use of the inclusion criteria. Upon finalisation of the data extraction form, the reviewers (Nadia Khaliq and Dr Carolina Machuca-Vargas) extracted the data and reasons for exclusion were listed.

Discrepancies during this process were resolved through consensus meetings. The reviewers extracted data regarding key elements of each study, including:

- Citation details such as first author and year of publication
- Study population including country or region, sample size and demographic indicators such as age and sex
- Study design, e.g., cross-sectional, longitudinal
- The follow-up period for longitudinal designs
- Whether the study examined mediation or moderation
- Exposure indicators (socioeconomic position and social relationship variables), and health outcomes assessed
- Statistical methods implemented and main results, e.g., odds ratios, relative risks.

During the protocol planning stage, it was expected that outcome measures would be both continuous – with results presented either as standardised or unstandardised beta coefficients; or categorical – with results presented as odds ratios, relative risks or hazard ratios.

4.3.8 Data synthesis and reporting

Studies were highly variable in statistical techniques implemented for mediation studies. Sixteen studies decomposed total effects on the components of direct and indirect effects making it inappropriate to combine these with studies adjusting for social relationships. A separate meta-analysis would have to be conducted through either one of two methods: multivariate meta-analysis of standardised direct and indirect effects, or meta-analytic structural equation modelling. Due to substantial heterogeneity between studies, I^2 statistic >60%, it was decided to report the results in a narrative synthesis with effect direction plots.

A modified version of effect direction plots (Boon and Thomson, 2021) is presented in the results section, with detailed descriptive tables presented in the appendices. Results from studies are reported as either positive (if there was evidence of mediation or moderation); mixed findings (if there was evidence of mediation or moderation in subgroups only); negative findings (if there was evidence of social relationships contributing to increased social inequalities in health); or null findings (if there was no evidence of mediation or moderation). Studies are further ordered by risk of bias, using colour-coding i.e., low (green), moderate (yellow) and high bias (red).

The Economic and Social Research Council Methods Programme guidelines (Popay *et al.*, 2006) have been used to guide the narrative synthesis, and the data were ordered alphabetically, presented by health outcome and grouped by:

1) Mediation analyses
    a) Self-rated health
    b) Mortality, chronic disease, and physical function
    c) Depression and mental health
2) Moderation analyses
    a) Self-rated health
    b) Mortality, chronic disease, and physical function
    c) Depression and mental health

Cross-sectional studies were assessed using a modified version of the Newcastle-Ottawa Quality Assessment Scale, assigning studies a maximum of ten points (Wells *et al.*, 2000; Modesti *et al.*, 2016) (Appendix 3). Longitudinal studies were assessed using the Newcastle-Ottawa Quality Assessment Scale for cohort studies, with studies achieving a maximum of nine points (Wells *et al.*, 2000) (Appendix 4). Assessments included representativeness of participants, statistical methods implemented, including identifying potential confounders, handling of missing data, attrition in longitudinal studies, how exposures and outcomes were measured, and any significant limitations of the study. Those that scored a total of eight or more points were considered to have a low risk of bias; six to seven points were considered to have a medium risk of bias, and five points or less were considered to have a high risk of bias (Appendix 5) (Ribeiro *et al.*, 2020).

4.4 Results

4.4.1 Article screening

Four hundred and thirty-four articles were retrieved from an initial 10,442 potential articles through article title screening. Of these, 155 duplicates were removed using Mendeley

(Foeckler, Henning and Reichelt, 2008), therefore, leaving 279 articles that were included in the abstract and title screening. One hundred and sixty-three articles were excluded at the abstract and title screening stage due to ineligibility. Forty-seven were excluded after reading the full-text due to ineligible exposures, mediators, or outcome or because they did not investigate the mediating or moderating role of social relationships. Sixty-nine studies fulfilled the criteria for the systematic review (Figure 4.1).

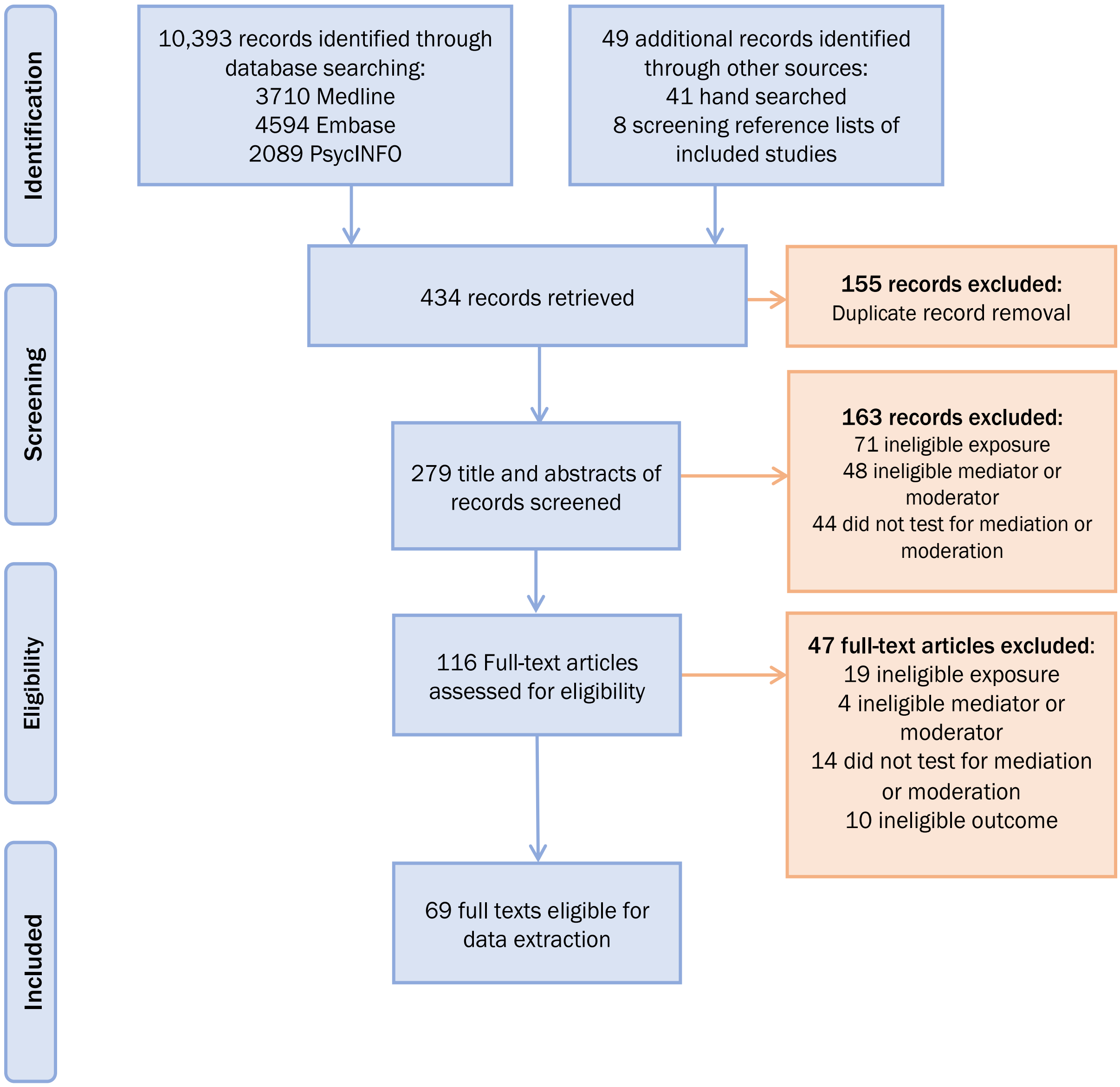

Figure 4.1 Study Selection – PRISMA flow diagram (Moher, Liberati, Tetzlaff, 2009)

4.4.2 Study characteristics

A total of 69 studies were identified for the narrative synthesis from 40 countries across six continents – most studies were conducted in North America and Europe (Figure 4.2). All studies were observational in design. Nineteen were longitudinal studies, and 51 were cross-sectional. Nine of the included studies limited their population to children or adolescents; 60 studies looked at adult populations, of which 33 studies focused on middle- and/or older-aged adults (Tables 4.1 and 4.2).

Forty-two studies explored the mediation effects of social relationships and 33 studies looked at the moderating role of social relationships (six studies explored both).

Measures of socioeconomic position were highly variable across all studies. Approximately a third of studies used education either independently, in combination with other socioeconomic variables or as part of a composite measure.

For the purposes of this PhD project, the narrative synthesis was not limited to high quality studies only – moderate and low-quality studies were also included. Excluding lower quality studies would have limited (1) the synthesis largely to social relationships mediating or moderating social inequalities in self-rated health, (2) the number of studies with large sample sizes, (3) reduced the number of studies that included adults aged 50 years and above within their sample, (4) reduced the number of studies that implemented the use of both structural and functional social relationship measures, (5) and those that reported null and negative findings. This would have made considerable implications on the interpretation of the results especially with regards to disentangling the importance of structural and functional social relationships in explaining social inequalities in health and being able to make comparisons between findings from my own study. This limitation is acknowledged and the results from the synthesis are interpreted with caution in the discussion in Section 4.5.

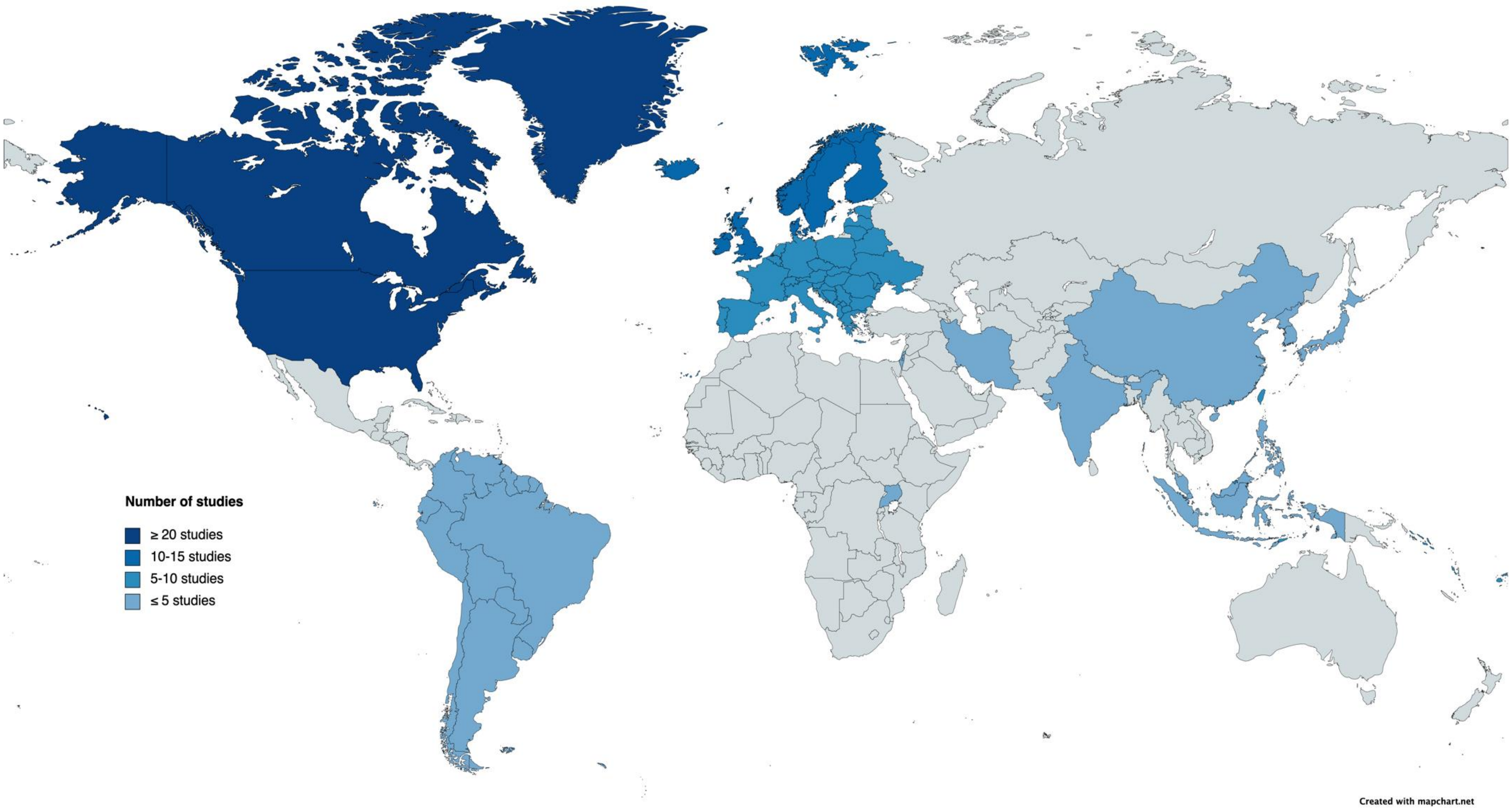

Figure 4.2 Distribution of countries included in studies

4.4.3 Studies assessing mediation

Of the 42 studies that assessed mediation, 26 utilised regression modelling to quantify the contribution of social relationships to associations between socioeconomic position and health, including the six studies that explored mediation and moderation. Sixteen studies provided estimates of mediation analysis through indirect and direct effects. The studies ranged mainly between low and moderate levels of bias and varied considerably by study characteristics (see Table 4.1 and Appendix 5). The sample size of the studies ranged from approximately 400 to 450,000 participants. The largest studies were conducted in North America (Gorman and Sivaganesan, 2007; Kim and Kawachi, 2007; Moor *et al.*, 2014), Europe (Von Dem Knesebeck and Geyer, 2007; Aldabe *et al.*, 2011; De Clercq *et al.*, 2012; Verhaeghe and Tampubolon, 2012; Moor *et al.*, 2014; Etman *et al.*, 2015; Vonneilich *et al.*, 2019; Meisters *et al.*, 2021), China (Wei *et al.*, 2018; Jin, Zhu and He, 2020; Zhang *et al.*, 2022) and the Middle East (Hassanzadeh *et al.*, 2016).

Social relationships mediating social inequalities in self-rated health

Self-rated health was assessed in 25 studies on mediation (Appendix 7). Only two were longitudinal (Klein *et al.*, 2012; Vonneilich *et al.*, 2012). Eleven cross-sectional and two longitudinal studies reported positive findings, i.e., a reduction in the magnitude of effect estimates for social inequalities in self-rated health after adjustment for structural and functional social relationship aspects in children (Due *et al.*, 2003; De Clercq *et al.*, 2012; Moor *et al.*, 2014; Gadermann *et al.*, 2016) and adults (Kim and Kawachi, 2007; Soskolne and Manor, 2010; Aida *et al.*, 2011; Klein *et al.*, 2012; Rios, Aiken and Zautra, 2012; Verhaeghe and Tampubolon, 2012; Vonneilich *et al.*, 2012; Cundiff, Kamarck and Manuck, 2016; Meisters *et al.*, 2021). Seven studies reported mixed findings, i.e., attenuation was found in subgroups only, where groups were defined by sex, socioeconomic indicator, or social relationship type in children (Salonna *et al.*, 2012) and adults (Sacker *et al.*, 2001; Von Dem Knesebeck and Geyer, 2007; Aldabe *et al.*, 2011; Rueda, 2012; Aartsen, Veenstra and Hansen, 2017; Vonneilich, Lüdecke and von dem Knesebeck, 2019). Five studies reported null findings, i.e., found that social relationships did not mediate social inequalities in self-rated health (Antonucci, Ajrouch and Janevic, 2003; Gorman and Sivaganesan, 2007; Platts and Gerry, 2017; Kaur *et al.*, 2018; Rodrigues *et al.*, 2021).

Cross-sectional studies

All cross-sectional studies on social gradients in children's self-rated health observed a mediating role of social relationships (Due *et al.*, 2003; De Clercq *et al.*, 2012; Salonna *et al.*, 2012; Moor *et al.*, 2014; Gadermann *et al.*, 2016). Accounting for social relationships attenuated between 5% and 78% of the association between socioeconomic position and self-rated health in children. Two studies explored sex-specific patterns for differences in social gradients of poor self-rated health. In one study, sex differences were only seen for one of the three socioeconomic indicators used; social support from the father explained 31% of the association between high financial strain and self-rated health among boys only (Salonna *et al.*, 2012). In a second cross-sectional study, social relationships (parental, peer, teacher and school relations) explained a larger proportion of the socioeconomic differences in physical health status for boys compared to girls (60% and 78%, respectively), with parental and school relations playing the most important role (Due *et al.*, 2003).

Similar to the studies in children, social gradients in adults' self-rated health also varied in the magnitude of the attenuation of social gradients in self-rated health. Adjustment for social relationships explained between 1% and 60% of the association between socioeconomic position and self-rated health (Sacker *et al.*, 2001; Von Dem Knesebeck and Geyer, 2007; Kim and Kawachi, 2007; Soskolne and Manor, 2010; Aida *et al.*, 2011; Aldabe *et al.*, 2011; Rios *et al.*, 2012; Rueda, 2012; Verhaeghe and Tampubolon, 2012; Cundiff *et al.*, 2016; Aartsen *et al.*, 2017; Vonneilich *et al.*, 2020; Meisters *et al.*, 2021).

Six cross-sectional studies in adults examined the mediating effect of both structural and functional social relationship measures (Kim and Kawachi, 2007; Soskolne and Manor, 2010; Aida *et al.*, 2011; Aldabe *et al.*, 2011; Aartsen *et al.*, 2017; Vonneilich *et al.*, 2019). Structural or functional measures explained up to 46% of the social gradients in self-rated health. However, in studies among adults that assessed mediation through functional measures only – either separately or within a composite measure – social relationships explained between 7% and 25% of the association between socioeconomic position and subjective health status (Sacker *et al.*, 2001; Von Dem Knesebeck and Geyer, 2007; Rios, Aiken and Zautra, 2012; Rueda, 2012; Cundiff, Kamarck and Manuck, 2016; Meisters *et al.*, 2021).

Five cross-sectional studies among adults examined sex-specific patterns of associations of socioeconomic position, social relationships, and self-rated health – three studies reported no significant differences between men and women (Aldabe *et al.*, 2011; Aartsen, Veenstra and Hansen, 2017; Vonneilich, Lüdecke and von dem Knesebeck, 2019). However, two cross-sectional studies among older adults reported a difference. In one cross-sectional study comparing two deprived regions to two more affluent areas, social support explained between 11% and 15% of the social inequalities in self-rated health for women but not men (Rueda, 2012). In the second European cross-sectional study, inconsistent sex differences were reported – some countries showed larger health benefits of social support among women, whereas, in other countries, health benefits were greater among men (Von Dem Knesebeck and Geyer, 2007).

High and moderate quality cross-sectional studies

The magnitude of effects for high quality cross-sectional studies was similar to those seen above – social relationships explained between 3.7% and 78% of the association between socioeconomic position and self-rated health (Due *et al.*, 2003; Soskolne and Manor, 2010; De Clercq *et al.*, 2012; Vonneilich, Lüdecke and von dem Knesebeck, 2019). Similarly, the magnitude of effect size across all studies of moderate quality ranged between 2.5% and 70.5% (Sacker *et al.*, 2001; Von Dem Knesebeck and Geyer, 2007; Kim and Kawachi, 2007; Aida *et al.*, 2011; Salonna *et al.*, 2012; Verhaeghe and Tampubolon, 2012; Rios, Aiken and Zautra, 2012; Rueda, 2012; Moor *et al.*, 2014; Cundiff, Kamarck and Manuck, 2016; Gadermann *et al.*, 2016; Aartsen, Veenstra and Hansen, 2017; Meisters *et al.*, 2021).

Longitudinal studies

Two longitudinal studies investigating the mediating role of social relationships in inequalities in self-rated health looked at German adult populations in two different regions (Klein *et al.*, 2012; Vonneilich *et al.*, 2012). One, high quality study focused on middle-aged and older adults aged 45 to 75 (Vonneilich *et al.*, 2012), whereas the second, moderate quality study looked at all adults aged 20 years and over (Klein *et al.*, 2012). Both studies explored the role of social relationships on the association between baseline socioeconomic position and health at the 5-year follow-up. The study looking at effects in older adults observed that up to 26.6% of the socioeconomic inequalities in self-rated health were explained by social relationships (Vonneilich *et al.*, 2012). In the study across adults aged 20 years and above, social relationships attenuated up to 35% of the SEP-SRH association (Klein *et al.*, 2012).

Social relationships mediating social inequalities in mortality risk, chronic disease, and physical function

Sixteen studies explored whether social relationships mediated socioeconomic inequalities in mortality, chronic diseases, and physical function in adults (Gorman and Sivaganesan, 2007; Kim and Kawachi, 2007; Daoud, Soskolne and Manor, 2009; Nilsson, Avlund and Lund, 2010; Soskolne and Manor, 2010; Aida *et al.*, 2011; Stringhini *et al.*, 2012; Veenstra and Patterson, 2012; Wang, Hoshi and Ai, 2015; Etman *et al.*, 2015; Zhang and Xiang, 2019; Meisters *et al.*, 2021; Adhikari and Uddin, 2022; Zhang *et al.*, 2022; Cao *et al.*, 2022; Lai, Ho and Woo, 2023). In addition, seven longitudinal studies assessed mortality, physical function, frailty or physical health (Nilsson, Avlund and Lund, 2010; Stringhini *et al.*, 2012; Veenstra and Patterson, 2012; Etman *et al.*, 2015; Adhikari and Uddin, 2022; Cao *et al.*, 2022; Lai, Ho and Woo, 2023). Finally, ten studies assessed the mediation effects of social relationships cross-sectionally: one study looked at the role of social relationships in cardiovascular health (Gorman and Sivaganesan, 2007); one study looked at oral health (Aida *et al.*, 2011), and six studies investigated either longstanding limiting illness (Daoud, Soskolne and Manor, 2009; Soskolne and Manor, 2010), physical function (Kim and Kawachi, 2007), health-related quality of life (Zhang and Xiang, 2019), or physical health[3] (Wang, Hoshi and Ai, 2015; Zhang *et al.*, 2022). Of all the studies, eight reported positive findings, three reported mixed findings, and five reported null findings.

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[3]Physical health or health status were terms coined by authors of each study and refer to an aggregate measure of self-reported health that included either (1) self-rated health, basic activities of daily living and instrumental activities of daily living (Wang, Hoshi and Ai, 2015) or (2) Instrumental activities of daily living (Zhang et al., 2022).

Cross-sectional studies

One study examined associations between socioeconomic position, loneliness, and self-reported chronic disease and reported positive findings – loneliness explained 21% of socioeconomic inequalities in chronic disease (Meisters *et al.*, 2021).

Four studies assessed mediation in physical function and reported positive or mixed results (Daoud *et al.*, 2009; Soskolne and Manor, 2010; Wang *et al.*, 2015; Zhang *et al.*, 2022). Whilst all reported social relationships mediate social inequalities in physical function, the contribution of structural or functional measures in explaining these associations varied by the type of measure used. In one study, structural social relationships – measured by social participation – attenuated up to 34% of the socioeconomic differences in physical function (Daoud, Soskolne and Manor, 2009). In another study, social capital – measured by individual- and community-level trust – and social participation attenuated between 21.4% and 34% of the educational gradient in limiting longstanding illness (Soskolne and Manor, 2010). The third study reported that interacting with friends or participating in organised group activities explained between 17.1% and 24.7% of the total effects of socioeconomic position on instrumental activities of daily living (Zhang *et al.*, 2022). The fourth study investigated the role of social interactions in mediating socioeconomic inequalities in health status and investigated sex-specific effects (Wang *et al.*, 2015). The study reported that although social interactions partly mediated social inequalities in health status among elderly adults, a greater proportion of the total effects of socioeconomic position on health status was explained by the indirect effect via social interactions among women compared to men (52.3% and 46.4%, respectively) (Wang *et al.*, 2015).

Four cross-sectional study reported null findings. In one study among older Japanese adults, voluntary membership and social trust did not mediate income inequalities in dental status i.e., number of remaining teeth (Aida *et al.*, 2011). In the second study, social networking time did not mediate income inequalities in physical health (Zhang and Xiang, 2019). In the third study, social capital did not mediate the association between mean state level income on recent days of activity limitation (Kim and Kawachi, 2007). Finally, in the fourth study, social support and social integration did not attenuate socioeconomic gradients in hypertension (Gorman and Sivaganesan, 2007).

Longitudinal studies

Two longitudinal studies reported positive findings (Adhikari and Uddin, 2022; Cao *et al.*, 2022). One study used data from The Norwegian panel study on Life course, Ageing, and Generation to assess physical function among older adults followed for ten years. The indirect effect of social support and social network contact frequency explained 6.3% and 3.9% of the variance in physical health models by income and education, respectively. The second study investigated the role of social participation as a mediator of socioeconomic inequality in survival rates after traumatic spinal cord injury in the USA. Social participation, measured by marital status, hours out of bed per day, days out of house per week and nights away from home during the past year, was protective against mortality risk among the most advantaged and explained up to 20% of the SEP-mortality association. When social participation measures were added, the final model was no longer statistically significant (Cao *et al.*, 2022).

Two longitudinal studies reported mixed findings (Stringhini *et al.*, 2012; Etman *et al.*, 2015). In one longitudinal study, social participation attenuated social inequalities in frailty, worsening by 7.7% in the 2-year follow-up for all countries combined when comparing the lowest to the highest educational group. However, when looking at countries individually, mediation effects were only seen in six of the eleven countries investigated (Sweden, Germany, The Netherlands, Belgium, France, and Spain) and ranged from 5.8% in Sweden to 10% in France (Etman *et al.*, 2015). Using prospective cohort data from the British Whitehall II Study, London-based civil servants were followed over twenty-four years to investigate cardiovascular-related mortality risk and all-cause mortality risk in adults. Social support estimated by structural (marital status, contact frequency with the network, social participation) and functional support (emotional support, practical support, negative aspects of close relationships) were assessed at three points between baseline and final follow-up in 2009. In addition, the study investigated sex-specific differences. Network score and marital status combined explained almost 30% of the associations between employment grade and cardiovascular mortality and all-cause mortality in men only. No significant associations were found between social support and mortality among women (Stringhini *et al.*, 2012).

Three of the seven longitudinal studies reported null findings (Nilsson *et al.*, 2010; Veenstra and Patterson, 2012; Lai *et al.*, 2023). One study reported no evidence for structural or functional social relationships mediating the association between financial assets and the onset of mobility disability at the 3-year follow-up (Nilsson *et al.*, 2010). The second study investigated functional impairments among older people and found that social isolation did not explain socioeconomic inequalities in activities of daily living during the 18- and 36-month follow-up periods (Lai, Ho and Woo, 2023). The third study looked at all-cause mortality risk from 1965 to 2000 in American adults from the Alameda County Study. Structural aspects of social relationships (number of close friends, affiliation with a voluntary association, church attendance) did not mediate income or education inequalities in mortality risk among this cohort of adults (Veenstra and Patterson, 2012).

High and moderate quality studies

There were eight high and moderate quality studies with effect sizes similar to those reported above (Daoud, Soskolne and Manor, 2009; Soskolne and Manor, 2010; Stringhini *et al.*, 2012; Etman *et al.*, 2015; Meisters *et al.*, 2021; Adhikari and Uddin, 2022; Cao *et al.*, 2022), except for one study whereby effect estimates were not readily available (Zhang and Xiang, 2019).

Among high and moderate quality cross-sectional studies, social relationships contributed between 21% and 63.2% of the magnitude of the effect for chronic conditions and long-standing limiting illness (Daoud, Soskolne and Manor, 2009; Soskolne and Manor, 2010; Meisters *et al.*, 2021).

For high and moderate quality longitudinal studies, social relationships explained 7.7% and up to 9.8% of the association between socioeconomic position and frailty and physical health, respectively (Etman *et al.*, 2015; Adhikari and Uddin, 2022). Social relationships also explained between up to 30% of the association between socioeconomic position and mortality (Stringhini *et al.*, 2012; Cao *et al.*, 2022).

Social relationships mediating social inequalities in depression and mental health

Cross-sectional studies

Only one cross-sectional study (high quality) reported psychological symptoms among children (Due *et al.*, 2003). Structural and functional social relationships attenuated 55.3% and 64.9% of the social gradient in psychological symptoms among adolescent girls and boys, respectively. Moreover, the effect estimates were no longer significant when social relationship measures were accounted for.

Twelve cross-sectional studies and one longitudinal study reported on mental health status among adults (Kim and Kawachi, 2007; Miller and Taylor, 2012; Rios, Aiken and Zautra, 2012; Rueda, 2012; du Prel, Iskenius and Peter, 2014; Hassanzadeh *et al.*, 2016; Han *et al.*, 2018; Wei *et al.*, 2018; Kaur *et al.*, 2018; Zhang and Xiang, 2019; Jin, Zhu and He, 2020; Meisters *et al.*, 2021; Zhang *et al.*, 2022).

Seven studies reported positive findings. In these studies, social relationships explained between 6% and 70.5% of the social inequalities in mental health (Kim and Kawachi, 2007; Miller and Taylor, 2012; Rios, Aiken and Zautra, 2012; Hassanzadeh *et al.*, 2016; Wei *et al.*, 2018; Zhang and Xiang, 2019; Meisters *et al.*, 2021). Of these studies, only one study was of low-bias and reported that social support attenuated up to 56.2% of the SEP-depression association among pregnant women (Wei *et al.*, 2018).

Five studies reported mixed findings (Rueda, 2012; du Prel, Iskenius and Peter, 2014; Han *et al.*, 2018; Kaur *et al.*, 2018; Zhang *et al.*, 2022). One study compared two groups of middle-aged German adults, 44 and 50 years. Social isolation explained 18.4% of the total effects of education on depressive symptoms, but only for the younger age group (du Prel *et al.*, 2014). In another study, only two of the three social participation measures mediated the SEP-mental health association and explained between 5.4% and 9.2% of the total effect of SEP on mental health (Zhang *et al.*, 2022). The third study investigated two social relationship factors for their mediating role in explaining social inequalities in depression (reciprocity and interpersonal trust). Only reciprocity mediated the association between household income and depressive symptoms in older Korean adults, explaining 66% of this association (Han *et al.*, 2018). Two studies examined sex-specific differences in mental health (Rueda, 2012; Kaur *et al.*, 2018). One study looked at regional socioeconomic development and compared two disadvantaged regions to two affluent areas in Spain. Poor mental health was seen in one of the two more affluent regions, with social support accounting for 6% of the social gradient in mental health for men only (Rueda, 2012). In the second study, although social capital mediated 34.7% of the total effect of socioeconomic position on mental health for the total sample, however, when stratified by sex, social capital mediated 42.9% of the total effect of socioeconomic position on mental health among women only (Kaur *et al.*, 2018).

High and moderate quality studies

Studies that looked at social relationships mediating the SEP-mental health and SEP-depression association were largely of a moderate quality. A wide variation in effect estimates was reported i.e., similar to those reported above. Social relationships attenuated between 3% and almost 65% of the association between socioeconomic position and mental health/depression (Due *et al.*, 2003; Kim and Kawachi, 2007; Rios, Aiken and Zautra, 2012; Rueda, 2012; du Prel, Iskenius and Peter, 2014; Wei *et al.*, 2018; Meisters *et al.*, 2021; Zhang *et al.*, 2022).

Longitudinal studies

One longitudinal study (moderate quality) investigated the role of social participation in explaining the association between poverty and depression among elderly Chinese people at baseline and 2- and 4-year follow-up periods. Social participation consisted of an 11-item composite measure including functional and structural components of social relationships, e.g., social support and interaction with the social network. Social participation partially mediated the association between poverty and depression, although the effect was modest - 6.4% of the total effects of poverty on depression was explained by social participation at baseline. However, no mediating effects were found during the 2-year and 4-year follow-up periods (Jin, Zhu and He, 2020).

Table 4.1 Effect direction plot for social relationships mediating social inequalities in health

First Author (Year)	Study Design (Follow-up)	Country	Sample size (n)	Age (range/ mean + SD)	SEP variable(s)	Social relationship variable	Outcome	Effect direction
Self-rated health								
High quality								
De Clercq (2012)	Cross-sectional	Belgium	10,915	9-18	Family affluence	Structural & Functional	Self-rated health	▲
Due (2003)	Cross-sectional	Denmark	5202	11-15	Family social class	Structural & Functional	Self-rated physical health	▲
Soskolne (2010)	Cross-sectional	Israel	1256	30-70	Education	Structural & Functional	Self-rated health	▲
Vonneilich (2012)	Longitudinal (5 years)	Germany	4146	45-75	Education Income Occupation	Structural & Functional	Self-rated health	▲
Vonneilich (2019)	Cross-sectional	Europe	289,979	15+	Education	Structural & Functional	Self-rated health	◀▶
Moderate quality								
Aida (2011)	Cross-sectional	Japan	3451	65-85	Gini coefficient	Structural & Functional	Self-rated health	▲
Antonucci (2010)	Cross-sectional	USA	798	40-93	Education	Structural & Functional	Self-rated health	▼
Aartsen (2017)	Cross-sectional	Norway	9224	40-81	Income Education Occupational status	Structural & Functional	Self-rated health	◀▶
Cundiff (2016)	Cross-sectional	USA	475	30-54	Subjective social rank	Functional	Self-rated health	▲
Gadermann (2016)	Cross-sectional	Canada	4168	9.7 (0.3)	Household income	Functional	Self-rated health	▲
Kim (2007)	Cross-sectional	USA	173,236	18+	Gini coefficient	Combination	Self-rated health	▲
Klein (2012)	Longitudinal (5 years)	Germany	3300	20-81	Education Income Occupation	Structural & Functional	Self-rated health	▲
Knesebeck (2007)	Cross-sectional	Europe	36,263	≥25	Education	Functional	Self-rated health	◀▶
Meisters (2021)	Cross-sectional	The Netherlands	445,748	19+	Composite SEP	Functional	Self-rated health	▲
Moor (2014)	Cross-sectional	Europe Canada	117,460	11-15	Family affluence	Combination	Self-rated health	▲

		Israel						
Platts (2016)	Cross-sectional	Ukraine	5451	25-73	Education	Combination	Self-rated health	▼
Rios (2012)	Cross-sectional	USA	3098	18+	Neighbourhood deprivation	Combination	Self-rated health	▲
Rodrigues (2021)	Cross-sectional	Brazil	4046	18+	Neighbourhood deprivation	Functional	Self-rated health	▼
Rueda (2012)	Cross-sectional	Spain	1602	65-85	Regional SEP	Functional	Self-rated health	◀▶
Sacker (2001)	Cross-sectional	UK	5391	20-59	Material deprivation Social advantage Social class	Functional	Self-rated health	◀▶
Salonna (2012)	Cross-sectional	Slovakia	1863	16.85 (1.1)	Family affluence Parental education Financial strain	Functional	Self-rated health	◀▶
Verhaeghe (2012)	Cross-sectional	UK	11,875	16+	Neighbourhood deprivation	Combination	Self-rated health	▲
Low quality								
Aldabe (2012)	Cross-sectional	Europe	12,421	18+	Occupation	Structural & Functional	Self-rated health	◀▶
Gorman (2007)	Cross-sectional	USA	29,816	25+	*Education	Structural & Functional	Self-rated health	▼
Kaur (2018)	Cross-sectional	India	1563	40.1 (15.6)	Composite SEP	Combination	Self-rated health	▼
Mortality, chronic disease, and physical function								
High quality								
Cao (2022)	Longitudinal (1 year)	USA	1540	18+	Income Employment Education	Structural	Mortality	▲
Etman (2014)	Longitudinal (2 years)	Europe	14,082	55+	Education	Structural	Frailty	◀▶
Soskolne (2010)	Cross-sectional	Israel	1256	30-70	Education	Structural & Functional	Limiting longstanding illness	▲
Stringhini (2012)	Longitudinal (24 years)	UK	9333	35-55	Occupation	Structural & Functional	Mortality	◀▶
Veenstra (2012)	Longitudinal (35 years)	USA	6157	21+	Education	Structural	Mortality	▼
Moderate quality								
Adhikari (2022)	Longitudinal (10 years)	Norway	2856	55+	Income education	Structural & Functional	Physical function	▲

Aida (2011)	Cross-sectional	Japan	3451	65-85	Gini coefficient	Structural & Functional	Oral health	▼
Daoud (2009)	Cross-sectional	Israel	902	30-70	Education	Structural & Functional	Limiting longstanding illness	▲
Kim (2007)	Cross-sectional	USA	173,236	18+	Gini coefficient	Combination	Activity limitation	▼
Lai (2023)	Longitudinal (18 months and 3 years)	China	1590	70+	Education Income	Structural	ADL	▼
Meisters (2021)	Cross-sectional	The Netherlands	445,748	19+	Composite SEP	Functional	Chronic disease	▲
Nilsson (2010)	Longitudinal (3 years)	Denmark	2825	74-80	Financial assets	Structural	Mobility	▼
Zhang (2022)	Cross-sectional	China	10,197	65+	Income Education Occupation	Structural	IADL	◀▶
Low quality								
Gorman (2007)	Cross-sectional	USA	29,816	25+	*Education	Structural & Functional	Hypertension	▼
Wang (2015)	Cross-sectional	Japan	7904	65-84	Education Income	Structural	Health status	▲
Zhang (2019)	Cross-sectional	USA	3330	42.9 (13.3)	Household income	Structural	Physical health	▼
Depression and mental health								
High quality								
Due (2003)	Cross-sectional	Denmark	5202	11-15	Family social class	Structural & Functional	Mental health	▲
Wei (2018)	Cross-sectional	China	12,382	29.4 (3.5)	Composite SEP	Functional	Depression	▲
Moderate quality								
du Prel (2014)	Cross-sectional	Germany	6339	44+	Education	Combination	Depression	◀▶
Han (2018)	Cross-sectional	Korea	5969	60+	Education Income	Functional	Depression	◀▶
Jin (2020)	Longitudinal (2- and 4-year follow-up)	China	17,250	45+	Poverty	Combination	Depression	◀▶
Kim (2007)	Cross-sectional	USA	173,236	18+	Gini coefficient	Combination	Mental health	▲
Meisters (2021)	Cross-sectional	The Netherlands	445,748	19+	Composite SEP	Functional	Psychological distress	▲

Rios (2012)	Cross-sectional	USA	3098	18+	Neighbourhood deprivation	Combination	Psychological distress	▲
Rueda (2012)	Cross-sectional	Spain	1602	65-85	Regional SEP	Functional	Mental health	◀▶
Zhang (2022)	Cross-sectional	China	10,197	65+	Income Education Occupation	Structural	Mental health	◀▶
Low quality								
Hassanzadeh (2016)	Cross-sectional	Iran	31,519	20+	Education Material goods	Combination	Mental health	▲
Kaur (2018)	Cross-sectional	India	1563	40.1 (15.6)	Composite SEP	Combination	Mental health	◀▶
Miller (2012)	Cross-sectional	USA	875	19-21	Composite SEP	Structural & Functional	Mental health	▲
Zhang (2019)	Cross-sectional	USA	3330	42.9 (13.3)	Household income	Structural	Mental health	▲

Effect direction: upward arrow ▲= positive findings, downward arrow ▼= null findings, sideways arrow ◀▶= mixed findings; Sample size: large arrow ▲ n > 10000; medium arrow ▲ n = 1000-10000; small arrow ▲ n < 1000; Study quality: denoted by row colour: green = low risk of bias; amber = some concerns; red = high risk of bias; *For additional SEP variables see Appendix 7

4.4.4 Studies assessing moderation

Of the 33 studies on moderation, 13 studies presented stratified results for different levels of social relationships, and the remainder tested for interaction effects between socioeconomic position and social relationship indicators. The effect direction plot in Table 4.2 shows that studies either reported positive effects, i.e., among those with better social relationships, the association between socioeconomic position and health was less strong (less inequality); mixed effects, i.e., not all subgroups of social relationship levels reduced the strength of the association between socioeconomic position and health; null effects, i.e., no moderation; negative effects, i.e., among those with better social relationships the association between socioeconomic position and health was stronger (more inequality). The risk of bias was generally moderate to high – further details can be found in Appendix 5. Sample sizes varied from 130 to over 173,000 participants, with the largest studies conducted in Europe, North America, South America, and Japan (Appendix 8).

When looking the quality of the studies – 9 studies were of high quality, 16 studies were of moderate quality, and 8 studies were of low quality. Given the greater number of high and moderate quality studies, findings are largely influenced by these studies and reported below.

Social relationships moderating social inequalities in self-rated health

Thirteen cross-sectional studies looked at the moderating role of social relationships in the association between socioeconomic position and self-rated health (Wu and Rudkin, 2000; Antonucci *et al.*, 2003; Drukker *et al.*, 2006; Gorman and Sivaganesan, 2007; Kim and Kawachi, 2007; Abel *et al.*, 2011; Ahnquist *et al.*, 2012; Salonna *et al.*, 2012; De Clercq *et al.*, 2012; Salihu *et al.*, 2017; Vincens, Emmelin and Stafström, 2018; Olofsson, Padyab and Malmberg, 2018; Roy *et al.*, 2018). In addition, four studies focused on children (Drukker *et al.*, 2006; Abel *et al.*, 2011; De Clercq *et al.*, 2012; Salonna *et al.*, 2012), six studies examined adults across all age groups (Gorman and Sivaganesan, 2007; Kim and Kawachi, 2007; Ahnquist, *et al.*, 2012; Salihu *et al.*, 2017; Roy *et al.*, 2018; Vincens *et al.*, 2018), and three examined older adults (Wu and Rudkin, 2000; Antonucci, Ajrouch and Janevic, 2003; Olofsson, Padyab and Malmberg, 2018).

Of the four studies that looked at adolescents, only one reported a positive finding. Higher levels of social cohesion flattened the social gradient in perceived subjective health and well-being among adolescents – a 9% reduction in odds of poor subjective health compared to adolescents without social cohesion (De Clercq *et al.*, 2012). On the other hand, three studies reported null findings, i.e., social support from parents, adults, and peers did not moderate the association between socioeconomic position and self-rated health (Drukker *et al.*, 2006; Abel *et al.*, 2011; Salonna *et al.*, 2012).

Overall, the findings from studies of adult populations suggest that associations between socioeconomic position and self-rated health are less strong in the presence of better social relationships – the difference in the magnitude of socioeconomic inequality ranged between 6% and 92% when comparing those with better to poorer social relationships.

Three studies reported a positive effect, i.e., that more favourable social relationships buffered the negative effect of socioeconomic position on self-rated health (Wu and Rudkin, 2000; Ahnquist *et al.*, 2012; Roy *et al.*, 2018). The largest of the three studies examined the buffering role of structural and functional social relationship measures and found that social participation and trust buffered the negative effect of economic hardship on self-rated health (Ahnquist *et al.*, 2012). Two studies investigated structural relationship measures by social participation (Roy *et al.*, 2018) or frequency of contact with children and household family network size (Wu and Rudkin, 2000). Both studies reported a buffering effect of social relationships against the negative effect of low socioeconomic position on self-rated health (Wu and Rudkin, 2000; Roy *et al.*, 2018).

Five cross-sectional studies reported mixed findings (Antonucci *et al.*, 2003; Gorman and Sivaganesan, 2007; Kim and Kawachi, 2007; Salihu *et al.*, 2017; Vincens *et al.*, 2018). Two studies reported that functional rather than structural social relationship measures had a moderating effect – in one study looking at South American adults, generalised and neighbourhood social trust buffered the negative effect of low education on poor subjective health (Vincens *et al.*, 2018), in the second study, emotional and financial social support buffered the negative effect of low education on self-rated health (Antonucci *et al.*, 2003). Three studies reported mixed evidence for better social relationships strengthening the association between income and poor health. In a small study, social support did not buffer the effect of low income on poorer self-rated health – low-income women with adequate levels of social support were 2.24 more likely (95% CI 1.52-3.41) to report poor self-rated physical health than low-income women with low levels of social support. However, when employment was taken as a measure of socioeconomic position, adequate levels of support compared to low levels of support were protective against poorer self-rated physical health for unemployed women (OR: 0.46; 95% CI 0.22–0.85) (Salihu *et al.*, 2017). In a large cross-sectional study, medium and high social capital strengthened the association between income and poor health in states with a higher mean income level. However, high state-level social capital weakened the association between low mean income and poor health (Kim and Kawachi, 2007). In a third large study, structural rather than functional social relationships were reported to have buffering effects – family network size and attending a group event buffered the negative effect of unemployment and never worked on poor SRH. However, for retired individuals, the network size strengthened the association between socioeconomic position and self-rated health (Gorman and Sivaganesan, 2007).

Three studies of representative adult populations explored sex-specific patterns between social relationships, socioeconomic position, and self-rated health (Ahnquist *et al.*, 2012; Roy *et al.*, 2018; Vincens *et al.*, 2018). However, the buffering effect of social relationships was similar for both women and men.

Social relationships moderating social inequalities in mortality, chronic diseases, and physical function

Three longitudinal studies (Hibbard and Pope, 1992; Veenstra and Patterson, 2012; Green, Doherty and Bugbee, 2022) investigated mortality risk. One cross-sectional study examined physical function through musculoskeletal disorders (Ahnquist *et al.*, 2012). Finally, six studies looked at chronic disease – three were cross-sectional in design (Gorman and Sivaganesan, 2007; Barber *et al.*, 2016; Craveiro, 2017), and three were longitudinal studies (Rael *et al.*, 1995; O'Brien, 2012; Andersson, 2016). Studies that investigated chronic disease focused on the following outcomes: cumulative risk of chronic disease, i.e., the measure of risk across four physiological systems (metabolic, cardiovascular, neuroendocrine and inflammatory); physical health, a composite measure of health that included the number of chronic conditions, activities of daily living and perceived health; disease burden, i.e., the number of chronic conditions, including, but not limited, to the following diseases: neurological, endocrine, cardiovascular, infectious diseases, musculoskeletal, gastrointestinal and sickness absence.

Cross-sectional studies

Only one study looked at children – social capital (social support and trust) at the neighbourhood level buffered the negative effect of low socioeconomic position on physical injuries among children in Canada (Elgar *et al.*, 2010).

Three cross-sectional studies reported mixed effects, and of these, two studies investigated sex-specific patterns. In a large European study, the association between socioeconomic position and health status was buffered by better social relationships in Central and Southern Europe; however, buffering effects were not seen in Northern Europe (Craveiro, 2017). In the second study, buffering effects of social cohesion on the association between neighbourhood disadvantage and cumulative risk of chronic disease were reported for men only (Barber *et al.*, 2016). Another study explored the moderation effects of social participation and social capital – measured by social trust – in relation to physical function. No interaction effects were reported between economic hardship and social participation. However, for those experiencing economic hardship, not having low social trust resulted in a lower likelihood of reporting musculoskeletal disorders than those with low social trust. Additionally, no meaningful differences in the magnitude of the buffering effects of low or adequate social relationship levels on musculoskeletal disorders were seen among socioeconomically disadvantaged women or men (Ahnquist *et al.*, 2012).

One study reported a negative effect – among those with better social integration and larger family network size, levels of social inequality in hypertension were greater (Gorman and Sivaganesan, 2007).

Longitudinal studies

When looking at longitudinal studies that explored social relationships moderating social inequalities in chronic disease, one study reported positive effects, four reported mixed findings, and one reported a negative finding.

Drawing on national survey data (Midlife Development in the United States – MIDUS), functional social relationships, namely emotional strain, was investigated for its buffering role in the education-health association. Low social strain buffered the negative effect of low education on chronic health and functional limitations at follow-up nine years later (O'Brien, 2012).

The second study, which utilised data from the US MIDUS Study, found that the positive and negative social support measured through parent-child emotional bonds did not buffer the negative impact of low parental socioeconomic position during childhood on chronic disease at midlife at baseline or follow-up ten years later. Instead, warmth and experiencing no abuse from the parent strengthened the association between low parental socioeconomic position and chronic disease (Andersson, 2016).

Three studies in the USA (Hibbard and Pope, 1992; Veenstra and Patterson, 2012; Green *et al.*, 2022) and one study in the UK (Rael *et al.*, 1995) reported mixed findings. Two studies carried out in the USA explored the buffering role of structural social relationships on mortality risk (Patterson and Veenstra, 2010; Green, Doherty and Bugbee, 2022) whereas the third study explored the buffering role of both functional social relationship measures on mortality risk (Hibbard and Pope, 1992). The larger of the three USA studies was based on participants who took part in the Almeda County Study – of the six structural measures explored, only church attendance and community group participation buffered the negative effect of low socioeconomic position on mortality risk (Veenstra and Patterson, 2012). In the second, smaller study of participants who took part in the Woodlawn Community Cohort Study, social integration at midlife buffered the negative effect of poverty in early life on mortality risk; however, no significant interactions were found between early poverty and social integration during young adulthood (Green *et al.*, 2022). The third US study investigated social support for its protective effect against mortality risk in employed versus unemployed women in the USA. Social support was measured by social support provided by the network of work colleagues for employed women and by community social support for unemployed women. High community social support appeared to moderate the effect of employment status on mortality risk among women. There was an 18% to 20% difference in the magnitude of employment inequality on the 15-year mortality risk between those with higher versus lower levels of community social support. However, where the reference group was employed with low social support, hazard ratios were non-significant for unemployed women with some community social support (HR: 1.80; 95% CI 0.90-3.30). (Hibbard and Pope, 1992).

Using data from the Whitehall II study, the UK-based longitudinal study investigated the role of social support and material problems at baseline (1985) on sickness absence, a measure of ill health, in British civil servants. Four social relationship measures were assessed: emotional support, practical support, negative support, and network structure. Overall, structural, and functional social relationship measures did not contribute to the social gradient in sickness absence by employment grade. With one exception: at the five-year follow-up period, the association between socioeconomic position and sickness absence was stronger among women with more emotional support. Additionally, network structures beyond the household made no difference to the association between material problems and long spells of sickness absence for both men and women (Rael *et al.*, 1995).

Social relationships moderating social inequalities in mental health

Eighteen studies evaluated the role of social relationships in moderating associations between socioeconomic position and mental health. Four studies assessed this role longitudinally, and the remaining studies were cross-sectional in design.

Seven cross-sectional studies among adults (Fone *et al.*, 2007; Kim and Kawachi, 2007; Kollannoor-Samuel *et al.*, 2011; Ahnquist *et al.*, 2012; Natamba *et al.*, 2017; Salihu *et al.*, 2017; Roy *et al.*, 2018), two cross-sectional studies among children (Elgar *et al.*, 2010; Nielsen *et al.*, 2015) and two longitudinal studies (Huurre *et al.*, 2007; Fone *et al.*, 2014) reported positive findings – better social relationships buffered the negative effect of low socioeconomic position and mental health.

Cross-sectional studies

Three studies among adults reported mixed findings (Ferraro and Su, 1999; Stafford *et al.*, 2008; Ng *et al.*, 2014). In one study among older adults in Singapore, the buffering effect was limited to social support from the network outside the immediate family. In another study, the buffering effect of better social relationships on the negative effect of financial strain on psychological distress varied by country and social relationship type. The social gradient in psychological distress appeared slightly flatter in the presence of better social integration in the family and friends' network for older adults in Korea and The Philippines and with social support for older adults in Malaysia. However, there was no evidence of social relationships buffering the negative effect of financial strain on distress in Fiji (Ferraro and Su, 1999). In the third study, better friendship ties and tolerance of others flattened the social gradient in common mental disorders among adults in England. However, higher attachment to the neighbourhood did not buffer the deleterious effect of household and neighbourhood deprivation on common mental disorders (Stafford *et al.*, 2008).

In one study, favourable levels of social participation appeared to strengthen the association between low income and depressive symptoms: where community-level social participation was at 1+SD level above the mean, the difference in the predicted prevalence of depressive symptoms between the highest and lowest socioeconomic position was 18.8% and 15.4% for men and women, respectively. Whereas, when community-level participation was at the mean level, the difference in the predicted prevalence of depressive symptoms between the highest and lowest socioeconomic position was 17.4% and 14.4% among men and women, respectively. (Haseda *et al.*, 2018).

One cross-sectional study reported null findings – no statistically significant associations were found between neighbourhood disadvantage, social cohesion and trust, and changes in mental health among children (Drukker *et al.*, 2006).

Three studies reported on sex-specific differences but found no sex differences in the magnitude of the protective effect of social relationship levels on poor mental health (Ahnquist *et al.*, 2012; Haseda *et al.*, 2018; Roy *et al.*, 2018).

Longitudinal studies

Two longitudinal studies reported positive findings (Huurre *et al.*, 2007; Fone *et al.*, 2014). In one longitudinal study (moderate-bias), the impact of low socioeconomic position (manual vs non-manual occupation) on depression at age 32 years was buffered by high social support at ages 16-, 22- and 32 years for both men and women (Huurre *et al.*, 2007). In a second, larger, low-bias, UK-based study, social cohesion at baseline buffered the negative effect of neighbourhood deprivation on mental health seven years later (Fone *et al.*, 2014).

In contrast, one, high-bias study reported negative findings (Uebelacker *et al.*, 2013). In a longitudinal study of post-menopausal American women, higher levels of social support strengthened the negative effect of income on depression at both baseline and follow-up. There were 47% greater odds of depression in the presence of high social support compared to low social support at baseline and follow-up (Uebelacker *et al.*, 2013).

One USA-based study reported null findings (moderate-bias): social support did not buffer the negative effect of education on depression among the MIDUS study participants (O'Brien, 2012).

Table 4.2 Effect direction plot for social relationships moderating social inequalities in health

First Author (Year)	Study Design (Follow-up)	Country	Sample size (n)	Age (range/mean + SD)	SEP	Social relationship variable	Outcome	Effect direction
Self-rated health								
High quality								
De Clercq (2012)	Cross-sectional	Belgium	10915	9-18	Family affluence	Structural & Functional	Self-rated health	▲
Moderate quality								
Abel (2011)	Cross-sectional	Europe	3979	12-14	Parental education	Functional	Self-rated health	▼
Ahnquist (2012)	Cross-sectional	Sweden	51,414	16-84	Economic hardship	Structural & Functional	Self-rated health	▲
Antonucci (2010)	Cross-sectional	USA	798	40-93	Education	Structural & Functional	Self-rated health	◄►
Kim (2007)	Cross-sectional	USA	173,236	18-65	Mean income	Combination	Self-rated health	◄►
Salihu (2017)	Cross-sectional	USA	132	18+	Income Employment	Functional	Self-rated physical health	◄►
Salonna (2012)	Cross-sectional	Slovakia	1863	16.85 (1.1)	*Education	Functional	Self-rated health	▼
Vincens (2018)	Cross-sectional	South America	10,426	18+	Education	Structural & Functional	Self-rated health	◄►
Low quality								
Drukker (2006)	Cross-sectional	The Netherlands	475	11-15	Neighbourhood disadvantage	Functional	Self-rated health	▼
Gorman (2007)	Cross-sectional	USA	29,816	25+	*Education	Structural & Functional	Self-rated health	◄►
Olofsson (2018)	Cross-sectional	Europe	54,741	50+	Education	Combination	Self-rated health	▼ neg
Roy (2018)	Cross-sectional	Canada	8737	18+	*Education	Structural	Self-rated health	▲
Wu (2000)	Cross-sectional	Malaysia	1346	50+	Literacy Occupation	Functional	Self-rated health	▲
Mortality, chronic disease, and physical function/injuries								
High quality								

Barber (2016)	Cross-sectional	USA	4408	21-85	Neighbourhood disadvantage	Functional	Chronic disease risk	◄►
Green (2022)	Longitudinal (52 years)	USA	1159	6-58	Poverty	Structural	Mortality	◄►
Hibbard (1992)	Longitudinal (15 years)	USA	1140	18-65	Employment status	Structural & Functional	Mortality	◄►
Rael (1995)	Longitudinal (5 years)	UK	4202	35-55	Employment grade	Structural & Functional	Sickness absence	◄►
Veenstra (2012)	Longitudinal (35 years)	USA	6157	21+	Education Income	Structural	Mortality	◄►
Moderate quality								
Ahnquist (2012)	Cross-sectional	Sweden	51,414	16-84	Economic hardship	Structural & Functional	Musculoskeletal disorders	◄►
Andersson (2016)	Longitudinal (10 years)	USA	1632	25-75	Parental SEP	Functional	Chronic conditions	▼ neg
Craveiro (2017)	Cross-sectional	Europe	33,489	66.31 (10.04)	Composite (education + income + wealth)	Structural & Functional	Chronic health	◄►
Elgar (2010)	Cross-sectional	Canada	9717	11-15	Family affluence	Functional	Physical injuries	▲
O'Brien (2012)	Longitudinal (10 years)	USA	3775	≥24	Education	Functional	Chronic health Physical function	▲
Low quality								
Gorman (2007)	Cross-sectional	USA	29,816	25+	*Education	Structural & Functional	Hypertension	▼ neg
Depression and mental health								
High quality								
Fone (2014)	Longitudinal (7 years)	UK	4426	18-74	Neighbourhood deprivation	Combination	Mental health	▲
Fone (2007)	Cross-sectional	UK	10,653	18-74	Area income deprivation	Combination	Mental health	▲
Stafford (2008)	Cross-sectional	UK	9082	16+	Deprivation	Structural & Functional	Common mental disorder	◄►
Moderate quality								
Ahnquist (2012)	Cross-sectional	Sweden	51,414	16-84	Economic hardship	Structural & Functional	Psychological distress	▲

Elgar (2010)	Cross-sectional	Canada	9717	11-15	Family affluence	Functional	Psychosomatic symptoms	▲
Haseda (2018)	Cross-sectional	Japan	87,656	65+	Income	Structural & Functional	Mental health	▼ neg
Huurre (2007)	Longitudinal (16 years)	Finland	2194	16-32	SEP (parental and own)	Combination	Mental health	▲
Kim (2007)	Cross-sectional	USA	173,236	18-65	Mean income	Combination	Mental health	◀▶
Natamba (2017)	Cross-sectional	Uganda	403	24.7 (5.0)	Food insecurity	Functional	Depression	▲
Ng (2014)	Cross-sectional	Singapore	2447	60+	Education Housing type	Combination	Mental health	◀▶
Nielson (2015)	Cross-sectional	Denmark	3549	11-15	Parental occupation	Functional	Mental health	▲
O'Brien (2012)	Longitudinal (10 years)	USA	3775	≥24	Education	Functional	Depressive symptoms	▼
Salihu (2017)	Cross-sectional	USA	132	18+	Income Employment	Functional	Mental health	▲
Low quality								
Drukker (2006)	Cross-sectional	The Netherlands	475	11-15	Neighbourhood disadvantage	Functional	Mental health	▼
Ferraro (1999)	Cross-sectional	Fiji Korea Malaysia Philippines	3277	50+	Financial strain	Structural & Functional	Mental health	◀▶
Kollannoor-Samuel (2011)	Cross-sectional	USA	211	56.4 (11.8)	Food insecurity	Functional	Depression	▲
Roy (2018)	Cross-sectional	Canada	8737	18+	*Education	Structural	Mental health	▲
Uebelacker (2013)	Longitudinal (3 years)	USA	67,972	50-79	Household income Financial stress	Functional	Mental health	▼ neg

Effect direction: upward arrow ▲= positive findings downward arrow ▼= null findings sideways arrow ◀▶= mixed findings ▼neg = negative findings; Sample size: Large arrow ▲ *n* > 10000; medium arrow ▲ *n* = 1000-10000; small arrow ▲ *n* < 1000; Study quality: denoted by row colour: green = low risk of bias; amber = some concerns; red = high risk of bias; *For additional SEP variables see Appendix 8

4.5 Discussion of Findings

This section summarises the results from the systematic review. A total of 69 studies were included in the narrative synthesis, of these, 42 studies looked at mediation and 33 studies explored moderation of the SEP-health association by social relationships. Most studies reported positive results (*n* = 43), i.e., that more satisfactory relationships either attenuated or partly explained the SEP-health association, or mixed results (*n* = 33). A sizeable proportion of null results (*n* = 17) were also reported across studies. Interestingly, among studies assessing for moderation of socioeconomic inequalities in health, 4 negative findings were reported, i.e., that among those with more satisfactory social relationships, the SEP-health association was stronger (Table 4.3).

Table 4.3 Summary of studies assessing mediation and moderation: a count of null, mixed, positive effects and negative effects

Outcome	**Mediation n = 42**			**Moderation n = 33**			
	Null findings (*n*)	Mixed findings (*n*)	Positive findings (*n*)	Null findings (*n*)	Mixed findings (*n*)	Positive findings (*n*)	Negative findings (*n*)
Self-rated health	5	7	13	3	5	4	1[a]
Chronic disease	3	0	3	0	4	1	1[b]
Physical function	3	2	2	0	1	2	0
Mortality	1	1	1	0	3	0	0
Mental health	0	6	7	2	4	10	2[c,d]
Total (*n*)	**12**	**16**	**26**	**5**	**17**	**17**	**4**

[a]Olofsson et al., (2018); [b]Andersson (2016); [c]Haseda et al., (2018); [d]Uebelacker et al., (2013)

4.5.1 Studies assessing mediation

Overall, social relationships partly explain social gradients in health in most studies. However, the evidence was somewhat mixed, and the contribution varied by social relationship measure.

In the studies on children, social relationships were measured by social support, network structure, and frequency of contact in two studies, and social participation and trust in another study. Irrespective of the social relationship indicator used, all studies found that social relationships partly explained social inequalities in health.

In the studies on adults, some patterns emerge when looking at the extent to which different social relationship aspects explain social inequalities in health. Ten studies looked at the independent effect of structural and functional aspects and reported positive or mixed effects. Of these, six studies found that structural social relationship measures were the only social relationship type that mediated social inequalities in health or had the strongest impact. When teasing out these associations further, it appears that multidimensional structural social relationship constructs e.g., social participation or social network index, seem to make the greatest contribution. Studies that utilised composite social relationship measures that included an aspect of the network structure and social participation, e.g., social capital, or simultaneously accounted for structural and functional social relationship measures, also reported mediation of social inequalities in health. Overall, when looking at the relative difference of structural and functional social relationships on health across all studies, slightly different patterns emerge. Structural measures appear to be more important than functional social relationships for objective or physical health outcomes. Whereas both structural and functional social relationships or aggregate social relationship measures were equally important for subjective health, especially for mental health outcomes. However, since multidimensional social relationship tools were utilised that included a mix of structural and functional dimensions, and in some cases, mutual adjustments of the model by structural and functional social relationships, definitive conclusions about patterns based on distinct aspects of social relationships cannot be made.

Sex-specific patterns

In the two studies involving children that assessed differences by sex, no clear patterns can be distinguished. Similarly, no meaningful sex-specific patterns can be discerned from studies of adult populations – either no differences by sex were reported or no consistent associations were found between social relationships and health when stratified by sex. In one longitudinal study, attenuation of the magnitude of association between socioeconomic position and mortality was seen for men only. Two cross-sectional studies looking at sex differences in self-rated health and mental health reported conflicting results. One small non-representative cross-sectional study reported greater attenuation in self-rated health for women and not men and vice-versa for mental health. However, in a second, larger, representative study, no sex differences were reported in self-rated health, whereas for mental health, mediation was reported for women only. Lastly, a third cross-sectional study reported that social relationships mediated a greater proportion of the total effects of socioeconomic inequalities on self-rated health among women.

4.5.2 Studies assessing moderation

Overall, better social relationships moderated the effect of socioeconomic position on self-rated health, mortality, physical function, and mental health, but again the evidence was not entirely consistent.

When looking at studies of children, no consistent patterns emerged – all five studies varied concerning the social relationship indicators used. Three studies reported that better social relationships buffered the negative effect of low socioeconomic position on health.

In studies looking at adults, structural and functional measures generally appear to weaken the socioeconomic position-health association. However, in some, albeit limited cases, no moderation of social inequalities in health is seen. In addition, studies often incorporated multiple aspects of structural and functional social relationships or assessed moderation through composite measures. As such, no clear patterns can be discerned – it is difficult to determine whether either structural or functional social relationship measures are driving buffering of the negative effect of low socioeconomic position on health.

There is limited evidence for moderation in the opposite direction to what was expected, i.e., more health inequality among those with better social relationships. Although no consistent patterns can be distinguished, the negative findings across two of the four studies relate to social support (Uebelacker *et al.*, 2013; Andersson, 2016).

Sex-specific patterns

Four of the six studies that assessed sex-specific patterns reported no significant differences in the buffering effect of social relationships between men and women.

4.5.3 Limitations of existing literature

Methodological bias in studies

Of the mediation studies, twelve studies had low levels of bias, 32 studies had moderate levels of bias, and ten studies had high levels of bias. Of studies looking at moderation, nine studies had low levels of bias, 22 had moderate levels of bias, and eleven had a high level of bias (Appendix 5). Most of the methodological limitations were due to insufficient information regarding the effect size estimate, for example, odds ratio without corresponding confidence intervals or unstandardised beta coefficients without corresponding standard errors, as well as lack of information regarding sample size justification, a lack of description of characteristics between respondents and non-respondents or reason for attrition, and not adjusting for at least the most important confounding factor. However, more biased studies did not report findings different from studies with low bias. Overall, the lower quality studies utilised suitable markers of socioeconomic position and social relationships when examining mediation and moderation of social inequalities in health. Therefore, although the inclusion of moderate- and high-bias studies may be a limitation of this systematic review, the results were interpreted and discussed considering the methodological limitation of the lower-quality studies.

Measurements and tools used for social relationships

Multiple definitions, tools and indices have been used to estimate associations between social relationships, socioeconomic position, and health; therefore, caution is needed to interpret the results and patterns observed. Some studies used validated measurement tools to measure social relationships, e.g., Social Integration Index. Other studies adapted scales to suit the population under investigation, for example, the Mannheim Interview on Social Support adapted by du Prel et al. (2014), to measure social isolation in middle-aged adults.

Lack of longitudinal studies

Most studies were cross-sectional in design; therefore, although associations can be estimated between indicators of socioeconomic position, social relationships, and health, the direction of associations cannot be determined, the temporality of pathways cannot be established, and reverse causality cannot be excluded. Implementing a longitudinal design to include bidirectional associations between socioeconomic position and health and between social relationships and health is important as there is evidence to support these pathways. Yet, they remain unexplored in studies assessing the mediating role of social relationships in explaining socioeconomic inequalities in health.

The nineteen longitudinal studies included in this review looked at mediation and moderation of social inequalities in health by social relationships. Of these, nine assessed mediation, nine assessed moderation and one assessed both mediation and moderation. Four studies found no evidence of mediation or moderation, and two reported negative effects, i.e., that social relationships strengthened the SEP-health association. Not all studies explored the independent effects of structural and functional social relationships studies – studies largely investigated the effect of either functional or structural measures or a combination measure that consisted of structural and functional components. Six studies looked at both structural and functional social relationship measures and found evidence of mediation or moderation of social inequalities in health. Of these, three studies reported that effects were largely driven by structural social relationship measures, and three studies reported that functional measures provided a greater contribution to mediating or moderating social inequalities in health. Therefore, it is difficult to discern whether structural and functional social relationship measures are equally important in contributing to the magnitude of the SEP-health association. These findings are similar to the cross-sectional studies, whereby no definitive conclusions can be made with regard to the type of social relationship measures driving mediation or moderation effects of social inequalities in health.

4.5.4 Strengths

One of the strengths of this review was the ability to comprehensively appraise and collate the plethora of scholarly literature to enable a clear overview of the evidence and highlight gaps in the literature and methodological bias to help inform future work. Moreover, this systematic review can help policymakers navigate the knowledge base on the role of social relationships in health inequalities.

Often narrative syntheses have been subject to criticism of bias due to a lack of transparency. A major strength of this narrative synthesis was that it was reported according to the UK's Economic and Social Research Council (ESRC) guidance (Popay *et al.*, 2006) to enable transparency between the data and conclusions made. Study findings were collated into a coherent written narrative, with descriptions of differences in characteristics of the studies, level of bias, and the use of structured tabulation to present the data. Additionally, having an explicit methodology that followed a detailed and pre-defined protocol has enabled methodological transparency and replicability and minimises bias.

4.5.5 Limitations of the systematic review

This systematic review's main limitation was the heterogeneity among studies. Consequently, it was not appropriate to conduct a meta-analysis of the data. Studies varied considerably in design, i.e., whether they were cross-sectional or longitudinal. Studies also had considerable statistical heterogeneity. Although most mediation studies used regression analysis, 16 studies utilised structural equation modelling (SEM). Therefore, extracting and computing effect estimates for a meta-analysis requires meta-analytic SEM (MASEM) (Cheung, 2015). However, pooling effect estimates becomes challenging when most studies present stratified effect estimates with little consistency in the stratification across studies (McKenzie and Brennan, 2022). With that said, given the diversity between studies, a meta-analysis would have been meaningless. Additionally, a meta-analysis of studies with bias increases the likelihood of a misleading result and may have compounded the pooled effect estimate (McKenzie and Brennan, 2022).

4.5.6 Conclusions and gaps in the literature

Most studies assessing mediation or moderation effects of social relationships in the association between socioeconomic position and health have reported on self-rated health or mental health. Some studies have also explored mortality, cardiovascular health, and physical function – two of which were findings from British cohorts. However, these were limited to London-based civil servants, as such, generalisability to the wider population is limited. Therefore, it would be important to assess social relationships as potential mediators and moderators of socioeconomic inequalities in health in a representative sample of older adults in the UK. As such, data will be taken from the English Longitudinal Study of Ageing (ELSA) – a large, prospective cohort study of people aged 50 years and above in England.

The quantitative part of this project will investigate a mix of subjective and objective health outcomes: self-rated heath, systolic and diastolic blood pressure, self-rated oral health, oral health-related quality of life and edentulousness. Although I am restricted by the measures available in the ELSA dataset, there are several reasons for why selecting these outcomes matter. Firstly, having self-rated health as a subjective measure of health will make this study directly comparable to past literature on social relationships mediating and moderating socioeconomic inequalities in self-rated health. Secondly, having a clinical measure will enable health to be measured via an objective marker. Finally, there is a lack of evidence concerning oral health both cross-sectionally and longitudinally. Therefore, it would be important to assess mediation and moderation effects to inform the extent to which social relationships play a role in social inequalities in self-rated health, blood pressure and oral health.

Very few studies explored the role of loneliness and social isolation as mediators or moderators in the association between socioeconomic position and health, yet their contribution to poor health, especially among older adults is well-established (Holt-Lunstad, Smith and Layton, 2010; Holt-Lunstad *et al.*, 2015; Valtorta, Kanaan, Gilbody, Ronzi, *et al.*, 2016). Moreover, loneliness and social isolation are part of the UK's public policy to promote healthy ageing and recent years has seen a raised public awareness of the adverse implications of loneliness and social isolation on health among older people (Age UK, 2018; Department for Digital Culture Media and Sport, 2018). Therefore, understanding the contribution of loneliness and social isolation explaining socioeconomic inequalities in health is imperative. Moreover, including social support as an additional social relationship measure will make this study comparable to the previous literature.

Furthermore, most studies have used regression modelling to assess whether social relationships mediate social inequalities in health – it may be contested whether adjusting for social relationship measures in regression models accurately depicts mediation effects. Using advanced statistical methods such as structural equation modelling (SEM) would disable indirect and direct pathways between socioeconomic position, social relationships, and health outcomes over time. Moreover, there is a lack of consideration for reciprocal associations among mediation studies. Although evidence for social causation, i.e., the pathway from socioeconomic position to health, is well established, there is also evidence to support a health selection pathway (Letelier *et al.*, 2022). A longitudinal design will enable assessing bidirectional associations between health and socioeconomic position and between health and social relationships.

Chapter 5. Methods for data analyses

Chapter Summary: This chapter fully describes the methodology implemented to address objectives 2 to 6 of this project. Section 5.1 presents detailed information on the English Longitudinal Study of Ageing dataset, including the survey design and structure, sampling response rates, and ethical considerations. Sections 5.2 to 5.5 describe the variables used in the study together with the rationale behind the choice of variable and how they were coded. I then proceed to describe the analytical samples used for cross-sectional and longitudinal analyses (Section 5.6). Finally, I explain the statistical methods used in this study including techniques implemented to handle missing data (Section 5.7).

The study was conducted in three stages: cross-sectional analyses modelled associations between socioeconomic position (exposures), social relationship variables, and health outcomes cross-sectionally using logistic and linear regression. Longitudinal analyses then assessed the extent to which social relationships mediate associations between socioeconomic position and health outcomes through structural equation modelling. Finally, social relationship measures were assessed for their role in moderating health inequalities cross-sectionally and only taken forward in longitudinal analyses for outcomes where moderation was evident.

5.1 Dataset: The English Longitudinal Study of Ageing

This project was based on secondary data analysis of the English Longitudinal Study of Ageing (ELSA). The ELSA was established in 2002 and is now in its tenth wave, representing 20 years of longitudinal data. It is a nationally representative, multidisciplinary, longitudinal panel study that includes a comprehensive array of repeated measures on health, social and economic well-being to track the dynamics in ageing. The ELSA follows more than 12,000 non-institutionalised older adults aged 50 years and over and their partners living in England (Steptoe *et al.*, 2013).

5.1.1 Sampling and response rates

A five-stage selection process was utilised to recruit participants for the ELSA study, summarised in Figure 5.1 below. Stage 1 involved 31,051 households invited for the

Health Survey for England (HSE), a large cross-sectional survey with data on health and biometric measures of people living in England. Households that responded to the HSE from 1998-2001 were used as the sampling frame for the ELSA wave 1 (Stage 2). Next, households with at least one age-eligible individual (50 years or over) were invited to participate (Stage 3). These individuals' health records showed that they were not deceased (Stage 4) and consented to be recontacted for subsequent waves (Stage 5).

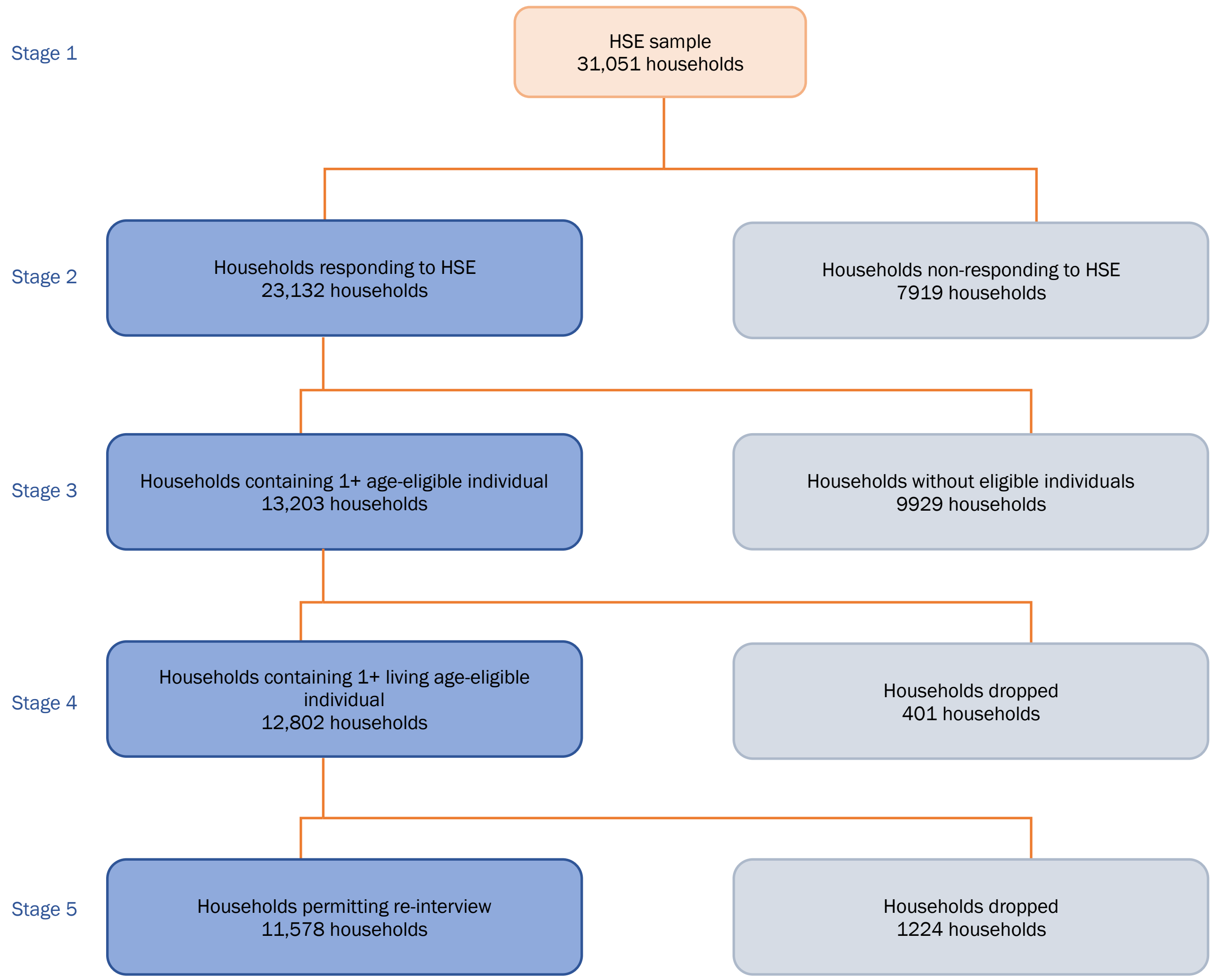

Figure 5.1 ELSA sample definition (adapted from Taylor *et al*., 2007)

More detailed information on participant eligibility criteria can be found in the ELSA wave 1 technical report (Taylor *et al.*, 2007). This sample selection method resulted in 11,578 households totalling 17,330 eligible participants for the ELSA at wave 1.

Respondents were classified as core cohort members if they fitted the age eligibility criteria (50 years and over), were part of the original HSE household, participated in the HSE survey[1] from which ELSA sample members for the initial and refreshment waves were selected, and took part in the ELSA interview when invited to join the study (Banks *et al.*, 2021).

Each core cohort was recruited from different years of the HSE and introduced to ELSA at different waves (see Table 5.1).

Table 5.1 Core cohorts and HSE source years (Banks et al., 2021)

Core Cohort[1]	Year invited to join ELSA	HSE year sourced from
1	2002/3	1998, 1999, 2001
3	2006/7	2001-2004
4	2008/9	2006
6	2012/13	2009-2011
7	2014/15	2011-2012

[1]Core cohort members also includes a very small number of people aged 50 years and over who did not take part in the HSE interview (Abell *et al.*, 2020).

To distinguish individuals as the core cohort of the continuing ELSA sample, age-eligible individuals who responded to wave 1 were renamed *'Cohort 1 Core Members'* C1CM. Follow-up interviews were conducted at biennial intervals, and sample refreshments were added at waves 3, 4, 6, 7, and 9 to ensure the study remained representative of those aged 50 and over. Individuals included in the refreshment samples were named *'Cohort X Core Members',* e.g., C3CM for Wave 3 and C4CM for Wave 4. Figure 5.2 illustrates the ELSA sample cohort selection profile.

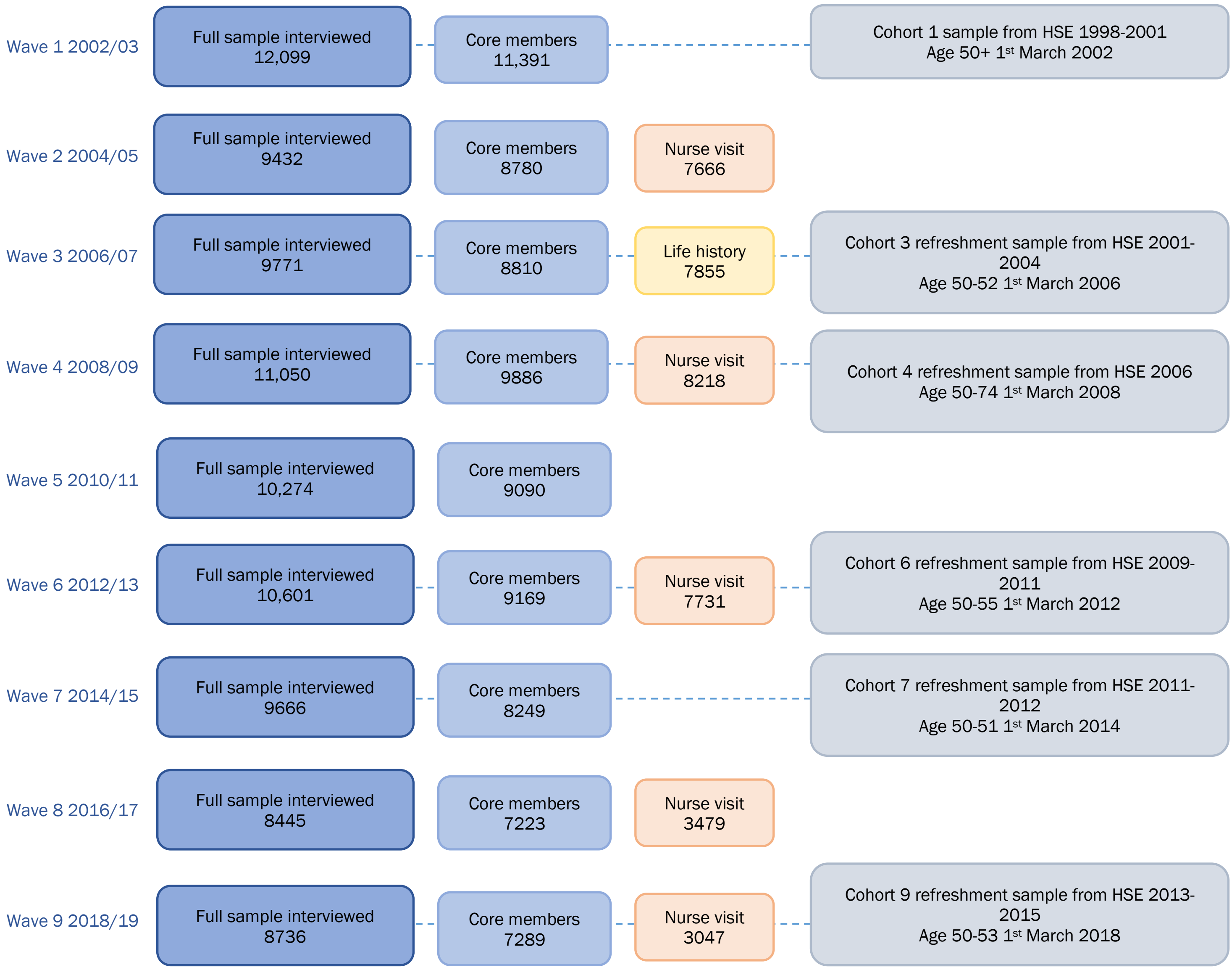

Figure 5.2 ELSA cohort profile: Wave 1 to Wave 9 (adapted from Steptoe et al. (2013) with information from NatCen Social Research (Banks *et al*., 2021)

Data collection for ELSA wave 1 (2002/03) included 12,099 individuals of the 17,330 who were eligible, representing a response rate of 70%. Of these, 11,391 were core members and 708 were young or new partners of the core members. The number of eligible participants at each ELSA wave and percentage response rates per wave ranged from 70% (wave 1) to 96% (wave 3) (Table 5.2).

Table 5.2 Response rates of ELSA members Waves 1-9 (adapted from Breeden et al., 2018 and Abell *et al*., 2020)

ELSA Wave	Number of completed interviews		
	Total eligible (*n*)	Full sample (*n*)	Response rate %
Wave 1	17,330	12,099	70
Wave 2	10,770	9432	88
Wave 3	10,180	9771	96
Wave 4	14,222	11,050	78
Wave 5	12,470	10,274	82
Wave 6	13,506	10,601	78
Wave 7	11,965	9666	81
Wave 8	11,793	8445	72
Wave 9	11,128	8736	79

Table 5.3 summarises the number of core members per cohort that responded at each wave of ELSA. Core members represented 83% to 94% of the total samples between waves 1 and 9. At wave 9, approximately half of the core members were from Cohort 1, 18% were from Cohort 4, 9% were from Cohort 3, 7% were from Cohort 6, and 3% were Cohort 9 core members.

Table 5.3 ELSA core members interviewed at Waves 1-9 (adapted from Breeden *et al*., 2018)

ELSA Wave	Core members						
	Total (*n*)	Cohort 1 (*n*)	Cohort 3 (*n*)	Cohort 4 (*n*)	Cohort 6 (*n*)	Cohort 7 (*n*)	Cohort 9 (*n*)
Wave 1	11,391	11,391	N/A	N/A	N/A	N/A	N/A
Wave 2	8780	8780	N/A	N/A	N/A	N/A	N/A
Wave 3	8810	7535	1275	N/A	N/A	N/A	N/A
Wave 4	9886	6623	972	2291	N/A	N/A	N/A
Wave 5	9090	6242	936	1912	N/A	N/A	N/A
Wave 6	9169	5659	1796	826	N/A	N/A	N/A
Wave 7	8429	4894	787	1606	661	301	N/A
Wave 8	7223	4219	723	1470	582	229	N/A
Wave 9	7289	3660	688	1307	523	212	899

5.1.2 ELSA survey structure

To date, nine waves of data are available: wave 1 (2002/03), wave 2 (2004/05), wave 3 (2006/07), wave 4 (2008/09), wave 5 (2010/11), wave 6 (2012/13), wave 7 (2014/15), wave 8 (2016/17), and wave 9 (2018/19). Data collection at each wave took place through face-to-face interviews with Computer Assisted Personal Interviewing (CAPI) and a self-completion questionnaire. The main interview consisted of repeated measures such as health, economics, psychosocial health, lifestyle, well-being, and cognitive function. The self-completion questionnaire covered health and well-being topics, such as quality of life, diet, social participation, and social networks. Questions have been similar across all waves, although topics are reviewed regularly with periodic changes – further details can be found elsewhere (Banks *et al.*, 2021).

In addition to the above, core members were offered follow-up nurse visits at waves 2, 4, 6, 8, and 9. The nurse visit included a biomedical assessment that involved collecting blood samples to extract biomarkers and DNA and assess anthropometry and physical functioning. Core ELSA participants who completed an interview in person, i.e., not by proxy, at waves 2, 4 and 6, were eligible for a nurse visit. Participants who were pregnant were excluded from having their blood pressure measured. Table 5.4 outlines the number of eligible members and relative response rates by wave.

Table 5.4 Productive nurse interviews and response rates by wave (NatCen Social Research, 2018)

ELSA Wave	Eligible (*n*)	Productive (*n*)	Response rates %
Wave 2	8780	7666	87.3
Wave 4	9592	8218	85.7
Wave 6	9169	7713	84.3
Wave 8	3714	3479	93.7
Wave 9	3640	3047	83.8

Data for this project was based on core cohort members from waves 2 to 7 and included data from the nurse interviews at waves 2, 4, and 6.

5.1.3 Ethical considerations

The NHS Research Ethics Committees granted ethical approval for all the ELSA waves under the National Research and Ethics Service (NRES), with all participants giving written informed consent (Breeden *et al.*, 2018; Banks *et al.*, 2021). The dataset used for this project was the UK ELSA archived data: ELSA Study Number 5050 (SN 5050). The ELSA SN 5050 data can be downloaded and used for research by registering with and accepting the UKDS End User Licence. All sensitive and disclosive data have been removed from the ELSA SN 5050 dataset and using these data does not require additional ethical approval or a special access licence from UKDS.

5.2 Outcome variables

Five diverse health outcomes assessing different dimensions of health that were measured between waves 2 and 7 were used in this study (Table 5.5). The rationale for selecting these outcomes has been described in the systematic review chapter (see Chapter 4). Two indicators measured self-perceived current health status: self-rated health and self-rated oral health. The third indicator represents long-term oral health status and accumulation of disease: edentulousness. The fourth was an indicator of oral health-related quality of life: oral impacts on daily performance. Lastly, the fifth indicator was a clinical measure of general health: blood pressure (systolic and diastolic).

Table 5.5 Study outcome variables per wave

Variables	ELSA Wave					
	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7
SRH[1]	✓		✓		✓	
Blood pressure	✓		✓		✓	
SROH[2]		✓		✓		✓
OHRQoL[3]		✓		✓		✓
Edentulousness		✓		✓		✓

[1]SRH = self-rated health; [2]SROH = self-rated oral health; [3]OHRQoL = oral health-related quality of life

Although the information on self-rated health is collected at every wave, information on blood pressure is collected every other wave at the nurse visit in ELSA. Therefore, data from waves 2, 4 and 6 was used for blood pressure and self-rated health. However, information on oral health is not collected at every wave, and information on edentulousness is not collected beyond wave 7. Therefore, waves 3, 5 and 7 were used in data analyses of self-rated oral health, oral health-related quality of life and edentulousness. For cross-sectional analyses, wave 2 was used to examine the general health outcomes, and wave 3 was used for the oral health outcomes.

5.2.1 Self-rated health

Self-rated health is a global general health measure designed to capture overall health and has been included in surveys since the 1940s (Ware, Davies-Avery and Donald, 1978; Brook *et al.*, 1979; Cartwright, 1984; Stewart, Hays and Ware, 1992). It is a well-established measure shown to be associated with mortality, functional status, chronic health conditions and sociodemographic factors (Kaplan and Camacho, 1983; Goldstein, Siegel and Boyer, 1984; Schoenfeld *et al.*, 1994; Idler and Kasl, 1995; Idler and Benyamini, 1997; Spiers *et al.*, 2003; Lazarevič and Quesnel-Vallée, 2022), and is important in measuring health in ageing research (Mossey and Shapiro, 1982; Benyamini, Leventhal and Leventhal, 2004; Ocampo, 2010). Additionally, self-rated health has been shown as an appropriate measure to capture overall health and functioning in both cross-sectional and longitudinal analyses (Lazarevič and Quesnel-Vallée, 2022). Self-rated health was measured using a single question that asks participants to rate their health on a 5-point Likert scale as either ‘excellent,’ 'very good,' 'good,' 'fair,' or 'poor'. A dichotomised variable was derived, categorising participants reporting self-rated health as either 'good' (excellent/very good/good) or 'poor' (fair/poor). Dichotomising self-rated health especially with large sample sizes is supported by the literature (Manor, Matthews and Power, 2000). Self-rated health will be referred to as SRH throughout the results chapters.

5.2.2 Blood pressure

Diastolic and systolic blood pressure are the strongest predictors of cardiovascular morbidity and mortality. Increases in both diastolic and systolic blood pressure are associated with an increased risk of CVD mortality (Lewington *et al.*, 2007; Lara *et al.*, 2015). Blood pressure data were collected at the nurse interviews at waves 2, 4, and 6. ELSA participants eligible for blood pressure measurements were asked to sit quietly for 5 minutes before the first measurement. Three resting measurements of systolic and diastolic blood pressure were taken at one-minute intervals on the participant's right arm using the Omron HEM 907. Participants were asked not to eat, smoke, drink alcohol or do any vigorous exercise for 30 minutes before their visit. The mean of the second and third systolic and diastolic blood pressure readings (ELSA-derived variables) was used. Often the first blood pressure measurement can be higher in anticipation of measurement or the sight of the blood pressure cuff, causing the blood pressure to rise due to an exaggerated alerting response in both normotensive ('white coat hypertension') and hypertensive people ('white coat' effect) (Williams *et al.*, 2004; National Institute for Health and Care Excellence (NICE), 2022).

There is currently no global consensus on hypertension thresholds. Guidelines from various bodies in UK (NICE), Europe (European Society of Cardiology and the European Society of Hypertension), Canada (Hypertension Canada), USA (American College of Cardiology/American Heart), and Australia (National Heart Foundation) have thresholds ranging from 130/90 mm HG to 140/90 mm HG for defining hypertension for most adults under the age of 80. In adults over the age of 80 years, thresholds for hypertension range between ≥150/90 mm HG to ≥160/90 mm HG in the UK and Europe, respectively. In Canada, the threshold for systolic hypertension is 120 mm HG in adults over the age of 75 years. Furthermore, recent evidence suggests that in adults aged 75 years and above, the current thresholds may be an inaccurate marker of hypertension. Evidence has shown that lower systolic blood pressure (≤130 mm HG) may actually be an indicator of declining health and high systolic blood pressure (140 mm HG to 150 mm HG) may be associated with better health and lower mortality risk in adults aged 75 years and above (Benetos, Petrovic and Strandberg, 2019; Masoli *et al.*, 2020).

For the purpose of this project, blood pressure was used as a continuous variable in cross-sectional and longitudinal analyses for three main reasons: (1) varying international guidelines on thresholds for hypertension (Benetos, Petrovic and Strandberg, 2019); (2) that these thresholds are not fixed and will vary according to older age (≥75 years), frailty, dementia and CVD-risk profile (Benetos, Petrovic and Strandberg, 2019; Masoli *et al.*, 2020); and (3) that the purpose of this project was to assess whether social inequalities in systolic blood pressure changed upon the inclusion of social relationships as mediators or moderators in SEP-BP association. For descriptive purposes only (for ease of data presentation), in addition to showing mean and standard deviations of blood pressure values in the analytical sample, blood pressure was dichotomised categorising participants as having either less than 140/90 mm HG or higher than 140/90 mm HG blood pressure. Cut-offs for high blood pressure were 90 mm HG and 140 mm HG, for diastolic and systolic blood pressure, respectively (Higgins *et al.*, 2011; NICE, 2019).

In participants receiving treatment for hypertension, the underlying blood pressure, i.e., the blood pressure that the individual would have without taking antihypertensive drugs, cannot be measured, and analysis is based on the observed blood pressure. Without appropriate correction, this may bias the results and underestimate the effect size (Tobin *et al.*, 2005). Therefore, data on relevant antihypertensive medication use were ascertained. Adjustments for treatment effects upon observed mean systolic and diastolic blood pressure values were made for participants who reported taking blood pressure-lowering medication at the time of data collection. A 10 mm HG constant was added to observed systolic and diastolic values among these participants – this follows the methodology implemented by Tobin et al. (2005), who have shown this adjustment procedure to be appropriate for population-based studies quantitatively measuring blood pressure.

5.2.3 Self-rated oral health

Self-rated oral health is a summary indicator that captures subjective current oral health status and is a valid, reliable and cost-effective tool to measure oral health (Gilbert *et al.*, 1998; Benyamini, Leventhal and Leventhal, 2004; Pattussi *et al.*, 2010; Ramos, Bastos and Peres, 2013), especially among older adults (Matthias *et al.*, 1995). Self-rated oral health is shown to be associated with future levels of self-rated health (Benyamini, Leventhal and Leventhal, 2004; Pattussi *et al.*, 2007, 2010), self-esteem and life satisfaction (Benyamini, Leventhal and Leventhal, 2004). Moreover, poor self-rated oral health is correlated with several clinical oral health outcomes, such as tooth loss, dental caries, periodontal disease, dental pain, and compromised chewing ability (Pattussi *et al.*, 2010).

Self-rated oral health was assessed by a single question "Would you say your dental health (mouth, teeth, or dentures) is excellent; very good; good; fair or poor?" Similar to the convention utilised in previous studies (Sabbah *et al.*, 2007; Tsakos *et al.*, 2011; Rouxel *et al.*, 2015), self-rated oral health was dichotomised into 'good' (excellent/very good/good) and 'poor' (fair/poor). For brevity, and ease of reading results, self-rated oral health will be represented by the acronym – SROH.

5.2.4 Oral health-related quality of life

Oral health-related quality of life (OHRQoL) was measured using a simplified version of the oral impacts on daily performance (OIDP) – a validated instrument that measures oral health-related quality of life among adult and older adult populations (Adulyanon, Vourapukjaru and Sheiham, 1996; Tsakos, Marcenes and Sheiham, 2001). Studies have shown that poor oral health negatively impacts the daily activities of older populations (Adulyanon, Vourapukjaru and Sheiham, 1996; Sheiham *et al.*, 2001; Steele *et al.*, 2004; Peterson and Brown, 2005). The OIDP is a commonly used OHRQoL tool that measures the extent to which oral disease affects an individual's daily functioning in terms of physical, psychological, and social activities (Locker and Allen, 2007). The theoretical framework of OIDP was modified from the World Health Organisation's (WHO) International Classification of Impairments, Disabilities and Handicaps (WHO, 1980) and adapted for dentistry (Locker, 1988).

A modified and validated 10-item OIDP instrument is a reliable tool for assessing OHRQoL in older British adults (Tsakos, Marcenes and Sheiham, 2001). This instrument measures the frequency, severity, and prevalence of oral impacts on daily performance (Table 5.6).

Table 5.6 Performances assessed in the Oral Impacts on Daily Performances (Tsakos, Marcenes and Sheiham, 2001)

Performances assessed in the Oral Impacts on Daily Performances
1. Eating food
2. Speaking clearly
3. Cleaning teeth and dentures
4. Doing light physical activities such as household activities
5. Going out, for example, to shop or visit someone
6. Sleeping
7. Relaxing
8. Smiling, laughing, and showing teeth without embarrassment
9. Becoming more emotional or more easily upset than usual
10. Enjoying contact with other people, e.g., relatives, friends, or neighbours

In ELSA, oral impacts were assessed through five commonly reported performances from the modified OIDP. Participants were asked about the prevalence of oral impacts on daily activities by asking: "In the past six months, have any problems with mouth, teeth, or dentures caused you to have any of the following?" Next, participants were asked to select any of the following relevant items:

1. Difficulty eating food
2. Difficulty speaking clearly
3. Problems with smiling, laughing, and showing teeth without embarrassment
4. Problems with emotional stability, for example, becoming more easily upset than usual
5. Problems enjoying the company of other people such as family, friends, or neighbours
6. None of these

Adopting the approach by Tsakos *et al.* (2011), the OHRQoL variable was dichotomised to distinguish between participants reporting at least one oral impact on daily performance against those who experienced none.

5.2.5 Edentulousness

Edentulousness was measured through self-assessment of the presence of natural teeth – self-rated tooth loss has been shown to be a valid measure of edentulousness (Gilbert, Chavers and Shelton, 2002; Pitiphat *et al.*, 2002).

Edentulousness reflects the accumulation of oral disease and dental treatment across the life course and is a robust measure of total tooth loss (Tsakos *et al.*, 2013). Edentulousness generally marks the end point of historical oral disease, primarily due to dental caries and advanced periodontal disease (Elani *et al.*, 2017; Patel *et al.*, 2021). A partially or completely absent dentition can be functionally limiting for older people (Österberg *et al.*, 1995; Matsuyama *et al.*, 2021), affecting quality of life and nutrition (Allen, 2005), cognitive decline (Tsakos *et al.*, 2015), dementia (Qi *et al.*, 2021) and is seen as an early marker of frailty in the elderly (Avlund *et al.*, 2011).

Participants were asked: "In relation to dental health, which of the following applies to you: 'no natural teeth and wear denture'; 'both natural teeth and denture(s)'; 'only natural teeth; neither natural teeth nor dentures.'" Following the convention by Tsakos *et al*. (2011) and Rouxel *et al*. (Rouxel *et al.*, 2015), a dichotomised variable was derived, categorising participants as dentate (only natural teeth/both natural teeth and denture) and edentate (no natural teeth and wearing denture/neither natural teeth nor denture). Dentate refers to those with either some or all of their natural teeth – a considerable variation exists in this group; participants with only one tooth and those with a full dentition are classified as dentate. Edentate refers to those who have no natural teeth.

5.3 Exposure variables

Three measures of socioeconomic position were used to capture associations between socioeconomic position and health outcomes: non-pension household wealth, education and occupational class (Banks, Karlsen and Oldfield, 2003).

5.3.1 Household non-pension wealth

Total household net non-pension wealth is an ELSA derived measure and was used as the socioeconomic indicator of wealth. This is a more appropriate measure than income to use among older adults and a better socioeconomic predictor for health in ELSA (Marmot *et al.*, 2003; Banks *et al.*, 2006). Non-pension wealth is the net total wealth and is the sum of savings and investments, the value of the home or other property (minus mortgage), business assets and physical wealth owned by the household minus any debt. Total net non-pension household wealth was derived from observed or imputed wealth and debt components (a total of 21 components) and generated by the Institute of Fiscal Studies (IFS). Detailed information on derivation of the household non-pension wealth variable is described elsewhere (Oldfield, 2011).

The IFS did not derive wealth for institutionalised participants due to the complexity surrounding allocation of their income and wealth and imputing missing values of wealth and debt (Oldfield, 2011). Furthermore, quintiles of wealth were not calculated for non-core cohort members of the ELSA (Oldfield, 2011). These individuals were assigned a 'system missing' value. Therefore, institutionalised, and non-core cohort members were excluded from analyses – further details on participant inclusion criteria are given in Section 5.6.

Quintiles of total household non-pension wealth were used for cross-sectional and longitudinal analyses. Additionally, household non-pension wealth is referred to as 'wealth' for brevity throughout the results chapters.

5.3.2 Education

Educational attainment was measured in ELSA by the highest qualification obtained. For this study, education consisted of three categories: less than O-level or equivalent; O-level to A-level or equivalent and higher than A-level.

5.3.3 Occupational class

Occupational class was assessed through the National Statistics socioeconomic classification (NS-SEC). The NS-SEC schema was constructed to measure employment status and is conceptually underpinned by the Goldthorpe Schema – a rigorous, sociological classification widely used in research that has been validated as a tool to predict health and educational outcomes (Rose and Pevalin, 2003; The Office of National Statistics (ONS), 2021). In addition, the nested properties of NS-SEC enable it to offer flexibility by allowing eight-, five- and three-level category variables.

For this project, the ELSA-derived three-level NS-SEC collapsed version was used. The three-level version uses the Office for National Statistics (ONS) guidelines placing participants into the following categories (The Office of National Statistics (ONS), 2021):

1. Managerial/Professional
2. Intermediate occupations
3. Routine and manual occupations

In ELSA, most older adults were no longer working; occupational status captured their last job. The ELSA-derived collapsed version also assigns those who have never worked, are in full-time education, unclassifiable or have an inadequately stated occupation as an additional separate 'other' category. This 4th category made up 1.6% of the total sample at wave 2 and 1.4% of the total sample at wave 3. Among the 'other' group was a sub-category of participants with a long-term illness or disability (n = 14 at wave 2; n = 15 at wave 3). However, since those with a long-term illness or disability contributed to <0.01% of the entire sample, it was decided to keep the 4th group as it included those unemployed without a long-term illness or disability.

5.4 Social relationship measures (potential mediating and moderating factors)

The wealth of evidence linking loneliness, social isolation, and social support and health has been firmly established (see Chapter 2). Loneliness, social isolation, and social support are embedded within the UN and WHO agenda for healthy ageing (2021-2030) (WHO, 2021b, 2021a). Furthermore, given the growing recognition by UK policymakers of the importance of social support, social isolation and loneliness to the health and well-being of older adults (Care Act 2014; Durcan and Bell, 2015; Crouch and Wright, 2018; Department for Digital, Culture, Media and Sport 2022) these social relationships markers were used in this study.

Social relationships consist of structural (quantitative) components, for example, the number and density of social bonds, or functional (qualitative) elements, for example, the extent and nature of social support (Islam *et al.*, 2006; Gottlieb and Bergen, 2010; Valtorta, Kanaan, Gilbody and Hanratty, 2016). However, due to the inconsistency in the terminology used to describe social relationships and the heterogeneity in tools used to operationalise social relationships, capturing social relationships is not straightforward (Valtorta, Kanaan, Gilbody and Hanratty, 2016). Therefore, the construction of social relationship measures used in this study were guided by (1) the established literature e.g., based on a validated tool (UCLA loneliness scale) or previous studies (social isolation and social support measures) (see Sections 5.4.1 to 5.4.3 below), (2) results from the systematic review and (3) the analytical framework.

ELSA includes a wealth of data on both the qualitative (e.g., loneliness and perceived social support) and quantitative aspects of social relationships – for example, information related to the number of social contacts, different relationship types (i.e., having a partner, children, relatives, and friends), and frequency of contact with members of participants' social network. Information on social relationships was collected across all waves through the self-completion questionnaire.

Four social relationship measures were used in this study: loneliness, social isolation, positive social support, and negative social support. Firstly, rather than using a single multidimensional measure combining all four social relationship variables, two distinct functional and structural social relationship measures were used: loneliness (functional) and social isolation (structural). Secondly, since a reasonable proportion of the studies included in the systematic review investigated the role of composite social relationships, positive and negative social support were constructed such that they included one element of structure, i.e., whether respondents had a child, partner, friend or relative, as well as a functional component, i.e., respondents' feelings about their social relationships. Having three different social relationship markers would distinguish which type of measure is more important in contributing to social inequalities in health.

Cross-sectional analyses assessed social relationship measures at single time points: wave 2 (for self-rated health and systolic blood pressure) and wave 3 (for self-rated oral health, OHRQoL and edentulousness). The longitudinal mediation analyses focused on five time points for self-rated health and blood pressure (waves 2 to 6), therefore, social relationships were assessed at waves 3 and 5 for general health outcomes. Longitudinal mediation analyses of oral health outcomes were based on waves 3 to 7, therefore, social relationships were assessed at waves 4 and 6 for oral health outcomes (for further details see Section 5.6.2).

For longitudinal moderation analyses social relationships were assessed at waves 2, 4 and 6 for general health outcomes and at waves 3, 5 and 7 for the oral health outcomes (for further details see Section 5.6.3). Further details on the social relationship variables used in this study are given below.

5.4.1 Loneliness

Loneliness in ELSA was measured using the University of California, Los Angeles (UCLA) three-item loneliness scale, a validated tool (Hughes *et al.*, 2004), designed to tap into the frequency and intensity of loneliness feelings. The three items are: How often do you feel you lack companionship? How often do you feel left out? How often do you feel isolated from others? For each question, participants selected one of three possible answers ranging in score from 1 to 3, 'hardly ever or never' (1), 'some of the time' (2) or 'often' (3).

Scores were summed to create a continuous scale; total scores ranged from 3 to 9, with a higher score indicating greater levels of loneliness – this followed the convention of previous research by Steptoe *et al*. (2013), Shankar *et al*. (2011, 2013) and Valtorta *et al*. (2018) and was the method implemented for cross-sectional and longitudinal analyses. For descriptive and moderation analyses, a dichotomous variable was also created with a score of 6 as the cut-off to distinguish between more and less lonely participants, in line with previous research (Shankar *et al.*, 2011; Steptoe, Shankar *et al.*, 2013; Valtorta *et al.*, 2018).

5.4.2 Social isolation

There were three main sources of literature upon which the social isolation index for which this project was based on, these are summarised below.

Shankar *et al*. (2011) used a 5-item social isolation measure that assigned a point for each of the following items: not married or cohabiting with a partner; less than monthly contact (in-person, telephone, or written/e-mail contact) with children, other immediate family, and friends; and not participating in any organisations. In contrast, Valtorta *et al*. (2018) and Bu *et al.* (2020) included two additional items to the Shankar *et al.* (2011) measure: not volunteering and not in current employment.

The social isolation index for this project was based on the measure by Bu *et al.* (2020) and Shankar *et al*. (2011). Participants were assigned one point for each of the following seven items: not married or cohabiting, less than monthly social contact with children, other relatives, and friends (in-person or telephone contact), not belonging to any social organisation or club, and not volunteering. Including volunteering allows capturing of social contact through the network of work colleagues. Unlike Valtorta *et al*. (2018) and Shankar *et al.* (2011), less than monthly contact through written or email contact were not included in the social isolation measure for this project – Bu *et al*. (2020) found that these items low factor loadings and therefore excluded them from their social isolation measure. Additionally, employment was not included as an item in the social isolation measure so as not to confound the association between socioeconomic position and health.

The social isolation scale ranged from 0 to 6 (higher scores indicated greater social isolation) and was used for the cross-sectional and longitudinal analyses. Additionally, tertiles of social isolation were created for descriptive analyses and moderation analyses – the lowest tertile represented participants with the lowest level of social isolation (details of construction of the social isolation measure is given below).

The item capturing whether participants were married, or cohabiting was a 3-category ELSA derived variable that was collapsed into a binary variable for this project: 1 = neither married or cohabiting 0 = married or cohabiting.

Questions pertaining to membership of an organisation were collected as part of the self-complete questionnaire. For the variable measuring belongness to an organisation, participants were asked if they were part of an organisation, society, or club or not. Organisations, clubs, or societies included being a member of: (1) a political party, trade union or environmental groups, (2) resident or neighbourhood watch groups, (3) church/other religious groups, (4) charitable organisations, (5) education, arts, or music groups/classes, (6) social clubs, (7) sports clubs/gym or (8) any other organisation, club, or society. Belongness to an organisation, club or society was dichotomised to a binary (0/1) variable whereby participants not belonging to any organisation, club or society were coded as 1 and those belonging to an organisation were coded as 0.

Questions related to social contact with children, relatives and friends were also collected as part of the self-complete questionnaire. Having less than monthly contact with a child(ren), friend(s) or relative(s) was coded 0/1: those with less than monthly contact assigned a code of 1, and those with equal to or more than monthly contact assigned a code of 0. Participants who responded as not having a child, friend or relative, i.e., 'not applicable', were kept rather than coded as missing and grouped with those with less than monthly contact. Dropping these participants from the sample would have limited the analyses to only those with children, relatives, *and* friends, i.e., having *all* relationship types. However, since this approach treats the lack of a relationship as the same as less than monthly contact, a sensitivity analysis on complete cases was carried out whereby these participants were excluded from analyses (see Figures A.16.1 to A16.3 Appendix 16).

5.4.3 Social support

Social support consisted of 4 relationship types (partner, family, children, friends) with 3 items (covering distinct aspects of positive or negative support) and 4 answer options for each item – these questions formed part of the self-complete questionnaire. Construction of the positive and negative social support variables is explained in detail below.

Participants were asked if they had a husband, wife or partner, any children, other immediate family, and friends. For those who confirmed, subsequent items captured positive and negative support within each relationship type (see Figure A.9.1, Appendix 9). Perceived positive support was measured using a 3-item scale covering empathy, dependability, and confiding. Perceived negative social support, i.e., conflict, was captured by three items: criticism, being let down, and annoyance. Possible answers ranged from a lot (1), some (2), a little (3), and not at all (4) – these were reverse-coded for this project. In line with previous research, scores were summed to obtain a negative and positive social support scale. Higher scores indicated higher perceived positive or negative social support (Stafford *et al.*, 2011). The positive support scale ranged from 0-48, and the negative social support scale ranged from 0-42. For descriptive and moderation analyses, the social support variables were converted into tertiles of support, with the lowest tertile representing the lowest levels of positive and negative social support.

Participants who responded as not having a child, friend, other immediate family, or partner, i.e., 'not applicable,' were coded as 0 rather than missing. For example, if a participant did not have any children, rather than removing these participants from the analyses, they were assigned a code of 0 which implied no positive support because of not having a child. Dropping these participants would risk losing those who may have answered positively to questions relating to other social contacts, i.e., a participant may not have any children but may have a partner, friends, or close relatives. A sensitivity analysis was performed on the complete cases to distinguish whether including those without having one or more of the relationship types (child, friend, relative or partner) would yield similar results to those with all relationship types (see Figures A.16.1 to A16.3 Appendix 16).

5.5 Covariates

5.5.1 Demographic characteristics

Demographic characteristics included sex (male or female) and age (ranging from 50 to 99). Age was used as a continuous variable in the analyses. For the purposes of descriptive analyses, it was also coded into four age groups to reflect different stages of life: 50-59 years; 60-69; 70-79; and 80 years or older. Given that social relationships were being tested for their role in mediating and moderating social inequalities in health, no additional covariates that could potentially be on the causal pathway between socioeconomic position and health were included and only age and sex were adjusted for.

5.6 Analytical sample at each wave

All the analytical samples, i.e., ELSA wave 2 to wave 7, were drawn from the core cohort members, i.e., cohort 1 core members and refreshment sample members, these respondents represent the population of interest sampled in ELSA. Participants were considered eligible core cohort members if they met all the following criteria:

1. Fitted the age eligibility for the ELSA cohort, i.e., aged 50 and over *and*,
2. Participated in the HSE survey *and*,
3. Participated in ELSA when invited to join the study *and*,
4. Were living at a private residential address in England

ELSA is a study of those aged 50 and above. As the study progresses, cohort members get older; therefore, it has been refreshed with additional samples of individuals in their early 50s. The data used for this project includes participants who formed part of the refreshment sample at waves 3, 4, 6 and 7. Additionally, the wave 3 refreshment sample included respondents who were younger partners of core cohort members at wave 1 (sampled from HSE 2001), these respondents were reclassified as core cohort 3 members as they met the age criteria when interviewed at wave 3.

Institutionalised participants and those who had proxy interviews were excluded from the study sample. ELSA did not pursue institutional interviews for cohort members, and only a subset of questions was asked during the proxy interviews. Therefore, the study sample excluded these participants.

5.6.1 Analytical samples for cross-sectional analyses – waves 2 and 3

The first part of the analysis focused on two singular time points using imputed data – waves 2 and 3. At wave 2, two analytical samples were drawn for wave 2, one each for blood pressure (n = 6639) and self-rated health (n = 8681). Figure 5.3 shows the complete case sample for wave 2. It is important to note that outcomes were not imputed (see Section 5.7.2: missing data and multiple imputation).

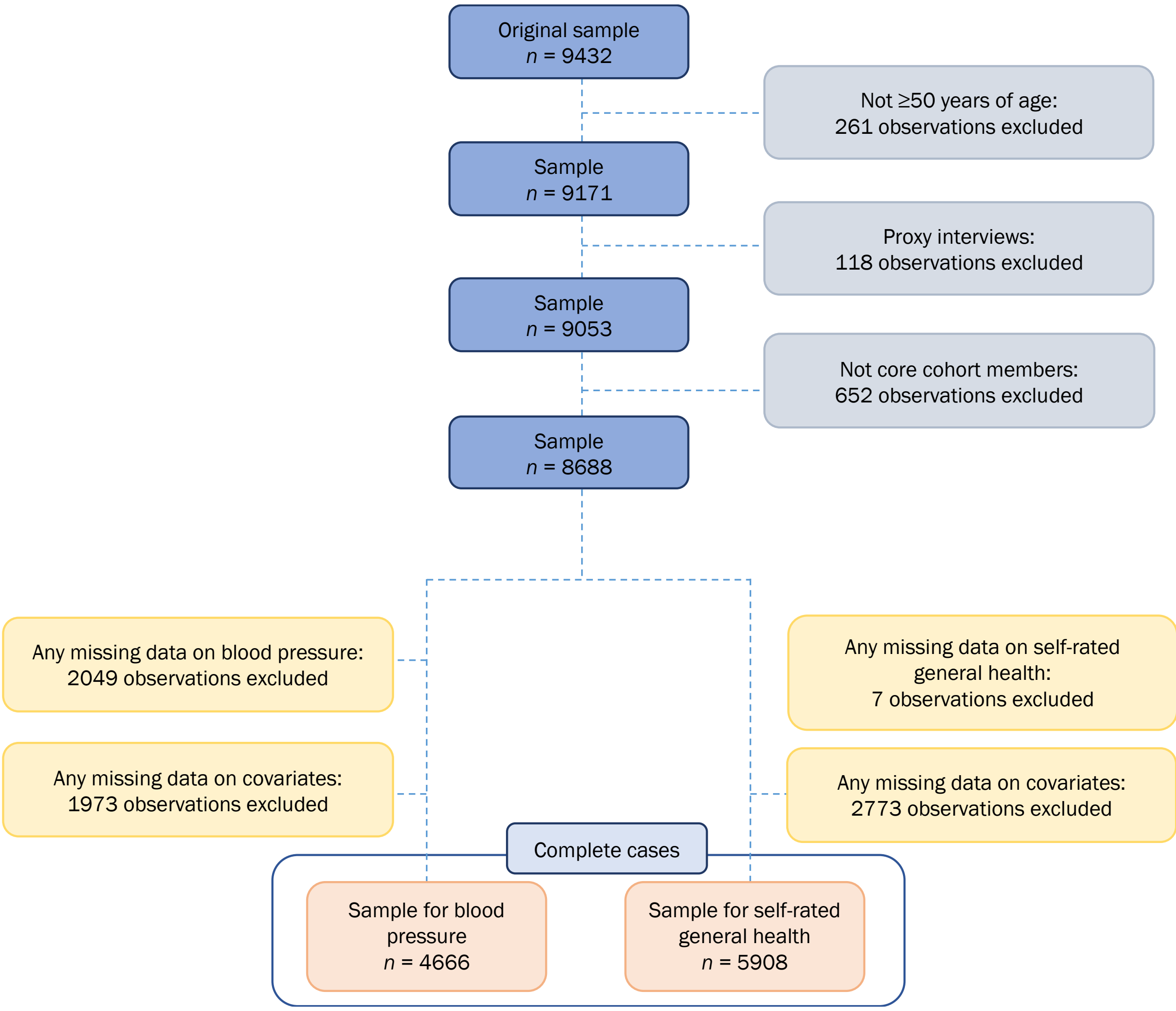

Figure 5.3 Wave 2 analytical sample – complete cases

For cross-sectional analyses of outcomes at wave 3, one sample was used for examining oral health outcomes (*n* = 8617): edentulousness, self-rated oral health and OHRQoL. Figure 5.4 shows the complete case sample for wave 3.

A complete case analyses was also done for sensitivity analyses. This consisted of two samples at wave 2, one each for blood pressure and self-rated health, and one sample at wave 3 for all three oral health outcomes (edentulousness, self-rated oral health and oral health-related quality of life).

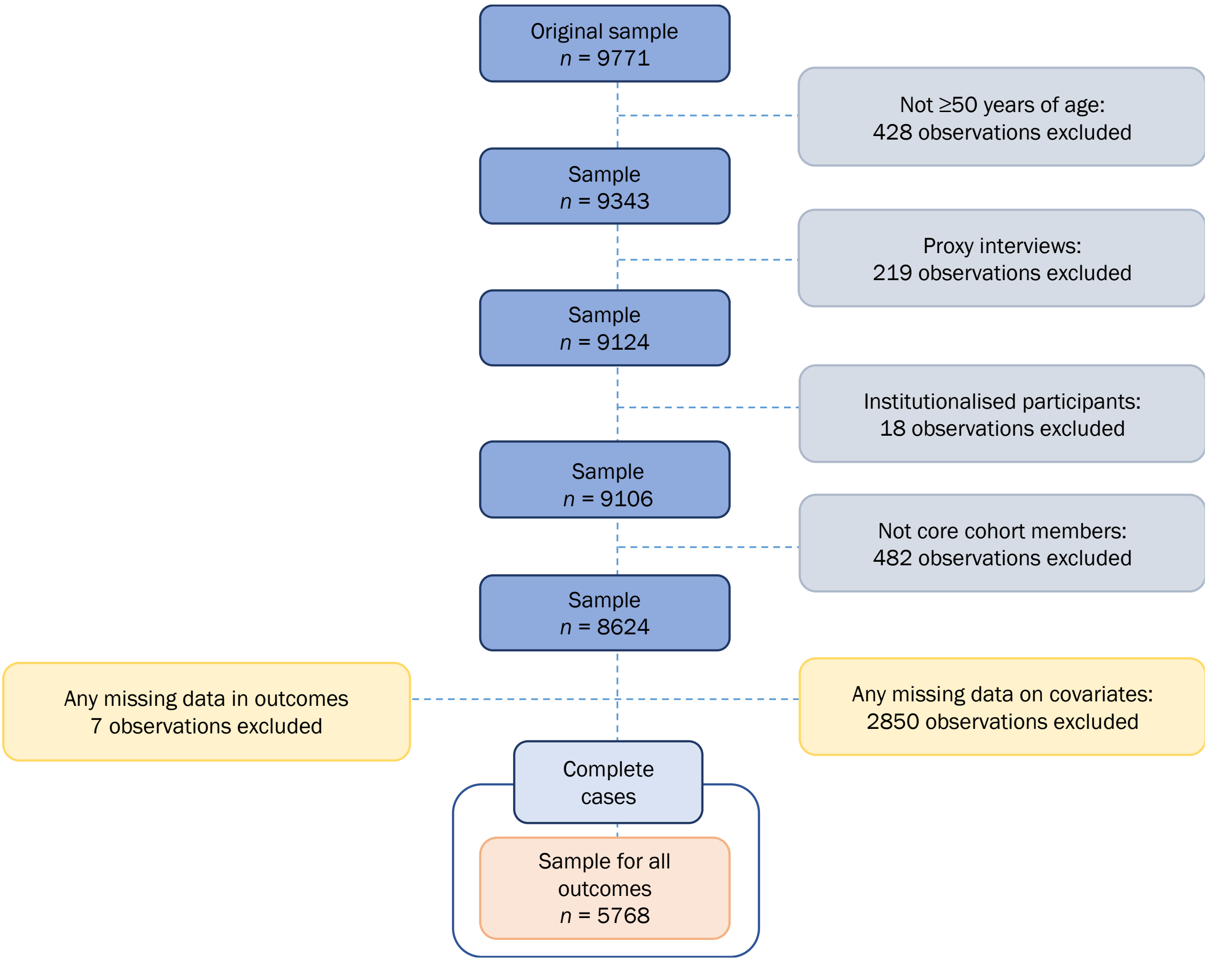

Figure 5.4 Wave 3 analytical sample – complete cases

5.6.2 Analytical samples for longitudinal analyses – SEM

The samples for longitudinal analyses of self-rated health and blood pressure were drawn from core members in private households that participated in any wave from wave 2 to wave 6 of ELSA (*n* = 12,723) (Figure 5.5).

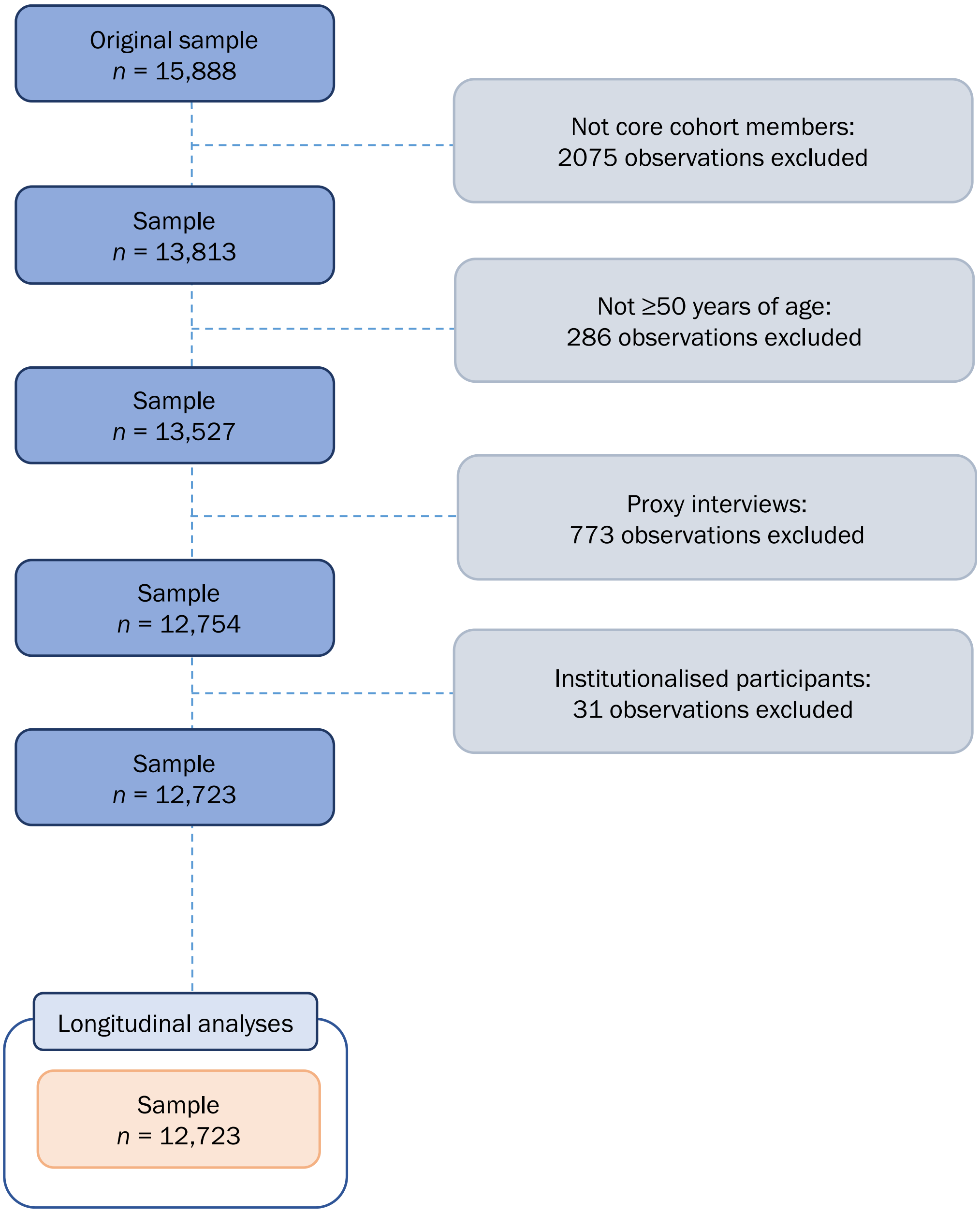

Figure 5.5 Longitudinal SEM sample – self-rated health and blood pressure[4]

For longitudinal analyses of oral health outcomes (self-rated oral health, oral health-related quality of life, edentulousness), core cohort members that participated in any wave from wave 3 to wave 7 of ELSA were included (n = 11,692) (Figure 5.6). Although three or more waves in longitudinal models are complex in structural equation modelling, they provide

[4]Core cohort members that took part in any of the following waves: 2 to 6

greater insight and accuracy regarding the relationships among variables compared to two-wave models (MacKinnon, 2008).

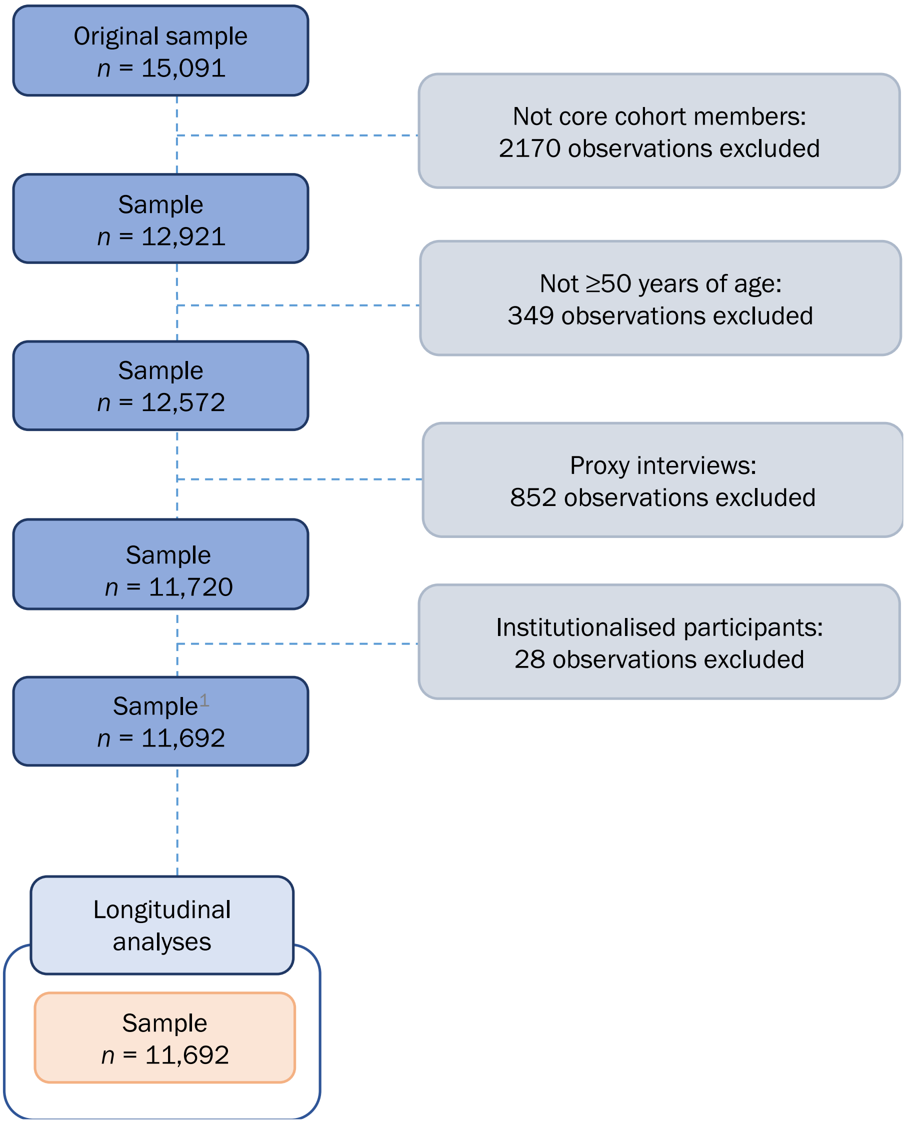

Figure 5.6 Longitudinal SEM sample – edentulousness, OHRQoL and self-rated oral health[5]

[5]Core cohort members that took part in any of the following waves: 3 to 7

5.6.3 Analytical samples for longitudinal analyses – Moderation

The sample for longitudinal moderation analyses of self-rated health and blood pressure, were drawn from core members in private households that participated in any wave from 2, 4 and 6 of ELSA (*n* = 12,594) (Figure 5.7).

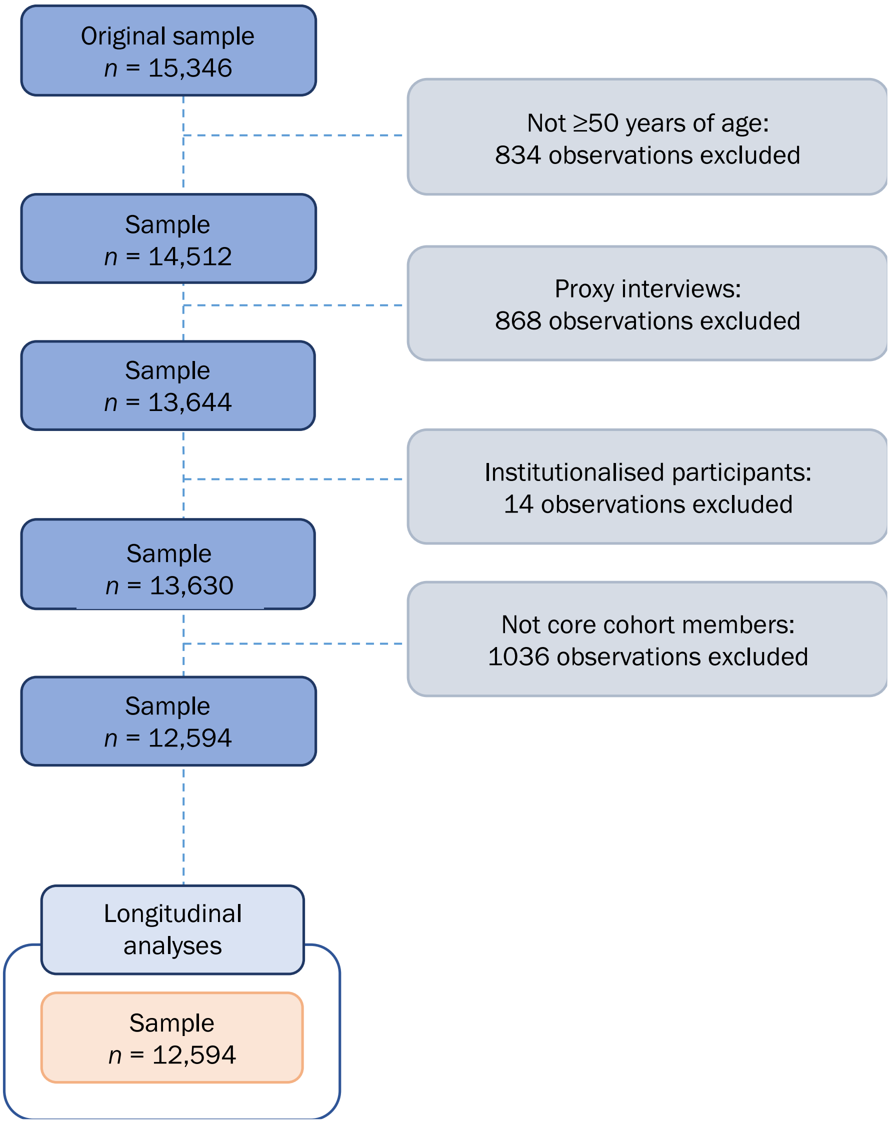

Figure 5.7 Longitudinal sample (moderation) – self-rated health and blood pressure[6]

[6]Core cohort members that took part in any of the following waves: 2, 4, 6

For longitudinal analyses of oral health outcomes (self-rated oral health, oral health-related quality of life, edentulousness), core cohort members that participated in any wave from 3, 5 and 7 of ELSA were included (*n* = 11,362) (Figure 5.8).

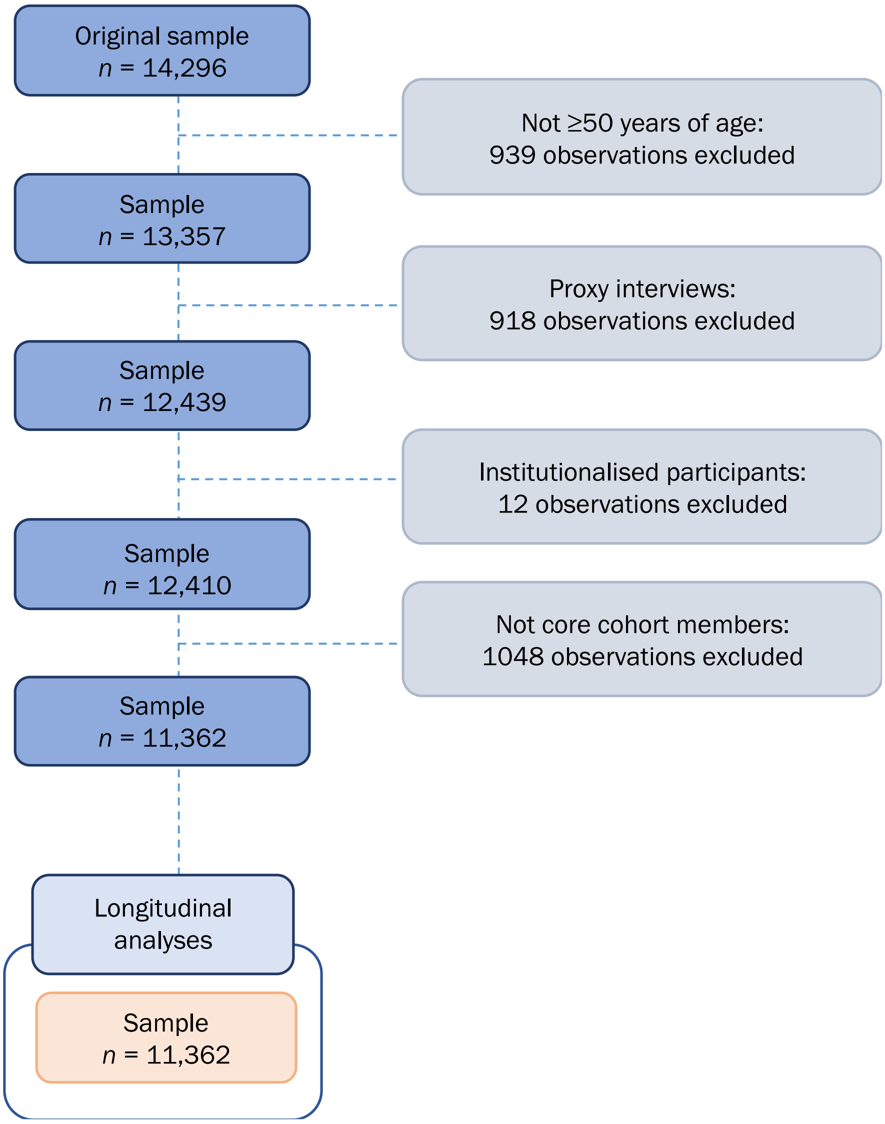

Figure 5.8 Longitudinal sample (moderation) – edentulousness, OHRQoL and self-rated oral health[7]

[7]Core cohort members that took part in any of the following waves: 3, 5 or 7

5.7 Statistical analyses

This section outlines the statistical methods used to address objectives 2 to 6 of this study. Analyses were performed using STATA MP 17.0 (descriptive and cross-sectional regression analyses, and random effects models for moderation) (StataCorp, 2021b) and Mplus 8.6 (structural equation modelling for longitudinal mediation analyses) (Muthén and Muthén, 2017). The significance level was set to ≤0.05, and all analyses were run separately for each of the five health outcomes (self-rated health, blood pressure, self-rated oral health, OHRQoL, and edentulousness).

Due to the complex sample design for ELSA, the effects of clustering and stratification were accounted for by conducting weighted analyses. Cross-sectional weights were defined for all eligible participants who responded to any given wave, including refreshment sample participants and those who missed any of the preceding waves through non-response. Weighting adjusted for item non-response to enable results to be representative of older adults in England.

However, only participants that took part in *all* waves of ELSA received a longitudinal weight; all other participants were classified as 'system missing'. Using longitudinal weights would have restricted the sample to 4062 core members who responded to *all* seven waves of ELSA. Core members from the original sample who returned to the study having missed a previous wave were not assigned a longitudinal weight (Littleford *et al.*, 2018; Banks *et al.*, 2021). Therefore, using the longitudinal weights was not appropriate for longitudinal analyses carried out for this project since it includes core cohort members that took part in *any* wave of ELSA between waves 2 and 7.

5.7.1 Descriptive analyses – cross-sectional samples (waves 2 and 3)

Descriptive analyses were conducted on the cross-sectional analytical samples. Firstly, the characteristics of the cross-sectional samples (waves 2 and 3) comparing participants with missing and complete data were assessed using the observed data. The statistical significance of the association between missingness and socioeconomic position, covariates, social relationships, and outcomes was tested using appropriate chi-squared (χ^2) test. Next, the characteristics of the samples at wave 2 and wave 3 are discussed –

weighted frequency distributions for the cross-sectional samples were presented on the observed data. In addition to descriptive tables, histograms for loneliness, social isolation and positive and negative social support are presented in Appendix A.11 (Figures A11.1 to A.11.8). Finally, the distribution of outcome variables by explanatory variables (socioeconomic indicators, social relationship measures, sex, and age) and social relationships by explanatory markers (socioeconomic position, age, and sex) were investigated via two-way tables using imputed data (see Section 5.7.2: missing data and multiple imputation). The distribution of outcomes by explanatory measures with complete cases are also presented in Appendix 14 (Tables A.14.1 to A.14.4) for comparison purposes.

The statistical significance of these associations was tested using appropriate bivariate regression (linear regression for systolic and diastolic blood pressure and logistic regression for all other outcomes and social relationship indicators).

5.7.2 Cross-sectional analyses (Objective 2-4)

Regression analyses

Cross-sectional analyses were used to address following objectives:

Objective 2: To assess social gradients in general and oral health outcomes.

Objective 3: To assess whether social relationships are socially patterned.

Objective 4: To assess cross-sectionally the extent to which adjusting for structural and functional aspects of social relationships attenuate social gradients in health outcomes.

Multivariable linear and logistic regression analyses was carried out on the imputed datasets for the following outcomes: blood pressure (linear regression models), self-rated health, self-rated oral health, OHRQoL, edentulousness (logistic regression models).

Social relationships were independently investigated for their role in explaining social inequalities in each health outcome after the model was adjusted for exposures and covariates:

1. Model 1: unadjusted model; crude associations run separately for each of the outcomes with the three exposure variables: household non-pension wealth measured in quintiles, participant's occupation measured by social class, and participants education measured by the level of education
2. Model 2: Model 1 additionally adjusted for sex and age
3. Model 3a: Model 2 additionally adjusted for loneliness
4. Model 3b: Model 2 additionally adjusted for social isolation
5. Model 3c: Model 2 additionally adjusted for positive social support
6. Model 3d: Model 2 additionally adjusted for negative social support
7. Model 4: Model 2 fully adjusted for all social relationship measures

Missing data and multiple imputation

Missing data are ubiquitous in quantitative and epidemiological research studies. In longitudinal studies, attrition poses an additional challenge. Failure to address missing data may yield incorrect standard errors and biased parameter estimates (White, Royston and Wood, 2011). In statistical analyses, assumptions of missing data follow the theoretical framework of Little and Rubin (2019). Three types of missingness have been described: missing completely at random (MCAR), missing at random (MAR) and missing not at random (MNAR) (Rubin, 1976; Little and Rubin, 2019). When data are MCAR, the probability of missing data on a variable X is unrelated to any observed or unobserved variable or to the underlying values of X itself (Rubin, 1976; Schafer and Graham, 2002; Carpenter and Kenward, 2013). When data are MAR, once all the data available are controlled for, any missingness that remains is completely random. In this case, the probability of missing data are only related to other observed data but not to underlying values of the variable with incomplete data (Rubin, 1976; Graham, 2009). With both MCAR and MAR, the missing data mechanism can be ignored. However, data that are MNAR are nonignorable since the probability of nonresponse in the data are related to the underlying unobserved values of the incomplete variable (Schafer and Graham, 2002; Carpenter and Kenward, 2013).

A common ad hoc method to address the missingness is listwise deletion, i.e., complete-case analysis. However, participants with complete data will often differ from those without complete data. For example, individuals who participate in research are often healthier and come from more affluent backgrounds than those who refuse (Graham, 2009).

Listwise deletion requires that the missing data are MCAR. When data are assumed to be MAR or MNAR or if the proportion of missing data is >5%, listwise deletion may lead to a loss of power and imprecise estimates (Peugh and Enders, 2004; Graham, 2009). Multiple imputation (MI), a recommended statistical method superior to deletion, will yield unbiased estimates when data are MAR or MCAR (Enders, 2006; Baraldi and Enders, 2010). Furthermore, MI will provide valid estimates even if the assumptions of normality of data are violated (Schafer, 1997, 1999; Demirtas, Freels and Yucel, 2008). Since missing data in this project were assumed to be MAR, MI was chosen to address the missingness. MI performs well in large samples with a considerable proportion of missing data, such as in this project (Johnson and Young, 2011).

Multiple imputation creates several copies of the dataset with different imputed values for each copy. The data in this project were imputed using the chained equation approach (MICE) using the MICE software in STATA MP 17.0. MICE was chosen due to its ability to handle different variable types, i.e., binary, categorical, and continuous. Missing values were estimated through a set of equations: logistic regression for binary variables, multinomial regressions for categorical variables, ordered regressions for categorical ordered variables, and linear regression for continuous variables.

Auxiliary variables, i.e., additional variables, were included for fine-tuning the imputation phase to improve the precision of the estimates and increase the likelihood of satisfying the MAR assumption (Graham, 2009; Baraldi and Enders, 2010). Auxiliary variables were included only in the imputation models and not in the analytical models. Auxiliary variables for the ELSA dataset were selected from the variables used to compute the weighting for waves 2 and 3, and whether they were predicting missingness in the analyses. The auxiliary variables were ethnicity, longstanding limiting illness, marital status, housing tenure, and type of household. Outcome variables were included in the imputation models to assist with imputing missing values for the independent variables. However, since the imputed values for outcomes do not meaningfully contribute to the analysis stage and only add extra ‘noise’ to estimates, they were excluded from the analytical models (von Hippel, 2007). This deletion method improves the power of estimates due to yielding accurate standard error estimates and narrower confidence intervals (von Hippel, 2007).

MI theory suggests using three to five imputed datasets (*m*) to ensure statistical efficiency. However, Graham *et al.* (2007) suggest m = 20 to 40 when the fraction of missing information (FMI) is between 0.1 and 0.7 to limit the loss of power, i.e., power falloff, to <1%. White *et al*., (2011) argue that statistical efficiency and reducing power falloff are not enough and that adequate reproducibility of results is crucial. Therefore, White *et al*. (2011) recommend that the number of imputed datasets should at least be equal to the percentage of missing data. Given the large proportion of missingness in the data used in this project, the number of imputed datasets follows the recommendation by White *et al*., (2011): m = 50 for wave 2 diastolic and systolic blood pressure sample, m = 34 for wave 2 self-rated health sample, and m = 40 for the wave 3 sample. The random-number seed was set as 2134 for reproducibility. For each sample, the estimates from the imputed datasets were pooled using appropriate Stata commands (mi).

Trace plots showing the predicted mean values and standard deviation values of all imputations indicated sufficient randomness, i.e., an absence of any sort of trend. Trace plots for all samples are presented in Appendix 13. Additionally, the results of cross-sectional analyses on imputed datasets were compared to the results of the complete case analyses for outcomes at waves 2 and 3 (see Appendix 15 Tables A.15.1 to A.15.6).

5.7.3 Longitudinal data analyses – mediation (Objective 5)

The following sections describe the methodology implemented to test the extent to which social relationships mediate (objective 5) social inequalities in health i.e., systolic blood pressure, self-rated health, self-rated oral health, edentulousness and OHRQoL, using longitudinal analyses.

The results of the cross-sectional analyses informed further analyses. Cross-sectional results from the cross-sectional chapter demonstrated clear gradients across all three socioeconomic indicators, i.e., household non-pension wealth, occupational status, and educational status. However, social gradients were steepest and clearest in the models using household non-pension wealth. Therefore, household non-pension wealth was used as the socioeconomic indicator in the longitudinal analyses. Furthermore, of the four social relationship measures, adjusting for loneliness and social isolation resulted in the greatest reductions in the magnitude of the SEP-health association for all health outcomes; therefore, these two social relationship measures were taken forward in the longitudinal mediation analyses. Additionally, cross-sectional analyses revealed no associations between diastolic blood pressure and explanatory variables; therefore, it was not taken forward for further longitudinal analyses.

Descriptive analyses were conducted on the longitudinal analytical samples, with frequency distributions assessed on the observed data. Next, the distribution of outcome variables by household non-pension wealth, social relationship measures, sex and age were investigated using the observed data.

Further statistical analyses to investigate the mediating role of social relationships in explaining social inequalities in health are discussed in detail below. Briefly, structural equation modelling (SEM) analyses using Mplus 8.6 was used to investigate the mediation effects of social relationships in explaining social inequalities in health.

Structural equation modelling

Structural equation modelling is a powerful data analytic framework for testing theories with statistical models and data (MacKinnon, 2008). It can assess complex and dynamic relationships within a web of observed and latent variables. SEM consists of exogenous variables, i.e., independent or exposure variables, that only have straight arrows pointing away from them and none pointing to them, and endogenous variables, i.e., dependent variables, that have at least one arrow pointed towards them (Gunzler *et al.*, 2013). Structural equation models are best represented by path diagrams in which arrows signify relationships between variables (see Figure 5.9). For example, in Figure 5.9, x_1 and x_2 are exogenous variables, whereas x_3-x_5 are endogenous variables. Correlations between variables are represented by curved, 2-headed arrows, as shown by c_{12} and c_{45} in the example below (Figure 5.9). An endogenous variable will have an error term (measurement error) associated with it; this is often seen as a small straight arrow pointing towards the variable – to keep the drawing simple, it may not be explicitly drawn. However, it is implicitly present (Gunzler *et al.*, 2013).

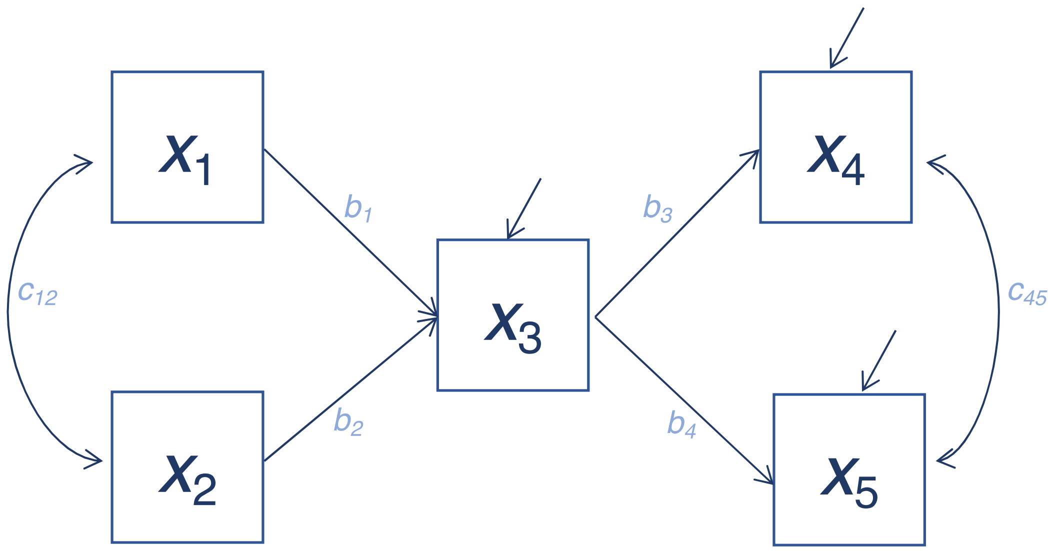

Figure 5.9 Path diagram in SEM

In Figure 5.9, the *i*th subject for variable x_3 is represented by the equation: $x_3i = b_1x_1i + b_2x_2i + e_3i$, i.e., the product of b_1 and x_1i plus the product of b_2 and x_2i plus the residual error of x_3 (e_3i). Similarly, paths between the other variables can be mathematically represented as:

$\Rightarrow$ $x_4i = b_3x_3i + e_4i$

$\Rightarrow$ $x_5i = b_4x_3i + e_5i$

The model in Figure 5.10 has a mediation or indirect path: the exogenous variables x_1 and x_2 act on an endogenous variable x_4 and x_5 through their influence (at least in part) on the intermediary endogenous variable x_3.

Mediation analyses in SEM is a technique by which direct and indirect paths from exposure (exogenous variable) to outcome (endogenous variable) are disentangled (MacKinnon, 2008; Gunzler *et al.*, 2013). For example, Figure 5.10 represents a simple mediation model in which the direct effect from the exposure variable 'X' to outcome variable 'Y' is represented by 'c`', and the indirect effect via the mediator (endogenous variable) 'M' is the product of *ab.* The other effect in the model is the total effect (*c'* + *ab*). The proportion of the total effect that is mediated is represented by: ab/(c' + ab), this provides important information on the relative magnitude of the mediated effect (MacKinnon, Warsi and Dwyer, 1995).

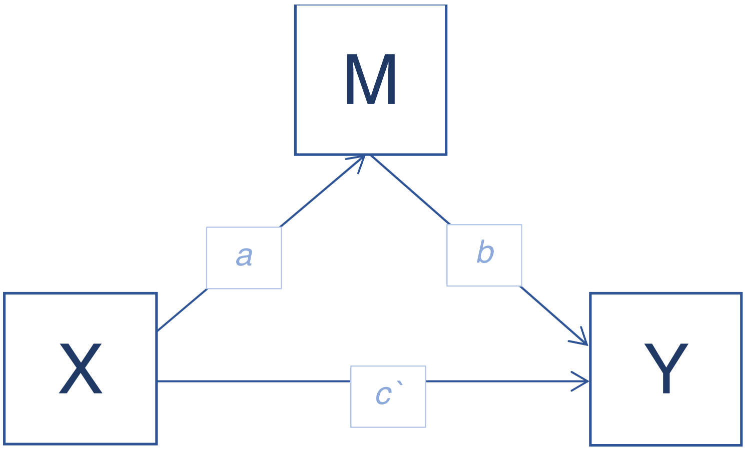

Figure 5.10 A simple mediation model illustrating a direct and indirect pathway from exposure to outcome

Structural equation modelling with mediating pathways was used to address objective 5. Social relationships i.e., loneliness and social isolation, were used as potential mediators in the association between household non-pension wealth (exposure variable) and five health outcomes (systolic blood pressure, self-rated health, edentulousness, self-rated oral health and oral health-related quality of life).

For this project, SEM models were run separately for each social relationship mediator. Parallel mediators can be included in a mediation model if they are known *not* to be causally associated, are also influenced by the exposure, and exert an influence on the outcome (Muthén, Muthén and Asparouhov, 2016). Parallel mediation models with two observed social relationship mediators were not run for two distinct reasons: social relationships being causally related; and wanting to understand the degree to which each mediator contributes to the total effects within each model.

The longitudinal autoregressive cross-lagged panel models

Figure 5.11 illustrates the initial longitudinal, five-wave-wave mediation model with cross-lagged paths that were specified to examine longitudinal mediation. This mediation model, i.e., cross-lagged panel model (CLPM), is an extension of the autoregressive CLPM model as described by Cole and Maxwell (2003), Rosel and Plewis (2008) and MacKinnon (2008). Firstly, associations two lags apart (two waves apart), i.e., between household non-pension wealth and health outcome, were specified. Secondly, associations one lag apart (one wave apart) i.e., between household non-pension wealth and social relationship measures (loneliness and social isolation), between social relationships and health outcomes, and between health outcomes and social relationships (i.e., cross-lagged paths – discussed below) were specified. Next, the stability of the measures was assessed by modelling relationships between the same variable over time, i.e., the autoregressive paths (s_1, s_2, s_3) (MacKinnon, 2008). Thirdly, indirect longitudinal (a_1b_1, a_2b_2, a_1b_3, and a_3b_2) paths between household non-pension wealth and health outcomes via social relationships were modelled. Direct paths from household non-pension wealth to social relationships (a_1, a_2, a_3), from social relationships to health outcomes (b_1, b_2, b_3) and from household non-pension wealth to health outcomes (c'_1, c'_2, c'_3) were also specified. Covariance between household non-pension wealth and health outcome at the first wave was also included. Finally, cross-lagged associations between household non-pension wealth, social relationships and health outcomes were considered such that the association of the outcome on household non-pension wealth (d_1) was estimated along with the outcome on social relationships (d_2). Although this model violates the temporal order of the exposure to mediator to outcome, it is more reasonable to assume that bidirectional associations exist between health and social relationships and between health and household non-pension wealth (MacKinnon, 2008).

The autoregressive longitudinal mediation model with cross-lagged associations, as described above, is expressed by the following equations:

$X_3 = s_1X_1 + d_1Y_1$

$X_5 = s_1X_3 + d_2Y_3$

$M_2 = a_1X_1 + d_1Y_1$

$M_4 = a_2X_1 + a_3X_3 + d_1Y_3 + s_2M_2$

$Y_3 = c'_1X_1 + b_1M_2$

$Y_5 = c'_2X_1 + c'_3X_3 + b_2M_2 + b_3M_4 + s_3Y_3$

Whereby ‘X’ represents household non-pension wealth, i.e., the exposure, ‘M’ represents social relationships, i.e., the mediator, and ‘Y’ represents the health outcome, i.e., the dependent variable – the associated subscript for ‘X’, ‘Y’ and ‘M’ represents the time point.

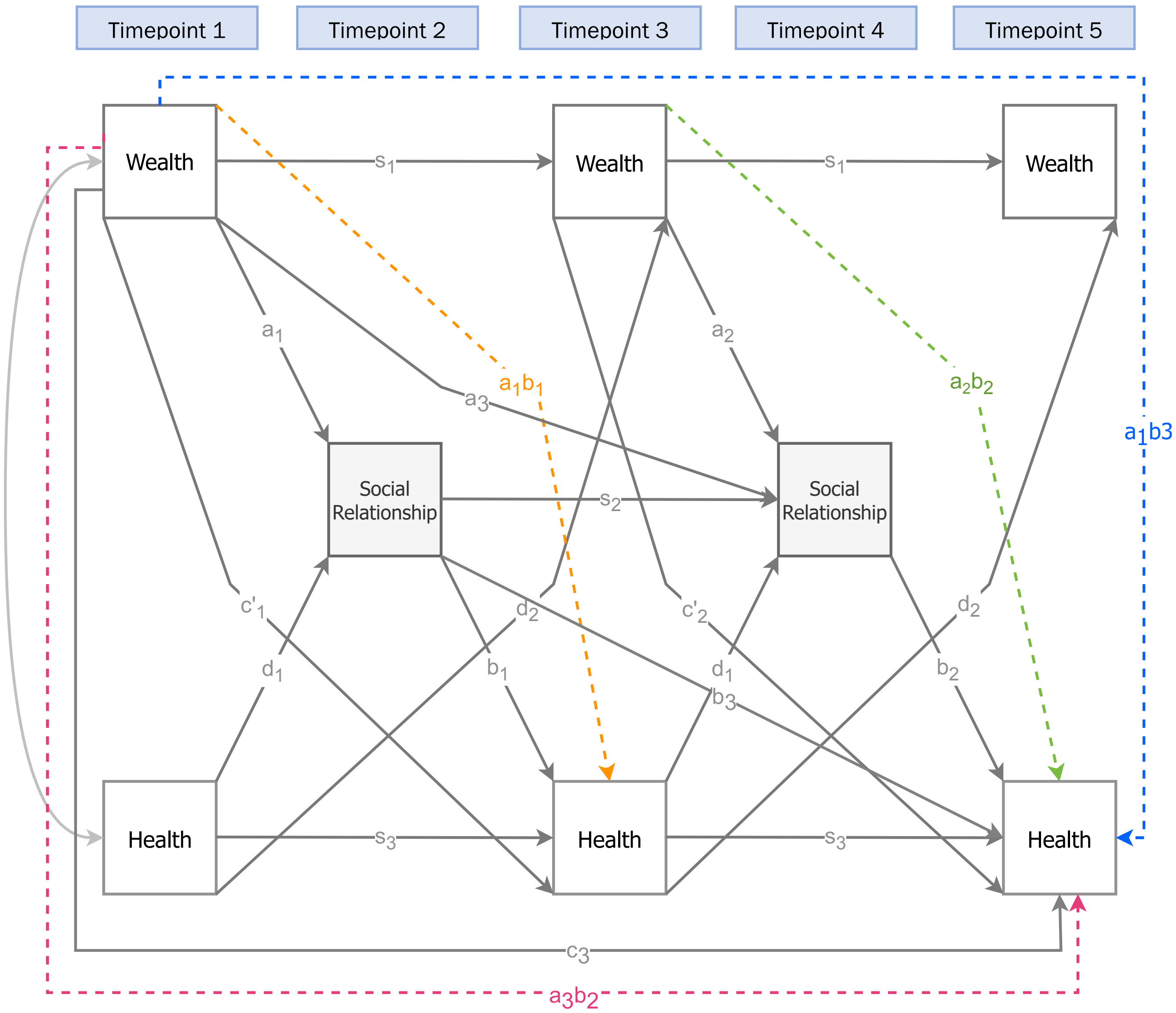

Figure 5.11 Autoregressive longitudinal mediation cross-lagged panel model

Unadjusted autoregressive SEM models with observed social relationship variables (loneliness and social isolation) were run separately for each outcome (see Appendix 18) and subsequently adjusted for the covariates sex and age at baseline. All outcomes except systolic blood pressure (continuous) were treated as binary variables. The best-fitting model was chosen based on the conceptual model (theory-driven) and statistical fit indices. The indices assessed for deterioration of model fit included the comparative fit index (CFI), Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA) and standardised root mean square (SRMR) for non-nested models. The Mplus output also presents the chi-square statistic for each model. However, since this is sensitive to sample size, it was not used to assess the goodness of model fit (Chen, 2007). Model fit was considered adequate for RMSEA values ≤0.08, CFI and TLI values ≥0.90 (Hu and Bentler, 1999) and good for RMSEA values ≤0.06, SRMR ≤0.08, CFI and TLI values ≥0.95 (Bentler, 1990). The values of the fit indices for the various models tested are presented in the results section for the adjusted models. For models with binary outcomes, i.e., self-rated health, self-rated oral health, OHRQoL and edentulousness, Akaike's Information Criterion (AIC, Akaike, 1987) Bayesian Information Criterion (BIC, Schwarz, 1978) and the Sample-Size Adjusted BIC (SABIC) were assessed for how well the model fits the data – the models with lower AIC, BIC and SABIC values were kept (see Appendix 19).

A backwards stepwise selection method was implemented to attain a parsimonious and easily interpretable model (Chapter 7, Section 7.2.3). Non-significant paths were removed from the full model one at a time until parsimony was achieved. However, non-significant paths from covariates to outcomes were kept where the evidence in the literature supports associations between the covariates and outcomes. At each stage, parsimonious fit indices were presented (Appendix 19).

Full information maximum likelihood – accounting for missing data in longitudinal mediation analyses

SEM using the full information maximum likelihood (FIML) was implemented to account for missing data rather than multiple imputation. Full information maximum likelihood is a modern and pragmatic missing data analysis technique that can handle missing data mechanisms that are MCAR or MAR in structural equation modelling (Schafer and Graham, 2002; Baraldi and Enders, 2010). In FIML, missing values on variable *X* are conditionally dependent on other observed variables in the data. It is important to note that, unlike multiple imputation, FIML does not impute missing values; instead, it utilises all the available raw data to obtain parameter estimates and standard errors (Enders, 2001b). The FIML method estimates a likelihood function for each participant based on all fully observed and partially observed cases to give probable values for the missing data during the estimation process (Enders, 2001b). Additionally, FIML yields unbiased parameter estimates and standard errors and is superior to ad hoc methods such as listwise or pairwise deletion (Enders and Bandalos, 2001; Zaninotto and Sacker, 2017). Although FIML assumes multivariate normality, it can be used in situations where the normality of the data are violated, for example, through the use of the robust maximum likelihood estimator (MLR) in Mplus (Enders, 2001a).

Longitudinal mediation analyses were conducted in Mplus 8.6. FIML was implemented in this project to address data missing at random by specifying the maximum likelihood estimation with robust standard errors (MLR) estimator. The MLR estimator is robust to violations of model assumptions such as non-normality of data distribution, accounts for missingness in the data and is appropriate for continuous and binary outcomes (Muthén, 2002; Muthén and Muthén, 2017).

5.7.4 Moderation analyses (Objective 6)

The following sections describe the methodology implemented to assess the extent to which social relationships moderate (objective 6) social inequalities in health, i.e., systolic blood pressure, self-rated health, self-rated oral health, edentulousness and OHRQoL.

Moderation analysis assesses whether a third variable, i.e., the moderator 'M,' changes the strength or the direction of the association between the exposure 'X' and outcome 'Y'. The moderator interacts with the exposure variable to influence the outcome (Figure 5.12).

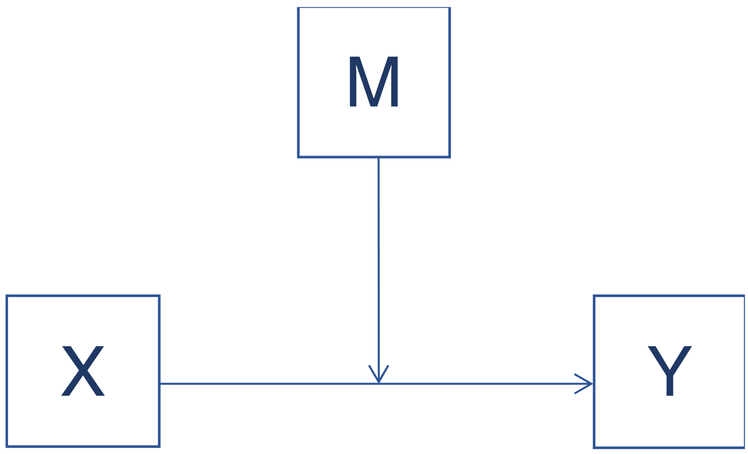

Figure 5.12 A simple moderation model illustrating a moderating effect on the pathway from exposure to outcome

In linear regression models, interaction terms can be included in an imputed dataset using the 'just another variable (JAV)' approach, however, this method is not recommended for logistic regression models (Seaman, Bartlett and White, 2012; Smith, Quartagno and Njagi, 2022). Smith and colleagues (2022) suggest implementing the 'substantive model compatible fully conditional specification' (SMCFCS) method, however, their simulation study included missingness on one variable within the interaction term. At present, there is sparse literature on interactions where both variables have missing data. Therefore, cross-sectional regression analyses were carried out on complete cases before exploring the data through longitudinal analyses.

All analyses were conducted in Stata MP 17.0. Cross-sectional results from Chapter 6 demonstrated that the steepest social gradients in the models were by household non-pension wealth. Therefore, the moderation analyses used household non-pension wealth as the socioeconomic indicator.

For cross-sectional moderation analyses, all social relationship measures (loneliness, social isolation, positive and negative social support) were included to ascertain which measures played a role in moderating socioeconomic inequalities in self-rated health, systolic blood pressure, self-rated oral health, OHRQoL and edentulousness. Social relationships were independently investigated for their role in moderating social inequalities in each health outcome after the model was adjusted for covariates (age and sex).

The models with and without interaction terms were compared to determine whether the effect of household non-pension wealth on health outcomes differed if interaction terms were included. Since weighted survey data analyses were performed, an adjusted Wald test was computed to compare models without and without interaction terms. Where an interaction was evident, stratified results by levels of the social relationship measure were presented. Results from the cross-sectional moderation analysis determined which models would be taken forward for longitudinal moderation analysis.

Longitudinal Analyses – Random Effects Modelling

Random effects modelling extends the conventional regression model to handle the correlation between the responses for the same person over time due to the longitudinal nature of data (Diggle, Liang and Zeger, 1994). Standard regression techniques do not take into account the intra-individual or within-person correlation. Ignoring the dependence between observations would result in incorrect inferences from the data for the underlying population (Diggle, Liang and Zeger, 1994). Random effects models allow the association between the outcome and the explanatory variable differ between participants over time whilst accounting for within-person correlation, for example, through including a random intercept (Carrière and Bouyer, 2002).

A random effect model with and inclusion of a random intercept can be represented by the following equation:

$$\text{logit}\,(E\,(Y_{ij} \mid X_{ij}, U_i)) = X_{ij}'\beta^* + U_{i0}$$

A binary outcome is represented by Y_{ij}, whereby Y represents the outcome, for example edentulousness corresponding to the *i*th wave of the study of the *j*th participant. Similarly, let X_{ij} denote the exposure, for example, wealth, corresponding the *i*th wave of the study of the *j*th participant. The random effects are represented by U_i and are assumed to vary from one individual to another i.e., it is the subject specific effect, according to a common distribution, often $u \sim \text{Normal}(0, \sigma_u^2)$. The variance, σ_u^2, has to be estimated and represents the extent of the unexplained between-individual variability. U_{i0} denotes the propensity to experience edentulousness, constant across all waves (Carrière and Bouyer, 2002).

Random effects models assume that data are missing at random (MAR), i.e., that the missingness depends only on observed variables (Little and Rubin, 1987). Maximum likelihood (ML) estimation was implemented for incomplete data so that all available information was used. ML estimates are consistent when the responses are MAR. Therefore, this technique not only included respondents who were present at all waves, but also those with missing data contributed information.

Cross-sectional moderation analyses informed further analyses. Since interactions were only evident between positive social support and wealth in the model for edentulousness, this was the only outcome that was taken forward for assessing moderation longitudinally. For this analysis, three waves of data were used: waves 3, 5 and 7 (see Section 5.6.3). Random effects logistic models were fitted with and without interactions between household non-pension wealth and positive social support – both models were run separately, and the results stored after each run for comparison using the postestimation Likelihood Ratio (LR) test. Since these models were nested, and analyses were not performed using longitudinal weights (see Section 5.7), it was appropriate to compare them using the LR test to ascertain whether the model with or without the interaction term was a better fit for the data. The LR postestimation test determines the best fitting model by testing whether the difference is statistically significant ($p \leq 0.05$). Models were stratified by levels of positive social support where results of the postestimation test were $p \leq 0.05$.

The `xtlogit` command was used to fit the random-intercept logistic models in Stata MP (version 17.0). This command provides ML estimation and uses adaptive Gauss-Hermite quadrature to approximate the integrals involved. In the `xtlogit` command, the `intpoints(40)` option (which stands for integration points) was used to ensure accurate estimates. The `quadchk` tool was used to determine that 40 integration points ensured a good quadrature approximation. This method fitted additional models with 27 and 53 integration points which were subsequently compared to the model with 40 integration points. Results of these models were compared to the original estimates with 40 integration points (Appendix 20). The relative difference was between 10^{-4} and 10^{-8}, therefore, suggesting that the choice of 40 integration points did not significantly affect the outcome and the results were reliable (StataCorp, 2021a).

Chapter 6. Results of cross-sectional analyses

Chapter Summary: This chapter presents results from the analyses of cross-sectional associations between socioeconomic position, social relationship measures, SRH, blood pressure, SROH, OHRQoL, and edentulousness. The analyses used data from wave 2 (2004/2005) and wave 3 (2006/2007) of the ELSA.

First, the characteristics of the three analytical samples, one each for blood pressure, SRH, and oral health outcomes, used in cross-sectional analyses are described. Second, the frequency distribution of health outcomes by age, sex, and explanatory variables is presented. Third, the associations between socioeconomic position and social relationships are examined. Thereafter, associations between socioeconomic position and health outcomes adjusting for social relationships and covariates are examined. Finally, results from linear and logistic regression models are discussed and summarised. All results are presented on imputed data except for descriptive characteristics of the samples that assess missingness, which are presented on observed data.

6.1 Descriptive statistics

Descriptive statistics for waves 2 and 3 are presented across five tables: 6.1 to 6.5. The initial wave 2 (2004/2005) sample consisted of 8688 core cohort, community-dwelling people aged 50 years and older, while the initial wave 3 (2006/2007) sample had 8624 core cohort participants.

6.1.1 Missing data and Item non-response

Missing data were explored for waves 2 and 3 separately. At wave 2, participants with any missing data comprised 32% of the initial sample used to examine SRH (2780 older adults) and 46.3% of the initial sample that examined blood pressure (4022 older adults). At wave 3, 31.5% of the initial sample examining SROH, OHRQoL and edentulousness had missing data (2716 older adults).

The extent of item non-response can be seen in Table 6.1. At wave 2, the highest proportion of missing data were observed for systolic and diastolic blood pressure (23.6%).

This was expected since data was only available for those who had the nurse visit (see Section 5.1.2) — all other health outcomes at waves 2 and 3 presented with <1% missingness. The social relationship variables (measured via self-completion questionnaire) also had high proportions of missingness, the highest being for social isolation (wave 2: 23.1%; wave 3: 24.4%) (see Appendix 10 for proportion of missingness in each social relationship item).

Table 6.1 Distribution of missing data (item non-response) – samples for cross-sectional analyses

Variables	Wave 2 (*n* = 8688)		Wave 3 (*n* = 8624)	
	Missing[1]		Missing[1]	
	n	%	*n*	%
Outcomes				
Systolic blood pressure	2049	23.6	N/A	N/A
Diastolic blood pressure	2049	23.6	N/A	N/A
Self-rated health	7	0.08	N/A	N/A
Self-rated oral health	N/A	N/A	4	0.05
Edentulousness	N/A	N/A	4	0.05
Oral health-related quality of life	N/A	N/A	3	0.03
Exposures				
Household non-pension wealth	119	1.4	287	3.3
Occupation	5	0.06	3	0.03
Education	7	0.08	4	0.05
Covariates				
Age	0	0	0	0
Sex	0	0	0	0
Mediators/moderators				
Loneliness	1101	12.7	1279	14.8
Social isolation	2005	23.1	2106	24.4
Positive social support	1590	18.3	1665	19.3
Negative social support	1862	21.4	1889	21.9

[1]Unweighted

Missingness for socioeconomic variables largely remained at <2%. However, missingness in wealth at wave 3 increased by almost 2% compared to wave 2 (Table 6.1).

6.1.2 Characteristics of participants with missing data (observed data)

Systematic differences in socioeconomic position, age, sex, social relationships, and outcomes between those with and without missing data were assessed and tested using

Pearson's Chi-squared (X^2) test and X^2 test for trend (where appropriate) (Table 6.2 and Table 6.3).

At wave 2, there was no significant difference in diastolic blood pressure between participants with and without missing data (Table 6.2). However, there were significant differences in the five other health outcomes (systolic blood pressure, SRH, SROH, edentulousness and OHRQoL) among individuals with and without missing data at waves 2 and 3. In addition, the prevalence of unfavourable outcomes was higher among those with missing data at both waves (Table 6.2 and 6.3).

A clear gradient in missing data was seen across all markers of socioeconomic position at waves 2 and 3, i.e., those with missing data were more disadvantaged (Table 6.2 and 6.3).

Generally, at waves 2 and 3, the proportion of those reporting less favourable social relationships was higher among those with missing data when compared to those without missing data (Table 6.2 and 6.3). However, at wave 3, there was no significant difference in the experience of positive social support and social isolation between respondents with and without missing data (Table 6.3).

At waves 2 and 3, missingness varied significantly by age and sex (Table 6.2 and 6.3). At waves 2 and 3, generally, the proportion of respondents with missing data differed by age, a greater proportion with missingness were in the oldest age group, i.e., ≥80-year-olds (Table 6.2 and 6.3). Finally, at waves 2 and 3, the proportion of females was higher among those with missing data (Tables 6.2 and 6.3).

Table 6.2 Descriptive characteristics of participants at wave 2: a comparison of participants with and without missing data (*n* = 8688) (observed data)

Variables	Total (*n* = 8688) *n* (%)[1]	Participants with complete data (*n* = 5908) %[1]	Participants with missing data (*n* = 2780) %[1]	p-value[2]
Wealth[3]				
Wealthiest	1831 (21.4)	23.4	16.7	<0.001
4th quintile	1758 (20.5)	21.8	17.8	
3rd quintile	1723 (20.1)	20.8	18.5	
2nd quintile	1703 (19.9)	18.8	22.3	
Least wealthy	1554 (18.1)	15.2	24.7	
Total	8569			
Occupation[4]				
Managerial	2647 (30.5)	33.6	24.0	<0.001
Intermediate	2119 (24.4)	25.0	23.1	
Routine	3779 (43.5)	40.3	50.4	
Other	138 (1.6)	1.1	2.5	
Total	8683			
Education[5]				
>A level	2098 (24.2)	26.9	18.4	<0.001
O level-A level	2034 (23.4)	25.9	18.2	
<O level	4549 (52.4)	47.2	63.4	
Total	8681			
Age				
50-59 years	2584 (29.7)	32.5	23.9	<0.001
60-69 years	2860 (32.9)	35.6	27.3	
70-79 years	2162 (24.9)	22.8	29.3	
≥80 years	1082 (12.5)	9.1	19.5	
Total	8688			
Sex				
Female	4783 (55.0)	54.2	56.9	0.019
Male	3905 (45.0)	45.8	43.1	
Total	8688			
Loneliness				
Not lonely	6134 (80.9)	81.7	77.8	<0.001
Lonely	1453 (19.1)	18.3	22.2	
Total	7587			
Social isolation				
Lower tertile	2889 (43.2)	43.8	38.6	0.021
Middle tertile	2050 (30.7)	30.3	33.4	
Upper tertile	1744 (26.1)	25.9	28.0	
Total	6683			

Positive support				
Lower tertile	2600 (36.6)	36.2	38.6	
Middle tertile	2422 (34.1)	33.7	36.1	0.006
Upper tertile	2076 (29.3)	30.0	25.4	
Total	7098			
Negative support				
Lower tertile	2296 (33.6)	34.2	29.9	
Middle tertile	2575 (37.7)	37.7	38.1	0.012
Upper tertile	1955 (28.6)	28.1	32.0	
Total	6826			
SRH[6]				
Excellent to good	6209 (71.5)	75.4	63.2	<0.001
Fair or poor	2472 (28.5)	24.6	36.8	
Total	8681			
SBP[7]				
<140 mm HG	3941 (59.4)	61.2	57.5	0.042
≥140 mm HG	2698 (40.6)	39.8	42.5	
Total	6639			
DBP[7]				
<90 mm HG	5786 (87.2)	87.0	87.4	0.659
≥90 mm HG	853 (12.8)	13.0	12.6	
Total	6639			

[1]Unweighted; *n* = number of individuals; *n*/% with missing data = number and percentage of individuals with at least one missing value within that group; [2]Pearson's X^2 test/X^2 test for trend; [3]Wealth = household non-pension wealth; [4]Occupation: managerial = managerial/profession, routine = routine/manual, Other = never worked/unemployed/other; [5]Education: level as specified and equivalent; [6]SRH = self-rated health; [7]SBP = systolic blood pressure, DBP = diastolic blood pressure; Analytical sample for blood pressure: participants with complete data *n* = 4666; participants with missing data *n* = 4022

Table 6.3 Descriptive characteristics of participants: a comparison between participants with and without missing data at wave 3 (n = 8624) (observed data)

Variables	Total (n = 8624) n (%)[1]	Participants with complete data (n = 5768) %[1]	Participants with missing data (n = 2857) %[1]	p-value[2]
Wealth[3]				
Wealthiest	1778 (21.3)	23.7	16.1	<0.001
4th quintile	1704 (20.4)	21.8	17.3	
3rd quintile	1691 (20.3)	20.1	20.7	
2nd quintile	1628 (19.5)	19.2	20.3	
Least wealthy	1536 (18.4)	15.2	25.6	
Total	8337			
Occupation[4]				
Managerial	2762 (32.0)	34.3	27.5	<0.001
Intermediate	2148 (24.9)	25.7	23.3	
Routine	3593 (41.7)	38.9	47.3	
Other	118 (1.4)	1.1	1.9	
Total	8621			
Education[5]				
>A level	2761 (32.0)	34.5	26.9	<0.001
O level-A level	2220 (25.8)	26.7	23.9	
<O level	3639 (42.2)	38.8	49.2	
Total	8620			
Age				
50-59 years	3021 (35.0)	34.1	36.9	<0.001
60-69 years	2570 (29.8)	33.4	22.5	
70-79 years	2000 (23.2)	23.0	23.5	
≥80 years	1033 (12.0)	9.5	17.1	
Total	8624			
Sex				
Female	4767 (55.3)	54.5	56.8	0.037
Male	3857 (44.7)	45.5	43.2	
Total	8624			
Loneliness				
Not lonely	5745 (78.2)	79.3	74.1	<0.001
Lonely	1600 (21.8)	20.7	25.9	
Total	7345			
Social isolation				
Lower tertile	2768 (42.5)	42.5	42.3	0.600
Middle tertile	1963 (30.1)	29.9	32.0	
Upper tertile	1787 (27.4)	27.6	25.7	
Total	6518			

Positive support				
Lower tertile	2441(35.1)	35.1	34.8	
Middle tertile	2372 (34.1)	34.3	33.3	0.543
Upper tertile	2146 (30.8)	30.6	31.9	
Total	6959			
Negative support				
Lower tertile	2338 (34.7)	36.0	27.3	
Middle tertile	2444 (36.3)	36.2	36.9	<0.001
Upper tertile	1953 (29.0)	27.8	35.8	
Total	6735			
SROH[6]				
Excellent to good	7048 (81.8)	83.2	78.8	<0.001
Fair to poor	1572 (18.2)	16.8	21.2	
Total	8620			
Edentulousness				
Dentate	7174 (83.2)	85.1	79.4	<0.001
Edentate	1446 (16.8)	14.9	20.6	
Total	8620			
OHRQoL[7]				
No impact	7883 (91.4)	92.5	89.2	<0.001
≥1 impact	738 (8.6)	7.5	10.8	
Total	8621			

[1]Unweighted; *n* = number of individuals; *n*/% with missing data = number and percentage of individuals with at least one missing value within that group; % in bold ≤0.05, *p*-values calculated using logistic regression; [2]Pearson's Chi-squared test; [3]Wealth = household non-pension wealth; [4]Occupation: managerial = managerial/profession, routine = routine/manual, Other = never worked/unemployed/other; [5]Education: level as specified and equivalent; [6]SROH = self-rated oral health; [7]OHRQoL = Oral health-related quality of life: no impact = no oral impact on daily performance, ≥1 = at least one oral impact on daily performance

6.1.3 General health outcomes at wave 2 - self-rated health, systolic and diastolic blood pressure

Table 6.6 shows that almost a third (29.2%) of wave 2 participants reported having fair to poor SRH. Mean systolic blood pressure was measured as 136.8 mm HG, and for almost 41% of participants systolic blood pressure was ≥140 mm HG. Although the mean diastolic blood pressure among respondents was reported as 76.5 mm HG, i.e., within the normal range for diastolic blood pressure, for approximately 13% of individuals diastolic blood pressure was ≥90 mm HG. The higher prevalence of systolic hypertension within this sample may be explained by the tendency of high income countries to see systolic blood pressure rising with age, and diastolic blood pressure plateauing at 60 years of age before decreasing (Franklin *et al.*, 1997; Banks *et al.*, 2006).

The mean diastolic blood pressure was approximately normally distributed and mean systolic blood pressure was very slightly skewed to the right – these are illustrated by histograms and tables with respective values of skewness and kurtosis (see Appendix 11).

6.1.4 Oral health outcomes at wave 3 - self-rated oral health, oral health-related quality of life and edentulousness

Table 6.7 shows that 18.8% of the analytical sample at wave 3 reported experiencing fair or poor SROH and 17.6% reported being edentate, i.e., having no teeth. 8.7% reported experiencing at least one impact on daily tasks such as eating, speaking, smiling, social contact with others and emotional stability (see Section 5.2.4 for OIDP index).

6.1.5 Socioeconomic position

According to Tables 6.6 and 6.7, it appears that for occupational class there was not much difference in prevalence between waves 2 and 3. At both waves 2 and 3, the largest occupational group was routine and manual occupation, and almost a third of the sample were those in managerial or professional occupations.

However, a more noticeable difference in prevalence was seen by level of education. At wave 2, the largest category by education was less than O-level or equivalent qualifications

(55%), whereas at wave 3, the sample was slightly more advantaged in terms of education. Those with less than A-level or equivalent qualifications comprised 45.6% of the wave 3 sample, however, unlike wave 2, almost a third of the sample also had higher than A-level qualifications (29.6%) (Table 6.7).

6.1.6 Social relationships

Mean scores for loneliness, social isolation, positive social support, and negative social support were similar at both waves 2 and 3 (Table 6.6 and 6.7). At waves 2 and 3, although most people experienced satisfactory social relationships, the prevalence of less favourable social relationships is worth noting. At wave 2, 20.7% of participants experienced loneliness. Participants in the highest tertile of positive social support scored between 41 to 48 whereas those in the lowest tertile had a score that ranged from 0 to 28. Participants in the lowest tertile of negative social support scored between 0 to 13 whereas those in the highest tertile had a score that ranged from 21 to 33. Finally, Participants in the highest tertile of social isolation scored between 3 to 6. A similar prevalence was seen at wave 3, with one exception: a slightly higher proportion of participants experienced loneliness at wave 3 than at wave 2 (22.8%).

The distribution of all social relationship indicators (loneliness, social isolation, and positive and negative social support) is illustrated by histograms in Figures A.12.1 to A.12.8 and Table A.12.1 (Appendix 12). Apart from negative social support and social isolation which were almost normally distributed at waves 2 and 3, loneliness and positive social support measures were skewed. Therefore, Spearman's rank test, a non-parametric test, was used to assess correlation coefficients (rho) between social relationship variables at waves 2 and 3. Loneliness, social isolation, and positive and negative social support measures were significantly correlated with each other, and these correlations were similar at waves 2 and 3 (Tables 6.4 and 6.5). Loneliness was positively but weakly correlated with social isolation, and negatively but moderately correlated with positive social support at both waves. In addition, loneliness was very weakly correlated with negative social support at waves 2 and 3 (Table 6.4 and 6.5). Social isolation was negatively and weakly correlated with negative social support and negatively and moderately correlated with positive social support at waves 2 and 3. Positive and negative social support were positively and weakly correlated at waves 2 and 3.

Table 6.4 Correlations between social relationship variables at wave 2: loneliness, social isolation, positive social support, and negative social support (*n* = 8681)

	Loneliness	Social isolation	Positive social support	Negative social support
Loneliness	1			
Social isolation	0.25***	1		
Positive social support	-0.40***	-0.58***	1	
Negative social support	0.04**	-0.37***	0.35***	1

Table display rho (*r*) values to indicate level of correlation; **p* <0.05; ****p* <0.001

Table 6.5 Correlations between social relationship variables at wave 3: loneliness, social isolation, positive social support, and negative social support (*n* = 8617)

	Loneliness	Social isolation	Positive social support	Negative social support
Loneliness	1			
Social isolation	0.27***	1		
Positive social support	-0.41***	-0.59***	1	
Negative social support	0.05**	-0.34***	0.33***	1

Table display rho (*r*) values to indicate level of correlation; **p* <0.05; ****p* <0.001

6.1.7 Covariates

At wave 2, 53.9% of the sample were women. The mean age of respondents was 66.8 years and almost 14% were in the oldest age category (≥80 years) (Table 6.4). A similar distribution was seen for age and sex at wave 3, however the oldest age group made up approximately 12% of the sample (Table 6.5).

Histograms illustrate age distribution at waves 2 and 3 in the Figures A.11.3 and A.11.4 (Appendix 11). Age was slightly skewed to the right at both waves 2 and 3 – skewness was 0.64 and 0.56, respectively and kurtosis was 2.95 and 2.68, respectively (Appendix 11).

Table 6.6 Description of analytical sample at wave 2 (imputed data)

Variables	ELSA wave 2 (n = 8681)			
	n	%[1]	Mean	SD
Wealth[2]				
Wealthiest	1752	20.2	N/A	N/A
4th quintile	1746	20.1		
3rd quintile	1740	20.1		
2nd quintile	1731	19.9		
Least wealthy	1712	19.7		
Occupation				
Managerial/professional	2443	28.1	N/A	N/A
Intermediate occupations	2063	23.8		
Routine	3983	45.9		
Other[3]	192	2.2		
Education[4]				
>A level	1951	22.5	N/A	N/A
O level-A level	1955	22.5		
<O level	4775	55.0		
Age				
50-59 years	2710	31.2	66.8	10.0
60-69 years	2717	31.3		
70-79 years	2076	23.9		
≥80 years	1178	13.6		
Sex				
Female	4681	53.9	N/A	N/A
Male	4000	46.1		
Loneliness				
Not lonely	6884	79.3	4.1	1.5
Lonely	1797	20.7		
Social isolation				
Lowest tertile	3478	40.1	1.8	1.2
Middle tertile	2681	30.9		
Highest tertile	2522	29.1		
Positive support				
Lowest tertile	3378	38.9	33.6	8.9
Middle tertile	2888	33.3		
Highest tertile	2415	27.8		
Negative support				
Lowest tertile	3124	36.0	17.3	6.0
Middle tertile	3154	36.3		
Highest tertile	2403	27.7		
SRH				
Excellent to good	6147	70.8	N/A	N/A
Fair or poor	2534	29.2		
SBP				
<140 mm HG	3932	59.2	136.8 mm HG	19.6
≥140 mm HG	2707	40.8		
DBP[5]				
<70 mm HG	5781	87.1	76.5 mm HG	11.7
≥70 mm HG	858	12.9		

[1]Weighted for non-response at wave 2; [2]Wealth = household non-pension wealth; [3]Occupation: Other = never worked/unemployed/other; [4]Education: level as specified and equivalent; [5]SBP = Systolic blood pressure, DBP = diastolic blood pressure *n* = 6639

Table 6.7 Description of the analytical sample at wave 3 (imputed data)

Variables	ELSA wave 3 (n = 8617)			
	n	%[1]	Mean	SD
Wealth[2]				
Wealthiest	1737	21.2	N/A	N/A
4th quintile	1729	20.1		
3rd quintile	1733	20.1		
2nd quintile	1720	19.9		
1st quintile	1698	19.7		
Occupation				
Managerial/professional	2515	29.2	N/A	N/A
Intermediate occupations	2095	24.3		
Routine/manual	3849	44.7		
Other[3]	158	1.8		
Education				
>A level	2552	29.6	N/A	N/A
O level-A level	2140	24.8		
<O level	3925	45.6		
Age				
50-59 years	3061	35.5	65.7	10.6
60-69 years	2638	30.6		
70-79 years	1847	21.4		
≥80 years	1071	12.4		
Sex				
Female	4584	53.2	N/A	N/A
Male	4033	46.8		
Loneliness				
Not lonely	6648	77.2	4.2	1.6
Lonely	1969	22.8		
Social isolation				
Lower tertile	3455	40.1	1.8	1.2
Middle tertile	2600	30.2		
Upper tertile	2562	29.7		
Positive support				
Lower tertile	3188	37.0	33.9	8.9
Middle tertile	2880	33.4		
Upper tertile	2549	29.6		
Negative support				
Lower tertile	3120	36.2	17.3	6.1
Middle tertile	3057	35.5		
Upper tertile	2440	28.3		
SROH[4]				
Excellent to good	6996	81.2	N/A	N/A
Fair to poor	1621	18.8		
Edentulousness				
Dentate	7103	82.4	N/A	N/A
Edentate	1514	17.6		
OHRQoL[5]				
No impact	7864	91.3	N/A	N/A
≥1 impact	753	8.7		

[1]Weighted for non-response at wave 2; [2]Wealth = household non-pension wealth; [3]Occupation: Other = never worked/unemployed/other; [4]SROH = self-rated oral health; [5]OHRQoL = oral health-related quality of life: no impact = no oral impact on daily performance, ≥1 = at least one oral impact on daily performance

6.2 Bivariate analyses

This section assessed social gradients in general and oral health outcomes among older adults in ELSA using imputed data (objective 2). Secondly, it assessed whether social relationships are socially patterned (objective 3).

Firstly, bivariate associations between all explanatory markers and health outcomes at wave 2 (SRH and blood pressure) and wave 3 (SROH, edentulousness, OHRQoL) were tested using logistic and linear regression as appropriate. Thereafter, associations between explanatory variables and social relationship measures were assessed using logistic regression.

6.2.1 Associations between socioeconomic position and health outcomes at waves 2 and 3

Social gradients were apparent for five of the six outcomes: SRH, systolic blood pressure (wave 2), SROH, OHRQoL, and edentulousness (wave 3) (Table 6.8 and 6.9). A social gradient was less clear for diastolic blood pressure (Table 6.8).

Household non-pension wealth

With each decreasing quintile of wealth, there was an increase in prevalence of poorer SRH and increase in mean systolic blood pressure, although the gradient was more pronounced for SRH than for systolic blood pressure (Table 6.8). No significant associations were seen between wealth and mean diastolic blood pressure (Table 6.8).

Steep wealth gradients were also seen in the prevalence of poor SROH, at least one oral impact on daily performance in the past six months, and edentulousness at wave 3 (Table 6.9). With greater socioeconomic disadvantage there was a marked increase in experiencing poor oral health. The steepest wealth gradient was seen for edentulousness (Table 6.9).

Occupational class

Table 6.8 shows occupational class gradients in SRH and mean blood pressure – as seen previously by wealth, the steepest gradient was seen in SRH. With decreasing advantage, there was an increase in the prevalence of fair to poor SRH and increase in mean systolic blood pressure. No significant association was seen between occupation and mean diastolic blood pressure among this sample (Table 6.8).

Table 6.9 displays occupational class gradients in SROH, OHRQoL, and edentulousness at wave 3. With decreasing advantage, there was an increase in the prevalence of fair to poor SROH, at least one oral impact on daily performance and total tooth loss. The prevalence of poor SROH was higher among routine and manual occupational class and those who never worked or were unemployed than among those in intermediate, professional, or managerial occupations. For OHRQoL and edentulousness, the proportions of those with at least one oral impact on daily performance and total tooth loss were highest for the never worked and unemployed occupational class. The gradients were steeper for OHRQoL and edentulousness than SROH.

Educational level

Table 6.8 displays education gradients in SRH, and mean blood pressure. As seen previously, with decreasing level of education, there was an increase in the prevalence of fair to poor SRH and mean systolic blood pressure at wave 2. The prevalence of poor SRH and highest mean systolic blood pressure was highest for those with less than O-level or equivalent qualifications. A slightly different pattern in prevalence was seen for mean diastolic blood pressure – mean diastolic blood pressure was lowest among those with less than O-level or equivalent qualifications (Table 6.8).

Table 6.9 shows education gradients in SROH, OHRQoL, and edentulousness at wave 3. The prevalence of poor SROH, edentulousness and poor OHRQoL was highest for those in the lowest educational group. The steepest gradient by education was seen for edentulousness (Table 6.9).

6.2.2 Associations between social relationships, self-rated health, and blood pressure at wave 2

Associations between social relationships and health outcomes were somewhat inconsistent. In line with expectations, poor SRH was more prevalent among those who felt more socially isolated, experienced less positive social support, or reported higher levels of loneliness. However, negative social support was not related to SRH (Table 6.8).

As expected, mean systolic blood pressure increased with increasing social isolation and decreased with increasing positive social support. However, an inverse association was seen with negative social support – participants in the highest tertile of negative support had a 4mm HG lower systolic blood pressure than those in the lower tertile of negative social support. No significant association was found between loneliness and systolic blood pressure. In addition, no significant associations were seen between any social relationship measures and diastolic blood pressure within this sample. With one exception: prevalence of the highest mean diastolic blood pressure was seen among those who experienced higher levels of negative social support (Table 6.8).

6.2.3 Associations between social relationships and oral health at wave 3

Across all oral health outcomes (SROH, OHRQoL, and edentulousness) at wave 3, respondents with less favourable social relationships reported poorer oral health. However, there was one exception: edentulousness was less prevalent among those reporting higher levels of negative social support. Additionally, OHRQoL was not significantly associated with negative social support (Table 6.9).

6.2.4 Associations between sex, age, and health outcomes at waves 2 and 3

As expected, older age was significantly associated with poorer health outcomes. Both prevalence of poor SRH and mean systolic blood pressure was seen with increasing age. In contrast, an inverse relationship was seen between age and diastolic blood pressure – i.e., with increasing age, there was a decrease in mean diastolic blood pressure (Table 6.8).

Table 6.9 shows an inverse relationship between age and the prevalence of poor SROH. An increasing prevalence of poorer OHRQoL and edentulousness was seen with increasing age (Table 6.9). Edentulousness was strongly associated with age – as was entirely expected; prevalence of total tooth loss was highest for adults aged 80 years and over.

Sex was not associated with systolic blood pressure or SRH at wave 2. However, sex was significantly associated with mean diastolic blood pressure: a 1.7 mm HG higher mean diastolic blood pressure was seen in men compared to women (Table 6.8).

At wave 3, sex was only significantly associated with edentulousness and SROH. Poor SROH was more frequently reported by men than women. However, prevalence of edentulousness was higher in women than men, 19.9% and 14.9%, respectively (Table 6.9).

Table 6.8 Distribution of general health outcomes by age, sex, and explanatory variables at wave 2 (imputed data)

Variables	Total: (*n* = 6639) *n* (%)[1]	Systolic blood pressure[2]		Diastolic blood pressure[2]		Total: (*n* = 8681) *n* (%)[1]	Fair to poor SRH (*n* = 2534)	
		Mean SBP mm HG (95%CI)[1]	*p*-value[3]	Mean DBP mm HG (95%CI)[1]	*p*-value[3]		% (95%CI)[1]	*p*-value[3]
Wealth[4]								
Wealthiest	1410 (21.2)	134.2 (133.2-135.2)	<0.001	76.6 (75.9-77.2)	0.338	1751 (20.2)	14.4 (12.5-16.2)	<0.001
4th quintile	1385 (20.8)	136.3 (135.2-137.4)		76.4 (75.8-77.1)		1746 (20.1)	20.5 (18.4-22.5)	
3rd quintile	1388 (20.9)	137.4 (136.2-138.7)		76.4 (75.7-77.1)		1741 (20.1)	24.3 (22.0-26.6)	
2nd quintile	1284 (19.4)	137.7 (136.6-138.9)		76.4 (75.7-77.1)		1731 (19.9)	37.6 (35.1-40.0)	
Least wealthy	1172 (17.7)	139.2 (137.8-140.5)		76.0 (75.2-76.8)		1712 (19.7)	49.8 (47.1-52.5)	
Occupation[5]								
Managerial	1921 (28.9)	134.9 (134.0-135.7)	<0.001	76.5 (76.0-77.0)	0.097	2443 (28.1)	19.0 (17.4-20.6)	<0.001
Intermediate	1582 (23.8)	136.9 (135.9-138.0)		76.7 (76.1-77.3)		2063 (23.8)	25.2 (23.3-27.1)	
Routine	2997 (45.1)	138.1 (137.3-138.8)		76.2 (75.8-76.7)		3983 (45.9)	36.6 (34.9-38.2)	
Other	139 (2.2)	138.7 (133.8-143.6)		73.1 (70.2-76.1)		192 (2.2)	48.7 (40.0-57.5)	
Education[6]								
>A-level	1525 (23.0)	134.1 (133.2-135.0)	<0.001	77.1 (76.5-77.7)	<0.001	1951 (22.5)	17.1 (15.3-18.8)	<0.001
O level-A level	1529 (23.0)	135.2 (134.2-136.1)		77.3 (76.8-77.9)		1955 (22.5)	21.4 (19.5-23.4)	
<O level	3585 (54.0)	138.8 (138.1-139.5)		75.7 (75.2-76.1)		4775 (55.0)	37.3 (35.8-38.9)	
Age								
50-59 years	2039 (30.7)	131.4 (130.5-132.2)	<0.001	78.8 (78.3-79.4)	<0.001	2710 (31.2)	23.0 (21.3-24.8)	<0.001
60-69 years	2110 (31.8)	136.1 (135.3-136.9)		77.6 (77.1-78.1)		2717 (31.3)	27.0 (25.2-28.8)	
70-79 years	1623 (24.4)	142.0 (140.9-143.0)		75.1 (74.5-75.7)		2076 (23.9)	33.6 (31.4-35.8)	
≥80 years	867 (13.1)	142.2 (140.6-143.8)		70.0 (69.1-71.0)		1178 (13.6)	40.8 (37.6-43.9)	
Sex								
Male	3043 (45.8)	137.3 (136.6-137.9)	0.122	77.3 (76.8-77.7)	<0.001	4000 (46.1)	28.9 (27.4-30.5)	0.616
Female	3596 (54.2)	136.6 (135.8-137.3)		75.6 (75.2-76.0)		4681 (53.9)	29.4 (28.0-30.8)	
Loneliness								

Not lonely	5313 (80.0)	136.8 (136.2-137.4)	0.551	76.5 (76.2-76.9)	0.051	6884 (79.3)	24.7 (23.4-25.9)	<0.001
Lonely	1326 (20.0)	137.2 (136.0-138.5)		75.7 (74.9-76.5)		1797 (20.7)	46.6 (43.9-49.3)	
Social isolation								
Lower tertile	2754 (41.5)	135.2 (134.4-135.9)		76.6 (76.1-77.0)		3478 (40.1)	20.3 (18.7-22.0)	
Middle tertile	2054 (30.9)	137.7 (136.7-138.7)	<0.001	76.4 (75.8-77.0)	0.182	2681 (30.9)	30.7 (28.6-32.7)	<0.001
Upper tertile	1831 (27.6)	138.6 (137.5-139.7)		76.0 (75.4-76.7)		2522 (29.0)	39.8 (37.5-42.2)	
Positive support								
Lower tertile	2513 (37.9)	138.7 (137.8-139.6)		76.4 (75.8-76.9)		3378 (38.9)	35.1 (33.2-36.9)	
Middle tertile	2224 (33.5)	136.2 (135.3-137.2)	<0.001	76.3 (75.8-76.9)	0.775	2888 (33.3)	27.1 (25.3-28.9)	<0.001
Upper tertile	1902 (28.6)	135.2 (134.3-136.2)		76.5 (75.9-77.0)		2415 (27.8)	23.5 (21.5-25.5)	
Negative support								
Lower tertile	2364 (35.6)	139.2 (138.2-140.2)		75.2 (74.6-75.8)		3124 (36.0)	30.2 (28.3-32.2)	
Middle tertile	2455 (37.0)	135.9 (135.1-136.8)	<0.001	76.7 (76.2-77.2)	<0.001	3154 (36.3)	27.8 (25.9-29.7)	0.616
Upper tertile	1820 (27.4)	135.1 (134.2-136.1)		77.4 (76.8-78.0)		2403 (27.7)	29.7 (27.6-31.8)	

[1]Weighted for non-response at wave 2; [2]*p*-values calculated using linear regression for blood pressure and logistic regression for SRH; [3]p-values calculated using linear regression for blood pressure and logistic regression for SRH; [4]Wealth = household non-pension wealth; [5]Occupation: Managerial = managerial/professional, Routine = routine/manual, Other = never worked/unemployed/other; [6]Education: level as specified and equivalent

Table 6.9 Distribution of oral health outcomes by age, sex, and explanatory variables at wave 3 (imputed data) (*n* = 8617)

Variables	Total: (*n* = 8617) *n* (%)[1]	Fair to poor SROH (*n* = 1621)		Edentulousness (*n* = 1514)		At least one daily impact (*n* = 753)	
		%[1] (95%CI)	*p*-value[2]	%[1] (95%CI)	*p*-value[2]	%[1] (95%CI)	*p*-value[2]
Wealth[3]							
Wealthiest	1737 (20.2)	13.2 (11.6-14.9)	<0.001	4.8 (3.7-5.9)	<0.001	5.3 (4.3-6.4)	<0.001
4th quintile	1728 (20.1)	15.2 (13.3-17.1)		10.5 (8.9-12.1)		7.8 (6.4-9.1)	
3rd quintile	1733 (20.1)	16.3 (14.5-18.2)		15.9 (14.1-17.8)		7.4 (6.1-8.7)	
2nd quintile	1721 (20.0)	21.8 (19.7-24.0)		23.8 (21.5-26.0)		9.9 (8.4-11.4)	
Least wealthy	1698 (19.7)	27.7 (25.3-30.1)		33.2 (30.7-35.7)		13.5 (11.6-15.3)	
Occupation[4]							
Managerial	2515 (29.2)	16.0 (14.6-17.5)	<0.001	8.8 (7.6-9.9)	<0.001	6.9 (5.9-7.9)	<0.001
Intermediate	2094 (24.3)	16.9 (15.2-18.6)		13.9 (12.4-15.5)		8.0 (6.8-9.2)	
Routine	3849 (44.7)	21.5 (20.1-22.9)		24.4 (22.9-25.9)		10.0 (8.9-11.0)	
Other	158 (1.8)	23.3 (14.8-31.8)		40.4 (30.8-49.9)		18.0 (10.1-25.9)	
Education[5]							
>A level	2552 (29.6)	16.1 (14.7-17.6)	<0.001	7.2 (6.1-8.2)	<0.001	7.0 (6.0-8.0)	<0.001
O level-A level	2140 (24.8)	17.9 (16.3-19.6)		10.6 (9.2-11.9)		8.0 (6.9-9.2)	
<O level	3925 (45.6)	21.1 (19.6-22.5)		28.1 (26.6-29.7)		10.3 (9.2-11.3)	
Age							
50-59 years	3061 (35.6)	21.1 (19.6-22.7)	0.003	5.1 (4.2-5.9)	<0.001	8.0 (7.0-9.0)	0.008
60-69 years	2638 (30.6)	17.9 (16.3-19.5)		13.6 (12.1-15.0)		8.2 (7.1-9.3)	
70-79 years	1847 (21.4)	16.5 (14.8-18.2)		27.4 (25.3-29.5)		9.5 (8.1-10.9)	
≥80 years	1071 (12.4)	18.4 (15.7-21.1)		46.2 (43.0-49.5)		10.8 (8.6-13.0)	
Sex							
Male	4033 (46.8)	20.4 (19.1-21.7)	0.001	14.9 (13.7-16.0)	<0.001	8.6 (7.7-9.6)	0.733
Female	4584 (53.2)	17.4 (16.3-18.6)		19.9 (18.7-21.1)		8.8 (8.0-9.7)	
Loneliness							
Not lonely	6644 (77.1)	16.6 (15.6-17.6)	<0.001	16.1 (15.0-17.1)	<0.001	6.9 (6.2-7.6)	<0.001
Lonely	1972 (22.9)	26.2 (23.9-28.4)		22.6 (20.5-24.8)		15.1 (13.3-16.9)	
Social isolation							
Lower tertile	3453 (40.1)	14.7 (13.3-16.1)	<0.001	10.6 (9.4-11.8)	<0.001	7.1 (6.1-8.1)	0.001
Middle tertile	2593 (30.1)	18.6 (16.9-20.4)		17.2 (15.5-18.9)		8.6 (7.4-9.9)	

Upper tertile	2571 (29.8)	24.5 (22.5-26.5)		27.3 (25.3-29.3)		11.1 (9.7-12.5)	
Positive support							
Lower tertile	3189 (37.0)	24.0 (22.4-25.6)		22.8 (21.1-24.4)		11.1 (9.9-12.4)	
Middle tertile	2881 (33.4)	17.0 (15.4-18.5)	<0.001	15.7 (14.2-17.2)	<0.001	8.9 (7.8-10.1)	<0.001
Upper tertile	2547 (29.6)	14.4 (12.9-16.0)		13.2 (11.6-14.8)		5.5 (4.6-6.5)	
Negative support							
Lower tertile	3107 (36.1)	16.5 (14.9-18.0)		25.4 (23.7-27.2)		8.5 (7.3-9.7)	
Middle tertile	3065 (35.5)	19.2 (17.6-20.9)	<0.001	14.5 (13.0-16.0)	<0.001	8.1 (7.0-9.2)	0.194
Upper tertile	2445 (28.4)	21.3 (19.4-23.1)		11.4 (9.9-12.9)		9.8 (8.5-11.2)	

[1]Weighted for non-response at wave 3; [2]*p*-values calculated using logistic regression; [3]Wealth = household non-pension wealth; [4]Occupation: Managerial = managerial/professional, Routine = routine/manual, Other = never worked/unemployed/other; [5]Education: level as specified and equivalent

6.2.5 Associations between socioeconomic position and social relationships at waves 2 and 3

This section assessed whether social relationships were socially patterned (objective 3), using imputed data. Bivariate associations were tested using logistic regression between socioeconomic position and social relationship measures. Socioeconomic position was associated with all measures of social relationships at waves 2 and 3 (Table 6.10 and 6.11). Overall, participants reporting poorer social relationships were more disadvantaged.

Household non-pension wealth

Generally, at wave 2, the steepest social gradients for loneliness, social isolation, and positive social support were seen when the socioeconomic position was measured by wealth. There was a stepwise increase in the prevalence of less favourable social relationship experiences with each lower socioeconomic level for loneliness, social isolation, and positive social support. However, the opposite was seen for the association between socioeconomic position and negative social support – the prevalence of negative support was lower among the least advantaged groups (Table 6.10).

Table 6.11 shows a similar social patterning of social relationships at wave 3 to that seen at wave 2.

Occupational class

At wave 2, the prevalence of feeling lonely, being in the highest tertile of social isolation and lowest tertile of positive social support was higher among those who were more disadvantaged. The prevalence of the highest level of negative social support was the lowest for those who were more disadvantaged (Table 6.10).

At wave 3, a similar social patterning of social relationships was observed. However, the gradients were slightly less steep than those at wave 2 (Table 6.11).

Educational level

Overall, the prevalence of less favourable social relationships increased with decreasing educational level at wave 2 (Table 6.10). The steepest education gradients were seen for loneliness and social isolation. The prevalence of negative social support at wave 2 was lowest among those with the lowest level of education, however, the gradient was less steep than that seen for loneliness, social isolation, and positive support.

Similar associations were observed at wave 3 (Table 6.11).

6.2.6 Associations between age, sex, and social relationships at waves 2 and 3

At waves 2 and 3, relatively steep gradients were seen in social relationships by age – a stepwise increase in the prevalence of reporting loneliness, social isolation, and less favourable positive social support with increasing age. With one exception: negative social support was less frequently reported at older ages (Table 6.10 and 6.11).

At wave 2, being lonely was more prevalent among females (23.9%) than males (17%). However, the prevalence of negative social support was higher for males (29.6%) than females (26.1%). Positive social support and social isolation were not significantly associated with sex (Table 6.10).

Similar associations were observed at wave 3. With one exception: unlike wave 2, social isolation was significantly associated with sex at wave 3. Moreover, social isolation was more prevalent among males (Table 6.11).

Table 6.10 Distribution of social relationship measures by socioeconomic position, age, and sex among participants at wave 2 (imputed data) (*n* = 8681)

Variables	Loneliness	Social isolation	Positive support	Negative support
	Lonely (*n* = 1326)	Upper tertile (*n* = 1831)	Lower tertile (*n* = 2513)	Upper tertile (*n* = 1820)
	% (95%CI)[1,2]	% (95%CI)[1,2]	% (95%CI)[1,2]	% (95%CI)[1,2]
Wealth[3]				
Wealthiest	11.9 (10.2-13.6)	16.2 (14.3-18.2)	25.5 (23.2-27.7)	30.5 (28.1-32.9)
4th quintile	15.4 (13.6-17.3)	20.4 (18.2-22.6)	31.9 (29.4-34.3)	30.1 (27.7-32.4)
3rd quintile	18.2 (16.2-20.3)	24.5 (22.1-27.0)	35.4 (32.9-38.0)	28.1 (25.6-30.5)
2nd quintile	24.4 (22.1-26.7)	34.3 (31.6-36.9)	43.0 (40.2-45.9)	26.9 (24.4-29.3)
Least wealthy	33.8 (30.9-36.7)	50.3 (47.3-53.4)	59.2 (56.2-62.2)	22.8 (20.3-25.3)
Occupation				
Managerial/professional	13.6 (12.2-15.0)	20.7 (18.9-22.4)	33.9 (31.9-35.9)	28.3 (26.4-30.1)
Intermediate occupations	20.1 (18.2-22.0)	26.6 (24.3-28.8)	36.7 (34.4-39.0)	27.8 (25.6-29.9)
Routine/manual occupations	24.8 (23.2-26.4)	34.7 (32.9-36.5)	42.5 (40.6-44.5)	27.9 (26.3-29.5)
Other[4]	32.5 (22.7-42.3)	45.6 (35.2-56.0)	51.9 (42.2-61.6)	14.2 (7.5-21.0)
Education[5]				
>A level	14.2 (12.5-15.8)	17.8 (16.0-20.0)	33.4 (31.2-35.6)	30.2 (28.1-32.4)
O level-A level	18.5 (16.8-20.3)	26.0 (23.8-28.1)	36.3 (34.0-38.5)	30.4 (28.2-32.6)
<O level	24.3 (22.8-25.7)	34.9 (33.2-36.6)	42.2 (40.5-44.0)	25.5 (24.1-27.0)
Age				
50-59 years	19.0 (17.3-20.7)	25.3 (23.4-27.3)	33.5 (31.4-35.6)	37.5 (35.4-39.6)
60-69 years	17.9 (16.2-19.5)	24.2 (22.4-26.1)	34.4 (32.3-36.4)	30.1 (28.2-32.0)
70-79 years	20.5 (18.6-22.5)	29.3 (26.9-31.6)	41.0 (38.6-43.5)	20.6 (18.6-22.6)
≥80 years	31.6 (28.1-35.0)	48.3 (44.6-52.1)	58.1 (54.6-61.5)	11.9 (9.5-14.2)
Sex				
Male	17.0 (15.5-18.4)	30.9 (28.4-31.7)[NS]	37.5 (35.8-39.2)[NS]	29.6 (28.0-31.1)
Female	23.9 (15.5-18.4)	28.2 (26.7-29.7)	40.1 (38.6-41.7)	26.1 (24.7-27.4)

[1]Weighted for non-response at wave 2; [2]Associations between social relationships and explanatory markers significant at $p<0.05$, *p*-values calculated using logistic regression; NS = non-significant; [3]Household non-pension wealth; [4]Other = never worked/unemployed/other; [5]Educational levels are those specified or equivalent in level

Table 6.11 Distribution of social relationship measures by socioeconomic position, age, and sex among participants at wave 3 (imputed data) (*n* = 8617)

Variables	Loneliness	Social isolation	Positive support	Negative support
	Lonely (*n* = 1972)	Upper tertile (*n* = 2517)	Lower tertile (*n* = 3189)	Upper tertile (*n* = 2445)
	% (95%CI)[1,2]	% (95%CI)[1,2]	% (95%CI)[1,2]	% (95%CI)[1,2]
Wealth[3]				
Wealthiest	13.9 (12.0-15.7)	14.6 (12.8-16.4)	25.4 (23.2-27.7)	29.4 (26.9-31.8)
4th quintile	16.8 (14.8-18.7)	21.3 (19.0-23.7)	28.4 (26.0-30.8)	30.0 (27.4-32.5)
3rd quintile	21.8 (19.5-24.1)	26.9 (24.5-29.3)	33.5 (30.8-36.1)	29.6 (27.1-32.1)
2nd quintile	26.2 (23.8-28.6)	35.8 (32.9-38.6)	42.6 (39.8-45.3)	29.4 (26.9-32.0)
Least wealthy	36.1 (33.3-38.8)	51.0 (47.9-54.0)	55.6 (52.5-58.7)	23.3 (20.7-25.9)
Occupation				
Managerial/professional	18.5 (17.0-20.1)	21.1 (19.4-22.8)	34.1 (32.2-36.1)	28.8 (26.9-30.7)
Intermediate occupations	21.0 (19.1-22.9)	27.9 (25.7-30.0)	35.1 (32.8-37.3)	29.1 (26.9-31.2)
Routine/manual occupations	26.4 (24.7-28.0)	36.1 (34.2-38.1)	39.3 (37.4-41.2)	28.2 (26.5-30.0)
Other[4]	32.1 (22.5-41.7)	41.2 (30.2-52.3)	53.5 (42.9-64.1)	15.9 (8.9-23.0)
Education[5]				
>A level	18.3 (16.7-20.0)	20.0 (18.3-21.8)	33.5 (31.5-35.5)	32.1 (30.2-34.1)
O level-A level	21.5 (19.6-23.4)	27.4 (25.3-29.6)	35.5 (33.3-37.7)	28.8 (26.6-30.9)
<O level	26.6 (24.9-28.3)	37.5 (35.6-39.5)	40.1 (38.2-42.0)	25.7 (24.0-27.4)
Age				
50-59 years	22.6 (20.9-24.3)	27.0 (25.1-28.8)	33.4 (31.5-35.4)	36.6 (34.6-38.)
60-69 years	21.0 (19.2-22.8)	26.2 (24.2-28.1)	32.4 (30.3-34.4)	30.9 (28.8-32.9)
70-79 years	21.3 (19.3-23.4)	30.6 (28.1-33.1)	38.4 (35.9-40.9)	20.5 (18.4-22.5)
≥80 years	31.1 (27.8-34.5)	45.7 (41.9-49.5)	56.2 (52.5-59.8)	12.3 (9.9-14.7)
Sex				
Male	19.4 (17.9-20.8)	30.9 (29.2-32.6)	36.8 (35.1-38.5)[NS]	30.2 (28.5-31.8)
Female	26.0 (24.6-27.4)	28.9 (27.3-30.5)	37.2 (35.7-38.7)	26.8 (25.4-28.2)

[1]Weighted for non-response at wave 3; [2]Associations between social relationships and explanatory markers significant at $p<0.05$, *p*-values calculated using logistic regression; NS = non-significant; [3]Household non-pension wealth; [4]Other = never worked/unemployed/other; [5]Educational levels are those specified or equivalent in level

6.3 Associations between socioeconomic position, social relationships, and health at wave 2 – results from logistic and linear regression analyses

Imputed data were used to assess cross-sectionally the extent to which loneliness, social isolation, positive and negative social support attenuate socioeconomic inequalities in SRH (n = 8681) and blood pressure (n = 6639) (Objective 4). Firstly, Model 1 estimated crude associations between socioeconomic position and outcomes before sequentially adjusting for sex and age (Model 2). Thereafter, all social relationship markers (loneliness, social isolation, positive and negative social support) were adjusted for separately (Models 3a-3d). Finally, Model 4 was mutually adjusted for all social relationship markers.

6.3.1 Self-rated health

Table 6.12 presents the estimates for the logistic regression analysis of SRH – the variable is coded so that the model predicts poor SRH. Adjusting for loneliness and social isolation provided greater reductions of the magnitude of the SEP-SRH association. Adjusting for positive social support attenuated less than 10% of the SEP-SRH association (Model 3c). Generally, adjusting for negative social support did not meaningfully contribute to attenuating the SEP-SRH association (Model 3d).

Household non-pension wealth

Table 6.12 presents the estimates for the logistic regression analysis of SRH – the variable is coded so that the model predicts poor SRH. According to the crude model (Model 1), the least wealthy older adults were almost six times more likely (OR: 5.92; 95% CI 4.95-7.09) to report fair or poor self-rated health compared to those in the wealthiest quintile. After adjustment for age and sex (Model 2), the odds of reporting fair or poor self-rated health attenuated by 9.8% (OR: 5.43; 95% CI 4.53-6.51).

Adjusting for loneliness and social isolation attenuated the association between wealth and SRH more than positive and negative social support. When compared to the wealthiest participants, loneliness (Model 3a) attenuated the wealth-SRH association between 13.7% and 25.1%, and social isolation (Model 3b) attenuated this association between 11.7%

and 21.2%, respectively. Adjusting for negative social support (Model 3d) appeared to increase the magnitude of the association between 1.9% and 6.1%.

Occupational class

In the age- and sex-adjusted model (Model 2), those in routine and manual occupations were 2.39 (95% CI 2.11-2.70) times more likely to report fair or poor SRH compared to those in managerial or professional occupations. Individuals who had never worked or were unemployed were over three times more likely to report fair or poor SRH compared to those in managerial or professional occupations (OR 3.32; 95% CI 2.29-4.82).

Adjusting for loneliness attenuated the magnitude of the occupation-SRH association by 22% and 20.1% for those who have never worked or were unemployed and for those in routine and manual occupations, respectively (Model 3a). A similar attenuation of the occupation-SRH association was seen after adjusting for social isolation: 21.1% and 20.1% reduction in the magnitude of the effect estimate for those who have never worked or were unemployed and for those in routine or manual occupations, respectively (Model 3b).

Educational level

After adjustment for age and sex, those with lowest level of education were 2.66 (95% CI 2.31-3.06) times more likely to report fair or poor SRH compared to those with higher than A-level or equivalent education. Adjusting for loneliness and social isolation appeared to result in a greater reduction in the magnitude of the education-SRH association compared to the social support markers. Controlling for loneliness (Model 3a) attenuated the education-SRH association by 12.7% and 19.4% and controlling for and social isolation (Model 3b) attenuated this association by 21.1% and 27.8%.

Mutually adjusted model

In the fully adjusted model 4, adjusting for all social relationship measures together reduced the magnitude of the association between socioeconomic position and SRH by up to 32.5% in models by wealth, by up to 38.1% in models by occupation, and by up to 36.1% in models by education.

In both independently and mutually adjusted models, wealth, occupation, and education were persistent predictors of fair to poor SRH independent of social relationship measures.

Table 6.12 Logistic regression models predicting fair/poor SRH among participants at wave 2 (imputed data) (n = 8681)

Models	Non-pension wealth (reference category: 5th quintile[1]) OR (95% CI)		Occupation (reference category: managerial/professional) OR (95% CI)		Education (reference category: higher than A-level) OR (95% CI)	
Model 1						
Crude association	4th quintile	1.54 (1.27-1.86)***	Intermediate	1.43 (1.25-1.65)***	O-level to A-level or equivalent	1.33 (1.13-1.56)**
	3rd quintile	1.92 (1.59-2.31)***	Routine/Manual	2.46 (2.18-2.77)***		
	2nd quintile	3.59 (3.00-4.29)***	Never worked/unemployed	4.05 (2.83-5.79)***	Less than O-level or equivalent	2.89 (2.52-3.31)***
	Least wealthy	5.92 (4.95-7.09)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.51 (1.25-1.83)***	Intermediate	1.42 (1.23-1.64)***	O-level to A-level or equivalent	1.36 (1.15-1.59)***
	3rd quintile	1.85 (1.53-2.22)***	Routine/Manual	2.39 (2.11-2.70)***		
	2nd quintile	3.46 (2.90-4.14)***	Never worked/unemployed	3.32 (2.29-4.82)***	Less than O-level or equivalent	2.66 (2.31-3.06)***
	Least wealthy	5.43 (4.53-6.51)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.44 (1.19-1.74)***	Intermediate	1.33 (1.15-1.54)***	O-level to A-level or equivalent	1.29 (1.10-1.53)**
	3rd quintile	1.70 (1.41-2.04)***	Routine/Manual	2.11 (1.86-2.39)***		
	2nd quintile	3.00 (2.51-3.59)***	Never worked/unemployed	2.81 (1.89-4.19)***	Less than O-level or equivalent	2.45 (2.12-2.83)***
	Least wealthy	4.32 (3.59-5.19)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.45 (1.20-1.76)***	Intermediate	1.34 (1.16-1.55)***	O-level to A-level or equivalent	1.26 (1.07-1.48)**
	3rd quintile	1.72 (1.43-2.08)***	Routine/Manual	2.11 (1.86-2.39)***		
	2nd quintile	3.09 (2.58-3.70)***	Never worked/unemployed	2.83 (1.93-4.15)***	Less than O-level or equivalent	2.31 (2.01-2.67)***
	Least wealthy	4.49 (3.73-5.41)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.49 (1.24-1.81)***	Intermediate	1.40 (1.22-1.62)***	O-level to A-level or equivalent	1.33 (1.13-1.57)**
	3rd quintile	1.81 (1.50-2.18)***	Routine/Manual	2.32 (2.05-2.62)***		
	2nd quintile	3.34 (2.79-4.00)***	Never worked/unemployed	3.16 (2.18-4.59)***	Less than O-level or equivalent	2.62 (2.27-3.01)***
	Least wealthy	5.04 (4.19-6.07)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.52 (1.26-1.84)***	Intermediate	1.42 (1.23-1.64)***	O-level to A-level or equivalent	1.36 (1.16-1.60)***
	3rd quintile	1.88 (1.56-2.26)***	Routine/Manual	2.39 (2.11-2.70)***		
	2nd quintile	3.54 (2.96-4.24)***	Never worked/unemployed	3.39 (2.33-4.92)***	Less than O-level or equivalent	2.67 (2.32-3.08)***
	Least wealthy	5.72 (4.76-6.87)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.41 (1.16-1.71)***	Intermediate	1.26 (1.09-1.47)**	O-level to A-level or equivalent	1.23 (1.04-1.45)*
	3rd quintile	1.63 (1.35-1.97)***	Routine/Manual	1.90 (1.67-2.16)***		
	2nd quintile	2.81 (2.34-3.37)***	Never worked/unemployed	2.54 (1.68-3.84)***	Less than O-level or equivalent	2.18 (1.88-2.53)***
	Least wealthy	3.99 (3.31-4.82)***				

OR (95% CI) weighted for non-response at wave 2; [1]5th quintile = wealthiest; NS = non-significant; *p <0.05; **p <0.01; ***p <0.001

6.3.2 Blood pressure

Systolic blood pressure

Linear regression models predicting systolic blood pressure (SBP) – measured on a continuous scale – in Table 6.13 show significant associations between socioeconomic position (SEP) and systolic blood pressure by wealth, occupation, and education. Social isolation appeared to offer the greatest reduction in the magnitude of the SEP-SBP association across all models. Adjusting for loneliness increased the strength of the association between wealth and systolic blood pressure across all models. Additionally, adjusting for negative social support did not meaningfully contribute to reducing the magnitude of the SEP-SBP association in any model.

Household non-pension wealth

Systolic blood pressure was higher among least wealthy persons compared to their most affluent peers (B: 4.94; 95% CI 3.26-6.63). This association remained significant but was attenuated after subsequent adjustment for age and sex (B: 2.72; 95% 1.05-4.39).

Models 3a to 3d show separate adjustment by social relationship measures. Adjusting for social isolation (Model 3b) and positive social support (Model 3c) reduced the magnitude of the wealth-SBP when comparing the least wealthy to the wealthiest group (B: 2.40; 95% CI 0.64-4.16; B: 2.36; 95% CI 0.64-4.08, respectively).

Occupational class

In Model 2 by occupation, respondents' systolic blood pressure was on average higher for those in manual or routine occupations than those in managerial or professional occupations (B: 2.44 95% CI 1.33-3.55). However, unlike the models by wealth, adjusting for social relationship measures attenuated a smaller proportion of the occupation-SBP association. After adjusting for social isolation (Model 3b), the coefficient for systolic blood pressure was reduced by 0.18 (B: 2.26; 95% CI 1.13-3.40). In Model 3c, adjusting for positive social support reduced the coefficient for systolic blood pressure by 0.09 (B: 2.35; 95% CI 1.23-3.46).

There was no difference in the coefficients for systolic blood pressure between those who never worked or were unemployed and those who were in managerial or professional occupations.

Educational level

In Model 2, respondents with less than O-level or equivalent qualifications had higher systolic blood pressure than those with higher than A-level or equivalent qualifications (B: 2.60; 95% CI 1.41-3.80). Adjusting for social isolation (Model 3b) reduced systolic blood pressure coefficient by 0.19 among the least educated (B: 2.41; 95% CI 1.20-3.63). Unlike the previous models by wealth and occupation, adjusting for positive social support did not meaningfully contribute to attenuating the education-systolic blood pressure association.

Mutually adjusted model

Finally, full adjustment by all social relationship measures generally provided little attenuation of coefficients in systolic blood pressure in models by occupation and education. With one exception: fully adjusting (Model 4) for all social relationship measures reduced the coefficient for systolic blood pressure by 0.13 (B: 2.59; 95% CI 0.80-4.38) for the least wealthy compared to the wealthiest individuals.

Diastolic blood pressure

Overall, linear regression models predicting high diastolic blood pressure did not show significant social gradients before (Table 6.14) and after adjustment for social relationship measures.

Table 6.13 Linear regression models predicting systolic blood pressure among participants at wave 2 (imputed data) (*n* = 6639)

Models	Non-pension wealth (reference category: 5th quintile[1]) B (95% CI)[2]		Occupation (reference category: managerial/professional) B (95% CI)[2]		Education (reference category: higher than A-level) B (95% CI)[2]	
Model 1						
Crude association	4th quintile	2.08 (0.58-3.58)**	Intermediate	2.09 (0.79-3.39)**	O-level to A-level or equivalent	1.10 (-0.18-2.38)^{NS}
	3rd quintile	3.23 (1.63-4.83)***	Routine/Manual	3.22 (2.08-4.36)***		
	2nd quintile	3.52 (1.99-5.05)***	Never worked/unemployed	3.85 (-1.14-8.85)^{NS}	Less than O-level or equivalent	4.71 (3.53-5.89)***
	Least wealthy	4.94 (3.26-6.63)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.58 (0.11-3.04)*	Intermediate	1.87 (0.59-3.15)**	O-level to A-level or equivalent	1.42 (0.17-2.67)*
	3rd quintile	2.45 (0.90-3.99)**	Routine/Manual	2.44 (1.33-3.55)***		
	2nd quintile	2.58 (1.08-4.09)**	Never worked/unemployed	0.04 (-4.97-5.05)^{NS}	Less than O-level or equivalent	2.60 (1.41-3.80)***
	Least wealthy	2.72 (1.05-4.39)**				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.61 (0.15-3.08)*	Intermediate	1.92 (0.64-3.20)**	O-level to A-level or equivalent	1.45 (0.20-2.70)*
	3rd quintile	2.52 (0.96-4.07)**	Routine/Manual	2.54 (1.42-3.67)***		
	2nd quintile	2.72 (1.19-4.25)***	Never worked/unemployed	0.20 (-4.82-5.23)^{NS}	Less than O-level or equivalent	2.67 (1.47-3.88)***
	Least wealthy	2.96 (1.24-4.69)**				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.51 (0.05-2.98)*	Intermediate	1.79 (0.51-3.07)**	O-level to A-level or equivalent	1.32 (0.07-2.57)*
	3rd quintile	2.34 (0.78-3.89)**	Routine/Manual	2.26 (1.13-3.40)***		
	2nd quintile	2.39 (0.86-3.92)**	Never worked/unemployed	-0.20 (-5.18-4.79)^{NS}	Less than O-level or equivalent	2.41 (1.20-3.63)***
	Least wealthy	2.40 (0.64-4.16)**				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.54 (0.07-3.00)*	Intermediate	1.83 (0.56-3.11)**	O-level to A-level or equivalent	1.37 (0.12-2.62)*
	3rd quintile	2.36 (0.81-3.91)**	Routine/Manual	2.35 (1.23-3.46)***		
	2nd quintile	2.42 (0.91-3.94)**	Never worked/unemployed	-0.11 (-5.10-4.87)^{NS}	Less than O-level or equivalent	2.55 (1.35-3.74)***
	Least wealthy	2.36 (0.64-4.08)**				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.57 (0.10-3.03)*	Intermediate	1.88 (0.60-3.16)**	O-level to A-level or equivalent	1.41 (0.16-2.66)*
	3rd quintile	2.43 (0.88-3.97)**	Routine/Manual	2.44 (1.33-3.55)***		
	2nd quintile	2.56 (1.06-4.07)**	Never worked/unemployed	0.02 (-4.98-5.02)^{NS}	Less than O-level or equivalent	2.60 (1.40-3.80)***
	Least wealthy	2.66 (0.98-4.34)**				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.58 (0.11-3.05)*	Intermediate	1.91 (0.63-3.19)**	O-level to A-level or equivalent	1.42 (0.16-2.67)*
	3rd quintile	2.44 (0.88-4.00)**	Routine/Manual	2.49 (1.34-3.64)***		
	2nd quintile	2.57 (1.03-4.12)**	Never worked/unemployed	0.14 (-4.86-5.14)^{NS}	Less than O-level or equivalent	2.68 (1.44-3.92)***
	Least wealthy	2.59 (0.80-4.38)**				

B (95% CI) weighted for non-response at wave 2; [1]5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Unstandardised beta coefficients; NS = non-significant; *$p \leq 0.05$; **$p < 0.01$; ***$p < 0.00$

Table 6.14 Linear regression models predicting high diastolic blood pressure among participants at wave 2 (imputed data) (*n* = 6639)

Models	Non-pension wealth (reference category: 5th quintile[1]) B (95% CI)[2]		Occupation (reference category: managerial/professional) B (95% CI)[2]		Education (reference category: higher than A-level) B (95% CI)[2]	
Model 1						
Crude association	4th quintile	-0.15 (-1.06, 0.77)	Intermediate	0.20 (-0.58, 0.98)	O-level to A-level or equivalent	0.24 (-0.55, 1.03)
	3rd quintile	-0.18 (-1.11, 0.76)	Routine/manual	-0.27 (-0.97, 0.43)		
	2nd quintile	-0.16 (-1.12, 0.80)	Never worked/unemployed	**-3.38 (-6.36, -0.40)***	Less than O-level or equivalent	**-1.41 (-2.12, -0.69)*****
	Least wealthy	-0.57 (-1.64, 0.49)				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	0.18 (-0.70, 1.07)	Intermediate	**0.79 (0.02-1.55)***	O-level to A-level or equivalent	0.31 (-0.46, 1.09)
	3rd quintile	0.40 (-0.51, 1.31)	Routine/manual	0.49 (-0.20, 1.17)		
	2nd quintile	0.53 (-0.37, 1.42)	Never worked/unemployed	0.04 (-2.79, 2.88)	Less than O-level or equivalent	0.39 (-0.33, 1.12)
	Least wealthy	1.03 (-0.001, 2.06)				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	0.19 (-0.70, 1.07)	Intermediate	**0.78 (0.02-1.55)***	O-level to A-level or equivalent	0.31 (-0.47, 1.09)
	3rd quintile	0.41 (-0.51, 1.32)	Routine/manual	0.49 (-0.21, 1.18)		
	2nd quintile	0.55 (-0.36, 1.45)	Never worked/unemployed	0.04 (-2.79, 2.87)	Less than O-level or equivalent	0.39 (-0.34, 1.12)
	Least wealthy	1.06 (-0.001, 2.12)				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	0.15 (-0.74, 1.04)	Intermediate	0.74 (-0.03, 1.50)	O-level to A-level or equivalent	0.25 (-0.53, 1.03)
	3rd quintile	0.35 (-0.57, 1.26)	Routine/manual	0.38 (-0.31, 1.08)		
	2nd quintile	0.44 (-0.48, 1.35)	Never worked/unemployed	-0.09 (-2.90, 2.72)	Less than O-level or equivalent	0.28 (-0.46, 1.02)
	Least wealthy	0.87 (-0.21, 1.95)				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	0.15 (-0.73, 1.04)	Intermediate	0.76 (-0.01, 1.52)	O-level to A-level or equivalent	0.28 (-0.50, 1.05)
	3rd quintile	0.34 (-0.57,1.25)	Routine/manual	0.42 (-0.27, 1.10)		
	2nd quintile	0.41 (-0.49, 1.31)	Never worked/unemployed	-0.09 (-2.89, 2.74)	Less than O-level or equivalent	0.35 (-0.37, 1.08)
	Least wealthy	0.75 (-0.30, 1.80)				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	0.19 (-0.70, 1.07)	Intermediate	**0.79 (0.02-1.55)***	O-level to A-level or equivalent	0.31 (-0.46, 1.09)
	3rd quintile	0.40 (-0.51, 1.31)	Routine/manual	0.49 (-0.20, 1.17)		
	2nd quintile	0.53 (-0.36, 1.43)	Never worked/unemployed	0.04 (-2.79, 2.88)	Less than O-level or equivalent	0.39 (-0.33, 1.12)
	Least wealthy	**1.04 (0.00-2.07)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	0.18 (-0.70, 1.07)	Intermediate	0.75 (-0.02, 1.53)	O-level to A-level or equivalent	0.30 (-0.48,1.08)
	3rd quintile	0.39 (-0.53, 1.31)	Routine/manual	0.40 (-0.31, 1.11)		
	2nd quintile	0.50 (-0.43, 1.42)	Never worked/unemployed	-0.07 (-2.87, 2.74)	Less than O-level or equivalent	0.41 (-0.34,1.17)
	Least wealthy	0.89 (-0.30, 1.99)				

B (95% CI) weighted for non-response at wave 2; [1]5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Unstandardised beta coefficients; NS = non-significant; *p ≤0.05; **p <0.01; ***p <0.001

6.4 Associations between socioeconomic position, social relationships, and oral health at wave 3 – results from logistic regression analyses

Imputed data were used to explore the extent to which social relationships attenuated socioeconomic inequalities in oral health. After exploring crude associations between socioeconomic position and outcomes, models were adjusted for sex and age. Thereafter, Models 3a to 3d were adjusted separately for loneliness, social isolation, positive social support, and negative social support. Finally, Model 4 was mutually adjusted for all social relationship markers.

6.4.1 Self-rated oral health

Table 6.15 reports estimates from cross-sectional models of SROH – the variable is coded so that the models predict poor SROH. Adjusting for loneliness (Model 3a) and social isolation (Model 3b) resulted in the greatest attenuation in associations between socioeconomic position and oral health outcomes. Across all models, adjusting for sex and age appeared to increase the odds of experiencing poor SROH when compared to the crude models. This suggests that the crude estimates were underestimating the true SEP-SROH association, i.e., that the crude estimates were negatively confounded. Furthermore, across all models, negative social support did not meaningfully contribute to attenuating the social gradients in SROH.

Household non-pension wealth

Results from the sex- and age-adjusted model (Model 2) by wealth show that those in the least wealthy quintile were 2.69 (95% CI 2.22-3.24) times more likely to report poorer SROH than those in the wealthiest quintile. Adjusting for loneliness and social isolation attenuated the wealth-SROH association between 20% and 25.4%, and between 25.6% and 29.6%, respectively (Models 3a and 3b). Of the social support measures, adjusting for positive social support reduced the magnitude of the wealth-SROH association between 9.4% and 22.5% (Model 3c).

There was no difference in the odds of experiencing poor SROH between those in the 4th quintile of wealth and wealthiest individuals.

Occupational class

Older adults in routine or manual jobs were 1.50 (95% CI 1.31-1.72) times more likely to report fair to poor SROH compared to their more advantaged peers (Model 2). Those who were unemployed or never worked were 1.94 (1.19-3.14) more likely to experience poor SROH compared to those in managerial or professional occupations. As seen in models by wealth, adjusting for loneliness and social isolation appeared to provide the greatest reductions in the magnitude of the occupation-SROH association. For those in routine and manual occupations, loneliness attenuated the odds of experiencing poor SROH by 22% (Model 3a), and social isolation attenuated this association by 34% (Model 3b). For those who never worked or were unemployed, loneliness and social isolation attenuated the occupation-SROH association by 24.5% and 20.2%, respectively. Positive social support was less influential, reducing the magnitude of the association by 8% for those in routine and manual occupations and by 12.8% for those who had never worked or were unemployed (Model 3c).

There was no difference in the odds of experiencing poor SROH between those in intermediate occupations and managerial and professional occupations.

Educational level

Respondents with less than O-level or equivalent education were 1.59 (95% CI 1.37-1.85) times more likely to report having fair to poor SROH compared to those with higher than A-level qualifications (Model 2: sex- and age-adjusted). For those with less than O-level or equivalent qualifications, adjusting for loneliness attenuated 16.9% of the SROH-education association (Model 3b) and social isolation attenuated 33.9% of the education-SROH association (Model 3c). Adjusting for positive social support contributed a 5.1% reduction in the magnitude of the education-SROH association.

There was no difference in the odds of experiencing poor SROH between those with O-level to A-level qualifications and those with higher than A-level qualifications.

Mutually adjusted model

Mutual adjustment (Model 4) by loneliness, social isolation and positive and negative social support showed a greater reduction in the magnitude of the SEP-SROH association. The SEP-SROH association was attenuated by up to 42.6% in Model 4 by wealth, up to 42% in Model 4 by occupation, and up to 37.3% in Model 4 by education.

Table 6.15 Logistic regression models predicting fair/poor SROH among participants at wave 3 (imputed data) (*n* = 8617)

Models	Non-pension wealth (reference category: 5th quintile[1]) OR (95% CI)		Occupation (reference category: managerial/professional) OR (95% CI)		Education (reference category: higher than A-level) OR (95% CI)	
Model 1						
Crude association	4th quintile	1.18 (0.96-1.44)^{NS}	Intermediate	1.06 (0.91-1.25)^{NS}	O-level to A-level or equivalent	1.14 (0.97-1.33)^{NS}
	3rd quintile	1.28 (1.05-1.56)*	Routine/Manual	1.43 (1.25-1.64)***		
	2nd quintile	1.83 (1.52-2.22)***	Never worked/unemployed	1.59 (0.98-2.57)^{NS}	Less than O-level or equivalent	1.39 (1.21-1.59)***
	Least wealthy	2.51 (2.08-3.03)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.20 (0.98-1.47)^{NS}	Intermediate	1.12 (0.96-1.32)^{NS}	O-level to A-level or equivalent	1.19 (1.01-1.39)*
	3rd quintile	1.32 (1.09-1.61)**	Routine/Manual	1.50 (1.31-1.72)***		
	2nd quintile	1.90 (1.57-2.29)***	Never worked/unemployed	1.94 (1.19-3.14)**	Less than O-level or equivalent	1.59 (1.37-1.85)***
	Least wealthy	2.69 (2.22-3.24)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.18 (0.96-1.46)^{NS}	Intermediate	1.09 (0.93-1.29)^{NS}	O-level to A-level or equivalent	1.16 (0.99-1.36)^{NS}
	3rd quintile	1.24 (1.02-1.51)*	Routine/Manual	1.39 (1.21-1.60)***		
	2nd quintile	1.72 (1.42-2.09)***	Never worked/unemployed	1.71 (1.05-2.78)*	Less than O-level or equivalent	1.49 (1.28-1.73)***
	Least wealthy	2.26 (1.86-2.75)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.15 (0.93-1.41)^{NS}	Intermediate	1.05 (0.90-1.24)^{NS}	O-level to A-level or equivalent	1.10 (0.94-1.29)^{NS}
	3rd quintile	1.23 (1.01-1.50)*	Routine/Manual	1.33 (1.16-1.54)***		
	2nd quintile	1.67 (1.37-2.02)***	Never worked/unemployed	1.75 (1.09-2.82)*	Less than O-level or equivalent	1.39 (1.19-1.62)***
	Least wealthy	2.19 (1.79-2.68)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.18 (0.96-1.45)^{NS}	Intermediate	1.12 (0.95-1.32)^{NS}	O-level to A-level or equivalent	1.17 (0.99-1.37)^{NS}
	3rd quintile	1.29 (1.05-1.57)*	Routine/Manual	1.46 (1.27-1.68)***		
	2nd quintile	1.75 (1.44-2.12)***	Never worked/unemployed	1.82 (1.13-2.95)*	Less than O-level or equivalent	1.56 (1.34-1.81)***
	Least wealthy	2.31 (1.90-2.80)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.20 (0.98-1.47)^{NS}	Intermediate	1.12 (0.95-1.32)^{NS}	O-level to A-level or equivalent	1.19 (1.02-1.39)*
	3rd quintile	1.33 (1.09-1.62)**	Routine/Manual	1.50 (1.30-1.72)***		
	2nd quintile	1.91 (1.57-2.31)***	Never worked/unemployed	1.96 (1.21-3.18)**	Less than O-level or equivalent	1.59 (1.37-1.84)***
	Least wealthy	2.74 (2.27-3.32)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.13 (0.92-1.39)^{NS}	Intermediate	1.05 (0.88-1.24)^{NS}	O-level to A-level or equivalent	1.11 (0.94-1.30)^{NS}
	3rd quintile	1.19 (0.97-1.45)^{NS}	Routine/Manual	1.29 (1.12-1.50)**		
	2nd quintile	1.56 (1.28-1.90)***	Never worked/unemployed	1.67 (1.03-2.71)*	Less than O-level or equivalent	1.37 (1.18-1.61)***
	Least wealthy	1.97 (1.60-2.42)***				

OR (95% CI) weighted for non-response at wave 3; [1]5th quintile = wealthiest; NS = non-significant; *p <0.05; **p <0.01; ***p <0.001

6.4.2 Oral health-related quality of life

Table 6.16 show gradients for OHRQoL in all socioeconomic indicators, with the steepest gradients in wealth (OHRQoL variable is coded so that the model predicts at least one oral impact on daily performance). As with SROH, adjusting for loneliness and social isolation appeared to drive the attenuation of the SEP-OHRQoL association. Adjusting for positive social support appeared to be important in the models by wealth only. Negative social support did not meaningfully contribute to the OHRQoL-SEP relationship. Furthermore, adjusting for sex and age contributed little to the attenuation of the SEP-OHRQoL association (less than 10%).

Household non-pension wealth

In the sex- and age-adjusted model, the least wealthy participants were 2.71 (95% CI 2.07-3.54) times more likely to report poor OHRQoL than their most affluent peers. The greatest reduction in the magnitude of the wealth-OHRQoL association was seen when loneliness was adjusted for in Model 3a (up to 39.2%). Adjusting for social isolation attenuated this association by up to 17.5%, and adjusting for positive social support reduced the odds of experiencing poor OHRQoL by up to 22.2%.

Occupational class

In Model 2, those who never worked or were unemployed were almost three times more likely to experience at least one impact on daily performance in the past six months (OR: 2.78; 95% CI 1.62-4.76) compared to those in managerial or professional occupations. In addition, respondents in routine or manual jobs were 1.47 (95% CI 1.21-1.79) times more likely to report poor OHRQoL than their more advantaged peers.

As seen in models by wealth, adjusting for loneliness contributed to the greatest reduction in odds of experiencing poor OHRQoL (Model 3a): 34% for those in routine or manual occupations and 23.6% attenuation for those who never worked or were unemployed. In Model 3b, adjusting for social isolation attenuated the occupation-OHRQoL association by 23.4% (routine/manual occupations) and 10.1% (never worked/unemployed). Unlike the model by wealth, adjusting for positive social support contributed little in attenuating the occupation-OHRQoL association (less than 10%) (Model 3c).

Educational level

Those with less than O-level or equivalent education were 1.48 (95% CI 1.21-1.82) times more likely to experience poor OHRQoL than those with higher than A-level qualifications (Model 2). Attenuation of the education-OHRQoL association was mainly driven when adjusted for by loneliness (Model 3a) and social isolation (Model 3b): a reduction in the magnitude of the effect by 29.2% and 27.1%, respectively. Adjusting for positive social support contributed less than 10% to the education-OHRQoL association.

There was no difference in the odds of experiencing poor OHRQoL between those with O-level to A-level qualifications and those with higher than A-level qualifications.

Mutually adjusted model

Mutually adjusting for loneliness, social isolation and positive and negative social support resulted considerably reduced the magnitude of the SEP-OHRQoL (Model 4): by up to 42.1% in the model by wealth, 21.3% and 40.4% in the model by occupation and by 33.3% in the model by education. However, despite accounting for social relationship measures, whether through independent or mutual adjustment, socioeconomic position remained a strong predictor of OHRQoL.

Table 6.16 Logistic regression models predicting at least one daily impact among participants at wave 3 (imputed data) (*n* = 8617)

Models	Non-pension wealth (reference category: 5th quintile[1]) OR (95% CI)		Occupation (reference category: managerial/professional) OR (95% CI)		Education (reference category: higher than A-level) OR (95% CI)	
Model 1						
Crude association	4th quintile	1.49 (1.13-1.99)**	Intermediate	1.17 (0.94-1.46)NS	O-level to A-level or equivalent	1.16 (0.93-1.45)NS
	3rd quintile	1.42 (1.07-1.88)*	Routine/Manual	1.49 (1.23-1.81)***		
	2nd quintile	1.96 (1.49-2.57)***	Never worked/unemployed	2.95 (1.72-5.07)***	Less than O-level or equivalent	1.53 (1.27-1.85)***
	Least wealthy	2.77 (2.14-3.60)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.48 (1.12-1.97)**	Intermediate	1.16 (0.93-1.46)NS	O-level to A-level or equivalent	1.17 (0.93-1.46)NS
	3rd quintile	1.40 (1.06-1.86)*	Routine/Manual	1.47 (1.21-1.79)***		
	2nd quintile	1.94 (1.48-2.54)***	Never worked/unemployed	2.78 (1.62-4.76)***	Less than O-level or equivalent	1.48 (1.21-1.82)***
	Least wealthy	2.71 (2.07-3.54)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.43 (1.08-1.91)*	Intermediate	1.11 (0.88-1.40)NS	O-level to A-level or equivalent	1.12 (0.89-1.40)NS
	3rd quintile	1.25 (0.95-1.66)NS	Routine/Manual	1.31 (1.08-1.60)**		
	2nd quintile	1.65 (1.25-2.17)***	Never worked/unemployed	2.36 (1.33-4.14)**	Less than O-level or equivalent	1.34 (1.09-1.64)**
	Least wealthy	2.04 (1.55-2.69)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.44 (1.09-1.92)*	Intermediate	1.12 (0.89-1.40)NS	O-level to A-level or equivalent	1.11 (0.89-1.39)NS
	3rd quintile	1.34 (1.01-1.78)*	Routine/Manual	1.36 (1.11-1.66)**		
	2nd quintile	1.80 (1.36-2.37)***	Never worked/unemployed	2.60 (1.53-4.43)***	Less than O-level or equivalent	1.35 (1.10-1.67)**
	Least wealthy	2.41 (1.81-3.20)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.46 (1.10-1.94)**	Intermediate	1.16 (0.92-1.45)NS	O-level to A-level or equivalent	1.15 (0.92-1.43)NS
	3rd quintile	1.36 (1.03-1.80)*	Routine/Manual	1.43 (1.18-1.74)***		
	2nd quintile	1.79 (1.36-2.35)***	Never worked/unemployed	2.65 (1.55-4.56)***	Less than O-level or equivalent	1.45 (1.18-1.79)***
	Least wealthy	2.33 (1.77-3.07)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.48 (1.11-1.97)**	Intermediate	1.16 (0.92-1.45)NS	O-level to A-level or equivalent	1.17 (0.94-1.46)NS
	3rd quintile	1.41 (1.07-1.87)*	Routine/Manual	1.47 (1.21-1.78)***		
	2nd quintile	1.95 (1.49-2.56)***	Never worked/unemployed	2.83 (1.65-4.86)***	Less than O-level or equivalent	1.48 (1.21-1.82)***
	Least wealthy	2.79 (2.13-3.64)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.42 (1.07-1.89)*	Intermediate	1.10 (0.88-1.39)NS	O-level to A-level or equivalent	1.11 (0.88-1.39)NS
	3rd quintile	1.25 (0.94-1.67)NS	Routine/Manual	1.28 (1.05-1.58)*		
	2nd quintile	1.61 (1.22-2.14)**	Never worked/unemployed	2.40 (1.37-4.21)**	Less than O-level or equivalent	1.32 (1.06-1.63)*
	Least wealthy	1.99 (1.49-2.66)***				

OR (95% CI) weighted for non-response at wave 3; [1]5th quintile = wealthiest; NS = non-significant; **p* <0.05; ***p* <0.01; ****p* <0.001

6.4.3 Edentulousness

Of all the oral health outcomes, effect estimates for edentulousness were the greatest (edentulousness, is coded so that the models predict total tooth loss) (Table 6.17). Unlike previous models looking at SROH and OHRQoL, only adjusting for social isolation appeared to be driving the attenuation of the effect estimates. Adjusting for loneliness and positive and negative social support contributed less than 5% of the SEP-edentulousness association.

Household non-pension wealth

In the sex- and age-adjusted model, least wealthy older adults were eight times more likely to experience edentulousness compared to the wealthiest individuals (OR: 8.02; 95% CI 6.14-10.49). Furthermore, individuals in the second least wealthy group were almost six times more likely to experience edentulousness compared to the wealthiest group (OR: 5.93; 95% CI 4.52-7.78).

Adjusting for social isolation attenuated the odds of experiencing edentulousness between 8.7% and 16.8% (Model 3b).

Occupational class

In the sex- and age-adjusted model by occupation, individuals in manual and routine occupations were 3.19 (95% CI 2.70-3.78) times more likely to experience edentulousness compared to those in managerial or professional occupations. Those who were unemployed or had never worked were 3.27 (95% CI 2.03-5.27) times more likely experience edentulousness than those in managerial or professional occupations.

As seen in models by wealth, adjusting by social isolation was the main driver of reductions in the magnitude of the occupation-edentulousness association, attenuating the odds of experiencing total tooth loss by 13.7% (routine or manual occupations) and 9.3% (unemployed or never worked).

Educational level

Those with less than O-level or equivalent qualifications were 3.28 (95% CI 2.75-3.91) times more likely to experience total tooth loss than those with higher than A-level qualifications (Model 2). Adjusting for social isolation attenuated the association between education and edentulousness by 15.8%.

Mutually adjusted model

Mutual adjustment for loneliness, social isolation, and positive and negative social support measures resulted in a reduction in the magnitude of the SEP-edentulousness association across all models: by up to 17.8% in the model by wealth, up to 16.9% in the model by occupation and up to 18.9% in the model by education (Table 6.17, Model 4).

Table 6.17 Logistic regression models predicting total tooth loss among participants at wave 3 (imputed data) (*n* = 8617)

Models	Non-pension wealth (reference category: 5th quintile[1])	OR (95% CI)	Occupation (reference category: managerial/professional)	OR (95% CI)	Education (reference category: higher than A-level)	OR (95% CI)
Model 1						
Crude association	4th quintile	2.33 (1.74-3.12)***	Intermediate	1.69 (1.41-2.03)***	O-level to A-level or equivalent	1.53 (1.24-1.89)***
	3rd quintile	3.76 (2.87-4.94)***	Routine/manual	3.36 (2.86-3.94)***	Less than O-level or equivalent	5.08 (4.29-6.02)***
	2nd quintile	6.19 (4.75-8.07)***	Never worked/unemployed	7.05 (4.66-10.67)***		
	Least wealthy	9.88 (7.62-12.80)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	2.03 (1.51-2.72)***	Intermediate	1.51 (1.24-1.84)***	O-level to A-level or equivalent	1.52 (1.23-1.88)***
	3rd quintile	3.29 (2.50-4.34)***	Routine/manual	3.19 (2.70-3.78)***	Less than O-level or equivalent	3.28 (2.75-3.91)***
	2nd quintile	5.93 (4.52-7.78)***	Never worked/unemployed	3.27 (2.03-5.27)***		
	Least wealthy	8.02 (6.14-10.49)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	2.02 (1.50-2.71)***	Intermediate	1.50 (1.23-1.83)***	O-level to A-level or equivalent	1.51 (1.21-1.87)***
	3rd quintile	3.25 (2.46-4.29)***	Routine/manual	3.11 (2.62-3.68)***	Less than O-level or equivalent	3.19 (2.67-3.81)***
	2nd quintile	5.83 (4.44-7.66)***	Never worked/unemployed	3.14 (1.96-5.04)***		
	Least wealthy	7.78 (5.92-10.21)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.94 (1.44-2.61)***	Intermediate	1.44 (1.18-1.76)***	O-level to A-level or equivalent	1.43 (1.15-1.78)**
	3rd quintile	3.09 (2.34-4.08)***	Routine/Manual	2.89 (2.43-3.43)***	Less than O-level or equivalent	2.92 (2.43-3.49)***
	2nd quintile	5.34 (4.06-7.04)***	Never worked/unemployed	3.06 (1.90-4.891)***		
	Least wealthy	6.84 (5.20-8.99)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	2.02 (1.50-2.72)***	Intermediate	1.52 (1.24-1.85)***	O-level to A-level or equivalent	1.51 (1.22-1.87)***
	3rd quintile	3.28 (2.48-4.32)***	Routine/Manual	3.17 (2.68-3.75)***	Less than O-level or equivalent	3.26 (2.73-3.89)***
	2nd quintile	5.87 (4.46-7.71)***	Never worked/unemployed	3.23 (2.02-5.18)***		
	Least wealthy	7.87 (6.00-10.32)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	2.02 (1.50-2.72)***	Intermediate	1.51 (1.24-1.84)***	O-level to A-level or equivalent	1.51 (1.22-1.88)***
	3rd quintile	3.28 (2.49-4.32)***	Routine/Manual	3.20 (2.70-3.79)***	Less than O-level or equivalent	3.28 (2.75-3.92)***
	2nd quintile	5.91 (4.50-7.75)***	Never worked/unemployed	3.24 (2.02-5.21)***		
	Least wealthy	7.94 (6.08-10.38)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.91 (1.42-2.57)***	Intermediate	1.42 (1.16-1.74)**	O-level to A-level or equivalent	1.42 (1.14-1.76)**
	3rd quintile	3.03 (2.29-4.00)***	Routine/Manual	2.82 (2.37-3.35)***	Less than O-level or equivalent	2.85 (2.37-3.42)***
	2nd quintile	5.29 (4.01-6.97)***	Never worked/unemployed	2.97 (1.85-4.77)***		
	Least wealthy	6.77 (5.14-8.93)***				

OR (95% CI) weighted for non-response at wave 3; [1]5th quintile = wealthiest; NS = non-significant; **p* <0.05; ***p* <0.01; ****p* <0.001

6.5 Summary of cross-sectional results

The results from the cross-sectional analyses showed that there were associations between socioeconomic position and five of the six health outcomes: SRH, systolic blood pressure, SROH, OHRQoL, and edentulousness: clear social gradients exist in these health outcomes. Overall, persons in the lowest socioeconomic groups were more likely to present with poor SRH, SROH, and OHRQoL, higher systolic blood pressure, and edentulousness. The steepest gradients were seen when socioeconomic position was measured by household non-pension wealth.

Results also show associations between socioeconomic position and loneliness, social isolation, and positive and negative social support. Clear social gradients were evident for three of the four social relationship measures: loneliness, social isolation, and positive social support – increasing disadvantage was associated with less satisfactory social relationships. Bivariate analyses showed the steepest socioeconomic gradients in social relationships by household non-pension wealth. Although all measures of socioeconomic position were significantly associated with negative social support, the social gradient was less evident, moreover, increasing disadvantage was associated with lower levels of negative support.

After introducing loneliness, social isolation, and social support into the regression models, associations between socioeconomic position and all outcomes reduced, but mostly remained significant. Independently adjusting for loneliness and social isolation resulted in greater reductions in the associations between socioeconomic position and three of the five health outcomes: SRH, SROH, and OHRQoL. For edentulousness and systolic blood pressure, only adjusting for social isolation resulted in meaningful attenuation of the SEP-edentulousness association. Adjustment by positive support provided mixed results across the different health outcomes – it was most relevant for SROH and OHRQoL. Negative social support did not make a meaningful contribution to reducing the magnitude of the SEP-health associations.

Results from regression analyses suggest that social relationships contribute to socioeconomic differences in SRH, systolic blood pressure, SROH, OHRQoL, and edentulousness, supporting the hypothesis that social relationships might be on the pathway between socioeconomic position and health outcomes. Furthermore, overall, the percentage attenuation in these associations was largest when the socioeconomic position was measured by wealth, for which social gradients were steepest.

The results from the cross-sectional analyses informed the measures taken forward in longitudinal analyses – namely household non-pension wealth as the marker for socioeconomic position, along with the following outcomes: SRH, systolic blood pressure, SROH, OHRQoL, and edentulousness. In addition, the following social relationship measures will be taken forward for longitudinal mediation analyses: social isolation and loneliness.

Chapter 7. Results of longitudinal mediation analyses (SEM)

Chapter summary: This chapter focuses on the results from the longitudinal mediation analyses using SEM. Firstly, I present a summary of the reasoning behind the measures used to examine the mediating role of social relationships in explaining socioeconomic inequalities in health. Secondly, I outline the methodology implemented for SEM and the rationale behind the final model taken forward to examine associations longitudinally. Thirdly, I present descriptive results for the longitudinal samples used in this chapter before discussing results from the SEM analyses. Finally, I summarise the findings considering the evidence.

7.1 Introduction

The systematic review (Chapter 4) provided some evidence that social relationships may partly explain social gradients in health. However, most studies were cross-sectional in design, and few studies used structural equation modelling to assess whether social relationships mediate the association between socioeconomic position and health. Additionally, there was a paucity of evidence on oral health outcomes and the role of social relationships in mediating social gradients in health among older people in the UK.

The results obtained from cross-sectional analyses presented in Chapter 5 are compatible with the hypothesis that social relationships are on the pathway between socioeconomic position and health. The cross-sectional results suggested that of the social relationship measures tested, social isolation and loneliness were the main drivers of attenuating associations between wealth and health. Therefore, the scope of this chapter was to examine longitudinally the role that loneliness and social isolation play in mediating socioeconomic inequalities in the following outcomes: SRH, systolic blood pressure, SROH, OHRQoL and edentulousness (objective 5).

The main hypothesis for this chapter is as follows: that social relationships will at least partially explain social inequalities in health longitudinally such that social relationships will mediate associations between socio-economic position and general (SRH and systolic blood pressure) and oral health (SROH, OHRQoL and edentulousness).

7.2 Methods

7.2.1 The analytical sample

Two samples were drawn for longitudinal analyses. For general health outcomes (systolic blood pressure and self-rated health), the sample comprised 12,723 ELSA core cohort members that took part in any wave from 2 to 6. For the oral health outcomes (self-rated oral health, OHRQoL and edentulousness), the sample consisted of 11,692 cohort members that took part in any waves 3 to 7 (see Chapter 5, Section 5.6.2, for further details). As data is collected biennially in ELSA, there was a 2-year lag between each wave and the next.

7.2.2 Mediation analyses with continuous and binary outcomes

Figure 7.1 illustrates two simple mediation models. Model 1 shows mediation with a continuous outcome. Model 2 shows mediation with a binary outcome (*Y*) – Y^* denotes the continuous latent response variable underlying the binary outcome (*Y*), such that when Y^* falls below a particular threshold (τ) $Y = 0$ is observed, and when Y^* is above a threshold (τ) $Y = 1$ is observed (see also Figure 7.2) (Muthén, Muthén and Asparouhov, 2016).

In Model 1, the continuous outcome case, the coefficient for the *a* path is the effect of the exposure (*X*) on the mediator (*M*) and therefore, a change in *M* when *X* increases by one unit. The coefficient for the *b* path can therefore be understood as a change in *Y* when *M* increases by one unit. In Model 2, the binary outcome case, the coefficient for the *a* path is the same as in Model 1, however, the coefficient for the *b* path is a change in Y^* when *M* increases by 1 unit.

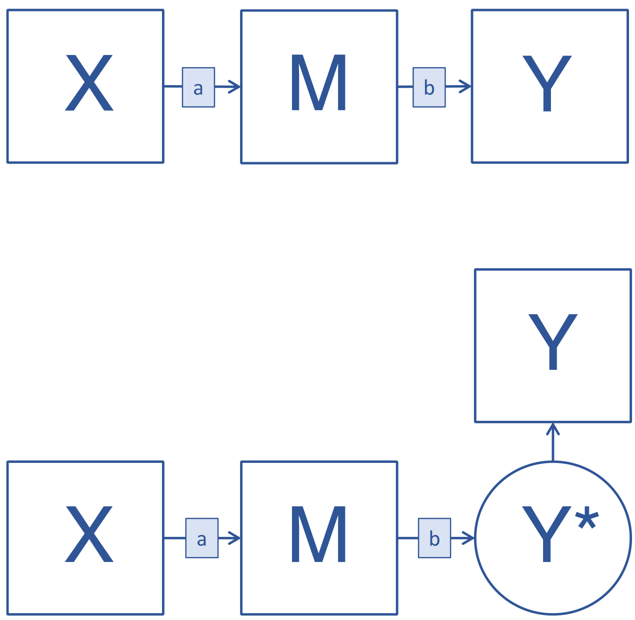

Figure 7.1 Indirect effect with a continuous and a binary outcome (adapted from Muthén, Muthén and Asparouhov, 2016)

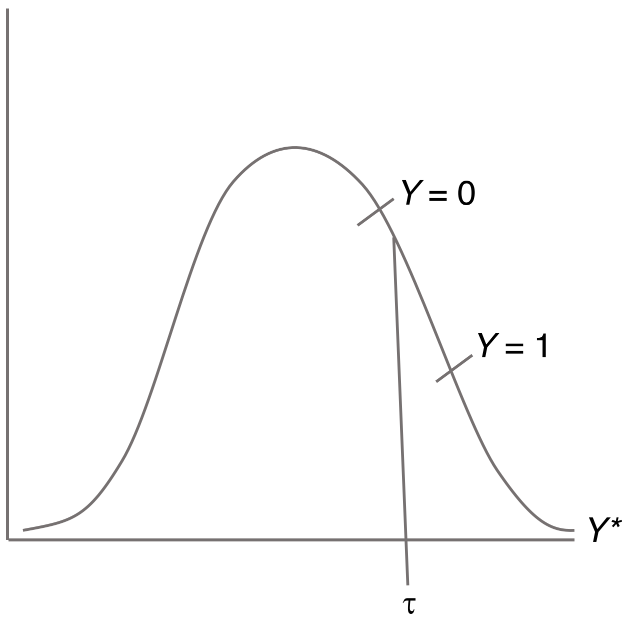

Figure 7.2 Y* formulation for logistic regression (adapted from Muthén, Muthén and Asparouhov, 2016)

Figure 7.2 shows that respondents with $Y = 1$ are not all the same, some are closer to τ and others are further from τ.

For the binary outcome case, a logistic function was chosen in Mplus by specifying LINK = LOGIT when using maximum likelihood estimation with robust standard errors (MLR). For direct effects involving binary outcomes, a higher value of X will impact the probability that $Y = 1$ (adapted from Muthén, Muthén and Asparouhov, 2016). In other words, an increase by one quintile of wealth will be associated with a lower probability of $Y = 1$, and in this case the beta coefficient will be negative. Since the logit function is the log odds as a linear function of X, Mplus will provide odds ratios (e^{log} odds) for the direct paths (Muthén, Muthén and Asparouhov, 2016). However, for the indirect effect involving binary outcomes, a linear regression is considered for the b path ($M \rightarrow Y^*$) and is not exponentiated in the Mplus output. Therefore, the magnitude of the association cannot be quantified for the indirect effects for all models with binary outcomes. As such, in line with common SEM reporting practice, and for purposes of consistency in reporting, beta coefficients with 95% confidence intervals and p-values are presented in the results tables, and the direction of the effect is discussed in the text throughout this chapter.

7.2.3 Estimation of models

Firstly, unadjusted cross-lagged SEM models were run (Tables A18.1-A.18.10 in Appendix 18, pg.). Following this, all models were adjusted for baseline age and sex. Throughout this chapter adjusted models are presented and unadjusted are provided in Appendix 18. The estimator used for SEM was MLR – this is robust to non-normality and missingness of the data; moreover, this characteristic of MLR meant that bootstrapping for standard errors and confidence intervals was not needed. MLR implements full information maximum likelihood (FIML) to account for missingness. In summary, FIML utilises all the available raw data for each respondent to obtain estimates and standard errors for the missing data (see Chapter 5, Section 5.7.3 for further details), and where cases have data missing on all variables, these are excluded from the analyses (between $n = 105$ and $n = 206$). Model fit indices such as the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI) or the Tucker Lewis Index (TLI) and modification indices were only available for systolic blood pressure. MLR with categorical or binary outcomes does not provide typical model fit indices as mentioned above, instead, it provides likelihood based on model fit information i.e., Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), Sample-size adjusted Bayesian Information Criterion (SABIC). Since models with binary outcomes were nested, it was appropriate to compare the model fit after removing non-significant paths using AIC, BIC, and SABIC.

Initially, all longitudinal mediating pathways were kept in the model as represented in Figure 7.3 (see Chapter 5, Section 5.7.3). Pathways for each outcome were estimated from wealth at time point 1 to health at time point 3 and time point 5 via loneliness and social isolation at time point 2 (a_1b_1 and a_2b_2); secondly, from wealth at time point 1 to health at time point 5 via loneliness and social isolation at time point 4 (a_3b_2); and finally, from wealth at time point 3 to health at time point 5 via loneliness and social isolation at time point 4 (a_1b_3). However, the indirect pathways a_1b_3 and a_3b_2 were not statistically significant for any of the examined outcomes. Therefore, these were removed through a stepwise backward elimination and a more parsimonious model was retained for each outcome. This resulted in the final model as illustrated in Figure 7.4. Results comparing the fit of nested models are presented in Appendix 19.

This chapter presents adjusted results based on the final model, i.e., the best fitting model, as represented by Figure 7.4. The following section describes the final model specification in more detail.

Standardised estimates are presented in the results tables and path diagrams for systolic blood pressure and unstandardised estimates are presented for all other outcomes (SRH, SROH, OHRQoL and edentulousness). The option for standardised estimates is currently unavailable for models with binary or categorical outcomes (confirmed by the Mplus support team)

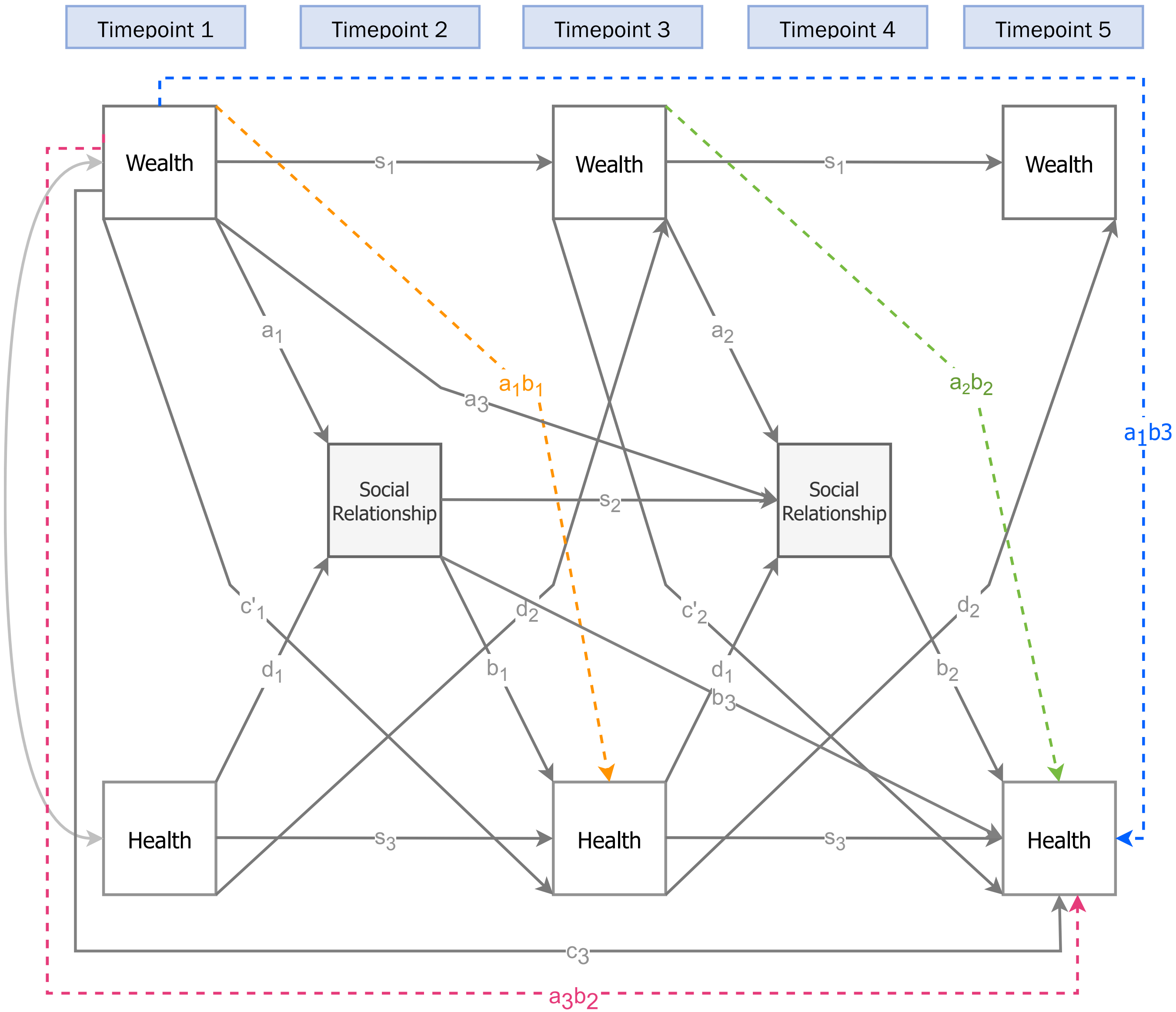

Figure 7.3 Diagrammatic representation of the initial autoregressive cross-lagged panel model used in SEM

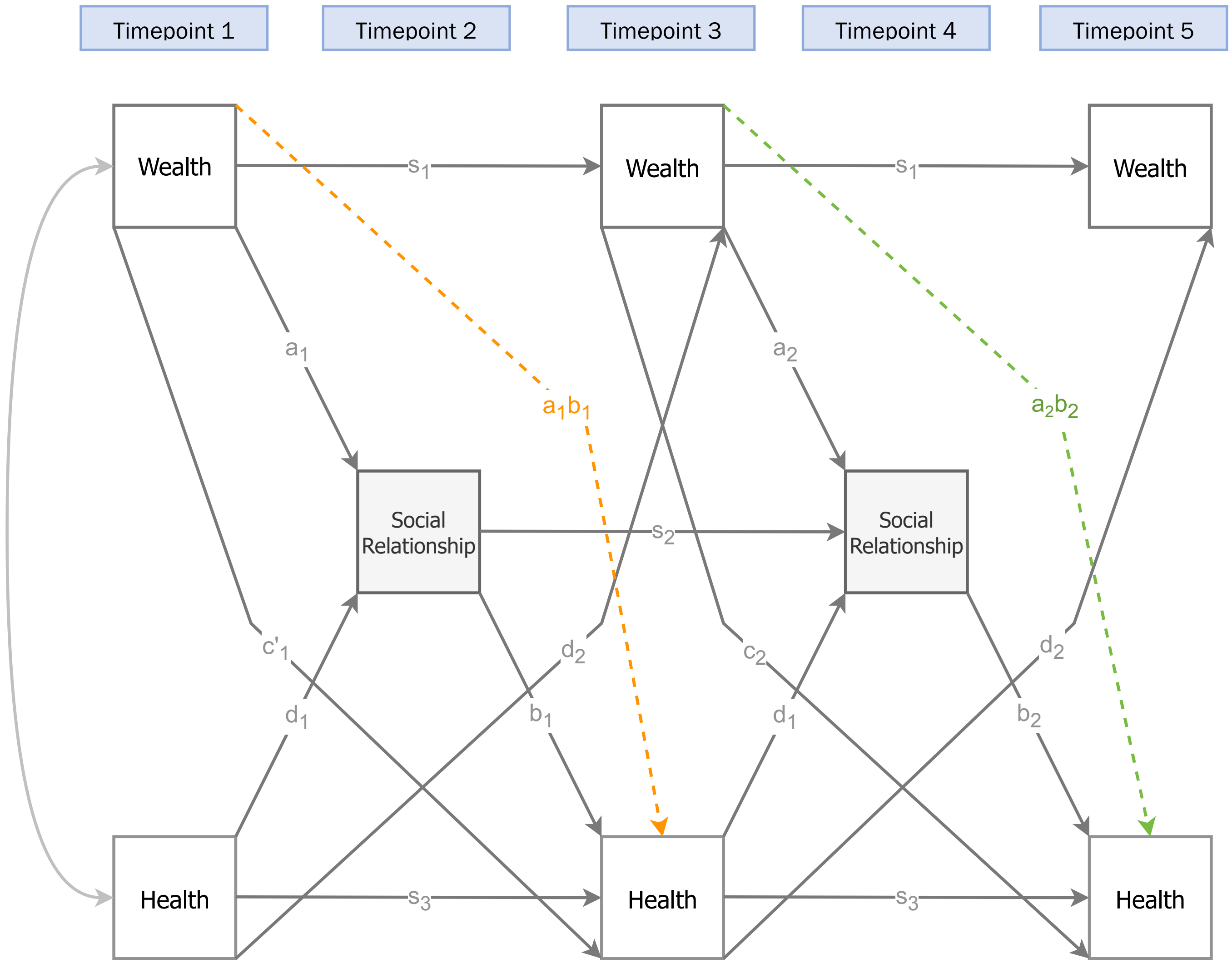

Figure 7.4 Diagrammatic representation of the final autoregressive cross-lagged panel model used in SEM

7.2.4 The autoregressive cross-lagged pathway model

As described in the methodology chapter (Chapter 5, Section 5.7.3), a series of autoregressive structural equation models were constructed for each outcome separately to assess direct and indirect pathways (see Figure 7.4). Results from cross-sectional analyses revealed that the steepest social gradients were by wealth, therefore, longitudinal models explored the direct effect of wealth on each outcome and the indirect effect of wealth on each outcome via social relationship markers (mediators). Loneliness and social isolation were assessed for their mediating role separately for each of the five outcomes – since a causal relationship between loneliness and social isolation cannot be excluded, they were not run as parallel mediators in the SEM models (Muthén, Muthén and Asparouhov, 2016). Therefore, there are two SEM models presented per outcome. The models also estimated longitudinal cross-lagged paths between outcomes and social relationship measures and between outcomes and wealth.

Figure 7.4 provides a diagrammatic representation of the autoregressive cross-lagged panel model (CLPM) implemented in the SEM analyses for all outcomes examined in this study (SRH, SBP, SROH, OHRQoL and edentulousness). The autoregressive cross-lagged model assumes bidirectional associations between wealth and health, and between health and social relationships.

The regression coefficients represented by paths s_1, s_2 and s_3 represent the autoregressive effects – these assess the stability of the measures from one wave to the next. The autoregressive effects indicate the proportion of variance in each variable that is carried forward to later waves. For example, how much of the wave-to-wave fluctuations in the probability of poor SRH can be explained by knowing the probability of poor SRH of the previous wave. Conceptually, this can be understood as the autoregressive paths indicating the extent to which poor SRH tends to linger on from one wave to the next. The assumption when modelling autoregression is that poor SRH at one time-point is associated with poor SRH at the next time-point.

Solid straight arrows represent paths showing both longitudinal direct effects (a, b, and c' paths) and cross-lagged longitudinal paths (d_1 and d_2). It is important to note that given the design of the autoregressive cross-lagged model, bidirectional associations were assumed between wealth and health, and between health and social relationships.

Dotted lines represent indirect paths (a_1b_1 and a_2b_2), i.e., mediating pathways, from wealth to outcome via the social relationship measure longitudinally. The longitudinal mediating pathways are colour-coded for ease of interpretation and understanding the pathway diagrams.

The size of the direct *c'* path and indirect *ab* paths gives the relative contribution of each pathway to the total effects of the model. The total effect indicates the sum of the indirect and direct paths, i.e., *ab + c'*. The proportion of the total effect mediated by loneliness and social relationships can be expressed by the equation: (ab/(ab+c') (MacKinnon, Warsi and Dwyer, 1995), and has been reported in the results tables.

7.2.5 Coding of variables

Exposure: wealth

Economists at the Institute of Fiscal Studies created an aggregate measure of wealth in ELSA – the variable is provided in the ELSA dataset as quintiles of the net total equivalised (non-pension) household wealth quintiles (Chapter 6) (Oldfield, 2011). The variable for wealth was coded such that a higher value was indicative of a higher quintile of wealth, i.e., the first quintile represents individuals in the lowest 20%, and the fifth quintile represents individuals in the top 20% in each ELSA wave (1= 1st quintile, 2 = second quintile, 3 = third quintile, 4 = fourth quintile, 5 = fifth quintile) (Oldfield, 2011). Wealth was not treated as a continuous variable for the purposes of SEM due to its wide variance and extreme values of wealth. For example, at wave 2 wealth ranged from £-126,990 to £ 9,319,227. After rescaling the variable by adding a recommended constant of 1000, the variance did not reduce to the optimal range (between 1 and 10 as advised by the Mplus support team). Furthermore, increasing the value of the constant to achieve the optimal variance resulted in model nonidentification. Therefore, to measure socioeconomic position, quintiles of wealth were used throughout the longitudinal analyses.

Outcomes: SBP, SRH, SRH, OHRQoL and edentulousness

Systolic blood pressure was a continuous variable measuring mm HG (millimetres of mercury), with higher values indicative of higher systolic blood pressure. Finally, all other health outcomes, i.e., self-rated health, self-rated oral health, OHRQoL and edentulousness, were dichotomous variables (0/1) such that the value '1' represented those with poorer health.

Mediators: loneliness and social isolation

Loneliness and social isolation were taken as observed variables on a continuous scale – the loneliness scale ranged from 3-9 (Cronbach's α = 0.90), and the social isolation scale ranged from 0-7 (Cronbach's α = 0.93) (for further details on derivation and coding of these variables please see Chapter 5).

Loneliness and social isolation were not modelled as latent variables in the CLPM's for the following reasons: (1) issues with partial measurement invariance, (2) instability of the measurement model, (3) nonconvergence of the measurement model. Considering these issues (discussed in detail below) it was decided to avoid using latent variables and to use loneliness and social isolation as observed variables in the models.

Partial measurement invariance

Initially, confirmatory factor analysis (CFA) was utilised to obtain latent constructs of loneliness and social isolation. CFA is a type of structural equation modelling that models a relationship between observed factor items and the unobserved latent factor. Tests of measurement invariance were undertaken to (1) estimate measurement error of factor items, (2) assess factorial validity, and (3) examine whether each latent variable functions and is interpreted in the same way across all time points and groups i.e., whether scores at one time point are psychometrically equivalent to scores at another time point (Schmitt and Kuljanin, 2008; Sass, 2011).

It is not unreasonable to have partial measurement invariance, as it is rare to have invariance across all factor items across all time points (Schmitt and Kuljanin, 2008).However, although partial scalar invariance was achieved for both loneliness and social isolation, some assumptions were violated. Firstly, multivariate normality is commonly required for ML estimation in CFA, since factor items for loneliness and social isolation were skewed, the normality issue was dealt with using MLR, an estimator robust to violations of normality. Therefore, fulfilling the first assumption. Secondly, although the assumption that the single-factor model held, i.e., that the factor items were believed to fit a single common factor, social isolation factor items were discrete and loneliness factor items were categorical, therefore violating the assumption that all factor items should be continuous. At present, there seems to be little guidance on the practical significance of partial measurement invariance (Schmitt and Kuljanin, 2008). Even if partial measurement invariance was considered, the concern was that the noninvariant factor items are no longer perfectly comparable, therefore caution would have been needed to interpret findings (Schmitt and Kuljanin, 2008). Moreover, noninvariance may consequently have affected invariance of the structural model (Schmitt and Kuljanin, 2008).

Instability of the measurement model

The second issue was regarding stability of latent constructs of loneliness and social isolation. The best loglikelihood could not be replicated for the model parameters when implementing random starting values (STARTS = 50), resulting in an unstable model. This suggested that it would have been difficult to extract meaningful information from the data (confirmed by the Mplus support team).

Nonconvergence of the model

Finally, when running models despite concerns regarding partial measurement invariance and model stability, the output returned fatal errors relating to the latent variable covariance matrix not being positive definite or failure in convergence of some models. Both problems suggested that the model needed to be changed (advised by Mplus support team).

7.3 Descriptive results

The mean age for the longitudinal samples was 65.8 years for the sample assessing SRH and systolic blood pressure (waves 2 to 6) and 64.8 years for the sample assessing oral health outcomes (waves 3 to 7). 53% of both samples were female (Appendix 17, Table 17.2 and 17.3).

The prevalence of poorer oral health outcomes increased with each wave. At wave 3, almost 19% reported experiencing fair to poor SROH, 16.2% reported having total tooth loss and almost 9% reported at least one oral impact on daily performance. However, at wave 7, just over 23% reported fair to poor SROH, almost 31% reported having total tooth loss and almost 11% reported at least one oral impact on daily performance (Table 7.1)

The prevalence of fair to poor SRH remained similar from waves 2 to 6: 28% of respondents at wave 2, and 27% at waves 4 and 6 reported experiencing reported experiencing fair to poor SRH (Table 7.1). The mean systolic blood pressure was almost normally distributed and reduced marginally across waves: respondents had a mean systolic blood pressure of 136.3 mm HG at wave 2, this reduced to 135.4 mm HG at wave 6 (Table 7.1).

Table 7.1 Prevalence of poor SROH, OHRQoL, SRH and being edentate, and mean and standard deviation for systolic blood pressure from waves 2 to 7 (observed data)

Waves	SROH	Edentate	OHRQoL	SRH	SBP (mm HG)	
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n*	Mean (SD)
Wave 2				2211 (28.4)	6066	136.3 (19.4)
Wave 3	1446 (18.9)	1219 (16.2)	664 (8.6)			
Wave 4				2305 (26.8)	7089	135.7 (18.9)
Wave 5	1434 (18.4)	1038 (13.1)	820 (10.3)			
Wave 6				2264 (26.7)	6883	135.4 (18.6)
Wave 7	1719 (23.4)	2706 (30.9)	804 (10.7)			

The mean social isolation and loneliness scores on the observed data remained relatively consistent at 1.8 and 4.2, respectively, across all waves (Table 7.2), except for the mean loneliness scores at waves 2 and 7, which were 4.1.

Loneliness was positively skewed across all waves – skewness, i.e., the symmetry of the distribution, ranged from 1.24 to 1.43 and kurtosis, i.e., the ‘peakedness’ ranged from 3.78 to 4.45 across all waves. Histograms (presented in Appendix 17) show a longer right tail and loneliness scores largely distributed towards the left of the tail. Social isolation was almost normally distributed – skewness ranged from 0.43 to 0.48 and kurtosis ranged from 2.81 to 2.92 (Appendix 17).

Table 7.2 Mean and standard deviation for loneliness and social isolation from waves 2 to 7 (observed data)

Waves	Social isolation score		Loneliness score	
	n	Mean (SD)	*n*	Mean (SD)
Wave 2	6150	1.8 (1.2)	7051	4.1 (1.5)
Wave 3	6024	1.8 (1.2)	6781	4.2 (1.6)
Wave 4	6996	1.8 (1.2)	7740	4.2 (1.6)
Wave 5	6816	1.8 (1.2)	7480	4.2 (1.5)
Wave 6	6837	1.8 (1.2)	7438	4.2 (1.5)
Wave 7	6140	1.8 (1.2)	6738	4.1 (1.5)

7.4 SEM results for longitudinal mediation models

This section presents the sex- and age-adjusted results of modelling direct and indirect paths between wealth, social relationships (loneliness and social isolation), and health (SRH, SBP, SROH, OHRQoL and edentulousness). Results from the autoregressive CLPM are presented separately for loneliness and social isolation for each outcome. In the model with loneliness, cases with missing on all variables (n = 105) were not included in the analysis.

Results for both models across each outcome showed strong associations for all the autoregressive paths, i.e., the direct effect of each variable on itself from one time point to the next.

The associations between wealth and loneliness, and between wealth and social isolation were in the expected direction for each outcome. In the longitudinal mediation models assessing SRH and SBP, higher levels of wealth at waves 2 and 4 were associated with lower levels of later loneliness and social isolation at waves 3 and 5. Similarly, in the longitudinal mediation models assessing SROH, OHRQoL and edentulousness, higher levels of wealth at waves 3 and 5 were associated with lower levels of later loneliness and social isolation at waves 4 and 6.

7.4.1 SEM results for longitudinal mediation models assessing self-rated health

The total effects of wealth on later SRH inclusive of the indirect pathways via loneliness (Figure 7.5) and social isolation (Figure 7.6), were in the expected direction and statistically significant in both models. In other words, greater wealth at wave 2 was associated with lower probability of reporting poor SRH at wave 4 via all represented direct and indirect pathways linking wealth (wave 2) and SRH (wave 4). Similarly, greater wealth at wave 4 was associated with a lower probability of experiencing poor SRH at wave 6 via all represented direct and indirect pathways linking wealth (wave 4) and SRH (wave 6). Since these total effects are decomposed into direct and indirect paths, they are discussed in turn and separately for each mediator below.

Mediation via loneliness

As expected, greater wealth was associated with lower probability of reporting poor SRH at later waves. The substantial direct path between wealth and later SRH, suggests that wealth at wave 2 remained a predictor of SRH at wave 4 (B -0.31, 95% CI -0.36, -0.27) and wealth at wave 4 remained a predictor of SRH at wave 6 (B -0.24, 95% CI -0.28, -0.19) independent of the effect of loneliness (Figure 7.5, Table 7.3)

The direct paths between loneliness and SRH were both significant and indicated that higher levels of loneliness at waves 3 were associated with a higher probability of poor SRH at wave 5 (B 0.18, 95% CI 0.13-0.22), and higher levels of loneliness at 5 were associated with a higher probability of poor SRH at wave 6 (B 0.17, 95% CI 0.13-0.21).

The indirect effects indicate the extent to which loneliness mediated the wealth-SRH association. Loneliness at wave 3 explained 9.5% of the total effect of wealth at wave 2 on SRH at wave 4. Therefore, loneliness partially mediated wealth-related inequalities in SRH, albeit less than 10%.

Cross-lagged paths (SRH ↔ Loneliness; SRH ↔ Wealth) were in the expected direction. Poor SRH at waves 2 and 4 was associated with greater levels of later loneliness, and higher levels of loneliness at waves 3 and 5 were associated with a greater probability of later poor SRH. Overall, pathways from SRH on later loneliness were larger in magnitude than those in the opposite direction. Higher wealth at waves 2 and 4 was associated with a lower probability of later poor SRH, and lower SRH at waves 2 and 4 was associated with lower levels of later wealth. However, the pathways from wealth to later SRH were larger in magnitude than from SRH to later wealth.

Mediation via social isolation

The direct path between wealth and later SRH, suggests that wealth remained a predictor of SRH, independent of the effect of social isolation. Greater wealth at wave 2 was associated with a lower probability of poor later SRH at wave 4 (B -0.31, 95% CI -0.36, -0.26), and higher levels of wealth at wave 4 was associated with a lower probability of poor later SRH at wave 6 (B -0.22, 95% CI -0.26, -0.17) (Figure 7.6, Table 7.4).

Direct effects from social isolation on later SRH were in the expected direction and significant. Higher levels of social isolation were associated with a higher probability of poor SRH at later waves (Social isolation W3 → SRH W4: B 0.12, 95% CI 0.06-0.18; Social isolation W5 → SRH W6: B 0.20, 95% CI 0.14-0.25)

The indirect effects indicate that social isolation at wave 3 explained 9.3% of the total effect of wealth at wave 2 on SRH at wave 4. Furthermore, social isolation at wave 5 explained 7% of the total effect of wealth at wave 4 on SRH at wave 6. Therefore, social isolation also partially mediated socioeconomic inequalities in SRH, albeit less than 10%.

Cross-lagged paths (SRH ↔ Social isolation; SRH ↔ Wealth) were largely in the expected direction. Poor SRH at waves 2 and 4 was associated with higher levels of later social isolation, and higher levels of social isolation at waves 3 and 5 were associated with a greater probability of poor later SRH. Overall, pathways from SRH on later social isolation were larger in magnitude than those in the opposite direction. With one exception: the pathway from SRH at wave 4 on social isolation at wave 5 was similar in magnitude to that from social isolation at wave 5 on later SRH at wave 6. Higher wealth at waves 2 and 4 was associated with a lower probability of later poor SRH, and poor SRH at waves 2 and 4 was associated with lower levels of later wealth. However, the pathways from wealth on later SRH were larger in magnitude than those in the opposite direction.

Summary of SEM results for SRH

In summary, loneliness and social isolation partially mediated the association between wealth and later SRH, although the contribution was modest. Secondly, a bidirectional association between SRH and social relationships was observed. The magnitude of the association between SRH and later loneliness and social isolation was larger than in the opposite direction. With one exception: social isolation at wave 5 on later SRH was similar in magnitude associated to the pathway in opposite direction. The association between wealth and later SRH was stronger than vice versa. Finally, wealth remained a persistent predictor of SRH independent and inclusive of the mediating effects of loneliness and social isolation.

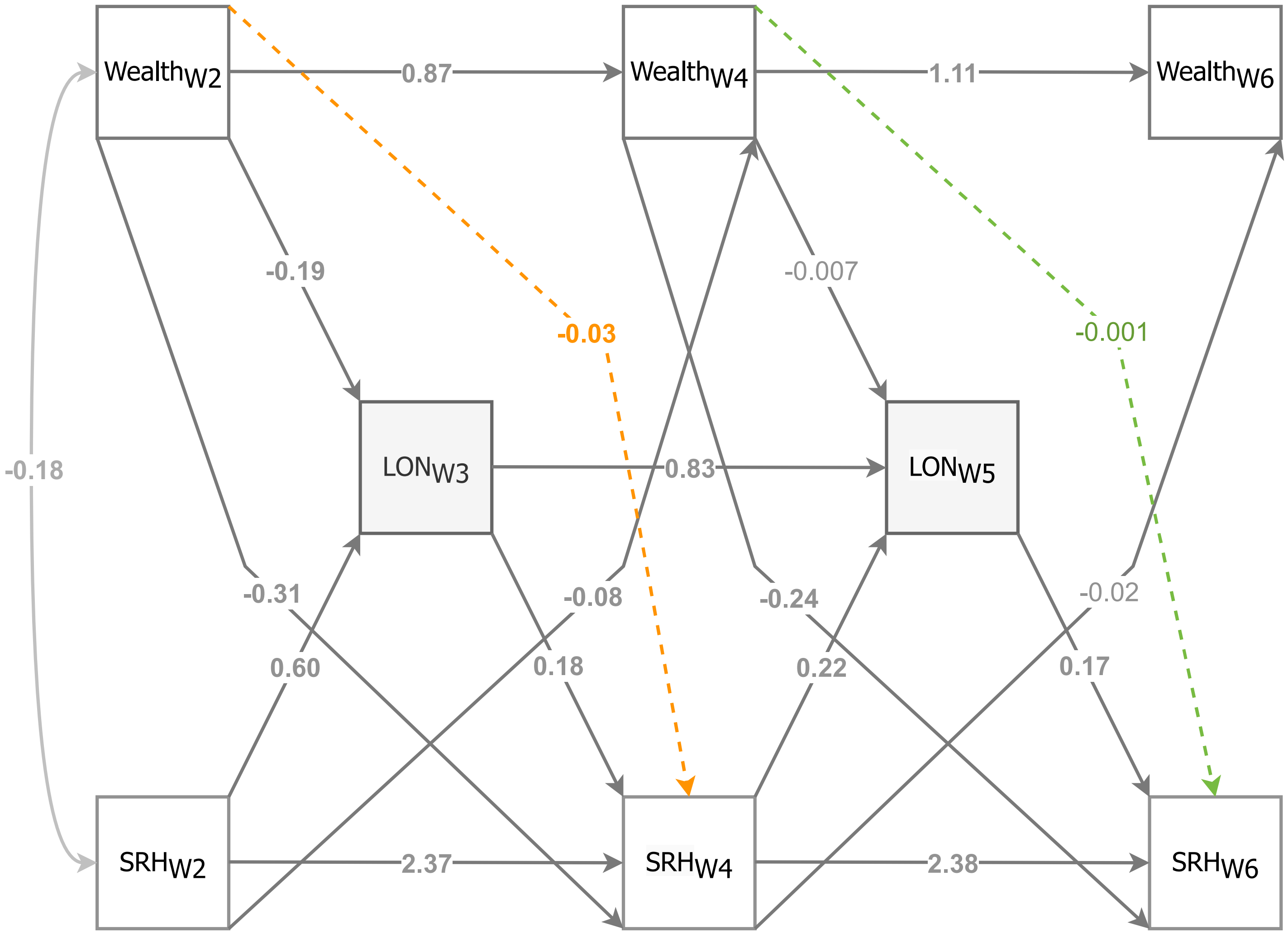

Figure 7.5 Adjusted cross-lagged pathways model for SRH via loneliness (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = least wealthy, quintile 5 = wealthiest; Self-rated health (SRH): 0 = very good/good, 1 = fair/bad/very bad; Loneliness (LON) = continuous scale (3-9); Orange dashed lines = indirect pathways a_1b_1; Green dashed line = indirect pathways a_2b_2

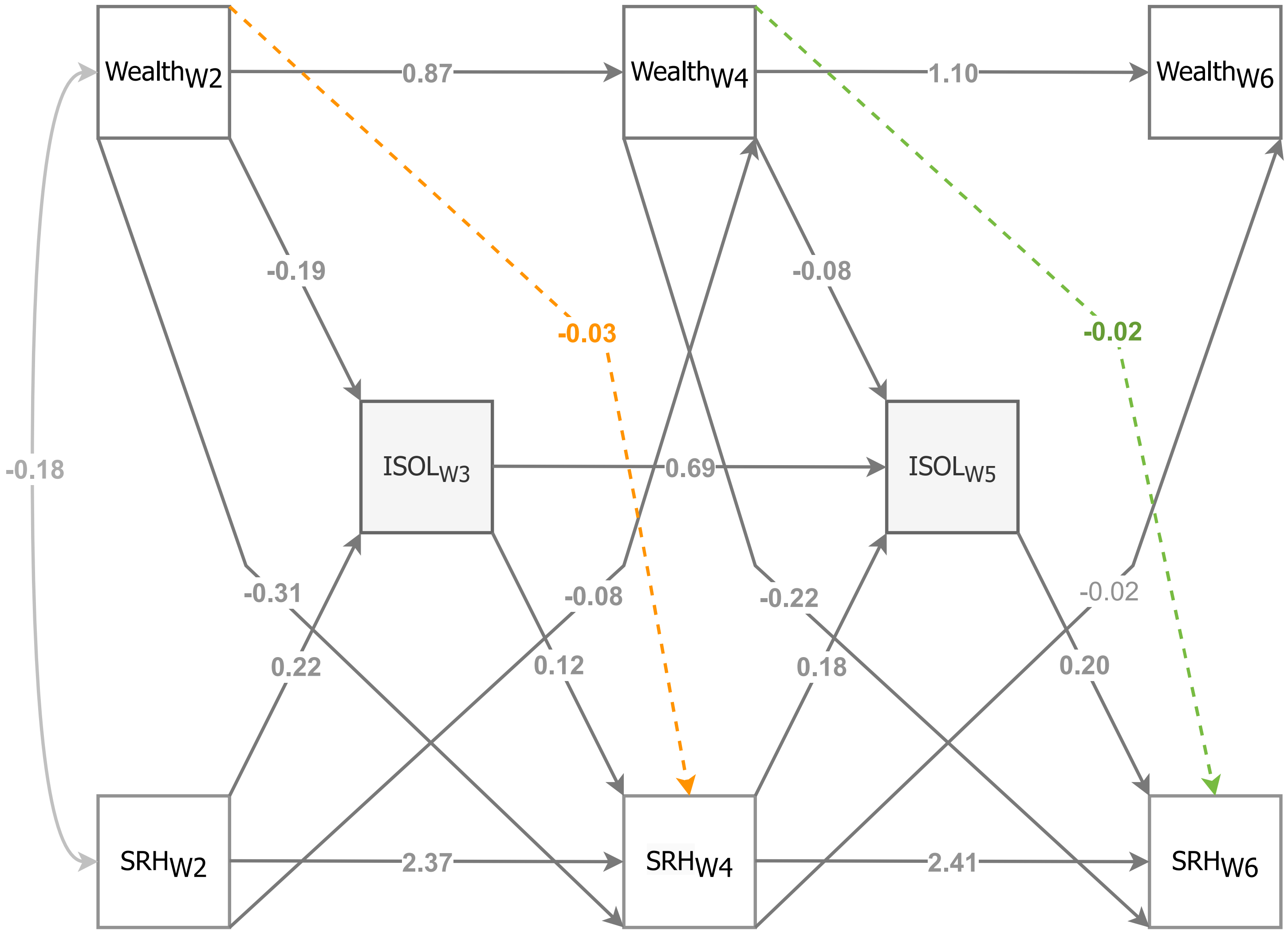

Figure 7.6 Adjusted cross-lagged pathways model for SRH via social isolation (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = wealthiest, quintile 5 = least wealthy; Self-rated health (SRH): 0 = very good/good, 1 = fair/bad/very bad; Social isolation (ISOL) = continuous scale (0-6); Orange dashed lines = indirect pathways a_1b_1; Green dashed line = indirect pathways a_2b_2

Table 7.3 Adjusted auto-regressive cross-lagged pathway model for self-rated health via loneliness (n = 12,618[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[2] → Wealth				
Wealth W2 → Wealth W4	0.868	0.857	0.879	<0.001
Wealth W4 → Wealth W6	1.114	1.035	1.194	<0.001
SRH → SRH				
SRH W2 → SRH W4	2.370	2.222	2.517	<0.001
SRH W4 → SRH W6	2.375	2.243	2.508	<0.001
Loneliness → Loneliness				
Loneliness W3 → Loneliness W5	0.830	0.694	0.967	<0.001
Direct effects				
Wealth → SRH				
Wealth W2 → SRH W4	-0.313	-0.359	-0.267	<0.001
Wealth W4 → SRH W6	-0.237	-0.280	-0.193	<0.001
Wealth → Loneliness				
Wealth W2 → Loneliness W3	-0.186	-0.213	-0.159	<0.001
Wealth W4 → Loneliness W5	-0.007	-0.041	0.028	0.695
Loneliness → SRH				
Loneliness W3 → SRH W4	0.177	0.134	0.221	<0.001
Loneliness W5 → SRH W6	0.166	0.126	0.206	<0.001
SRH → Loneliness				
SRH W2 → Loneliness W3	0.601	0.499	0.703	<0.001
SRH W4 → Loneliness W5	0.220	0.124	0.316	<0.001
SRH → Wealth				
SRH W2 → Wealth W4	-0.075	-0.121	-0.029	0.001
SRH W4 → Wealth W6	-0.021	-0.066	0.024	0.361
Indirect effects				
Wealth W2 to SRH W4				
Total effect	-0.346	-0.391	-0.300	<0.001
Total indirect effect	-0.033	-0.042	-0.023	<0.001
Wealth W2 → Loneliness W3 → SRH W4	-0.034	-0.042	-0.023	<0.001
Wealth W4 to SRH W6				
Total effect	-0.238	-0.282	-0.193	<0.001
Total indirect effect	-0.001	-0.007	0.005	0.694
Wealth W4 → Loneliness W5 → SRH W6	-0.001	-0.007	0.005	0.694
Proportion of total effects mediated (%)[§]				
Wealth W2 → Loneliness W3 → SRH W4	9.5			
Measuring Model Fit				
AIC[3]	216982.061			
BIC[4]	217324.434			
SABIC[5]	217178.251			

[1]Data set contains cases with missing on all variables that were not included in the analysis (n = 105); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (ab/(ab+c'), (MacKinnon, Warsi and Dwyer, 1995)

Table 7.4 Adjusted auto-regressive cross-lagged pathway model for self-rated health via social isolation (n = 12,573[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[2] → Wealth				
Wealth W2 → Wealth W4	0.867	0.856	0.879	<0.001
Wealth W4 → Wealth W6	1.109	1.030	1.189	<0.001
SRH → SRH				
SRH W2 → SRH W4	2.417	2.270	2.563	<0.001
SRH W4 → SRH W6	2.405	2.273	2.536	<0.001
Social isolation → Social isolation				
Social isolation W3 → Social isolation W5	0.693	0.672	0.714	<0.001
Direct effects				
Wealth → SRH				
Wealth W2 → SRH W4	-0.310	-0.359	-0.262	<0.001
Wealth W4 → SRH W6	-0.215	-0.260	-0.169	<0.001
Wealth → Social isolation				
Wealth W2 → Social isolation W3	-0.274	-0.295	-0.253	<0.001
Wealth W4 → Social isolation W5	-0.078	-0.096	-0.061	<0.001
Social isolation → SRH				
Social isolation W3 → SRH W4	0.119	0.057	0.180	<0.001
Social isolation W5 → SRH W6	0.198	0.142	0.254	<0.001
SRH → Social isolation				
SRH W2 → Social isolation W3	0.218	0.146	0.290	<0.001
SRH W4 → Social isolation W5	0.178	0.117	0.239	<0.001
SRH → Wealth				
SRH W2 → Wealth W4	-0.079	-0.125	-0.032	0.001
SRH W4 → Wealth W6	-0.023	-0.068	0.023	0.326
Indirect effects				
Wealth W2 to SRH W4				
Total effect	-0.343	-0.388	-0.298	<0.001
Total indirect effect	-0.032	-0.050	-0.015	<0.001
Wealth W2 → Social isolation W3 → SRH W4	-0.032	-0.050	-0.015	<0.001
Wealth W4 to SRH W6				
Total effect	-0.230	-0.274	-0.186	<0.001
Total indirect effect	-0.016	-0.021	-0.010	<0.001
Wealth W4 → Social isolation W5 → SRH W6	-0.016	-0.021	-0.010	<0.001
Proportion of total effects mediated (%)[§]				
Wealth W2 → Social isolation W3 → SRH W4	9.3			
Wealth W4 → Social isolation W5 → SRH W6	7.0			
Measuring Model Fit				
AIC[3]	204264.831			
BIC[4]	204599.600			
SABIC[5]	204456.595			

[1]Data set contains cases with missing on all variables that were not included in the analysis (n = 150); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (ab/(ab+c')), (MacKinnon, Warsi and Dwyer, 1995)

7.4.2 SEM results for longitudinal mediation models assessing systolic blood pressure

No total effects or direct effects from wealth on later systolic blood pressure were significant in the models with loneliness or social isolation. Additionally, no significant indirect effects via loneliness or social isolation were found. No bidirectional associations were found between loneliness or social isolation and systolic blood pressure, or between wealth and systolic blood pressure. However, some notable direct effects were seen, these are discussed below.

Loneliness

In the model that included loneliness, other than the autoregressive paths and pathways from wealth to loneliness, only one other statistically significant direct path was found. A higher level of systolic blood pressure at wave 2 was associated with lower levels of later wealth at wave 4 (Figure 7.7, Table 7.5).

Social isolation

In the model that included social isolation, other than the autoregressive paths and pathways from wealth to social isolation, two additional statistically significant direct associations were found. A higher level of systolic blood pressure at wave 2 was associated with a lower level of later wealth at wave 4. Finally, systolic blood pressure at wave 2 was associated with a greater level of later social isolation at wave 3 (Figure 7.8, Table 7.6).

Summary of SEM results for systolic blood pressure

In summary, wealth did not predict later systolic blood pressure, nor was there any evidence for mediation of wealth inequalities in systolic blood pressure by loneliness or social isolation. However, there was some limited evidence to support an association between higher systolic blood pressure and lower levels of later wealth.

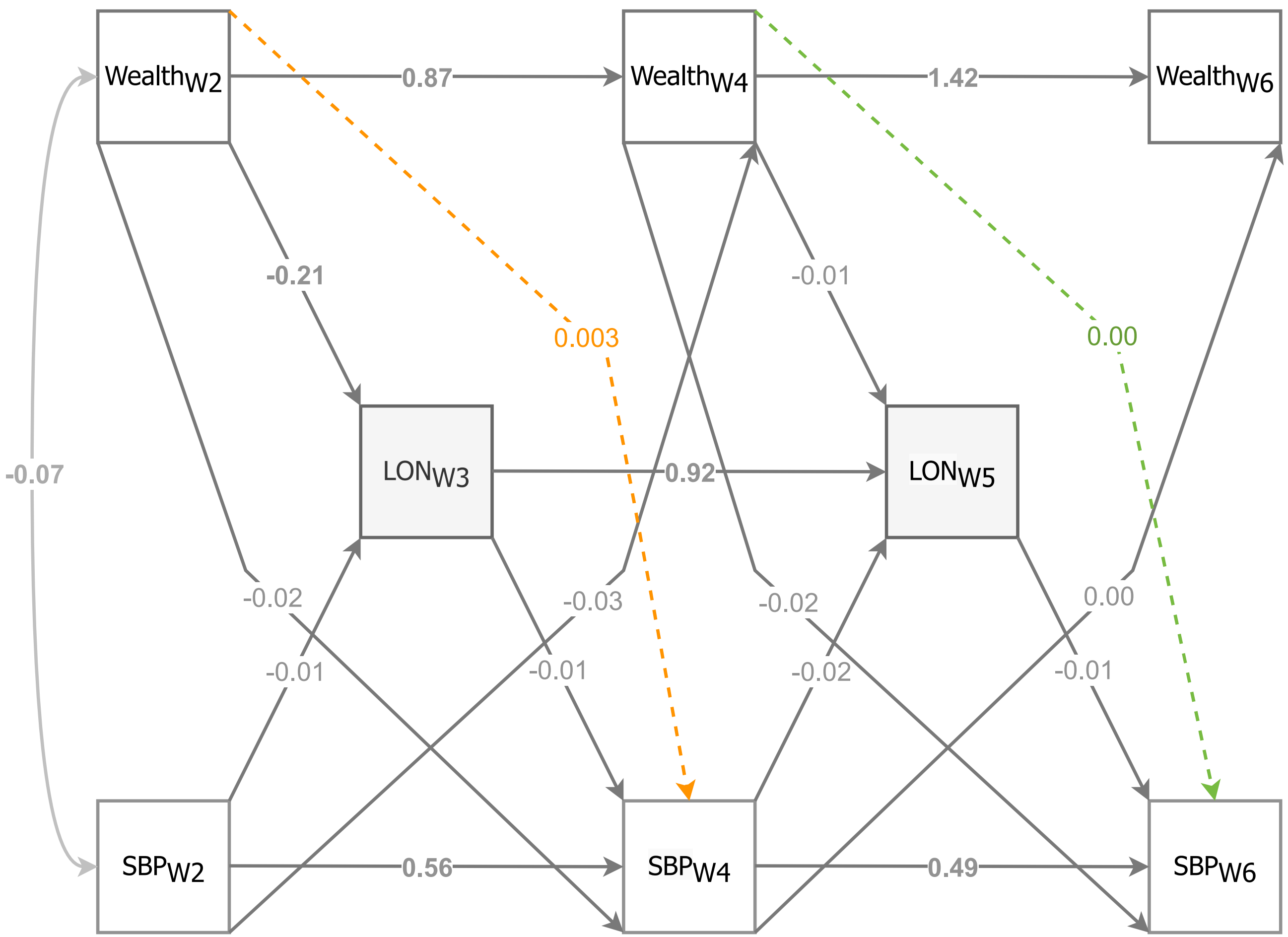

Figure 7.7 Adjusted cross-lagged pathways model for systolic blood pressure via loneliness (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = least wealthy, quintile 5 = wealthiest; Systolic blood pressure (SBP) = continuous scale; Loneliness (LON) = continuous scale (3-9); Orange dashed lines = indirect pathways a_1b_1; Green dashed line = indirect pathways a_2b_2

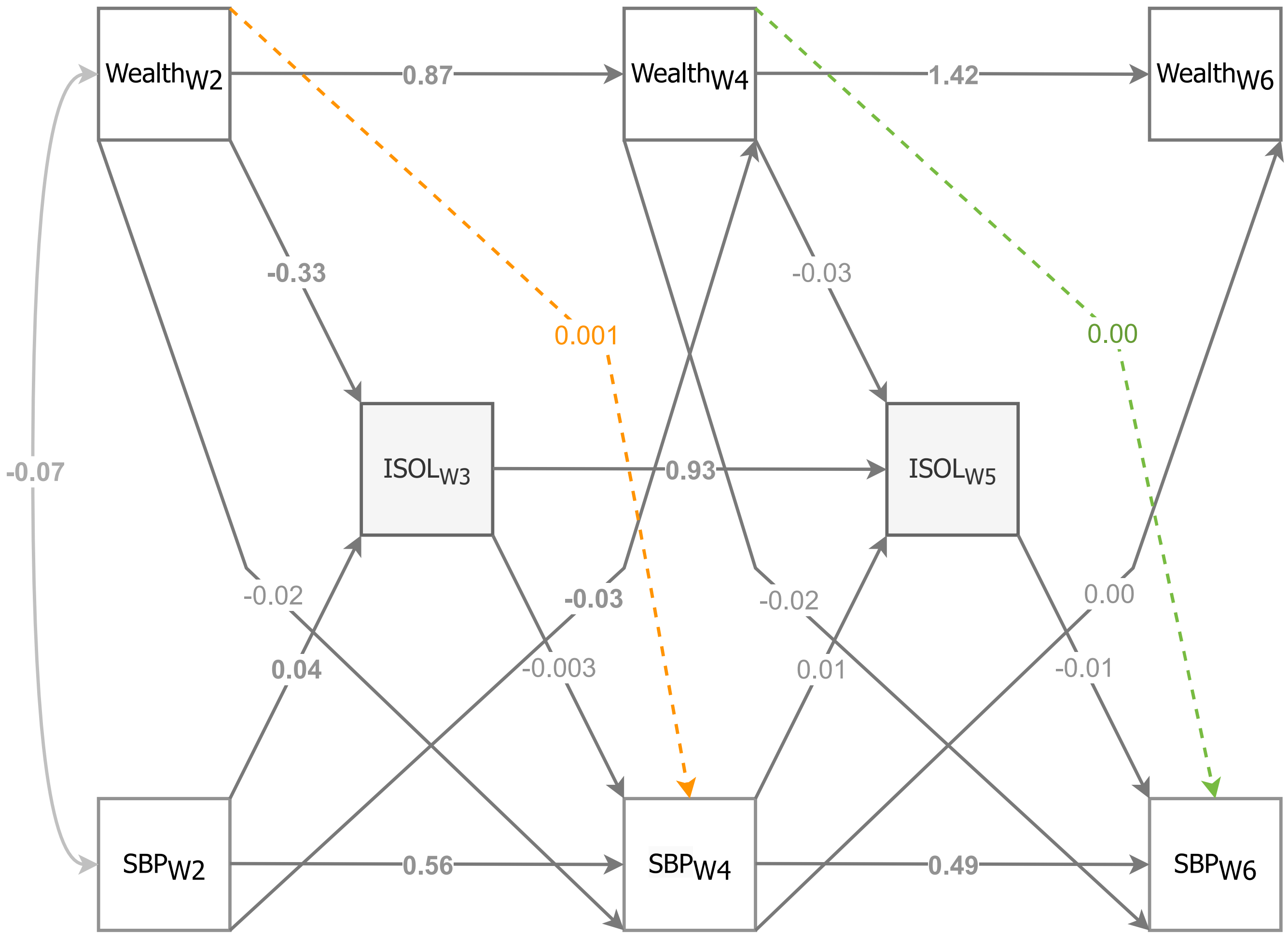

Figure 7.8 Adjusted cross-lagged pathways model for systolic blood pressure via social isolation (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = wealthiest, quintile 5 = least wealthy; Systolic blood pressure (SBP) = continuous scale; Social isolation (ISOL) = continuous scale (0-6); Orange dashed lines = indirect pathways a_1b_1; Green dashed line = indirect pathways a_2b_2

Table 7.5 Adjusted auto-regressive cross-lagged pathway model for systolic blood pressure via loneliness (n = 12,594[1])

	Estimate (β)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[2] → Wealth				
Wealth W2 → Wealth W4	0.870	0.861	0.877	<0.001
Wealth W4 → Wealth W6	1.424	1.289	1.559	<0.001
SBP → SBP				
SBP W2 → SBP W4	0.559	0.535	0.582	<0.001
SBP W4 → SBP W6	0.488	0.459	0.516	<0.001
Loneliness → Loneliness				
Loneliness W3 → Loneliness W5	0.920	0.738	1.072	<0.001
Direct effects (Longitudinal)				
Wealth → SBP				
Wealth W2 → SBP W4	-0.021	-0.044	0.002	0.069
Wealth W4 → SBP W6	-0.015	-0.036	0.006	0.162
Wealth → Loneliness				
Wealth W2 → Loneliness W3	-0.210	-0.234	-0.186	<0.001
Wealth W4 → Loneliness W5	-0.012	-0.051	0.028	0.557
Loneliness → SBP				
Loneliness W3 → SBP W4	-0.013	-0.038	0.011	0.289
Loneliness W5 → SBP W6	-0.010	-0.032	0.013	0.403
SBP → Loneliness				
SBP W2 → Loneliness W3	-0.014	-0.042	0.013	0.313
SBP W4 → Loneliness W5	-0.016	-0.038	0.006	0.153
SBP → Wealth				
SBP W2 → Wealth W4	-0.026	-0.039	-0.014	<0.001
SBP W4 → Wealth W6	0.000	-0.015	0.015	0.982
Indirect effects (Longitudinal)				
Wealth W2 to SBP W4				
Total effect	-0.018	-0.041	0.004	0.108
Total indirect effect	0.003	-0.002	0.008	0.289
Wealth W2 → Loneliness W3 → SBP W4	0.003	-0.002	0.008	0.289
Wealth W4 to SBP W6				
Total effect	-0.015	-0.035	0.006	0.164
Total indirect effect	0.000	0.000	0.001	0.634
Wealth W4 → Loneliness W5 → SBP W6	0.000	0.000	0.001	0.634
Measuring Model Fit				
CFI[3]	0.996			
TLI[4]	0.990			
RMSEA[5]	0.021			
SRMR[6]	0.012			

[1]Data set contains cases with missing on all variables that were not included in the analysis (n = 129); [2]Household non-pension wealth; [2]Systolic blood pressure; [3]Comparative Fit Index; [4]Tucker-Lewis Index; [5]Root Mean Square Error of Approximation; [6]Standardised Root Mean Residual

Table 7.6 Adjusted auto regressive cross-lagged pathway model for systolic blood pressure via social isolation (n = 12,547[1])

	Estimate (β)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[2] → Wealth				
Wealth W2 → Wealth W4	0.870	0.862	0.878	<0.001
Wealth W4 → Wealth W6	1.420	1.286	1.554	<0.001
SBP → SBP				
SBP W2 → SBP W4	0.559	0.535	0.582	<0.001
SBP W4 → SBP W6	0.488	0.460	0.517	<0.001
Social isolation → Social isolation				
Social isolation W3 → Social isolation W5	0.932	0.818	1.046	<0.001
Direct effects (Longitudinal)				
Wealth → SBP				
Wealth W2 → SBP W4	-0.020	-0.044	0.004	0.100
Wealth W4 → SBP W6	-0.016	-0.038	0.005	0.141
Wealth → Social isolation				
Wealth W2 → Social isolation W3	-0.330	-0.353	-0.306	<0.001
Wealth W4 → Social isolation W5	-0.033	-0.071	0.005	0.092
Social isolation → SBP				
Social isolation W3 → SBP W4	-0.003	-0.029	0.024	0.842
Social isolation W5 → SBP W6	-0.013	-0.037	0.011	0.293
SBP → Social isolation				
SBP W2 → Social isolation W3	0.035	0.008	0.062	0.011
SBP W4 → Social isolation W5	0.007	-0.015	0.029	0.527
SBP → Wealth				
SBP W2 → Wealth W4	-0.026	-0.039	-0.014	<0.001
SBP W4 → Wealth W6	0.000	-0.015	0.015	0.974
Indirect effects (Longitudinal)				
Wealth W2 to SBP W4				
Total effect	-0.019	-0.042	0.003	0.094
Total indirect effect	0.001	-0.008	0.010	0.842
Wealth W2 → Social isolation W3 → SBP W4	0.001	-0.008	0.010	0.842
Wealth W4 to SBP W6				
Total effect	-0.016	-0.038	0.006	0.147
Total indirect effect	0.000	0.000	0.001	0.370
Wealth W4 → Social isolation W5 → SBP W6	0.000	0.000	0.001	0.370
Measuring Model Fit				
CFI[3]	0.996			
TLI[4]	0.990			
RMSEA[5]	0.021			
SRMR[6]	0.011			

[1]Data set contains cases with missing on all variables that were not included in the analysis (n = 176); [2]Household non-pension wealth; [2]Systolic blood pressure; [3]Comparative Fit Index; [4]Tucker-Lewis Index; [5]Root Mean Square Error of Approximation; [6]Standardised Root Mean Residual

7.4.3 SEM results for longitudinal mediation models assessing self-rated oral health

The total effects of wealth on later SROH inclusive of the indirect pathways via loneliness (Figure 7.9) and social isolation (Figure 7.10), were in the expected direction and statistically significant in both models. A higher level of wealth at wave 3 was associated with a lower probability of poor later SROH at wave 5 via all represented direct and indirect pathways linking wealth (wave 3) and SROH (wave 5). Similarly, a higher level of wealth at wave 5 was associated with a lower probability of poor later SROH at wave 7 via all represented direct and indirect pathways linking wealth (wave 5) and SROH (wave 7).

Mediation via loneliness

As expected, greater wealth at wave 5 was associated with a lower probability of poor later SROH at wave 5 (B -0.10, 95% CI -0.15, -0.05), and greater wealth at wave 5 was associated with a lower probability of poor later SROH at wave 7 (B -0.18, 95% CI -0.22, -0.13) independent of loneliness (Figure 7.9, Table 7.7).

Direct effects from loneliness on later SRH were in the expected direction and statistically significant. A higher level of loneliness at wave 4 was associated with a higher probability of poor later SROH at wave 5 (B 0.16, 95% CI 0.12-0.21), and a higher level of loneliness at wave 6 was associated with a higher probability of poor later SROH at wave 7 (B 0.10, 95% CI 0.06-0.14).

Results found an indirect effect of wealth on SROH via loneliness. Loneliness at wave 4 explained 26.5% of the total effect of wealth at wave 3 on SROH at wave 5. However, loneliness did not mediate the association between wealth at wave 5 and SROH at wave 7.

Cross-lagged associations were only seen between SROH and loneliness and these were in the expected direction. Poor SROH at waves 3 and 5 was associated with greater levels of later loneliness at waves 4 and 6, and higher levels of loneliness at waves 4 and 6 were associated with a higher probability of poor later SROH at waves 5 and 7. Overall, pathways from SROH on loneliness were larger in magnitude than the pathways in the opposite direction. A bidirectional association between wealth and SROH was not evident.

Mediation via social isolation

Greater wealth at wave 3 was associated with a lower probability of poor SROH at wave 5 (B -0.09, 95% CI -0.14, -0.04), and greater wealth at wave 5 was associated with a lower probability of poor SROH at wave 7 (B -0.16, 95% CI -0.21, -0.11) (Figure 7.10, Table 7.8).

Direct effects show that higher levels of social isolation at wave 4 were associated with a higher probability of poor later SROH at wave 5 (B 0.15, 95% CI 0.09-0.21), and higher levels of social isolation at wave 6 were associated with a higher probability of poor later SROH at wave 7 (B 0.13, 95% CI 0.08-0.19).

Results found an indirect effect of wealth on SROH via social isolation. Social isolation at wave 4 explained 30.6% and 4.2% of the total effects of wealth on later SROH (waves 5 and 7, respectively).

Cross-lagged associations were evident between SROH and social isolation, these were also in the expected direction. Higher levels of social isolation at waves 4 and 6 were associated with a higher probability of poor later SROH at waves 5 and 7. Poor SROH at waves 3 and 5 were associated with a higher level of later social isolation at waves 6 and 7, however the pathway from SROH at wave 5 on social isolation at wave 6 was not statistically significant. Overall, pathways from SROH on social isolation were stronger than the pathways in the opposite direction. A bidirectional association between wealth and SROH was not evident.

Summary of SEM results for SROH

In summary, loneliness and social isolation partially mediated the association between wealth and later SROH, although the contribution was modest for some pathways. Social isolation appeared to play a greater role in mediating wealth inequalities in SROH than loneliness. Secondly, a bidirectional effect between SROH and social relationships was observed. The magnitude of the pathway from SROH on loneliness and from SROH on social isolation was larger than in the opposite direction. No bidirectional association was observed between poor SROH and wealth.

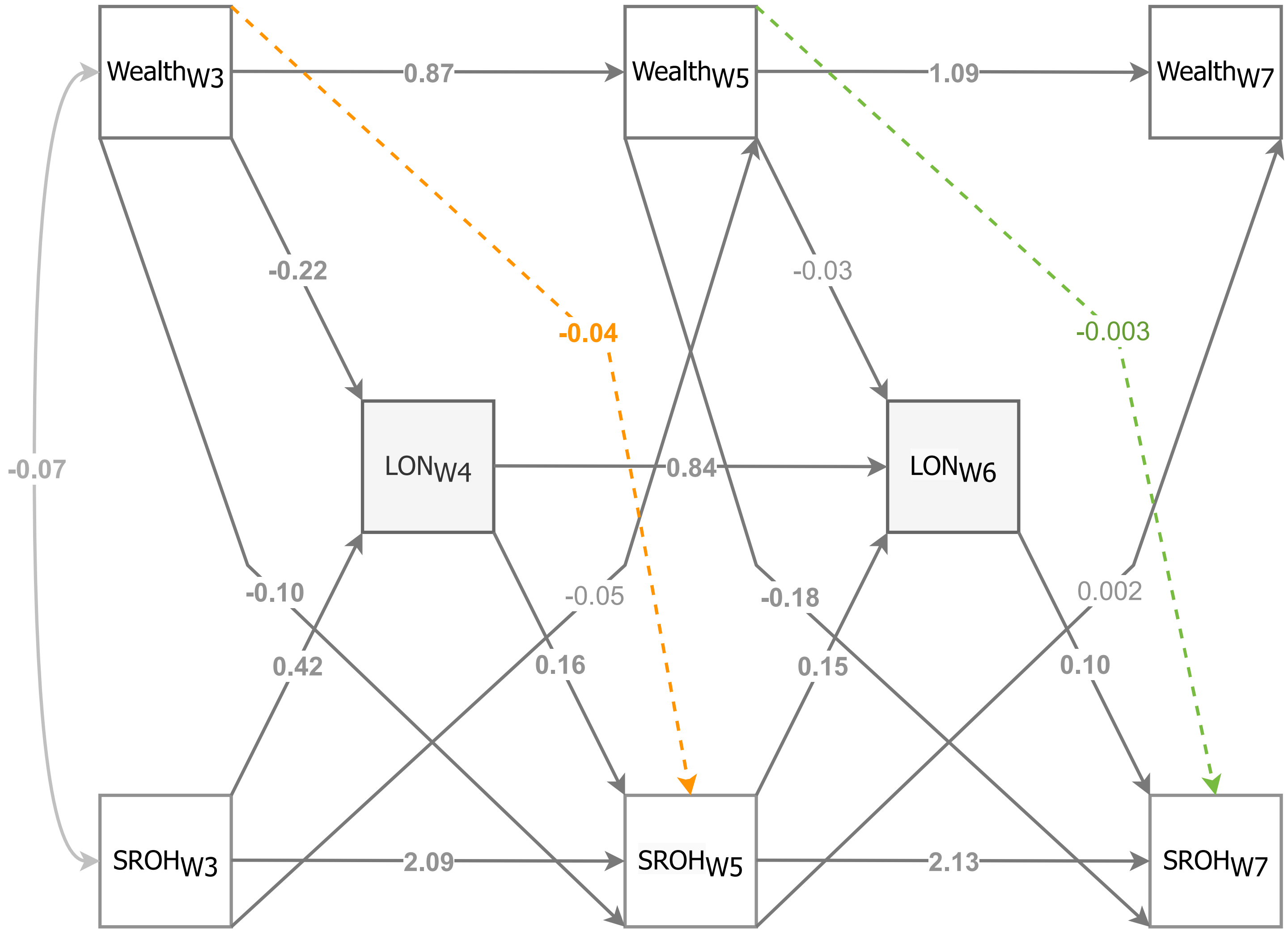

Figure 7.9 Adjusted cross-lagged pathways model for SROH via loneliness (bold values $p<0.05$; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = least wealthy, quintile 5 = wealthiest; Self-rated oral health (SROH): 0 = excellent/very good/good, 1= fair/poor; Loneliness (LON) = continuous scale (3-9); blue dashed lines = indirect pathways a_1b_1, a_2b_2, and a_3b_3; orange dashed lines = indirect pathways a_1b_2 and a_3b_4; green dashed line = indirect pathways a_2b_3 and a_4b_5

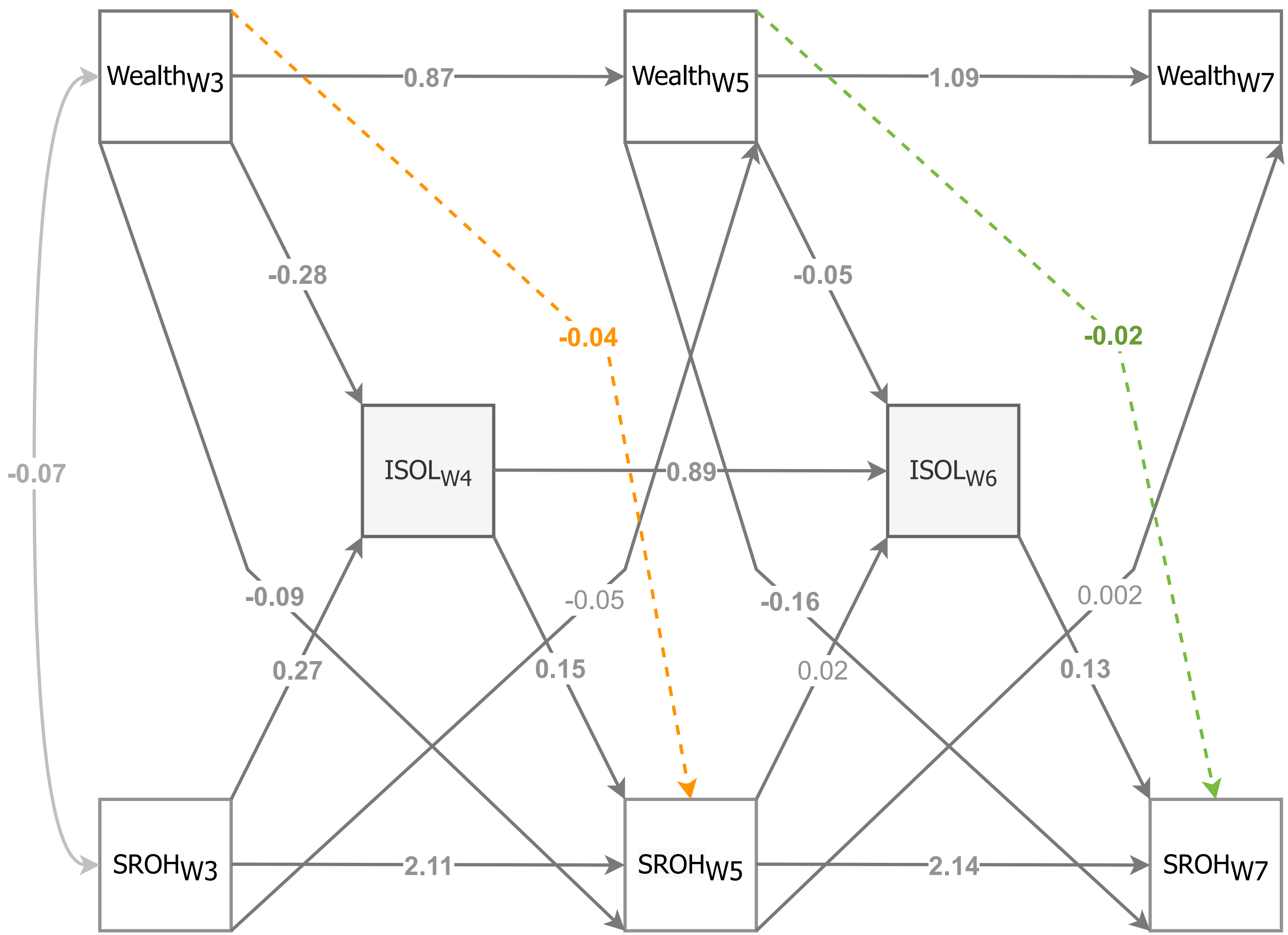

Figure 7.10 Adjusted cross-lagged pathways model for SROH via social isolation (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = least wealthy, quintile 5 = wealthiest; Self-rated oral health (SROH): 0 = excellent/very good/good, 1= fair/poor; Social isolation (ISOL) = continuous scale (0-6); blue dashed lines = indirect pathways a_1b_1, a_2b_2, and a_3b_3; orange dashed lines = indirect pathways a_1b_2 and a_3b_4; green dashed line = indirect pathways a_2b_3 and a_4b_5

Table 7.7 Adjusted auto-regressive cross-lagged pathway model for self-rated oral health via loneliness (n = 11,535[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[2] → Wealth				
Wealth W3 → Wealth W5	0.867	0.856	0.879	<0.001
Wealth W5 → Wealth W7	1.092	0.959	1.225	<0.001
SROH → SROH				
SROH W3 → SROH W5	2.093	1.939	2.248	<0.001
SROH W5 → SROH W7	2.128	1.983	2.273	<0.001
Loneliness → Loneliness				
Loneliness W4 → Loneliness W6	0.837	0.689	0.985	<0.001
Direct effects				
Wealth → SROH				
Wealth W3 → SROH W5	-0.100	-0.148	-0.051	<0.001
Wealth W5 → SROH W7	-0.175	-0.221	-0.130	<0.001
Wealth → Loneliness				
Wealth W3 → Loneliness W4	-0.221	-0.247	-0.195	<0.001
Wealth W5 → Loneliness W6	-0.025	-0.063	0.013	0.205
Loneliness → SROH				
Loneliness W4 → SROH W5	0.164	0.122	0.206	<0.001
Loneliness W6 → SROH W7	0.102	0.060	0.144	<0.001
SROH → Loneliness				
SROH W3 → Loneliness W4	0.421	0.305	0.538	<0.001
SROH W5 → Loneliness W6	0.152	0.055	0.249	0.002
SROH → Wealth				
SROH W3 → Wealth W5	-0.049	-0.100	0.002	0.062
SROH W5 → Wealth W7	0.002	-0.041	0.045	0.935
Indirect effects				
Wealth W3 to SROH W5				
Total effect	-0.136	-0.184	-0.088	<0.001
Total indirect effect	-0.036	-0.046	-0.026	<0.001
Wealth W3 → Loneliness W4 → SROH W5	-0.036	-0.046	-0.026	<0.001
Wealth W5 to SROH W7				
Total effect	-0.178	-0.223	-0.133	<0.001
Total indirect effect	-0.003	-0.007	0.001	0.214
Wealth W5 → Loneliness W6 → SROH W7	-0.003	-0.007	0.001	0.214
Proportion of total effects mediated (%)[§]				
Wealth W3 → Loneliness W4 → SROH W5	26.5			
Measuring Model Fit				
AIC[3]	207148.981			
BIC[4]	207487.225			
SABIC[5]	207341.043			

[1]Data set contains cases with missing on all variables that were not included in the analysis (n = 157); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (ab/(ab+c'), (MacKinnon, Warsi and Dwyer, 1995)

Table 7.8 Adjusted auto-regressive cross-lagged pathway model for self-rated oral health via social isolation (*n* = 11,486[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[2] → Wealth				
Wealth W3 → Wealth W5	0.866	0.855	0.878	<0.001
Wealth W5 → Wealth W7	1.090	0.957	1.223	<0.001
SROH → SROH				
SROH W3 → SROH W5	2.112	1.958	2.267	<0.001
SROH W5 → SROH W7	2.138	1.993	2.282	<0.001
Social isolation → Social isolation				
Social isolation W4 → Social isolation W6	0.891	0.774	1.009	<0.001
Direct effects				
Wealth → SROH				
Wealth W3 → SROH W5	-0.092	-0.143	-0.042	0.001
Wealth W5 → SROH W7	-0.161	-0.208	-0.114	<0.001
Wealth → Social isolation				
Wealth W3 → Social isolation W4	-0.276	-0.296	-0.257	<0.001
Wealth W5 → Social isolation W6	-0.054	-0.087	-0.020	0.002
Social isolation → SROH				
Social isolation W4 → SROH W5	0.149	0.089	0.209	<0.001
Social isolation W6 → SROH W7	0.132	0.075	0.190	<0.001
SROH → Social isolation				
SROH W3 → Social isolation W4	0.267	0.186	0.347	<0.001
SROH W5 → Social isolation W6	0.019	-0.045	0.082	0.565
SROH → Wealth				
SROH W3 → Wealth W5	-0.049	-0.101	0.003	0.063
SROH W5 → Wealth W7	0.002	-0.041	0.045	0.938
Indirect effects				
Wealth W3 to SROH W5				
Total effect	-0.134	-0.181	-0.086	<0.001
Total indirect effect	-0.041	-0.058	-0.027	<0.001
Wealth W3 → Social isolation W4 → SROH W5	-0.041	-0.058	-0.027	<0.001
Wealth W3 to SROH W7				
Total effect	-0.168	-0.214	-0.122	<0.001
Total indirect effect	-0.007	-0.012	-0.002	0.009
Wealth W5 → Social isolation W6 → SROH W7	-0.007	-0.012	-0.002	0.009
Proportion of total effects mediated (%)§				
Wealth W3 → Social isolation W4 → SROH W5	30.6			
Wealth W5 → Social isolation W6 → SROH W7	4.2			
Measuring Model Fit				
AIC[3]	194098.488			
BIC[4]	194436.536			
SABIC[5]	194290.354			

[1]Data set contains cases with missing on all variables that were not included in the analysis (*n* = 206); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; §The proportion of the total effect that is mediated: (ab/(ab+c'), (MacKinnon, Warsi and Dwyer, 1995)

7.4.4 SEM results for longitudinal mediation models assessing oral health-related quality of life

Total effects of wealth on later OHRQoL inclusive of the indirect pathways were in the expected direction and statistically significant in both models. Greater wealth at wave 3 was associated with a lower probability of poor later OHRQoL at wave 5 via all represented direct and indirect pathways linking wealth (wave 3) and OHRQoL (wave 5). Similarly, greater wealth at wave 5 was associated with a lower probability of poor later OHRQoL at wave 7 via all represented direct and indirect pathways linking wealth (wave 5) and OHRQoL (wave 7) (Figures 7.11 and 7.12, Tables 7.9 and 7.10).

Mediation via loneliness

The direct effect of wealth on poor OHRQoL suggests that greater wealth was associated with a lower probability of poor OHRQoL at later waves. Greater wealth at wave 5 was associated with a lower probability of poor later OHRQoL at wave 5 (B -0.12, 95% CI -0.18, -0.06), and greater wealth at wave 5 was associated with a lower probability of poor later OHRQoL at wave 7 (B -0.22, 95% CI -0.28, -0.16) independent of loneliness.

The direct effect of loneliness on later OHRQoL was in the expected direction and statistically significant – higher levels of loneliness at wave 4 was associated with a higher probability of later poor OHRQoL at wave 5 (B 0.19, 95% CI 0.15, 0.24), and higher levels of loneliness at wave 6 was associated with a higher probability of later poor OHRQoL at wave 7 (B 0.15, 95% CI 0.10, 0.20) (Figure 7.11, Table 7.9).

Overall, indirect pathways suggest that loneliness mediated wealth inequalities in OHRQoL, however there were notable differences between effect estimates for some pathways. Loneliness explained 26.2% of the total effects of wealth at wave 3 on OHRQoL at wave 5. However, loneliness did not mediate the total effects of wealth at wave 5 on OHRQoL at wave 7.

Cross-lagged associations were only seen between loneliness and OHRQoL and were in the expected direction. Poor OHRQoL at waves 3 and 5 were associated with a higher level of loneliness at waves 4 and 6; and higher levels of loneliness at waves 4 and 6 were associated with a higher probability of poor OHRQoL at waves 5 and 7. Generally, paths from OHRQoL on loneliness were larger in magnitude than the paths in the opposite direction. There were no bidirectional associations between wealth and OHRQoL.

Mediation via social isolation

The direct effect of wealth on poor OHRQoL suggests that higher levels of wealth were associated with a lower probability of poor later OHRQoL at wave 5 (B: -0.13, 95% CI -0.20, -0.07) and wave 7 (B: -0.23, 95% CI -0.29, -0.17) (Figure 7.12, Table 7.10).

Higher levels of social isolation at wave 4 were associated with a higher probability of poor later OHRQoL at wave 5 (B 0.12, 95 % CI 0.04-0.19), and higher levels of social isolation at wave 6 were associated with a greater probability of poor later OHRQoL at wave 7 (B 0.07, 95% CI 0.001-0.15).

Overall, indirect pathways suggest that social isolation mediated wealth inequalities in OHRQoL, with some differences. Social isolation explained almost 20% of the total effects of wealth at wave 3 on OHRQoL at wave 5. However social isolation did not mediate the total effects of wealth at wave 5 on OHRQoL at wave 7.

Cross-lagged associations were only seen between social isolation and OHRQoL, and these were in the expected direction. Poor OHRQoL at waves 3 and 5 was associated with higher levels of social isolation at waves 4 and 6, and higher levels of social isolation at wave 4 was associated with a greater probability of poor later OHRQoL at wave 5. However, higher levels of social isolation at wave 6 was associated with a lower probability of poor later OHRQoL at wave 7, although this path was not statistically significant. Generally, paths from OHRQoL on social isolation were larger in magnitude than the paths in the opposite direction. With one exception, the path from social isolation at wave 6 on OHRQoL at wave 7 was slightly larger in magnitude than that from OHRQoL at wave 5 on social isolation at wave 6. There were no bidirectional associations between wealth and OHRQoL.

Summary of SEM results for OHRQoL

In summary, loneliness and social isolation partially mediated the association between wealth at wave 3 and later OHRQoL at wave 5 only. Secondly, a bidirectional effect between OHRQoL and social relationships was observed. However, the magnitude of the association between OHRQoL and loneliness and from OHRQoL social isolation was larger than in the opposite direction. No bidirectional association was found between poor OHRQoL and wealth.

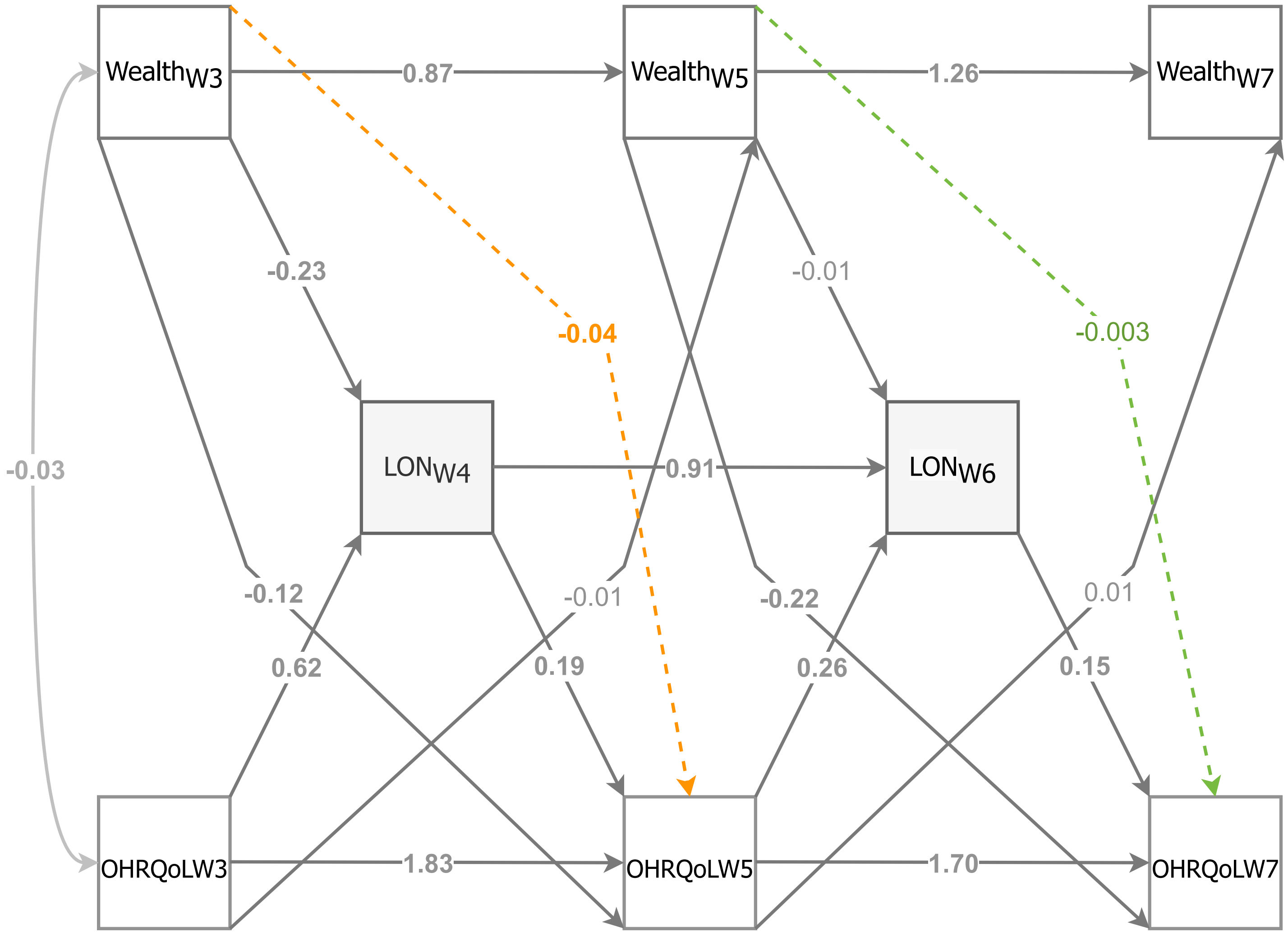

Figure 7.11 Adjusted cross-lagged pathways model for OHRQoL via loneliness (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = poorest, quintile 5 = wealthiest; Oral health-related quality of life (OHRQoL): 0 = no impact on daily performance 1= at least one oral impact on daily performance; Loneliness (LON) = continuous scale (3-9); blue dashed lines = indirect pathways a_1b_1, a_2b_2, and a_3b_3; orange dashed lines = indirect pathways a_1b_2 and a_3b_4; green dashed line = indirect pathways a_2b_3 and a_4b_5

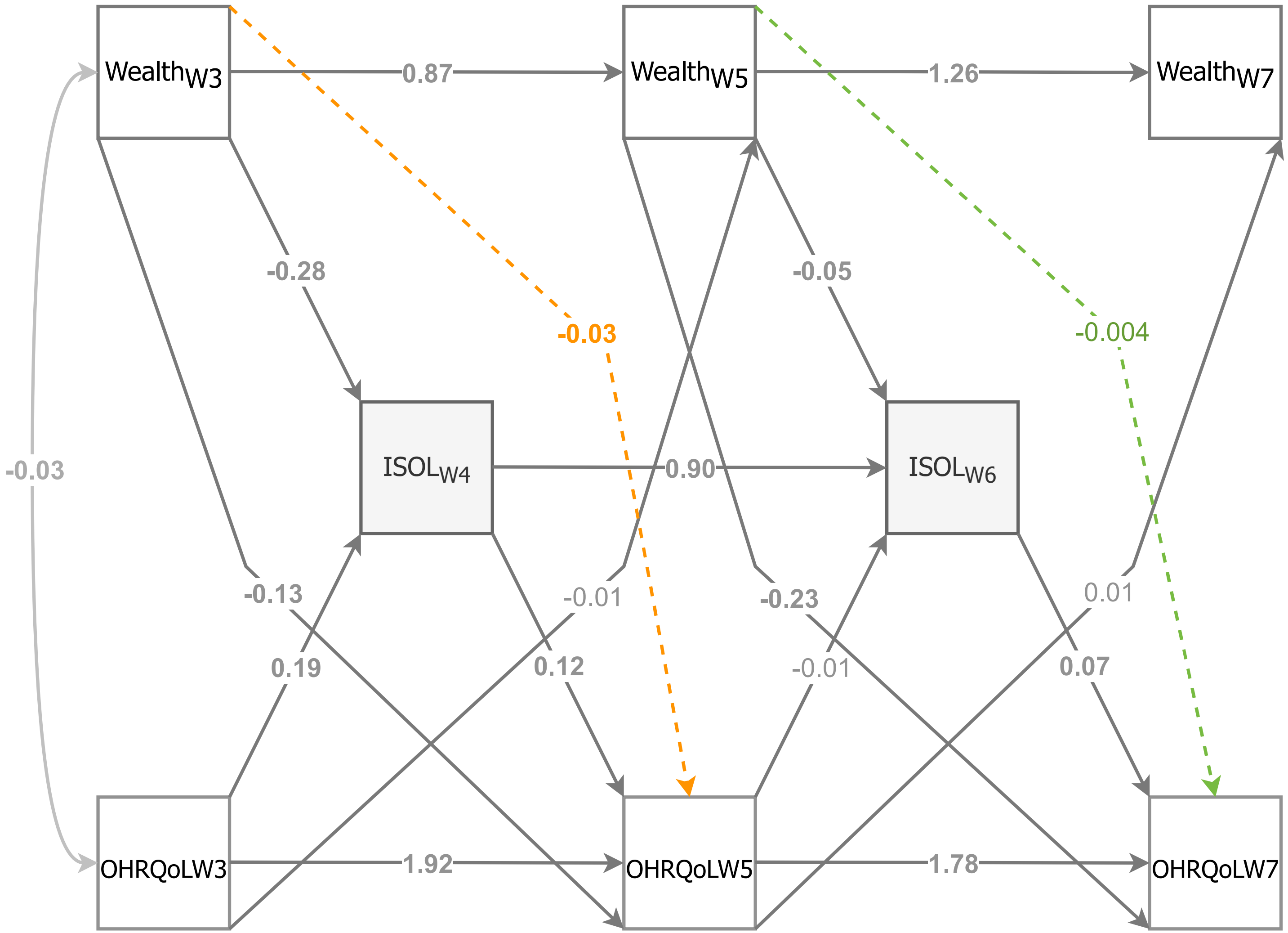

Figure 7.12 Adjusted cross-lagged pathways model for OHRQoL via social isolation (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth (Wealth): quintile 1 = poorest, quintile 5 = wealthiest; Oral health-related quality of life (OHRQoL): 0 = no impact on daily performance 1= at least one oral impact on daily performance; Social isolation (ISOL) = continuous scale (0-6); blue dashed lines = indirect pathways a_1b_1, a_2b_2, and a_3b_3; orange dashed lines = indirect pathways a_1b_2 and a_3b_4; green dashed line = indirect pathways a_2b_3 and a_4b_5

Table 7.9 Adjusted auto-regressive cross-lagged pathway model for oral health-related quality of life via loneliness (n = 11,535[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[2] → Wealth				
Wealth W3 → Wealth W5	0.869	0.858	0.880	<0.001
Wealth W5 → Wealth W7	1.257	1.055	1.460	<0.001
OHRQoL → OHRQoL				
OHRQoL W3 → OHRQoL W5	1.825	1.610	2.041	<0.001
OHRQoL W5 → OHRQoL W7	1.696	1.501	1.890	<0.001
Loneliness → Loneliness				
Loneliness W4 → Loneliness W6	0.913	0.770	1.057	<0.001
Direct effects (Longitudinal)				
Wealth → OHRQoL				
Wealth W3 → OHRQoL W5	-0.120	-0.180	-0.061	<0.001
Wealth W5 → OHRQoL W7	-0.220	-0.278	-0.162	<0.001
Wealth → Loneliness				
Wealth W3 → Loneliness W4	-0.225	-0.251	-0.199	<0.001
Wealth W5 → Loneliness W6	-0.009	-0.046	0.028	0.636
Loneliness → OHRQoL				
Loneliness W4 → OHRQoL W5	0.193	0.146	0.240	<0.001
Loneliness W6 → OHRQoL W7	0.150	0.101	0.199	<0.001
OHRQoL → Loneliness				
OHRQoL W3 → Loneliness W4	0.617	0.457	0.777	<0.001
OHRQoL W5 → Loneliness W6	0.261	0.136	0.386	<0.001
OHRQoL → Wealth				
OHRQoL W3 → Wealth W5	-0.012	-0.078	0.055	0.730
OHRQoL W5 → Wealth W7	0.009	-0.042	0.060	0.737
Indirect effects (Longitudinal)				
Wealth W3 to OHRQoL W5				
Total effect	-0.164	-0.222	-0.105	<0.001
Total indirect effect	-0.043	-0.055	-0.032	<0.001
Wealth W3 → Loneliness W4 → OHRQoL W5	-0.043	-0.055	-0.032	<0.001
Wealth W5 to OHRQoL W6				
Total effect	-0.221	-0.280	-0.163	<0.001
Total indirect effect	-0.001	-0.007	0.004	0.637
Wealth W5 → Loneliness W6 → OHRQoL W7	-0.001	-0.007	0.004	0.637
Proportion of total effects mediated (%)[§]				
Wealth W3 → Loneliness W4 → OHRQoL W5	26.2			
Measuring Model Fit				
AIC[3]	197828.999			
BIC[4]	198167.243			
SABIC[5]	198021.061			

[1]Data set contains cases with missing on all variables that were not included in the analysis (n = 157); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (ab/(ab+c'), (MacKinnon, Warsi and Dwyer, 1995)

Table 7.10 Adjusted auto-regressive cross-lagged pathway model for oral health-related quality of life via social isolation (*n* = 11,486[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[2] → Wealth				
Wealth W3 → Wealth W5	0.868	0.857	0.880	<0.001
Wealth W5 → Wealth W7	1.257	1.053	1.460	<0.001
OHRQoL → OHRQoL				
OHRQoL W3 → OHRQoL W5	1.915	1.702	2.128	<0.001
OHRQoL W5 → OHRQoL W7	1.775	1.584	1.966	<0.001
Social isolation → Social isolation				
Social isolation W4 → Social isolation W6	0.904	0.780	1.029	<0.001
Direct effects (Longitudinal)				
Wealth → OHRQoL				
Wealth W3 → OHRQoL W5	-0.134	-0.196	-0.072	<0.001
Wealth W5 → OHRQoL W7	-0.234	-0.294	-0.173	<0.001
Wealth → Social isolation				
Wealth W3 → Social isolation W4	-0.283	-0.302	-0.263	<0.001
Wealth W5 → Social isolation W6	-0.052	-0.086	-0.017	0.003
Social isolation → OHRQoL				
Social isolation W4 → OHRQoL W5	0.115	0.043	0.188	0.002
Social isolation W6 → OHRQoL W7	0.073	0.001	0.145	0.046
OHRQoL → Social isolation				
OHRQoL W3 → Social isolation W4	0.191	0.079	0.304	0.001
OHRQoL W5 → Social isolation W6	-0.005	-0.084	0.074	0.901
OHRQoL → Wealth				
OHRQoL W3 → Wealth W5	-0.014	-0.081	0.053	0.692
OHRQoL W5 → Wealth W7	0.011	-0.040	0.062	0.673
Indirect effects (Longitudinal)				
Wealth W3 to OHRQoL W5				
Total effect	-0.166	-0.225	-0.108	<0.001
Total indirect effect	-0.033	-0.053	-0.012	0.002
Wealth W3 → Social isolation W4 → OHRQoL W5	-0.033	-0.053	-0.012	0.002
Wealth W5 to OHRQoL W7				
Total effect	-0.237	-0.297	-0.178	<0.001
Total indirect effect	-0.004	-0.008	0.001	0.097
Wealth W5 → Social isolation W6 → OHRQoL W7	-0.004	-0.008	0.001	0.097
Proportion of total effects mediated (%)[§]				
Wealth W3 → Social isolation W4 → OHRQoL W5	19.9			
Measuring Model Fit				
AIC[3]	184887.046			
BIC[4]	185225.095			
SABIC[5]	185078.912			

[1]Data set contains cases with missing on all variables that were not included in the analysis (*n* = 206); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (ab/(ab+c'), (MacKinnon, Warsi and Dwyer, 1995)

7.4.5 SEM results for longitudinal mediation models assessing edentulousness

The total effects of wealth on later edentulousness inclusive of the indirect pathways via loneliness and social isolation, were in the expected direction and statistically significant in both models. Greater wealth at wave 3 was associated with a lower probability of later edentulousness at wave 5 via all represented direct and indirect pathways. Similarly, greater wealth at wave 4 was associated with a lower probability of later edentulousness at wave 6 via all represented direct and indirect pathways. Since these total effects are decomposed into direct and indirect paths, these are discussed below (Figures 7.13 and 7.14, Tables 7.11 and 7.12).

Mediation via loneliness

Direct paths between wealth and edentulousness were in the expected direction – greater levels of wealth at wave 3 was associated with a lower probability of later edentulousness at wave 5 (B -0.29, 95% CI -0.37, -0.20), and greater levels of wealth at wave 5 was associated with a lower probability of later at wave 7 (B -0.23, 95% CI -0.27, -0.19) (Figure 7.13, and Table 7.11).

No indirect mediating pathways were found from wealth on later edentulousness via loneliness.

Cross-lagged associations (Edentulousness ↔ Loneliness; Edentulousness ↔ Wealth) were mixed. No associations were found between loneliness and edentulousness in both directions. However, there was some evidence to support a bidirectional association between wealth and edentulousness. Greater wealth at waves 3 and 5 were associated with a lower probability of edentulousness at waves 5 and 7, and edentulousness at waves 3 and 5 was associated with lower levels of wealth at wave 5 and 7. However the pathway from edentulousness at wave 5 on wealth at wave 7 was not statistically significant.

Mediation via social isolation

Direct paths between wealth and edentulousness were in the expected direction – greater levels of wealth at wave 3 were associated with a lower probability of later edentulousness at wave 5 (B -0.31, 95% CI -0.40, -0.22), and greater wealth at wave 5 was associated with a lower probability of later edentulousness at wave 7 (B -0.22, 95% CI -0.26, -0.18) (Figure 7.14, Table 7.12).

Mixed findings were observed for associations between social isolation and later edentulousness. Higher levels of social isolation at wave 4 were associated with a lower probability of edentulousness at wave 5, however this association was not statistically significant. Higher levels of social isolation at wave 6 were associated with a greater probability of edentulousness at wave 7 (B 0.06, 95% CI 0.08-0.11).

Overall, social isolation did not mediate the wealth-edentulousness association. However, it is worth noting one potentially mediating pathway, albeit a weak association, from wealth at wave 5 on a lower probability of later edentulousness at wave 7 (B: -0.003, 95% CI -0.006, 0.000; p = 0.06). Although, this explained less than 5% of the total effects of wealth at wave 5 on edentulousness at wave 7.

There was some evidence for cross-lagged associations (Edentulousness ↔ Social Isolation; Edentulousness ↔ Wealth). Edentulousness at wave 5 was associated with greater social isolation at wave 6, and social isolation at wave 6 was associated with greater probability of edentulousness at wave 7. Wealth at waves 3 and 5 was associated with a lower probability of edentulousness at waves 5 and 7, and edentulousness at waves 3 and 5 was associated with lower levels of wealth at waves 5 and 7, however the pathway from edentulousness at wave 5 on wealth at wave 7 was not statistically significant.

Summary of SEM results for edentulousness

Overall, loneliness and social isolation did not explain wealth inequalities in edentulousness. However, there might be some evidence of mediation by social isolation, although the contribution was very modest at 1.4% of the total effects (Wealth W5 → Social isolation W6 → Edentulousness W7). Some caution is needed in extrapolating this result as the effect estimate was small and *p* = 0.06. Secondly, only a bidirectional effect between edentulousness and social isolation was observed. However, the magnitude of the association between edentulousness and social isolation was larger than in the opposite direction. Furthermore, a bidirectional association between edentulousness and wealth was also observed, however, the pathway from wealth to edentulousness was larger in magnitude than in the opposite direction. As seen in previous models, wealth remained a persistent and strong predictor of edentulousness.

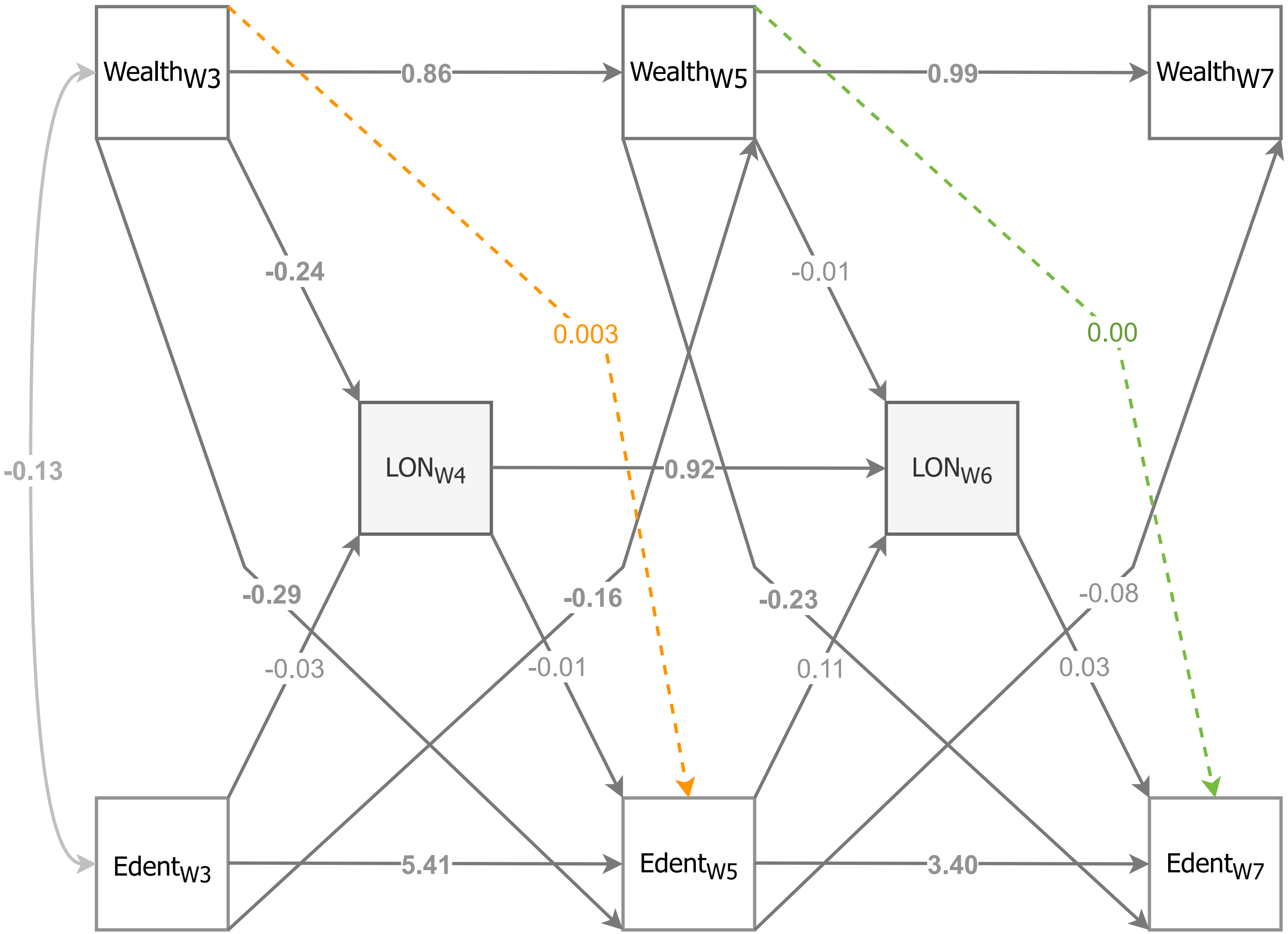

Figure 7.13 Adjusted cross-lagged pathways model for edentulousness via loneliness (bold values p<0.05; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth: quintile 1 = poorest, quintile 5 = wealthiest; Edentulousness (Edent): 0 = dentate 1= edentate; Loneliness (LON) = continuous scale (3-9); blue dashed lines = indirect pathways a_1b_1, a_2b_2, and a_3b_3; orange dashed lines = indirect pathways a_1b_2 and a_3b_4; green dashed line = indirect pathways a_2b_3 and a_4b_5

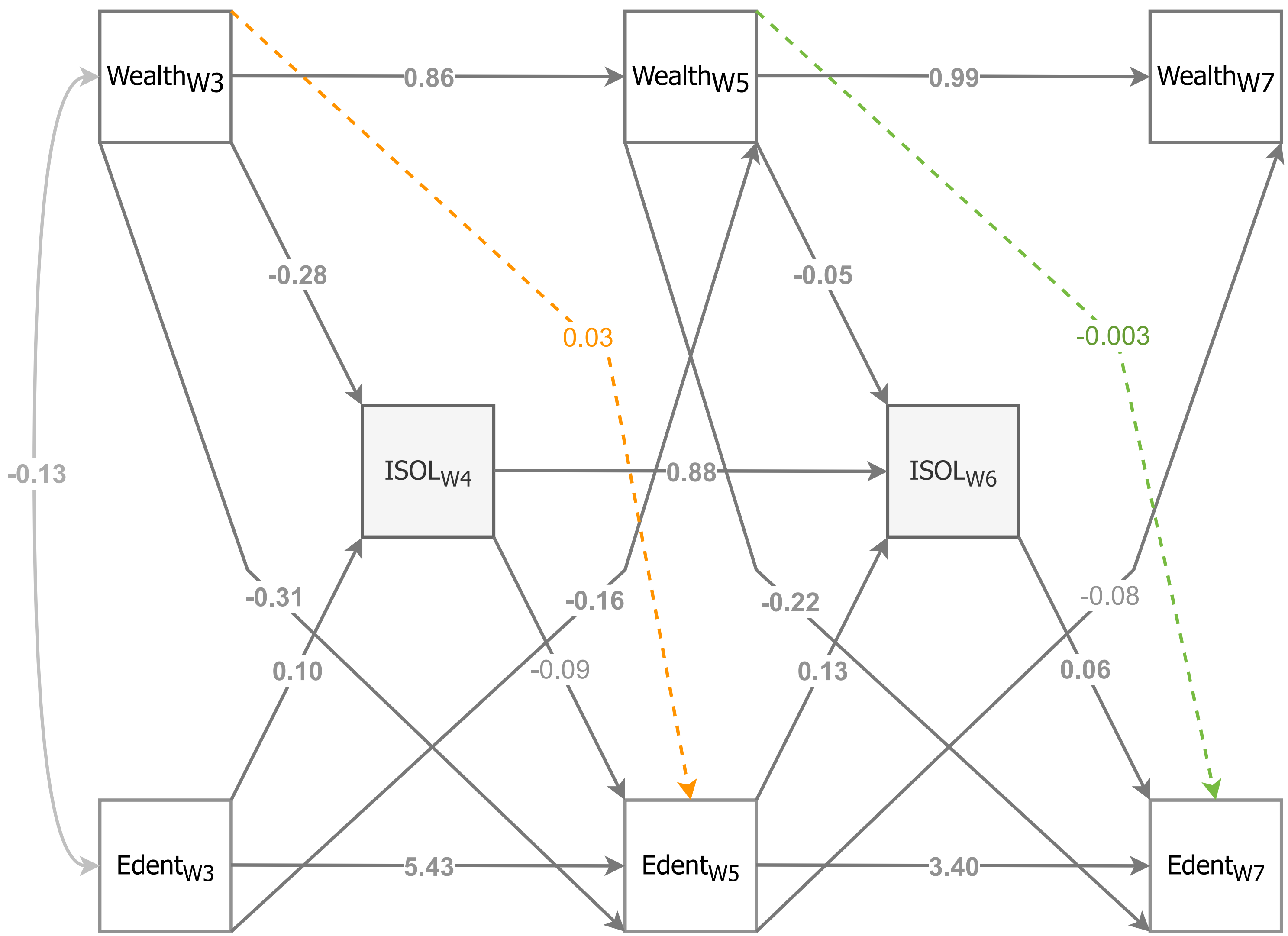

Figure 7.14 Adjusted cross-lagged pathways model for edentulousness via social isolation (bold values $p<0.05$; dashed lines indicate indirect effects)

Model adjusted for baseline age and sex; Household non-pension wealth: quintile 1 = poorest, quintile 5 = wealthiest; Edentulousness (Edent): 0 = dentate 1= edentate; Social isolation (ISOL) = continuous scale (0-6); blue dashed lines = indirect pathways a_1b_1, a_2b_2, and a_3b_3; orange dashed lines = indirect pathways a_1b_2 and a_3b_4; green dashed line = indirect pathways a_2b_3 and a_4b_5

Table 7.11 Adjusted auto-regressive cross-lagged pathway model for edentulousness via loneliness (*n* = 11,535[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[2] → Wealth				
Wealth W3 → Wealth W5	0.860	0.848	0.872	<0.001
Wealth W5 → Wealth W7	0.991	0.873	1.109	<0.001
Edentulousness → Edentulousness				
Edentulousness W3 → Edentulousness W5	5.412	5.131	5.694	<0.001
Edentulousness W5 → Edentulousness W7	3.399	3.069	3.729	<0.001
Loneliness → Loneliness				
Loneliness W4 → Loneliness W6	0.920	0.747	1.093	<0.001
Direct effects (Longitudinal)				
Wealth → Edentulousness				
Wealth W3 → Edentulousness W5	-0.288	-0.372	-0.204	<0.001
Wealth W5 → Edentulousness W7	-0.228	-0.267	-0.188	<0.001
Wealth → Loneliness				
Wealth W3 → Loneliness W4	-0.237	-0.264	-0.210	<0.001
Wealth W5 → Loneliness W6	-0.008	-0.050	0.035	0.725
Loneliness → Edentulousness				
Loneliness W4 → Edentulousness W5	-0.013	-0.095	0.070	0.763
Loneliness W6 → Edentulousness W7	0.032	-0.005	0.069	0.089
Edentulousness → Loneliness				
Edentulousness W3 → Loneliness W4	-0.034	-0.162	0.094	0.605
Edentulousness W5 → Loneliness W6	0.109	-0.005	0.223	0.062
Edentulousness → Wealth				
Edentulousness W3 → Wealth W5	-0.162	-0.215	-0.109	<0.001
Edentulousness W5 → Wealth W7	-0.077	-0.177	0.023	0.134
Indirect effects (Longitudinal)				
Wealth W3 to Edentulousness W5				
Total effect	-0.285	-0.368	-0.202	<0.001
Total indirect effect	0.003	-0.017	0.023	0.762
Wealth W3 → Loneliness W4 → Edentulousness W5	0.003	-0.017	0.023	0.762
Wealth W5 to Edentulousness W7				
Total effect	-0.228	-0.267	-0.189	<0.001
Total indirect effect	0.000	-0.002	0.001	0.729
Wealth W5 → Loneliness W6 → Edentulousness W7	0.000	-0.002	0.001	0.729
Measuring Model Fit				
AIC[3]	202976.378			
BIC[4]	203314.623			
SABIC[5]	203168.440			

[1]Data set contains cases with missing on all variables that were not included in the analysis (*n* = 157); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC

Table 7.12 Adjusted auto-regressive cross-lagged pathway model for edentulousness via social isolation (*n* = 11,486[1])

	Estimate (B)	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[2] → Wealth				
Wealth W3 → Wealth W5	0.860	0.848	0.872	<0.001
Wealth W5 → Wealth W7	0.989	0.870	1.108	<0.001
Edentulousness → Edentulousness				
Edentulousness W3 → Edentulousness W5	5.425	5.141	5.709	<0.001
Edentulousness W5 → Edentulousness W7	3.395	3.065	3.726	<0.001
Social isolation → Social isolation				
Social isolation W4 → Social isolation W6	0.877	0.747	1.008	<0.001
Direct effects (Longitudinal)				
Wealth → Edentulousness				
Wealth W3 → Edentulousness W5	-0.311	-0.403	-0.220	<0.001
Wealth W5 → Edentulousness W7	-0.218	-0.259	-0.177	<0.001
Wealth → Social isolation				
Wealth W3 → Social isolation W4	-0.282	-0.302	-0.262	<0.001
Wealth W5 → Social isolation W6	-0.052	-0.088	-0.017	0.004
Social isolation → Edentulousness				
Social isolation W4 → Edentulousness W5	-0.089	-0.201	0.022	0.117
Social isolation W6 → Edentulousness W7	0.058	0.008	0.107	0.022
Edentulousness → Social isolation				
Edentulousness W3 → Social isolation W4	0.103	0.005	0.200	0.039
Edentulousness W5 → Social isolation W6	0.125	0.046	0.204	0.002
Edentulousness → Wealth				
Edentulousness W3 → Wealth W5	-0.164	-0.217	-0.111	<0.001
Edentulousness W5 → Wealth W7	-0.078	-0.179	0.022	0.127
Indirect effects (Longitudinal)				
Wealth W3 to Edentulousness W5				
Total effect	-0.286	-0.370	-0.203	<0.001
Total indirect effect	0.025	-0.006	0.057	0.116
Wealth W3 → Social isolation W4 → Edentulousness W5	0.025	-0.006	0.057	0.116
Wealth W5 to Edentulousness W7				
Total effect	-0.221	-0.262	-0.181	<0.001
Total indirect effect	-0.003	-0.006	0.000	0.061
Wealth W5 → Social isolation W6 → Edentulousness W7	-0.003	-0.006	0.000	0.061
Proportion of total effects mediated (%)[§]				
Wealth W5 → Social isolation W6 → Edentulousness W7	1.4			
Measuring Model Fit				
AIC[3]	189811.705			
BIC[4]	190149.754			
SABIC[5]	190003.571			

[1]Data set contains cases with missing on all variables that were not included in the analysis (*n* = 206); [2]Household non-pension wealth; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (ab/(ab+c'), (MacKinnon, Warsi and Dwyer, 1995)

7.5 Summary of longitudinal SEM results

This chapter examined the mediating role of social isolation and loneliness in explaining wealth inequalities in the following health outcomes: SRH, systolic blood pressure, SROH, OHRQOL and edentulousness using autoregressive CLPM.

The descriptive statistics show that the mean social isolation score remained similar across all waves – although there was a slight increase in the mean score at waves 5 and 6 at 1.8. Similarly, the mean loneliness score was the same across all waves – 4.2 across waves 3 to 6. The mean age for both longitudinal samples was also very similar: 66 years and 65 years for the waves 2 to 6 and waves 3 to 7 samples, respectively. Mean systolic blood pressure reduced slight across waves from 136 mm HG at wave 2 to 135 mm HG at wave 6.

The autoregressive coefficients for household non-pension wealth, health outcomes and social relationship measures show that these measures positively predicted themselves over time and that individual differences in these constructs were relatively stable between waves of measurement.

Throughout this study, wealth remained a strong predictor of poor health for most health outcomes independent of the indirect effects through loneliness and social isolation. With one exception: there was little support for an association between wealth and later systolic blood pressure. Wealth also predicted later levels of loneliness and social isolation, such that with greater advantage respondents experienced lower levels of loneliness and social isolation.

Direct effects have been established between loneliness, social isolation, and SRH, SROH, OHRQoL and edentulousness. With one exception: only social isolation was associated with later edentulousness. As expected, higher levels of loneliness and social isolation were associated with poorer later health.

There was some, albeit mixed evidence, that social relationships mediate associations between wealth and later health outcomes in three of the five health outcomes: SRH, SROH and OHRQoL. There appears to be a questionable mediating role of social isolation in explaining wealth inequalities in edentulousness. It is possible that loneliness and social isolation play a more important role in mediating subjective rather than objective health outcomes. Of the social relationship measures examined in this study, both loneliness and social isolation appeared to play similarly important roles in explaining wealth inequalities in health (Table 7.13).

Table 7.13 Percentage of total effect mediated by loneliness and social isolation

	Loneliness (%)	Social isolation (%)
SRH		
Wealth W2 → SRH W4	9.5	9.3
Wealth W4 → SRH W6	-	7.0
SBP		
Wealth W2 → SBP W4	-	-
Wealth W4 → SBP W6	-	-
SROH		
Wealth W3 → SROH W5	26.5	30.6
Wealth W5 → SROH W7	-	4.2
OHRQoL		
Wealth W3 → OHRQoL W5	26.2	19.9
Wealth W5 → OHRQoL W7	-	-
Edentulousness		
Wealth W3 → Edentulousness W5	-	-
Wealth W5 → Edentulousness W7	-	(1.4%)

As expected, greater wealth was associated with better health 4 years later, therefore supporting well established literature on social causation, i.e., that socioeconomic position influences health (Letelier *et al.*, 2022). Interestingly, there was, albeit limited evidence for an effect in the reverse direction – that poor health may influence later wealth, i.e., health selection. SRH, systolic blood pressure and edentulousness were associated with lower levels of later wealth, although generally, the association from wealth to poor later health was stronger than in the opposite direction. With one exception: the association between increasing systolic blood pressure and lower levels of later wealth was stronger than wealth on later systolic blood pressure. It is possible that a feedback loop mechanism may be playing a role (at least for SRH and edentulousness) as suggested in the Conceptual Framework for Social Determinants of Health (Solar and Irwin, 2010) – it is reasonable to expect that if lower wealth is associated with poorer health, then poorer health may affect an individual's level of wealth. It is also plausible that poor health may impact later wealth because of moving out of the labour market e.g., early retirement.

Cross-lagged effects of social relationships and health were more consistent than the bidirectional association between wealth and health. A bidirectional association was established for four of the five health outcomes: SRH, SROH, OHRQoL and edentulousness. Generally, the paths from health to later loneliness and social isolation were stronger than the paths in the opposite direction.

Chapter 8. Do social relationships moderate social inequalities in health?

8.1 Introduction

The systematic review provided some evidence to support the hypothesis of social relationships buffering the negative effects of socioeconomic disadvantage on health outcomes. However, some studies reported moderation in the opposite direction to what was expected, i.e., the association between socioeconomic position and health being stronger (more inequality) in the presence of better social relationships. The systematic review also highlighted two main gaps with regards to assessing to role of social relationships in moderating social inequalities in health: firstly, the dearth of studies assessing moderation longitudinally and secondly the lack of studies looking at these associations among older adults in the UK.

This chapter presents the results of regression analyses exploring whether loneliness, social isolation, positive and negative social support moderate socioeconomic inequalities in health outcomes (systolic blood pressure, SRH, SROH, OHRQoL and edentulousness) (Objective 6).

8.2 Methods – cross-sectional moderation

To begin with, the moderating role of loneliness, social isolation, positive and negative social support on the association with household non-pension wealth and health was assessed cross-sectionally at waves 2 and 3. Since earlier cross-sectional analyses (Chapter 6) revealed steepest social gradients by wealth, it was decided to take this forward as a marker of socioeconomic position in the analysis pertaining to this chapter. Exploring moderation cross-sectionally was a cross-sectional step to ascertain which social relationships measures should be assessed for their buffering role in the wealth-health association longitudinally. Sensitivity analyses carried out in chapter 5 revealed little difference in effect estimates between complete and imputed cases. Furthermore, there is currently no literature to support the use of 'substantive model compatible fully conditional specification' (SMCFCS) when estimating models in an imputed dataset where there is missingness on both variables within an interaction term (see Chapter 5, Section 5.7.4) Therefore, cross-sectional analyses were carried out on complete cases rather than an imputed dataset.

Firstly, crude models were fitted to the data followed by age- and sex-adjusted models. Secondly, interactions between wealth and social relationship measures were modelled using linear and logistic regression models for the health outcomes (SRH, systolic blood pressure, SROH, OHRQoL and edentulousness) as appropriate. Interactions were specified separately for each social relationship marker, therefore, there were four interaction models per outcome. Next, a Wald test was performed to test whether the interaction term was equal to zero. A non-significant ($p \geq 0.05$) interaction term strongly suggested that removing the interaction term from the model would not substantially reduce the fit of that model. Since analyses was done on survey data, the likelihood ratio (LR) test to compare nested models could not be used. The Wald test approximates the LR test, but with the advantage that it only requires estimating one model.

Analyses were performed in Stata MP Version 17.0, on complete cases with one sample each for systolic blood pressure (n = 4666) and self-rated health (n = 5902) and one sample for all three oral health outcomes (n = 5768).

The following models were specified:

1. Model 1: Crude model assessing the association between household non-pension wealth and health outcome
2. Model 2: Model 1 additionally adjusted for sex and age
3. Model 3a: Model 2 additionally adjusted for wealth*loneliness
4. Model 3b: Model 2 additionally adjusted for wealth*social isolation
5. Model 3c: Model 2 additionally adjusted for wealth*positive social support
6. Model 3d: Model 2 additionally adjusted for wealth*negative social support

The interaction between wealth and social relationship variables was specified using '##' in Stata. The '##' specifies a full factorial of the variable, i.e., main effects for each variable and the interaction.

Results from the cross-sectional analyses suggested that positive social support moderates the wealth-edentulousness association. Therefore, moderation by positive social support for the wealth-edentulousness association was assessed longitudinally using waves 3, 5 and 7.

8.3 Cross-sectional moderation analyses – waves 2 and 3

No meaningful interactions between wealth and social relationship measures were observed for SRH, systolic blood pressure, SROH or OHRQoL. Overall, there was no evidence that the association between wealth and systolic blood pressure, SRH, SROH, and OHRQoL differed by levels of loneliness, social isolation, positive social support, or negative social support (Tables 8.1 to 8.4).

Table 8.1 Logistic regression models predicting fair to poor SRH among participants at wave 2 (observed data) (*n* = 5908)

Variables	Model 1[1] OR (95% CI)	Model 2[1] OR (95% CI)	Model 3a[1] OR (95% CI)	Model 3b[1] OR (95% CI)	Model 3c[1] OR (95% CI)	Model 3d[1] OR (95% CI)
Wealth[2]						
4th quintile	1.54 (1.22-1.94)	1.52 (1.21-1.92)	1.89 (0.95-3.76)	1.48 (1.01-2.18)	1.38 (0.54-3.54)	1.14 (0.53-2.46)
3rd quintile	1.77 (1.41-2.22)	1.74 (1.39-2.19)	1.56 (0.80-3.04)	1.30 (0.89-1.91)	3.31 (1.38-7.97)	2.18 (1.01-4.73)
2nd quintile	3.46 (2.78-4.31)	3.40 (2.73-4.24)	4.14 (2.15-7.96)	2.61 (1.76-3.85)	4.06 (1.74-9.49)	3.17 (1.56-6.46)
Least wealthy	5.86 (4.68-7.35)	5.52 (4.39-6.93)	4.89 (2.50-9.54)	3.72 (2.40-5.75)	7.26 (3.08-17.10)	5.62 (2.74-11.50)
Covariates						
Age		1.02 (1.01-1.03)	1.02 (1.01-1.03)	1.02 (1.01-1.03)	1.02 (1.01-1.03)	1.03 (1.02-1.03)
Sex (Male)		1.17 (1.04-1.33)	1.25 (1.11-1.42)	1.15 (1.03-1.30)	1.17 (1.04-1.32)	1.15 (1.02-1.30)
Loneliness			1.35 (1.20-1.53)			
Wealth*Loneliness						
4th quintile			0.94 (0.79-1.10)			
3rd quintile			1.00 (0.86-1.17)			
2nd quintile			0.93 (0.80-1.08)			
Least wealthy			0.97 (0.84-1.13)			
Social isolation				1.10 (0.95-1.27)		
Wealth*Social isolation						
4th quintile				1.01 (0.83-1.22)		
3rd quintile				1.14 (0.95- 1.38)		
2nd quintile				1.11 (0.92-1.33)		
Least wealthy				1.13 (0.93-1.36)		
Positive social support					0.99 (0.97-1.01)	
Wealth*Positive support						
4th quintile					1.00 (0.98-1.03)	
3rd quintile					0.98 (0.96-1.00)	
2nd quintile					0.99 (0.97-1.02)	
Least wealthy					0.99 (0.96-1.01)	
Negative social support						1.03 (0.99-1.06)
Wealth*Negative support						
4th quintile						1.02 (0.98-1.06)
3rd quintile						0.99 (0.95-1.03)
2nd quintile						1.00 (0.97-1.04)
Least wealthy						1.00 (0.96-1.04)

[1]Models weighted for item non-response at wave 3; [2]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy)

Table 8.2 Linear regression models predicting systolic blood pressure among participants at wave 2 (observed data) (*n* = 4666)

Variables	Model 1[1] B (95% CI)	Model 2[1] B (95% CI)	Model 3a[1] B (95% CI)	Model 3b[1] B (95% CI)	Model 3c[1] B (95% CI)	Model 3d[1] B (95% CI)
Wealth[2]						
4th quintile	1.32 (-0.33, 2.97)	1.01 (-0.60, 2.62)	-0.30 (-5.43, 4.84)	-0.69 (-3.27, 1.91)	-2.12 (-9.21, 4.98)	0.78 (-4.80, 6.36)
3rd quintile	2.76 (0.99-4.53)	2.30 (0.58-4.01)	2.68 (-2.48, 7.84)	0.27 (-2.36, 2.90)	0.91 (-6.01, 7.83)	4.56 (-0.70, 9.81)
2nd quintile	3.25 (1.52-4.98)	2.66 (0.96-4.35)	4.20 (-0.96, 9.37)	1.21 (-1.63, 4.05)	2.21 (-4.72, 9.13)	3.76 (-1.49, 9.00)
Least wealthy	5.28 (3.30-7.26)	3.35 (1.40-5.30)	0.32 (-5.78, 6.42)	5.44 (1.05-9.83)	-2.04 (-9.69, 5.62)	3.14 (-2.54, 8.81)
Covariates						
Age		0.43 (0.36-0.49)	0.43 (0.36-0.50)	0.42 (0.35-0.49)	0.42 (0.35-0.49)	0.42 (0.35-0.49)
Sex (Male)		2.13 (1.05-3.21)	2.07 (0.98-3.16)	2.11 (1.03-3.19)	2.11 (1.04-3.19)	2.16 (1.07-3.24)
Loneliness			-0.35 (-1.29, 0.58)			
Wealth*Loneliness						
4th quintile			0.35 (-0.96, 1.66)			
3rd quintile			-0.07 (-1.32, 1.17)			
2nd quintile			-0.32 (-1.55, 0.90)			
Least wealthy			0.71 (-0.69, 2.12)			
Social isolation				-0.13 (-1.08, 0.82)		
Wealth*Social isolation						
4th quintile				1.09 (-0.29, 2.46)		
3rd quintile				1.20 (-0.15, 2.55)		
2nd quintile				0.77 (-0.61, 2.15)		
Least wealthy				-0.78 (-2.54, 0.97)		
Positive support					-0.10 (-0.24, 0.03)	
Wealth*Positive support						
4th quintile					0.09 (-0.11, 0.28)	
3rd quintile					0.04 (-0.16, 0.23)	
2nd quintile					0.01 (-0.19, 0.20)	
Least wealthy					0.16 (-0.07, 0.39)	
Negative support						0.01 (-0.19, 0.21)
Wealth*Negative support						
4th quintile						0.01 (-0.28, 0.31)
3rd quintile						-0.13 (-0.40, 0.14)
2nd quintile						-0.06 (-0.34, 0.21)
Least wealthy						0.02 (-0.30, 0.33)

[1]Models weighted for item non-response at wave 3; [2]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy)

Table 8.3 Logistic regression models predicting fair or poor SROH among participants at wave 3 (observed data) (*n* = 5768)

Variables	Model 1[1] OR (95% CI)	Model 2[1] OR (95% CI)	Model 3a[1] OR (95% CI)	Model 3b[1] OR (95% CI)	Model 3c[1] OR (95% CI)	Model 3d[1] OR (95% CI)
Wealth[2]						
4th quintile	1.18 (0.92-1.51)	1.20 (0.94-1.53)	0.87 (0.42-1.79)	1.02 (0.67-1.54)	0.95 (0.34-2.61)	2.09 (0.91-4.83)
3rd quintile	1.25 (0.99-1.59)	1.29 (1.02-1.64)	1.11 (0.56-2.20)	1.04 (0.68-1.59)	1.37 (0.53-3.51)	2.42 (1.09-5.39)
2nd quintile	1.90 (1.51-2.38)	1.94 (1.55-2.43)	2.30 (1.20-4.44)	1.39 (0.90-2.16)	1.86 (0.75-4.58)	3.81 (1.79-8.09)
Least wealthy	2.41 (1.90-3.04)	2.52 (1.99-3.20)	2.13 (1.07-4.23)	1.64 (0.99-2.70)	2.45 (1.00-5.99)	3.79 (1.79-8.03)
Covariates						
Age		0.99 (0.98-1.00)	0.99 (0.98-1.00)	0.99 (0.98-1.00)	0.99 (0.98-1.00)	0.99 (0.98-1.00)
Sex (Male)		1.30 (1.13-1.50)	1.37 (1.19-1.58)	1.28 (1.11-1.47)	1.27 (1.10-1.47)	1.29 (1.12-1.49)
Loneliness			1.18 (1.05-1.32)			
Wealth*Loneliness						
4th quintile			1.07 (0.91-1.26)			
3rd quintile			1.02 (0.88-1.18)			
2nd quintile			0.94 (0.82-1.09)			
Least wealthy			1.00 (0.87-1.15)			
Social isolation				1.11 (0.95-1.29)		
Wealth*Social isolation						
4th quintile				1.08 (0.88-1.34)		
3rd quintile				1.09 (0.89-1.35)		
2nd quintile				1.12 (0.92-1.38)		
Least wealthy				1.13 (0.92-1.39)		
Positive social support					0.98 (0.96-1.00)	
Wealth*Positive support						
4th quintile					1.01 (0.98-1.04)	
3rd quintile					0.98 (0.97-1.02)	
2nd quintile					1.00 (0.97-1.03)	
Least wealthy					1.00 (0.97-1.02)	
Negative social support						1.04 (1.01-1.08)
Wealth*Negative support						
4th quintile						0.97 (0.93-1.01)
3rd quintile						0.97 (0.93-1.01)
2nd quintile						0.96 (0.93-1.00)
Least wealthy						0.98 (0.94-1.02)

[1]Models weighted for item non-response at wave 3; [2]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy

Table 8.4 Logistic regression models predicting at least one oral impact among participants at wave 3 (observed data) (*n* = 5768)

Variables	Model 1[1] OR (95% CI)	Model 2[1] OR (95% CI)	Model 3a[1] OR (95% CI)	Model 3b[1] OR (95% CI)	Model 3c[1] OR (95% CI)	Model 3d[1] OR (95% CI)
Wealth[2]						
4th quintile	1.68 (1.21-2.34)	1.65 (1.19-2.29)	1.08 (0.41-2.85)	1.62 (0.93-2.82)	2.33 (0.62-8.70)	2.49 (0.78-7.97)
3rd quintile	1.26 (0.89-1.78)	1.24 (0.88-1.76)	0.68 (0.25-1.86)	1.22 (0.68-2.21)	2.50 (0.64-9.69)	1.95 (0.61-6.28)
2nd quintile	1.99 (1.44-2.74)	1.98 (1.43-2.73)	1.25 (0.49-3.21)	2.13 (1.14-3.97)	4.00 (1.12-14.33)	3.27 (1.08-9.92)
Least wealthy	2.42 (1.73-3.39)	2.33 (1.65-3.29)	0.91 (0.32-2.58)	1.74 (0.83-3.63)	3.26 (0.86-12.32)	3.77 (1.28-11.14)
Covariates						
Age		1.01 (1.00-1.02)	1.01 (1.00-1.02)	1.01 (1.00-1.02)	1.01 (1.00-1.02)	1.02 (1.01-1.04)
Sex (Male)		1.11 (0.91-1.36)	1.22 (1.00-1.50)	1.10 (0.90-1.36)	1.10 (0.90-1.35)	1.09 (0.89-1.34)
Loneliness			1.18 (0.99-1.39)			
Wealth*Loneliness						
4th quintile			1.10 (0.89-1.36)			
3rd quintile			1.12 (0.90-1.39)			
2nd quintile			1.08 (0.88-1.32)			
Least wealthy			1.15 (0.94-1.42)			
Social isolation				1.10 (0.88-1.38)		
Wealth*Social isolation						
4th quintile				1.00 (0.75-1.33)		
3rd quintile				0.99 (0.74-1.32)		
2nd quintile				0.93 (0.70-1.25)		
Least wealthy				1.07 (0.79-1.45)		
Positive social support					0.99 (0.96-1.02)	
Wealth*Positive support						
4th quintile					0.99 (0.95-1.03)	
3rd quintile					0.98 (0.94-1.02)	
2nd quintile					0.98 (0.94-1.01)	
Least wealthy					0.99 (0.95-1.03)	
Negative social support						1.06 (1.01-1.11)
Wealth*Negative support						
4th quintile						0.98 (0.92-1.04)
3rd quintile						0.98 (0.92-1.04)
2nd quintile						0.97 (0.92-1.03)
Least wealthy						0.98 (0.92-1.04)

[1]Models weighted for item non-response at wave 3; [2]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy)

8.4 Results from cross-sectional interaction between wealth and positive social support for edentulousness (wave 3)

Table 8.5 displays results for the effect of wealth on edentulousness when the interaction terms were fitted between wealth and social relationship measures. The Wald test was suggestive of a potential overall interaction effect between wealth and positive social support (p = 0.002). Models were therefore run, stratified by tertiles of positive social support – stratified results are presented in Table 8.6 and discussed below.

Overall, wealth inequality was higher among those with the most positive social support. Least wealthy respondents in the highest level of positive social support, i.e., upper tertile of positive social support, individuals had a 9.26 (95% CI 4.65-18.43) greater likelihood of experiencing total tooth loss than those in the wealthiest group.

Least wealthy individuals in the lowest level of positive social support reported experiencing just over 6 times greater odds (95% CI 3.83-9.69) of total tooth loss compared to the wealthiest respondents.

Overall, when looking at the stratified results, it appears that among individuals with more support the association between wealth and edentulousness was stronger (extent of inequality was greater). In other words, positive social support did not appear to buffer the negative affect of low affluence on dentate status for this group.

These cross-sectional results warranted further exploration longitudinally.

Table 8.5 Logistic regression models predicting edentulousness among participants at wave 3 (observed data) (*n* = 5768)

Variables	Model 1[1] OR (95% CI)	Model 2[1] OR (95% CI)	Model 3a[1] OR (95% CI)	Model 3b[1] OR (95% CI)	Model 3c[1] OR (95% CI)	Model 3d[1] OR (95% CI)
Wealth[2]						
4th quintile	2.24 (1.61-3.12)	1.99 (1.43-2.79)	2.98 (1.10-8.13)	1.64 (0.87-3.10)	1.06 (0.31-3.63)	1.58 (0.53-4.74)
3rd quintile	3.40 (2.49-4.65)	3.15 (2.29-4.34)	5.68 (2.23-14.46)	4.00 (2.21-7.26)	0.50 (0.15-1.66)	1.77 (0.62-5.07)
2nd quintile	6.06 (4.48-8.20)	6.23 (4.57-8.50)	12.00 (4.79-30.04)	8.41 (4.63-15.27)	1.05 (0.35-3.17)	3.27 (1.18-9.04)
Least wealthy	8.83 (6.52-11.98)	7.58 (5.5410.37)	11.64 (4.59-29.51)	5.96 (3.17-11.21)	3.33 (1.10-10.03)	5.48 (1.99-15.13)
Covariates						
Age		1.09 (1.08-1.10)	1.09 (1.08-1.10)	1.08 (1.07-1.09)	1.09 (1.08-1.10)	1.09 (1.08-1.10)
Sex (Male)		0.92 (0.79-1.09)	0.93 (0.79-1.09)	0.91 (0.78-1.07)	0.92 (0.78-1.08)	0.92 (0.78-1.08)
Loneliness			1.17 (0.97-1.40)			
Wealth*Loneliness						
4th quintile			0.90 (0.71-1.14)			
3rd quintile			0.86 (0.70-1.06)			
2nd quintile			0.85 (0.69-1.04)			
Least wealthy			0.89 (0.72-1.09)			
Social isolation				1.27 (1.02-1.60)		
Wealth*Social isolation						
4th quintile				1.06 (0.79-1.43)		
3rd quintile				0.85 (0.64-1.11)		
2nd quintile				0.81 (0.62-1.06)		
Least wealthy				1.00 (0.76-1.30)		
Positive social support					0.96 (0.94-0.99)	
Wealth*Positive support						
4th quintile					1.02 (0.98-1.06)	
3rd quintile					1.06 (1.02-1.09)	
2nd quintile					1.05 (1.02-1.09)	
Least wealthy					1.02 (0.99-1.06)	
Negative social support						0.98 (0.92-1.03)
Wealth*Negative support						
4th quintile						1.01 (0.95-1.08)
3rd quintile						1.03 (0.97-1.10)
2nd quintile						1.04 (0.98-1.10)
Least wealthy						1.02 (0.96-1.08)

[1]Models weighted for item non-response at wave 3; [2]Wealth = quintiles: 1 = 5th quintile (wealthiest)

Table 8.6 Logistic regression models predicting edentulousness among participants at wave 3: stratified by positive social support (observed data) (*n* = 5768)

Variables	Lower tertile of positive support[1] OR (95% CI)	Middle tertile of positive support[1] OR (95% CI)	Upper tertile of positive support[1] OR (95% CI)
Wealth[2]			
4th quintile	1.67 (0.96-2.91)	2.51 (1.44-4.36)	1.81 (0.95-3.44)
3rd quintile	2.20 (1.32-3.68)	2.63 (1.50-4.60)	5.39 (2.98-9.75)
2nd quintile	4.12 (2.56-6.63)	6.53 (3.83-11.15)	10.20 (5.51-18.89)
Least wealthy	6.09 (3.83-9.69)	7.28 (4.20-12.63)	9.26 (4.65-18.43)
Covariates			
Age	1.08 (1.07-1.09)	1.09 (1.07-1.11)	1.12 (1.09-1.14)
Sex (Male)	0.88 (0.68-1.14)	0.95 (0.71-1.27)	0.84 (0.61-1.16)

[1]Models weighted for item non-response at wave 3; [2]Wealth = quintiles: 1 = 5th quintile (wealthiest)

8.5 Longitudinal moderation analysis - edentulousness

The sample for longitudinal moderation analysis was previously described in Chapter 5 (Section 5.6.3). The initial sample consisted of 11,362 respondents that took part in ELSA in any of the following waves: 3, 5 and 7. In this sample, 4809 individuals had complete data. Therefore, some respondents dropped out at some point, never returning after missing a wave (monotone missingness) whereas others returned in the study (intermittent missingness) (Table 8.7).

Table 8.7 Missingness patterns at waves 3,5 and 7 (*n* = 11362)

Frequency	Percentage	Missingness pattern
4809	42.3	111
1880	16.6	1..
1726	15.2	.11
1263	11.1	11.
1044	9.2	..1
522	4.6	.1.
118	1.0	1.1

To understand whether social relationships buffered the negative effect of low wealth on edentulousness among individuals, random effects models were fitted to the data. In a longitudinal study, the responses for any one person over time are likely to be highly correlated. This correlation must be considered for a valid inference to be made. Random effects models allow covariances and correlations to vary between individuals.

Fitting random effects in Stata requires the dataset to be in long form. Once the data were converted to long form, a series of random effects models were fitted:

1. Model 1: null model, i.e., just the constant as a predictor for a random effects model that allows individuals to have randomly varying intercepts
2. Model 2: crude model modelling association between household non-pension wealth and edentulousness
3. Model 3: Model 2 additionally adjusted for sex and age

4. Model 3a: Model 3 additionally adjusted for social relationship variables[8]
5. Model 3b: Model 3 additionally adjusted for wealth*social relationship interaction[9]

For the longitudinal dataset, since survey weights were not implemented (See Chapter 5, Section 5.7), the likelihood ratio (LR) test was used to evaluate the difference between nested models, i.e., model 3a was nested in model 3b. The LR test compares the log likelihoods of the two models and tests whether this difference is statistically significant. Therefore, unlike the Wald test, the LR test required two models to be run, i.e., Model 3a and 3b, and then to compare them. Where the difference was found to be statistically significant ($p \geq 0.05$), then the less restrictive model (model 3b) was seen as a better fit for the data than the more restrictive model (model 3a).

Random effects models in Stata utilises maximum likelihood (ML) estimation for incomplete data such as these whereby all information for respondents is used. Thus, not only respondents who were present at all waves, but also those with missing data contribute information. If the model is specified correctly, ML estimates are consistent when the responses are missing at random (Rabe-Hesketh and Skrondal, 2012).

In random effects models, the effect estimates tend to be more extreme than those for ordinary logistic regression models. In an ordinary logistic model, the errors are assumed to have a standard logistic distribution, and the residual variance is fixed at $\pi^2/3 \sim 3.29$. However, in a random effects model, adding random effects increases the residual variance (estimated at 19.37), therefore, the coefficients of the other variables in the model increase in absolute value compared to the ordinary logistic models (Rabe-Hesketh and Skrondal, 2012). An alternative to the random effects model is the marginal model, however, marginal models require that data are missing completely at random (MCAR). Whereas the random effects model requires less stringent assumptions about missing data and will handle models with data that are missing at random (MAR) as in this study (Carrière and Bouyer, 2002).

[8]Fitted separately for loneliness, social isolation, and positive and negative social support measures.

[9]Fitted separately for loneliness, social isolation, and positive and negative social support measures.

8.5.1 Longitudinal moderation results

Figure 8.1 shows the distribution of edentulousness by quintiles of wealth across each of the three waves (3, 5 and 7) (a description of the data for all waves can be found in Appendix 17, Table A.17.2). The proportion of individuals with total tooth loss increased with time across all quintiles of wealth. However, as entirely expected, the greatest proportion of edentulousness was seen among the least wealthy individuals across all waves. The greatest prevalence of edentulousness was seen at wave 7, given this is an ageing cohort and tooth loss is associated with ageing (Thorstensson and Johansson, 2010), this too was expected.

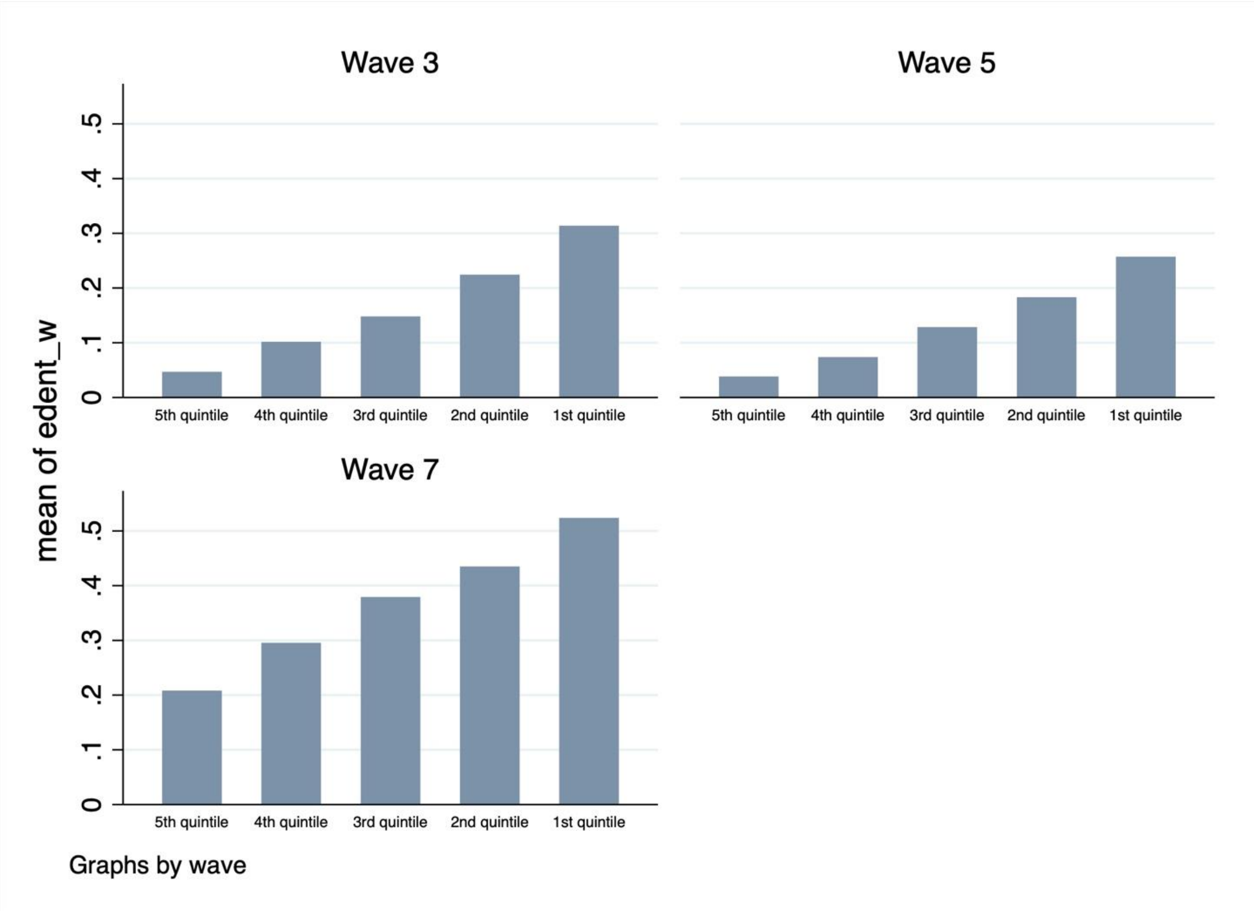

Figure 8.1 Distribution of edentulousness by quintiles of wealth across waves 3, 5 and 7 (*n* = 9373)

5th quintile = wealthiest, 1st quintile = least wealthy; 3, 5 and 7 = wave 3, wave 5 and wave 7

Tables 8.8-8.11 show results from the random effects models that were fitted to explore whether loneliness, social isolation, and positive and negative social support moderate socioeconomic inequalities in edentulousness. A strong association between wealth and edentulousness can be observed representing a very steep gradient in edentulousness. However, based on assessment of the LR test and the significance of the interaction terms, no meaningful interactions between wealth*loneliness (Table 8.8), wealth*social isolation (Table 8.9), and wealth*negative support (Table 8.10) were observed for edentulousness. Therefore, only results for interactions between wealth and positive social support (Table 8.11) are discussed below.

Table 8.8 Random effects models predicting edentulousness: interaction between wealth quintiles and loneliness (waves 3, 5, 7) (*n* = 9373)

	Model 1 (Null model)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 3a OR (95% CI)	Model 3b OR (95% CI)
Constant	0.11 (0.10-0.12)	0.03 (0.03-0.04)	7.82×10^{-9} (2.08×10^{-9}, 2.94×10^{-8})	7.73×10^{-9} (1.83×10^{-9}, 3.27×10^{-8})	5.40×10^{-9} (1.15×10^{-9}, 2.53×10^{-8})
Wealth[1]					
4^{th} quintile		2.17 (1.82-2.59)	2.18 (1.73-2.74)	2.18 (1.71-2.76)	3.32 (1.64-6.73)
3^{rd} quintile		3.83 (3.20-4.59)	3.95 (3.11-5.02)	3.85 (2.99-4.94)	6.14 (3.05-12.36)
2^{nd} quintile		5.69 (4.74-6.84)	7.76 (6.04-9.97)	7.58 (5.80-9.85)	11.45 (5.63-23.25)
Least wealthy		10.74 (8.86-13.01)	17.34 (13.17-22.82)	16.76 (12.47-22.53)	20.29 (9.81-41.94)
Covariates					
Sex (male)			0.89 (0.75-1.05)	0.89 (0.75-1.06)	0.89 (0.75-1.06)
Age			1.24 (1.22-1.26)	1.24 (1.21-1.26)	1.24 (1.21-1.26)
Loneliness				1.03 (0.99-1.08)	1.13 (0.98-1.29)
Wealth*Loneliness					
4^{th} quintile					0.90 (0.76-1.06)
3^{rd} quintile					0.89 (0.75-1.05)
2^{nd} quintile					0.90 (0.76-1.06)
Least wealthy					0.95 (0.80-1.11)
Insig2u	1.53 (1.42-1.63)	1.33 (1.22-1.43)	2.11 (1.96-2.27)	2.09 (1.92-2.26)	2.10 (1.93-2.26)
Sigma_u	2.15 (2.04-2.26)	1.94 (1.84-2.05)	2.87 (2.66-3.10)	2.85 (2.62-3.09)	2.85 (2.62-3.10)
ICC	0.58 (0.56-0.61)	0.53 (0.51-0.56)	0.72 (0.68-0.75)	0.71 (0.68-0.74)	0.71 (0.68-0.75)

[1]Wealth = quintiles: 1 = 5^{th} quintile (wealthiest), 5 = 1^{st} quintile (least wealthy); Sigma_u = between person variability; ICC = intraclass correlation

Table 8.9 Random effects models predicting edentulousness: interaction between wealth quintiles and social isolation (waves 3, 5, 7) (*n* = 9373)

	Model 1 (Null model)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 3a OR (95% CI)	Model 3b OR (95% CI)
Constant	0.11 (0.10-0.12)	0.03 (0.03-0.04)	7.82×10^{-9} (2.08×10^{-9}, 2.94×10^{-8})	1.15×10^{-8} (2.58×10^{-9}, 5.15×10^{-8})	1.14×10^{-8} (2.52×10^{-9}, 2.24×10^{-8})
Wealth[1]					
4th quintile		2.17 (1.82-2.59)	2.18 (1.73-2.74)	2.24 (1.75-2.87)	2.05 (1.36-3.10)
3rd quintile		3.83 (3.20-4.59)	3.95 (3.11-5.02)	3.74 (2.88-4.84)	3.55 (2.30-5.46)
2nd quintile		5.69 (4.74-6.84)	7.76 (6.04-9.97)	6.89 (5.24-9.06)	9.11 (5.76-14.40)
Least wealthy		10.74 (8.86-13.01)	17.34 (13.17-22.82)	15.13 (11.07-20.66)	12.69 (7.48-21.52)
Covariates					
Sex (male)			0.89 (0.75-1.05)	0.87 (0.73-1.04)	0.86 (0.72-1.03)
Age			1.24 (1.22-1.26)	1.23 (1.20-1.25)	1.23 (1.20-1.25)
Social isolation				1.23 (1.15-1.31)	1.23 (1.05-1.44)
Wealth*Social isolation					
4th quintile					1.05 (0.86-1.29)
3rd quintile					1.03 (0.84-1.26)
2nd quintile					0.88 (0.72-1.08)
Least wealthy					1.07 (0.87-1.32)
Insig2u	1.53 (1.42-1.63)	1.33 (1.22-1.43)	2.11 (1.96-2.27)	2.06 (1.88-2.24)	2.06 (1.88-2.24)
Sigma_u	2.15 (2.04-2.26)	1.94 (1.84-2.05)	2.87 (2.66-3.10)	2.80 (2.56-3.06)	2.80 (2.56-3.06)
ICC	0.58 (0.56-0.61)	0.53 (0.51-0.56)	0.72 (0.68-0.75)	0.70 (0.66-0.74)	0.70 (0.67-0.74)

[1]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy); Sigma_u = between person variability; ICC = intraclass correlation

Table 8.10 Random effects models predicting edentulousness: interaction between wealth quintiles and negative social support (waves 3, 5, 7) (*n* = 9373)

	Model 1 (Null model)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 3a OR (95% CI)	Model 3b OR (95% CI)
Constant	0.11 (0.10-0.12)	0.03 (0.03-0.04)	7.82 x 10^{-9} (2.08 x 10^{-9}, 2.94 x 10^{-8})	1.49 x 10^{-8} (3.64 x 10^{-9}, 6.12 x 10^{-8})	1.65 x 10^{-8} (3.70 x 10^{-9}, 7.35 x 10^{-8})
Wealth[1]					
4th quintile		2.17 (1.82-2.59)	2.18 (1.73-2.74)	2.15 (1.69-2.74)	2.33 (1.11-4.87)
3rd quintile		3.83 (3.20-4.59)	3.95 (3.11-5.02)	3.64 (2.83-4.68)	3.24 (1.55-6.77)
2nd quintile		5.69 (4.74-6.84)	7.76 (6.04-9.97)	7.43 (5.71-9.66)	5.97 (2.87-12.42)
Least wealthy		10.74 (8.86-13.01)	17.34 (13.17-22.82)	16.15 (12.07-21.61)	13.27 (6.36-27.72)
Covariates					
Sex (male)			0.89 (0.75-1.05)	0.88 (0.75-1.05)	0.88 (0.75-1.05)
Age			1.24 (1.22-1.26)	1.23 (1.20-1.25)	1.23 (1.20-1.25)
Negative social support				1.01 (1.00-1.03)	1.01 (0.98-1.04)
Wealth*Negative support					
4th quintile					1.00 (0.96-1.04)
3rd quintile					1.01 (0.97-1.05)
2nd quintile					1.01 (0.97-1.05)
Least wealthy					1.01 (0.97-1.05)
lnsig2u	1.53 (1.42-1.63)	1.33 (1.22-1.43)	2.11 (1.96-2.27)	1.97 (1.79-2.14)	1.97 (1.80-2.14)
Sigma_u	2.15 (2.04-2.26)	1.94 (1.84-2.05)	2.87 (2.66-3.10)	2.67 (2.45-2.91)	2.67 (2.45-2.92)
ICC	0.58 (0.56-0.61)	0.53 (0.51-0.56)	0.72 (0.68-0.75)	0.68 (0.65-0.72)	0.69 (0.65-0.72)

[1]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy); Sigma_u = between person variability; ICC = intraclass correlation

Looking at model 3 (Table 8.11), the estimated conditional odds (given the subject-specific random intercept, age, and sex) for a subject in the lowest quintile of wealth was OR 17.34 (95% CI 13.17-22.82). Therefore, the odds of being edentate for a given respondent increased by seventeen-fold if they were in the poorest group compared to the wealthiest.

The estimated intraclass correlation coefficient (ICC) was 0.72 (rho, ρ) (Model 3). The ICC can be interpreted as the proportion of the total variance in edentulousness due to differences between respondents (i.e., the variance in the random intercept) after controlling for sex and age. Therefore, 72% of the variance in the 'latent propensity' to be edentate, beyond that explained by wealth, sex, and age, can be attributed to other characteristics of the respondents.

Sigma_u (σ_u) is the unexplained variability between participants over time. The estimate for σ_u, i.e., the random effects standard deviation, was 2.87. Therefore, the likelihood of being edentate over time was much more due to the respondents' unobserved characteristics than due to age or sex (fixed covariates).

Adding positive social support in model 3a made marginal contributions to a change in the main effect estimates. Furthermore, since the variability in positive social support was lower than the unexplained between-individual variability (σ_u), the odds of being edentate were probably due to unobserved characteristics other than wealth, positive support, age, or sex (Model 3a). In Model 3b, 69% of the variance (ICC) in the 'latent propensity' to be edentate, beyond that explained by wealth, positive social support, wealth*positive support, sex, and age, can be attributed to other characteristics of the respondents. Model 3b shows that estimates for the interaction (wealth*positive support) across all quintiles of wealth are close to 1. Additionally, including an interaction term between wealth and positive support in Model 3b did little improve the model fit compared to one without the interaction term (Model 3a) (LR test *p*-value (0.055). Therefore, there was not enough evidence to stratify the sample by tertiles of positive social support.[10]

[10]Although there was not enough evidence to warrant results being stratified by tertiles of positive support, these are presented in Table A21.1, Appendix 21 for comparison with stratified cross-sectional moderation results

Table 8.11 Random effects models predicting edentulousness: interaction between wealth quintiles and positive social support (waves 3, 5, 7) (*n* = 9373)

	Model 1 (Null model)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 3a OR (95% CI)	Model 3b OR (95% CI)
Constant	0.11 (0.10-0.12)	0.03 (0.03-0.04)	7.82×10^{-9} (2.08×10^{-9}, 2.94×10^{-8})	1.72×10^{-8} (4.18×10^{-9}, 7.12×10^{-8})	2.67×10^{-8} (5.46×10^{-9}, 1.30×10^{-7})
Wealth[1]					
4th quintile		2.17 (1.82-2.59)	2.18 (1.73-2.74)	2.18 (1.72-2.77)	1.44 (0.54-3.86)
3rd quintile		3.83 (3.20-4.59)	3.95 (3.11-5.02)	3.75 (2.93-4.81)	2.16 (0.81-5.73)
2nd quintile		5.69 (4.74-6.84)	7.76 (6.04-9.97)	7.59 (5.84-9.87)	2.61 (0.98-6.94)
Least wealthy		10.74 (8.86-13.01)	17.34 (13.17-22.82)	16.64 (12.40-22.34)	16.14 (6.13-42.53)
Covariates					
Sex (male)			0.89 (0.75-1.05)	1.00 (0.99-1.01)	0.87 (0.73-1.03)
Age			1.24 (1.22-1.26)	1.22 (1.20-1.25)	1.22 (1.20-1.25)
Positive social support				1.00 (0.99-1.01)	0.99 (0.97-1.01)
Wealth*Positive support					
4th quintile					1.01 (0.98-1.04)
3rd quintile					1.02 (0.99-1.04)
2nd quintile					1.03 (1.00-1.06)
Least wealthy					1.00 (0.97-1.03)
lnsig2u	1.53 (1.42-1.63)	1.33 (1.22-1.43)	2.11 (1.96-2.27)	1.98 (1.81-2.15)	1.98 (1.81-2.15)
Sigma_u	2.15 (2.04-2.26)	1.94 (1.84-2.05)	2.87 (2.66-3.10)	2.69 (2.47-2.93)	2.69 (2.47-2.93)
ICC	0.58 (0.56-0.61)	0.53 (0.51-0.56)	0.72 (0.68-0.75)	0.69 (0.65-0.72)	0.69 (0.65-0.72)

[1]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy); Sigma_u = between person variability; ICC = intraclass correlation

8.6 Summary of moderation results

There was little evidence so support social relationships moderating associations between wealth and health cross-sectionally. Linear and logistic models with interaction terms between wealth and social relationships (loneliness, social isolation, positive and negative social support) revealed no statistically significant interactions for SRH, systolic blood pressure, SROH and OHRQoL. With one exception: cross-sectionally there was evidence of an interaction between wealth and positive social support for edentulousness. However, stratified cross-sectional results showed that the association between wealth and edentulousness was stronger (more inequality) among those who reported more positive support. Longitudinal analysis produced similar results.

The cross-sectional results may be reflective of those found in other studies, whereby SEP and health were more strongly associated among those with more satisfactory social relationships compared to those with less satisfactory relationships (Hibbard and Pope, 1992; Gorman and Sivaganesan, 2007; Andersson, 2016; Olofsson, Padyab and Malmberg, 2018). However, it is plausible that the cross-sectional results may be due to type II (β) error. In other words, that the statistically significant post-estimation tests (Wald test) may be a result of chance testing and not a true representation of what is happening in the population. Additionally, the post-estimation test (LR test) used to compare the nested random effects longitudinal models was marginally non-significant (p = 0.055) – taken together with the wide confidence intervals from the cross-sectional results, suggest that results may not be very reliable, and effect modification by positive social support is not evident. Given the larger sample size of the longitudinal dataset minimising the likelihood of a β error, it is possible that the longitudinal results lean in favour of no interaction between positive social support and wealth. With that said, what was observed is that moderation was in the unexpected direction – the hypothesis that social support might compensate for the detrimental impact of socioeconomic disadvantage was not supported.

Chapter 9. Discussion

Chapter summary: The main aim of this doctoral thesis was to investigate whether structural and functional aspects of social relationships, measured through loneliness, social isolation, and positive and negative social support, mediate or moderate socioeconomic inequalities in selected health outcomes (self-rated health and blood pressure, self-rated oral health, oral health-related quality of life and edentulousness). In this chapter, I revisit this project's aims and objectives and summarise my doctoral thesis's contribution to current evidence. I also address the project's strengths and limitations and identify potential gaps for future research before outlining implications for policy and practice within the UK.

9.1 Do social relationships mediate or moderate social inequalities in health? – Evidence from the systematic review

The aim of the systematic review (Chapter 4) was to give an overview of the current literature on the mediating and moderating role of social relationships in explaining social inequalities in health (Objective 1). A narrative synthesis was conducted on 69 studies, of which 42 studies explored mediation and 33 explored moderation – six explored both mediation and moderation.

To my knowledge, this is the first systematic review that included studies examining all types of social relationships as mediators and moderators of social inequalities in any health outcome without restricting the population group. Although two previous studies were systematic reviews (Uphoff *et al.*, 2013; Moor, Spallek and Richter, 2017), one focused on social capital moderating socioeconomic inequalities in health (Uphoff *et al.*, 2013) and the other study examined social relationships in mediating socioeconomic inequalities in self-rated health only (Moor, Spallek and Richter, 2017). However, in more recent of these two studies, social relationships were part of broader psychosocial measures, therefore, attributing attenuation of the magnitude of the SEP-SRH association to social relationships alone is difficult (Moor, Spallek and Richter, 2017). Three other previous studies were either literature reviews (Carlson and Chamberlain, 2003; Vyncke *et al.*, 2013) or a scoping review (Keim-Klärner *et al.*, 2023). The two literature reviews focused on social capital, with the most recent of the two focusing on neighbourhood social capital and limiting their population group to children only (Vyncke *et al.*, 2013). Although the scoping review examined both moderating and mediating socioeconomic inequalities in health, it too focused on one particular domain of social relationships – social networks (Keim-Klärner *et al.*, 2023).

Overall, this systematic review found that among studies examining mediation, social relationships partly attenuated social gradients in health, with a wide range of effect sizes across studies. Social relationships attenuated between 1% and 78% of the magnitude of the SEP-SRH association, between 4% and 52% of the SEP-health association[11], up to 30% of the SEP-mortality association, and between 5% and 70% of the SEP-depression association. The variety in the magnitude of the attenuation of social gradients seen in this systematic review are comparable to previous reviews. In the scoping review by Keim-Klärner *et al*. (2023), seven of the nine studies reported that social networks mediated between 2.5% and 35% of socioeconomic inequalities in health. Similarly, in a literature review by Vyncke *et al*. (2013), social capital mediated between 2.4% and 35% of socioeconomic inequalities in adolescent well-being. However, in the review by Vyncke *et al*. (2013), only two of the five studies included observed mediation effects of social capital in the SEP-health association. In the systematic review by Moor et al. (2017), social relationships contributed between 4% and 49% to the SEP-SRH association.

Overall, the findings on moderation align with previous systematic and scoping reviews (Uphoff *et al.*, 2013; Vyncke *et al.*, 2013; Keim-Klärner *et al.*, 2023). In most of the studies examining moderation, having better social relationships buffered the negative effect of socioeconomic disadvantage on health. However, some studies did not find that favourable social relationships compensated for socioeconomic disadvantage. Such null findings were also reported in the reviews by Uphoff *et al*. (2013) and Keim-Klärner *et al*. (2023). A possible explanation offered by the review authors is that disadvantaged groups may not have the same access to social capital as their more advantaged peers (Uphoff *et al.*, 2013), or that social networks through the power they exert, may encourage the uptake of health damaging behaviours among individuals from lower socioeconomic backgrounds more than among the socioeconomically more advantaged (Keim-Klärner *et al.*, 2023). It could be that socioeconomic disadvantage affords less favourable social relationships that

[11]In mediation studies, health refers to chronic conditions and physical functions

then exacerbate poor health, therefore enhancing the negative effect of low socioeconomic position on health.

Previous reviews found it challenging to draw definitive conclusions regarding the importance of any one dimension of social relationship over another (Carlson and Chamberlain, 2003; Uphoff *et al.*, 2013; Vyncke *et al.*, 2013; Moor, Spallek and Richter, 2017; Keim-Klärner *et al.*, 2023). Evidence from this systematic review was inconclusive on the relative importance of the different dimensions of social relationships, i.e., structural, or functional, in moderating socioeconomic inequalities in health. However, in this systematic review, some patterns emerged when looking at the relative difference of structural and functional social relationships in mediating socioeconomic inequalities in health. It may be that different dimensions of social relationships are important for different health outcomes. Results from this systematic review observed structural measures as more important than functional social relationships for objective or physical health outcomes. Whereas both structural and functional social relationships or aggregate social relationship measures were equally important in studies that examined subjective health, especially for mental health outcomes – a finding observed in studies irrespective of whether SEM was implemented to formally test for mediation pathways. The differing effect of different dimensions of social relationships for health is also supported by other reviews, for example, a recent scoping review observed that the influence of social networks was particularly relevant for behavioural outcomes such as BMI, alcohol consumption and smoking (Keim-Klärner *et al.*, 2023). In another literature review, although firm conclusions could not be made, there was some suggestion that of the neighbourhood social capital examined, neighbourhood social cohesion and social control (both included multiple aspects of functional social relationships) were more important than neighbourhood community participation, collective efficacy, and neighbourhood social bonding for adolescent well-being (Vyncke *et al.*, 2013). Another reason for the difference seen in the relative contribution of structural and functional social relationships on health the systematic review for this project could be the substantial heterogeneity in the tools used to measures health and social relationships. For example, some studies utilised validated tools such as the Berkman and Syme Social Network Index to measure structural social relationships, or the Close Persons Questionnaire to measure social support, whilst others used single item questions, such as the number of close social ties or questions regarding perceived availability of emotional support. Other studies used aggregate measures that combined structural and functional measures of social relationships. Such diversity in measures makes it difficult to establish a consensus across studies regarding the importance of structural and functional social relationship measures for health overall – an observation shared by previous reviews (Carlson and Chamberlain, 2003; Uphoff *et al.*, 2013; Vyncke *et al.*, 2013; Moor, Spallek and Richter, 2017; Keim-Klärner *et al.*, 2023). Previous reviews also reported large heterogeneity among studies included in their reviews, even when focusing on one social relationship domain e.g., social capital (Carlson and Chamberlain, 2003; Uphoff *et al.*, 2013; Vyncke *et al.*, 2013) or social networks (Keim-Klärner *et al.*, 2023). It is also plausible that the difficulty in disentangling the importance of structural and functional social relationship measures may be due to the inconsistency in using established frameworks to guide the selection of social relationship measures – for example, Valtorta's framework for classifying social relationships (Valtorta, Kanaan, Gilbody and Hanratty, 2016). Study design may also have implications on establishing one social relationship domain as more important than the other. For example, most studies assessed social relationships at single time points rather than as repeated measures of social relationships over time. Interestingly, in this systematic review, the included longitudinal studies appeared to favour structural social relationship measures as more important for health – a pattern that also emerged in the most recent scoping review (Keim-Klärner *et al.*, 2023).

Finally, what has consistently emerged from this systematic review and most previous reviews, is the support for social relationship measures as intermediate determinants of health (Uphoff *et al.*, 2013; Vyncke *et al.*, 2013; Moor, Spallek and Richter, 2017; Keim-Klärner *et al.*, 2023). Overall, this systematic review, corroborated previous findings that structural and functional social relationships partially explained socioeconomic inequalities in health. This systematic review also observed that those from more disadvantaged backgrounds had less favourable social relationships, and consequently poorer social relationships were linked to socioeconomic inequalities in health.

9.2 Social gradients in the prevalence of health outcomes

The second objective was to assess social gradients in self-rated health, systolic and diastolic blood pressure, self-rated oral health, oral health-related quality of life and edentulousness among UK older adults. It was hypothesised that there would be stepwise, linear gradients in health outcomes among older adults. In line with this hypothesis, findings from Chapter 6 showed that greater disadvantage was associated with poorer health across five diverse health outcomes: self-rated health, systolic blood pressure, self-rated oral health, oral health-related quality of life, and edentulousness. A social gradient was not evident for diastolic blood pressure.

Cross-sectional analyses assessed associations between three markers of socioeconomic position: household non-pension wealth, occupational class, and education, and health outcomes (self-rated health, systolic blood pressure, self-rated oral health, oral health-related quality of life and edentulousness). The steepest gradients were seen when the socioeconomic position was measured by household non-pension wealth. One reason for this could be that in ELSA wealth is composed of 22 different observed or imputed wealth and debt components, therefore, making it a robust measure of socioeconomic position. Furthermore, wealth may be more important for older people since it is associated with accumulated economic assets, and therefore, an important indicator of financial resources in older age, whereas education and occupational class – typically acquired earlier in life or in midlife – do not reflect cumulative socioeconomic position (Demakakos *et al.*, 2008). Wealth may also be a more precise measure of contemporary, and therefore, older persons' 'permanent' socioeconomic position once they have left the labour market (Banks, Karlsen and Oldfield, 2003). Overall, a higher proportion of participants with poor health were seen with increasing disadvantage, corroborating previous findings for oral health (Sabbah *et al.*, 2007; Tsakos *et al.*, 2011), ischaemic heart disease (Marmot *et al.*, 1991; Sabbah *et al.*, 2007), cardiovascular risk factors (Ferrie *et al.*, 2002), and self-rated health (Ferrie *et al.*, 2002; Sabbah *et al.*, 2007). Social inequalities in health are a universal finding, and results from this study confirm something widely known.

Overall, associations were not found between socioeconomic position and mean diastolic blood pressure – a finding supported by the ELSA wave 2 summary reports that also observed no association between wealth and diastolic blood pressure (Pierce *et al.*, 2006). However, this finding is in contrast to a Whitehall II study in which a socioeconomic gradient (measured by employment grade) was evident in prevalence of diastolic blood pressure (Ferrie *et al.*, 2002). A plausible reason for the importance of systolic blood pressure over diastolic blood pressure in this study could be that systolic rather than diastolic blood pressure is more critical as a risk factor for cardiovascular disease (CVD) among adults aged 60 years and over (Kannel, Gordon and Schwartz, 1971; Franklin, 1999; Pinto, 2007), whereas participants in the Whitehall II study were aged 35-55 years and at an age when diastolic blood pressure has not yet started to plateau or fall. However, there was one exception in the present study: an association was observed between education and diastolic blood pressure, but no clear gradient was found. This finding is echoed by another study that examined educational inequalities in blood pressure – a difference between the most educated and all other categories in prevalence of diastolic blood pressure was reported among men, but no trend in the prevalence of diastolic pressure was found among women (Silventoinen *et al.*, 2005). However, the difference in prevalence between the most and least educated individuals as reported in the present study was opposite to what has been reported in other studies: those with the highest educational level had a higher mean diastolic blood pressure than the most disadvantaged individuals. Ageing is more strongly associated with a fall in diastolic blood pressure and an increase in systolic blood pressure, mainly due to ageing-related arterial stiffness (Franklin and Wong, 2013). Therefore, a possible explanation for the findings from this study could be due to the age-related differences in educational attainment – those in the highest education group in the ELSA sample used in this study (wave 2) were younger than those with the least education, therefore, a lower diastolic blood pressure would be expected among older than younger participants.

9.3 Social gradients in social relationships

The third objective was to ascertain whether social relationships were socially patterned. The third hypothesis was that both structural and functional measures of social relationships follow a social gradient. For three of the four social relationship measures this was true, the more advantaged an individual's socioeconomic position, the lower the prevalence of social isolation and loneliness and the greater the prevalence of positive social support. However, contrary to the hypothesis, increasing advantage was associated with a greater prevalence of negative social support (see Chapter 6).

Previous empirical studies have also demonstrated that lower socioeconomic position is associated with less satisfactory social relationships, especially among older people, with results comparable to those from this study. For example, in a meta-analysis, more advantaged older individuals reported lower levels of loneliness (Pinquart and Sorensen, 2001). In several European cross-sectional studies, lower socioeconomic position has also been associated with lower social participation among older persons across Europe (Niedzwiedz *et al.*, 2016); a greater prevalence of social isolation (Weyers *et al.*, 2008; Röhr *et al.*, 2022) and inadequate levels of social support among older adults in Germany (Weyers *et al.*, 2008); a larger social network size, lower levels of loneliness and higher levels of social support among Norwegian older adults (Aartsen, Veenstra and Hansen, 2017). Similar findings were reported in longitudinal studies of varying follow-up lengths. For example, in a previous study using data from ELSA, participants had a greater likelihood of reporting lower structural and functional social capital among (Rouxel *et al.*, 2015). In a Whitehall II study, over a 24-year follow-up period, lower employment grades were associated with less emotional support, more negative support, and having a lower network score (Stringhini *et al.*, 2012). Similar results are reported in other OECD countries, for example, over a 3-year follow-up period, lower socioeconomic position was associated with living alone, lower levels of social participation and less diversity of the social network among older people in Denmark (Nilsson, Avlund and Lund, 2010). Similarly, in a 2-year follow-up study among older adults who took part in the Survey of Health, Ageing and Retirement in Europe, lower educated persons were less likely to participate in social activities compared to their higher educated peers (Etman *et al.*, 2015).

It is well known that older age is pivotal in driving changes in social relationships – widowhood, retirement, the loss of friends and relatives and declining health may make older people more likely to be socially isolated and lonely (Cornwell and Waite, 2009; Aartsen and Jylhä, 2011; Chawla *et al.*, 2021; WHO, 2021b). It is also conceivable that socioeconomic advantage may afford a more extensive social network which would reduce the likelihood of being socially isolated and increase the availability of more meaningful social connections, which in turn would result in perceiving lower levels of loneliness and higher levels of positive social support (Aartsen, Veenstra and Hansen, 2017). Conversely, poorer individuals tend to be more vulnerable, more likely to be in poorer health and less well socially integrated, which may lead to loneliness and isolation (WHO, 2021b). Lower socioeconomic position may prevent older individuals from fully engaging in certain social activities that cost money, therefore, withdrawing from wider society and their network of friends and family (Agarwal *et al.*, 2021). Greater socioeconomic disadvantage may make some local services inaccessible, for example, because of being unable to afford local transport in areas poorly connected by public transport networks, therefore reducing social participation, and increasing the likelihood of becoming more social isolated from one's social network. For older individuals facing greater socioeconomic hardship and poor health, it may also be challenging to leave home or participate in the local social environment or interact with others (Niedzwiedz *et al.*, 2016). Therefore, the impact of greater socioeconomic disadvantage may compound the association between ageing, poor health, and less satisfactory relationships.

The direction of the association between socioeconomic position and negative social support was opposite to that of hypothesised: greater disadvantage was associated with experiencing less negative social support. This finding is contrary to much of the literature. There is some evidence that suggests lower socioeconomic position being associated with a greater prevalence of social support among older adults (Weyers *et al.*, 2008) – it could be that in this sample, more disadvantaged older adults perceive less conflict when interacting with members of their social network. It may be contested that more disadvantaged individuals tend to have a more restricted social network 'radius', which may lead to having fewer friends but more family and kinship ties. It may also be possible that higher socioeconomic position is linked with demanding work obligations or frequent absence from home, therefore access to social ties, and maintaining social relationships both within and beyond that of the friends and family network becomes more challenging (Weyers *et al.*, 2008).

9.4 Summary of key findings from quantitative data analyses

Table 9.1 presents a summary of the key results from the cross-sectional and longitudinal analyses of the present study examining social relationships in mediating and moderating socioeconomic inequalities in health. Overall, when looking at attenuation of the magnitude of the SEP-health association, social isolation was important for all five outcomes and loneliness was important for four health outcomes. The influence of positive social support was limited, it appeared to play a role in contributing to the wealth and occupation gradients for self-rated oral health and the wealth gradient for OHRQoL. Negative support did not meaningfully contribute to the attenuation of the SEP gradient for any health outcome. Results from Chapter 6 have shown that social gradients across all outcomes were steepest when socioeconomic position was measured by wealth.

When looking at the overview of mediation results from the longitudinal SEM analyses, mediation of the wealth-health association was seen via loneliness and via social isolation for three of the five health outcomes. There was limited evidence for a bidirectional effect between wealth and health – this was only seen for self-rated health and edentulousness. However, bidirectional associations between health and loneliness were seen for three of the four outcomes, and between health and social isolation for four of the five outcomes.

Regarding moderation cross-sectionally and longitudinally, the present study found no evidence for interactions between wealth and social relationships for any outcome. With one exception: an interaction was observed between positive social support and wealth for edentulousness. However, positive support appeared to strengthen the association between socioeconomic disadvantage and edentulousness.

These results are discussed in further detail in Sections 9.5 and 9.6 below.

Table 9.1 Summary of key findings – an overview of results

Social relationship measure	Regression modelling – attenuation of socioeconomic gradients by social relationships[1,2]				
	SRH	SBP	SROH	OHRQoL	Edentulousness
Functional social relationships					
Loneliness	YES	N/A	YES	YES	YES
Positive social support	NO	N/A	YES[3]	YES[3]	NO
Negative social support	NO	N/A	NO	NO	NO
Structural social relationships					
Social isolation	YES	N/A	YES	YES	YES
	Structural equation modelling (SEM)[4]				
Mediation effects					
Wealth → Loneliness → Health	YES	NO	YES	YES	NO
Wealth → Social isolation → Health	YES	NO	YES	YES	NO
Bidirectional effects					
Wealth ↔ Health	YES	NO	NO	NO	YES
Health ↔ Loneliness	YES	NO	YES	YES	NO
Health ↔ Social isolation	YES	NO	YES	YES	YES
	Moderation[5,6]				
Interaction effect					
Wealth*Loneliness	NO	NO	NO	NO	NO
Wealth*Social isolation	NO	NO	NO	NO	NO
Wealth*Positive support	NO	NO	NO	NO	YES[7]
Wealth*Negative support	NO	NO	NO	NO	NO
Stratified effects					
Positive support as a buffer	N/A	N/A	N/A	N/A	NO
Positive support strengthened association	N/A	N/A	N/A	N/A	YES[7]

[1]Adjusted for each social relationship measure separately; [2]Attenuation of odds ratio's ≥10%; [3]≥10% attenuation of odds ratio's only in models by wealth and occupation for SROH and in models by wealth for OHRQoL; [4]Fully adjusted models (age- and sex-adjusted); [5]Interaction effects for cross-sectional analyses of all outcomes; [6]Interaction and stratified effects for longitudinal analyses of edentulousness [7]Positive social support strengthened the effect of material disadvantage on edentulousness cross-sectionally and longitudinally

9.5 Do social relationships mediate socioeconomic inequalities in health?

The fourth objective was to assess, cross-sectionally the extent to which structural and functional aspects of social relationships attenuate social gradients in health outcomes. For this objective, it was hypothesised that accounting for social relationships cross-sectionally would attenuate the social gradient in health. In line with this hypothesis, findings from Chapter 6 show that social isolation and loneliness contributed to explaining socioeconomic differences in self-rated health, systolic blood pressure, self-rated oral health, oral health-related quality of life and edentulousness. Positive social support was most relevant for self-rated oral health and oral health-related quality of life when the socioeconomic position was measured by wealth. Negative social support did not contribute to attenuating associations between socioeconomic position and health. Moreover, no socioeconomic gradients were found in diastolic blood pressure (Table 9.1).

The fifth objective was to assess longitudinally the extent to which social relationships mediate associations between indicators of socioeconomic position and health outcomes. The fifth hypothesis was that social relationships would mediate social inequalities in health longitudinally. Results from Chapter 7 found that loneliness and social isolation partially mediated wealth inequalities in three of the five outcomes: self-rated health, self-rated oral health, and oral health-related quality of life. However, social isolation and loneliness made very modest contributions to mediating socioeconomic inequalities in self-rated health. There was little evidence to support the mediating role of loneliness and social isolation in explaining wealth inequalities in systolic blood pressure and edentulousness (Table 9.1).

Overall, findings from this project support socioeconomic position as a fundamental structural determinant of health. Throughout this project, wealth remained a strong predictor of poorer health independent of the effect of social relationships. Findings from this project also provide some evidence to support social relationships as mediating socioeconomic inequalities in health among older adults, at least in part, although the size of the contribution was modest. Findings from this project also support the WHO framework designating social relationships as cross-cutting the structural and intermediate determinants of health (Solar and Irwin, 2010). Since the present study has shown that greater socioeconomic advantage was generally associated with lower levels of loneliness and social isolation, which in turn contributed to better health. A possible explanation may be that socioeconomic advantage may be providing access to developing and maintaining social relationships that, and that more favourable social relationships may also be facilitating access to resources supportive of health. Findings from this project concur with previous empirical studies, three of which are based on comparable populations from OECD counties. For example, in a large study among adults in The Netherlands, loneliness attenuated 20% and 16% of the socioeconomic inequalities in self-rated health in older adults aged 65 to 80 years and those aged 80 years and above, respectively (Meisters *et al.*, 2021). However, more conservative findings were reported in a study using data from the Norwegian study on the life course, aging, and generation study (NorLAG) – loneliness explained between 4% and 8% of the total effect of socioeconomic position on physical health among 40-year-old to 80-year-old men and women, respectively (Aartsen, Veenstra and Hansen, 2017). Mixed findings were reported in another study involving adults who partook in the German lidA-study of civil servants – of the two birth cohorts (1959 and 1965), social isolation explained 18.4% of the total effect of education on depression among the younger age group only (du Prel, Iskenius and Peter, 2014). Interestingly, in a study among Chinese people aged 70 and above living in Hong Kong, social isolation did not mediate of socioeconomic inequalities in activities of daily living at the 18-month and 36-month follow-up periods (Lai, Ho and Woo, 2023). However, this study may not be directly comparable in terms of cohort or economic development. Participants were older than those in this project (70 years to 80 years and above). The urban development of Hong Kong is different from the UK – local amenities and community centres designed to provide essential social networks for daily living are clustered around residential areas, there are pockets of green spaces within each residential district and the built environment encourages people to walk or use public transport. This may have buffered some of the effect of social isolation among older people (Lai, Ho and Woo, 2023).

Among the four social relationship measures examined in the present study, the main drivers explaining socioeconomic inequalities in health, at least in part, were loneliness, a functional social relationship measure, and social isolation, a structural social relationship measure. Findings from the cross-sectional analyses have shown that loneliness attenuated between 17% and 39% of the SEP-health gradient and social isolation attenuated between 14% and 34% of the SEP-health gradient. Whereas positive social support attenuated 22% of the wealth gradient in self-rated oral health and OHRQoL, and 13% of the occupation gradient in self-rated oral health – beyond this, positive social support did not meaningfully contribute to attenuating the SEP-health gradient for any other outcome. This finding is not surprising given that past evidence has consistently established links between loneliness, social isolation and both morbidity and mortality (Holt-Lunstad, Smith and Layton, 2010; Holt-Lunstad *et al.*, 2015; Valtorta, Kanaan, Gilbody, Ronzi, *et al.*, 2016; Leigh-Hunt *et al.*, 2017). Social isolation is a multidimensional social relationship construct, which may explain why social isolation made a stronger contribution to socioeconomic inequalities in the selected outcomes than social support in this project. Literature has demonstrated that having a multifaceted social relationship measure can potentially tap into different pathways through which social relationships influence health (Holt-Lunstad, Smith and Layton, 2010; Vonneilich *et al.*, 2012). Additionally, there is some evidence, albeit limited, to favour loneliness over social support in partially explaining socioeconomic inequalities in health (Aartsen, Veenstra and Hansen, 2017). An explanation for the importance of loneliness as a functional measure over social support could be because the former was measured using a validated tool.

In the current project, the contribution of loneliness and social isolation longitudinally, was more modest. Loneliness mediated 9.5% of the wealth inequalities in self-rated health, and 26% of the wealth inequalities in self-rated oral health and OHRQoL. Social isolation mediated up to 9% of the wealth-SRH gradient, up to 31% of the wealth-SROH gradient, and 20% of the wealth-OHRQoL gradient. Loneliness and social isolation appear more relevant in mediating socioeconomic inequalities in subjective than objective health measures. It is possible that this finding may result from same-source bias, i.e., that people who view their health as poorer might also perceive their relationships more negatively, perhaps due to underlying life satisfaction felt as being less than adequate. Since the number of studies with which direct comparisons can be made is limited, it is difficult to reach a definitive conclusion for this finding. Overall, is appears that among studies that assessed mediation of subjective health outcomes among older adults, both structural and functional social relationships are important. However, findings from this study are contrary to what has been reported in previous studies with regards to objective outcomes. Although studies assessing mediation in hard clinical outcomes are limited, it appears that social relationships do explain socioeconomic inequalities in objective health, at least in part, and that structural measures might be more important than functional social relationship measures. For example, in a recent scoping review, social networks were important in mediating a diverse range of health-related outcomes, including objective measures, however, the authors did suggest that the relative importance of structural and functional social relationships may be related to the health outcome assessed (Keim-Klärner *et al.*, 2023). In the longitudinal study by Stringhini *et al*. (2012), structural social relationship measures (social network size and marital or cohabiting status) rather than functional social relationships (perceived social support) attenuated the SEP-mortality association among London-based civil servants aged between 33 and 55 years. In another longitudinal study among Norwegian older adults, social support and contact frequency partially explained the SEP-physical health association. Although self-reported, the physical health measure had some more 'objective' health-related items such as daily physical functioning (Adhikari and Uddin, 2022). The difference in findings between the current study and previous empirical studies may be due to considerable heterogeneity regarding study design, populations, outcomes, social relationship measures and socioeconomic measures – a limitation that previous reviews have also mentioned (Vyncke *et al*., 2013; Moor, Spallek and Richter, 2017; Keim-Klärner *et al*., 2023).

The current study corroborates previous findings regarding bidirectional associations between socioeconomic position and health. Overall, the pathway from wealth to health, i.e., the social causation pathway, was stronger than the pathway from health to wealth, i.e., the health causation pathway. The stronger evidence for social causation from this project is universally acknowledged (Chandola *et al.*, 2003; Letelier *et al.*, 2022; Hoffmann, Kröger and Pakpahan, 2018; Kröger, Pakpahan and Hoffmann, 2015).

Furthermore, this study also found reciprocal associations between social relationships and health, which are also in line with previous empirical studies (Luo *et al.*, 2012; Rouxel *et al.*, 2017; Tsur *et al.*, 2019; Phillips *et al.*, 2022; Yun *et al.*, 2023). There are some explanations that may explain this bidirectional association. Firstly, poorer social relationships may function through several interrelated pathways, i.e., behavioural, psychological, and physiological, to impact health (see Chapter 2). Secondly, this study investigated health in older age – a timepoint in life when a sizeable proportion of older adults suffer worsening health (Vos *et al.*, 2017; Kingston *et al.*, 2018; GBD 2019 Ageing Collaborators, 2022) – this may interfere with social contact and interaction, therefore, resulting in greater levels of loneliness and social isolation (Phillips *et al.*, 2022). Poorer health may also operate through a psychosocial pathway to affect loneliness and social isolation. For example, adverse health may impact mental health, self-esteem and self-confidence, which may, in turn, increase social withdrawal, therefore increasing loneliness and social isolation (Rouxel *et al.*, 2017; Hajek, Kretzler and König, 2022). An interesting finding was that the pathway from health to social relationships seemed stronger than in the opposite direction – a result supported by the literature (Luo *et al.*, 2012; Phillips *et al.*, 2022). A possible explanation could be that a greater proportion of older individuals are transitioning to a point in life where there is a shift in focus from work and raising a family to health (Tsur *et al.*, 2019), and maintaining good health is needed for daily functioning and maintaining relationships. Some inconsistencies were also found; no bidirectional associations were evident between edentulousness and loneliness, however bidirectional associations were found between edentulousness and social isolation. Being edentate was more strongly associated with greater levels of social isolation than in the opposite direction. In ELSA, edentulousness is more prevalent among adults aged 80 years and above – a group that tends to have a greater capacity to buffer the effects of loneliness (Ukraintseva, Yashin and Arbeev, 2016). Therefore, it is possible that social isolation is more important for edentate individuals than loneliness.

9.6 Do social relationships moderate socioeconomic inequalities in health?

The sixth objective of this project was to assess whether loneliness, social isolation, and positive and negative social support moderate socioeconomic inequalities in health among older people. The hypothesis for this final objective was that favourable social relationships would buffer social gradients in health. There was a suggestion of effect modification by social support in edentulousness, however, the results did not support the buffering hypothesis. Instead, social gradients in edentulousness were steeper among those with more social support (Chapter 8) (Table 9.1).

Overall, this study did not support social relationships as moderators of the association between socioeconomic position and health. The only association was found cross-sectionally: the moderation of wealth inequalities in edentulousness by positive social support. However, findings were opposite to the hypothesised association. Results from the longitudinal analyses were marginally statistically non-significant, but taken together with evidence from the cross-sectional study, suggest that the association between wealth and edentulousness became stronger at higher levels of positive social support. Although it appears counterintuitive, this finding is supported by some empirical studies (Uebelacker *et al.*, 2013; Andersson, 2016; Haseda *et al.*, 2018; Olofsson, Padyab and Malmberg, 2018). However, findings from the overwhelming majority of previous empirical studies have generally shown that social relationships buffer the negative effect of low socioeconomic position on health, and therefore, these findings also need to be considered.

The systematic review from this thesis highlighted two studies among older adults as reporting a negative effect of social relationships in moderating the SEP-health association. For example, in a study among Japanese older adults, civic participation strengthened the association between low income and depression (Haseda *et al.*, 2018). In another Europe-wide study, among those with a low educational level, there was a greater likelihood of poor self-rated health among those with higher satisfaction with the social network in Northern Europe (Olofsson, Padyab and Malmberg, 2018). No interactions were found between educational level and social relationships on self-rated health in any other European region (Olofsson, Padyab and Malmberg, 2018). Although direct comparisons are difficult due to differences across these studies with regards to heterogeneity in exposures, outcomes, and social relationship measures, a general overall comparison can still be made. A possible explanation for the findings from this project in light of these two previous studies may be that not all social relationships foster better health. What may seemingly appear as more favourable levels of social relationships may be perceived as emotionally demanding for more disadvantaged individuals who consequently fare worse for health (Haseda *et al.*, 2018). Another explanation could be that although disadvantaged individuals may perceive the availability of some or a lot of emotional support from a partner, children, friends, and family, they may be restricted in accessing support from all the social network members, and therefore may lack access to the social resources that could be more beneficial for health (Uphoff *et al.*, 2013). It is also possible that health-benefiting behaviours are not necessarily acquired when individuals consider friends or relatives supportive (Smith and Christakis, 2008), especially given that individuals from lower socioeconomic groups may be more likely to collectively adopt health-averse behaviours.

As mentioned earlier, there are a plethora of previous studies that have reported positive findings and have shown buffering effects of more favourable social relationships on the SEP-health association. For example, in a systematic review by Uphoff *et al*. (2013), social capital was found to buffer some of the negative effect of low socioeconomic position on health across diverse populations, including minority groups, and different age groups. In a large Europe-wide cross-sectional study, social participation was found to be more beneficial for health (self-rated health + ADL+ chronic conditions) among the most disadvantaged older adults, however, this effect was found in Southern and Central Europe only (Craveiro, 2017). When looking at longitudinal studies although findings were mixed, overall, more favourable social relationships generally show buffering of socioeconomic disadvantage on poor health. In one study, neighbourhood social cohesion was found to buffer the negative effect of neighbourhood deprivation on the change in mental health among adults (mean age of 50.5 years) seven years later (Fone *et al.*, 2014). Another study found that low negative support (criticism from family, friends, or spouse) buffered the negative effect of low education on chronic health and functional limitations among adults aged 24 to 75 years (mean age of 46.4 years) (O'Brien, 2012). Three studies that examined mortality risk found structural social relationship measures moderated the SEP-mortality associations: social integration at midlife buffered the negative effect of early life poverty on mortality risk among middle aged African American's (Green, Doherty and Bugbee, 2022); social participation, measured by community involvement, was shown to moderate the effect of unemployment on mortality risk among women (mean age at follow-up was 42 years) (Hibbard and Pope, 1992); some aspects of social participation (church membership and community participation) were protective against mortality for more disadvantaged adults aged 21 to 80 years and above (Veenstra and Patterson, 2012).

Overall, it is important to note that the findings from this project suggest greater inequality among those with more support, but only for one outcome, i.e., edentulousness. Given the wide confidence intervals, this result may is not reliable enough to draw any firm conclusions.

9.7 Strengths and limitations

9.7.1 Strengths

Methodology of the systematic review

This systematic review comprehensively assessed the mediating and moderating role of social relationships in explaining social inequalities in health using a robust methodological foundation. This involved (1) the development and subsequent registration and publication of a systematic review protocol, (2) strict eligibility criteria, (3) the use of validated reporting standards i.e., PRISMA and PRESS, (4) the use of a validated tool (effect direction plots) to present the results, and finally (5) following the Economic and Social Research Council Methods Programme guidelines to guide the narrative synthesis.

Limitations should be considered when interpreting findings from the systematic review. It is possible that findings may have been affected by the quality of the included studies. A validated appraisal tool was used to assess methodological quality, and those rated low quality were largely due to the use of self-reported outcomes, and heterogeneity in social relationship measures – not all studies utilised validated tools. However, all studies included social relationship measures based on sound theory. Moreover, since effect estimates and the direction of the effects were similar when studies were limited to high and moderate quality studies suggests that inconsistencies were minimal (Huguet *et al.*, 2013).

Study setting and data quality: The English Longitudinal Study of Ageing (ELSA)

One of the strengths of this doctoral research project was the use of the ELSA dataset to conduct secondary data analyses. ELSA is a rich, high-quality, large, multidisciplinary dataset. It has a wealth of measures that reflect the social, socioeconomic, sociodemographic, and health experiences among a nationally representative sample of older people in England. Therefore, allowing findings from this study to be generalisable to older adults among the wider population in the UK. ELSA also has a broad range of social relationship variables, such as, loneliness, social and civic participation, and social support. Having detailed information on social relationship measures enabled the construction and use of the multiple measures used throughout this project: loneliness, social isolation, positive and negative social support. Moreover, it is one of the few UK datasets that also includes oral health measures (Abell *et al.*, 2020). Additionally, as a prospective dataset, it enabled longitudinal analyses of social relationships in meditating and moderating socioeconomic inequalities in health.

Inclusion of structural and functional social relationship measures

Another strength of this project was the use of clearly distinguished structural and functional social relationship measures. Unlike previous studies that used a single item or question to reflect social isolation or an index that consists of subjective and objective criteria, e.g., The Berkman-Syme Social Network Index, this study utilised measures to capture the objective situation of social isolation. Moreover, the 3-item UCLA loneliness scale was used to measure loneliness. This enabled assessing loneliness on a reliable and validated scale for adults.

This study measured social support as positive and negative – the items used to construct these measures reflect emotional social support. Conceptually social support has been divided into four domains: emotional, informational, appraisal, and instrumental. Many previous studies have used single items or questions, or a construct that has included different aspects of the domains of social support. Research suggests that the social support domains should be studied independently to understand their impact on health better (Newsom *et al.*, 2005a) – mainly because it is thought that the domains of social support differ in their consequences on different health outcomes (Newsom *et al.*, 2005b; Muñoz-Laboy *et al.*, 2013).

Studying social isolation, loneliness, and positive and negative social support separately allowed a direct comparison between the effect of structural and functional measures in explaining socioeconomic inequalities in health. Furthermore, compared to the studies included in the systematic review, no other study has explored objective social isolation, subjective loneliness, and social support in explaining socioeconomic inequalities in health.

The use of objective and subjective health outcome measures

This is among the few studies assessing subjective and objective health using a robust clinical marker (blood pressure). Only one other study of those included in the systematic review explored hypertension as an outcome. However, this was a self-reported measure whereby participants were asked a single question if they had ever been diagnosed with hypertension by a doctor or healthcare professional (Gorman and Sivaganesan, 2007). Unlike the nurse-measured blood pressure available in ELSA, a self-administered question may subject responses to bias due to social approval (Hebert *et al.*, 1995). Additionally, this project is one of the few that assessed mediation and moderation of socioeconomic inequalities in subjective and objective oral health. Only one other study explored the mediation of an objective oral health outcome – this was captured by the number of remaining teeth as a measure of dental status (Aida *et al.*, 2011). However, it is essential not to restrict epidemiological research to clinical oral health indicators and to include measures incorporating well-being and quality of life, such as OHRQoL.

Furthermore, Aida et al. (2011) assessed self-rated health as a measure of overall health and dentate status. In contrast, this study included self-rated oral health – a measure that captures information not fully captured by self-rated health (Benyamini, Leventhal and Leventhal, 2004). Since research is shifting from a biomedical paradigm to one that includes comprehensive measures of subjective health, it is essential to have measures that tap into the broader sense of health (Benyamini, Leventhal and Leventhal, 2004). Moreover, having both subjective and objective measures is also a robustness check of the findings, i.e., whether they are similar for more subjective or more objective outcomes – this also allows enables the examination of any patterns that may emerge.

The use of advanced statistical techniques

This project implemented advanced analytical techniques, such as structural equation modelling to assess the complex associations between social relationships, socioeconomic position, and health longitudinally. Unlike multiple regression, SEM is a system of regression equations that considers all paths *simultaneously* rather than sequentially while also considering measurement error (Raykov and Marcoulides, 2006; Beran and Violato, 2010). SEM also has greater statistical power than multiple regression modelling (Beran and Violato, 2010). Most previous studies included in the systematic review, that implemented SEM assessed depression and mental health, or self-reported health, and were cross-sectional in design. Only two studies implemented SEM to assess mediation longitudinally. One focused on self-reported physical health and concluded that the network structure (frequency of contact with friends) and social support (emotional, informational, appraisal, and instrumental support from friends) partially mediated the association between socioeconomic position and physical health among older adults in Norway. The second study focused on depressive symptoms and concluded that social participation partially mediated the effect of poverty on depression among middle-aged and older Chinese adults, but at baseline only (Jin, Zhu and He, 2020). Overall, findings from both studies lend support to those from this project, however, there were some notable differences. Neither study explored cross-lagged associations between health outcomes and socioeconomic position and between social relationships and health outcomes. Secondly, one study used a single question (frequency of contact with friends) to measure structural social relationships, along with perceived social support from friends as a measure of functional social connections; however, the latter measure was limited to social support from friends only (Adhikari and Uddin, 2022). The second study used social participation as an aggregate measure of structural and functional social relationship measures (Jin, Zhu and He, 2020). Additionally, they tested bidirectional pathways from poverty to depression and reported a stronger association from depression to poverty than in the opposite direction – a finding contrary to what has been reported in this project. However, Jin et al (2020) modelled the social causation pathway (mediators: social participation, living conditions, life satisfaction, health-related behaviours) and health selection pathway (mediators; unemployment, ADL, health expenses) separately in SEM with differing mediators which may explain their findings. Therefore, this is the first project to implement SEM, including distinct structural and functional social relationship measures as mediators and multiple health outcomes. This is also the first study assessing longitudinal mediation in older adults' oral health outcomes.

Another strength of this project was the use of full information maximum likelihood (FIML) to handle missing data in longitudinal mediation and moderation analyses. Furthermore, multiple imputations by chained equations (MICE) were utilised to address missing data in the cross-sectional analyses. Failing to account for missing data in statistical analysis can bias effect estimates and standard errors, with the latter resulting in incorrect confidence intervals (White, Royston and Wood, 2011). Both FIML and MICE are considered asymptomatically equivalent; both perform well and are known to give reliable effect estimates (Collins, Schafer and Kam, 2001; Graham, 2003; Evans *et al.*, 2019).

9.7.2 Limitations

Data availability in ELSA

Unlike self-rated health, oral health data in ELSA are not captured at every wave. For example, although self-rated oral health and OHRQoL have been measured at waves 3, 4, 5, 7, 9 and 10, edentulousness has only been measured at waves 3, 5 and 7. This limited the number of waves that could be utilised in longitudinal data analyses. However, the study used data collected over eight years despite this limitation.

Another limitation is that ELSA only includes community-dwelling individuals aged 50 years and above. ELSA does not have information on institutionalised older adults; therefore, results may not be generalisable to this cohort. Institutionalised individuals, e.g., those in care homes or hospices, are more likely to suffer from poorer health and social relationships and be socioeconomically disadvantaged.

Attrition can also pose a problem in longitudinal analyses. Some participants will drop out of the study at some point due to moving out of England, death, becoming institutionalised, or refusal to be recontacted in future study waves. Since sampling in ELSA was carefully determined by a set of stringent eligibility criteria to reflect characteristics of older people across the wider population in England, non-randomised attrition will potentially impede this representativeness. Generally, non-respondents tend to be those from more disadvantaged socioeconomic groups and in poorer health compared to respondents (Slymen *et al.*, 1996; Young, Powers and Bell, 2006), therefore, potentially leading to under-representation of cohorts that would be important to retain especially in health inequalities research. However, in this project, FIML was used in longitudinal analyses, and MICE was used in cross-sectional analyses. Both methods are appropriate to address missingness and account for non-response (Collins, Schafer and Kam, 2001; Graham, 2003; Evans *et al.*, 2019).

Self-reported measures

Understanding how individuals evaluate their health using self-reported health measures has become increasingly important in epidemiological and health surveys. While these are widely available in ELSA, overall, individuals tend to evaluate their health more optimistically (Kaplan and Baron-Epel, 2003). There is also a question of underestimating the true effect size in the context of health inequalities research due to health expectations being partly socially driven. For example, individuals from higher socioeconomic groups will have a higher expectation of what constitutes 'good' health (Johnston, Propper and Shields, 2009). However, whilst this study had several subjective health measures (self-rated health, self-rated oral health, OHRQoL), these measures were either based on validated instruments or have been assessed as robust measures of subjective health (Idler and Kasl, 1995; Idler and Benyamini, 1997; Tsakos, Marcenes and Sheiham, 2001; Pitiphat *et al.*, 2002; Benyamini, Leventhal and Leventhal, 2004). Furthermore, this study did not report solely on subjective health outcomes, and included a clinical measure (blood pressure), and a self-reported objective measure (edentulousness). Including both subjective and objective health outcome measures enabled important differences in findings for objective versus subjective measures to be identified in this project – for example, the relevance of social relationships in mediating subjective rather than objective health outcomes as discussed in Section 9.4. Although direct comparisons between self-reported subjective health and blood pressure cannot be made as they are measures of different health conditions, a more general comparison of objective and subjective health can be made. It would have been more desirable to have clinical oral health measures, but these are not available in ELSA. Edentulousness, although a self-reported measure, was a more objective measure of lifetime oral health as it captures historical oral health, whereas self-rated oral health and OHRQoL measure current perceptions of oral health.

Statistical techniques

Observed versus latent variables

Sum scores assume that questionnaire items are free from measurement error and are equally important. However, these assumptions are not always reasonable to make. Factor analysis assumes that item responses are explained partly by an underlying trait, i.e., the latent factor, and partly by measurement error and can partial out this error. It permits intercorrelations between factor items since the same underlying construct influences them. Factor analysis assigns weights, i.e., factor loadings, for each factor item, based on the proportion of variance explained by that item. This determines which items are stronger manifestations of the underlying trait.

Latent constructs of social relationships would have been preferred in SEM as they could have captured relationships more broadly and explained more of the inequality in the SEM models. Additionally, latent variables can adjust for measurement error, and therefore, reduce the bias in effect estimates for the *a*, *b*, and *a***b* paths in large samples – latent variables are less likely than observed variables to produce Type I errors (Ledgerwood and Shrout, 2011). However, due to the issues with model specification and model convergence described in Chapter 7, latent variables had to be dropped in favour of observed social relationship measures, i.e., those based on sum scores. With that said, research also suggests a trade-off between accuracy and precision of effect estimates when using latent variables compared to observed variables that can make inference about mediation more complicated. Given that observed variables yield greater precision, they also result in models with greater statistical power (Ledgerwood and Shrout, 2011). Additionally, given the sample size used in this project and reliability of the social relationship measures (Cronbach's α for social isolation = 0.89; Cronbach's α for loneliness = 0.94), using social relationships as observed variables were less likely to have produced inflated Type I errors in the effect estimates.

Causal inference

Historically, due to their longitudinal nature, panel models in SEM have been thought of as causal models, and often the two terms have been used interchangeably (Kenny, 1979; Bentler, 1980). This has primarily stemmed from two key aspects of causation: (1) that longitudinal models generally lend support to causal claims through temporal precedence of predictors and outcomes, (2) and due to simultaneous modelling of direct and indirect pathways (Selig and Little, 2012; Bollen and Pearl, 2013). Instead, SEM is an inference tool that may help build a case for plausible causal assumptions for specific models (Selig and Little, 2012; Bollen and Pearl, 2013). It is important to note that SEM does not attempt to make causal inferences from modelling associations alone, especially with observational data. The difficulty with observational data is the possibility of associations between predictors, mediators, and outcomes with unmeasured external variables, that some literature suggests can only be avoided by randomised control trials (Selig and Little, 2012). However, randomised control trials are not feasible. In the context of the research questions posed in this project.

This study aimed to identify the impact of one variable on another across time and to gauge how and for whom this effect occurs. Given the complexities of modelling longitudinal data with a mixture of ordinal, continuous and binary variables, implementing an autoregressive cross-lagged panel model with mediation effects were the most appropriate design for this project (Selig and Little, 2012). Furthermore, the cross-lagged panel models included lag-2 effects, i.e., two waves apart, were estimated between the exposure (wealth) and outcome and included nested lag-1 effects[12]. Including lag-2 effects is important as a means to give indications of favouring causal inference (Lüdtke and Robitzsch, 2021). Although the autoregressive cross-lagged panel model violated the temporal precedence of the variables due to estimating reciprocal associations, omitting these associations would have assumed that these associations were zero, which would have been an inaccurate assumption (MacKinnon, 2008). A careful trade-off needs to be considered between plausibility and complexity when designing a longitudinal mediation study which I believe this project has done.

9.8 Future research

9.8.1 Incorporating oral health outcomes as part of general health

Historically, dental care has been treated separately from medical care (Simon, 2016). Yet the head cannot be severed from the body, and oral and general health share common risk factors (Watt and Sheiham, 2012). If we are to encourage an integrated approach, oral health cannot remain divorced from the healthcare system. This can be achieved more through the inclusion of clinical oral health measures in large representative surveys and

[12]Lag-1 effects were those estimated one wave apart between the exposure i.e., wealth and mediators (social isolation and loneliness), and between the mediator and outcome.

by incorporating oral health measures as part of overall health in future health inequalities research.

9.8.2 Social relationships mediating and moderating socioeconomic inequalities in different populations

This project examined social relationships as mediating and moderating socioeconomic inequalities in health within a high-income country (HIC). As highlighted by the systematic review, very few studies concerning social relationships in mediating and moderating health inequalities have taken place in low- or middle-income countries (LMIC). It is not clear whether the association between social relationships, socioeconomic position and health found in this project and similar studies across HICs, extend to non-western and less economically developed countries. It would be interesting to compare findings from LMIC to those from HIC among older populations. Since cultures vary in their value of interpersonal relationships, the prevalence of less satisfactory social relationships are expected to vary between individualist and collectivist cultures – this may potentially result in differences in social relationships in mediating or moderating socioeconomic inequalities in health.

9.8.3 Validation of social relationship measures

Unlike the UCLA tool used for measuring loneliness, the constructs of social isolation, positive and negative support measures are unvalidated. However, they were based on previous research to aid reliability. Having validated measures may aid in having a more robust indicator to accurately assess objective social isolation and distinguish it from the more subjective social support measures. Measures of isolation are often constructed as aggregate measures of both structural and functional social support measures, for example, in the study by du Prel *et al*. (2014) social isolation was captured by frequency of contact with the social network, number of social network members, and social support (instrumental and financial). However, a multidimensional tool that includes both structural and functional social relationship domains make it increasingly difficult to disaggregate which social relationship domain, i.e., structural or functional, is more influential in mediating or moderating socioeconomic inequalities in health. Additionally, validating positive and negative social support measures would help distinguish these from other subjective social relationship measures, such as loneliness. More importantly, having validated and robust tools to measure social relationships would improve comparability between studies. Future research could use exploratory factor analysis followed by confirmatory factor analysis to construct and develop an appropriate measurement scale for social isolation and positive and negative social support.

9.9 Policy implications

9.9.1 Tackling socioeconomic inequalities in health

Findings from this doctoral thesis have generally shown that socioeconomic position remains a strong driver of the social gradient in health among older people in England. Therefore, those from more disadvantaged groups are likely to remain disadvantaged over time. If the UK is to add healthy years to a disadvantaged older person's life expectancy, the social gradient cannot be overlooked or downplayed in favour of social relationships as mediator or moderators in explaining social gradients in health – social relationships may partly explain these social gradients, but as this project has shown, social relationships are also driven by social inequalities. If the UK is to provide a positive environment in which people are born, grow, work and age, the focus of addressing social inequalities in health should not simply be for the most disadvantaged decile within society, but rather a universal approach that is proportionate to the level of socioeconomic disadvantage is needed to improve the health of all of the gradient is to be flattened (Marmot, Allen, Boyce, *et al.*, 2020). The Government has committed to the WHO's Healthy Ageing agenda. As such, to ensure longevity and, more importantly, extend a healthy life to all, they must remain committed to improving older people’s material conditions from a life course perspective. Meanwhile, issues like social isolation and loneliness should not be disregarded. Social relationships are also socially patterned i.e., suggesting that material conditions may affect people’s ability to maintain relationships, and poor social relationships are linked with many detrimental health outcomes. A joined-up, cross-sector approach is needed to address socioeconomic inequalities in health and in social relationships if the UK is to provide social environments that foster greater health equality and positive social relationships to enhance better health for all.

9.9.2 Social relationships in policy

Social isolation and loneliness have received increasing attention over the past decade, with policies developed in many countries to tackle loneliness. In the UK, tackling loneliness and social isolation has been a critical strategy since 2015. Addressing loneliness in the community is incorporated into Social Prescribing as a part of NHS England's comprehensive model of personalised care (NHS England, 2022). Social prescribing addresses an individual's non-medical needs – care navigators will help to provide social support by signposting or connecting patients to relevant resources or assets, e.g., organisations and events, in their local community (Tierney *et al.*, 2020).

This study supports the implementation of recent UK-wide strategies addressing the importance of social relationships among older adults to promote healthy ageing as stated in their consensus to healthy ageing policy paper published in February 2023. OHID, the Centre for Ageing Better, the NHS and other partner organisations have proposed a vision for healthy ageing in England, which includes promoting social participation, engagement, and social support to aid health and well-being (Office for Health Improvement and Disparities, 2023).

It is pertinent to highlight that material factors need to be addressed and must remain central to the public health issue of loneliness and social relationships overall, otherwise we end up victim blaming groups within society as often the case in relation to health behaviours.

9.9.3 Incorporating oral health as part of the wider health frameworks

This study also supports integrating oral health into general health. If oral health outcomes were not included in this study, findings would have reflected that loneliness and social isolation did not meaningfully contributing to socioeconomic inequalities in health, since they explained less than 10% of the wealth-SRH association and did not contribute to explaining wealth inequalities in systolic blood pressure. Since this project has highlighted that loneliness and social isolation are important in partially explaining socioeconomic inequalities in both subjective general and oral health measures, it is important to consider them together. Moreover, the risk factors shared by oral and general health are similar, therefore, health improvement strategies should not consider them separately.

More opportunities to integrate oral health into the general health framework will encourage researchers, the Government, and healthcare systems to view oral health as equally important as general health.

9.10 Conclusion

Findings from this PhD project highlight the importance of socioeconomic position as a structural determinant of a range of diverse health outcomes. The socioeconomic gradients persist in systolic blood pressure, self-rated health, self-rated oral health, OHRQOL and edentulousness among older adults in England. Whilst social isolation and loneliness partially mediate socioeconomic inequalities in health, they only explain a small proportion of the effect of wealth on health. However, less consistent evidence was found for social relationships moderating socioeconomic inequalities in health. These findings highlight the need to remain primarily focused on tackling the broader, upstream determinants of health, but also secondary factors such as loneliness and social isolation, both public health concerns, should also remain part of the ageing and health inequalities agenda. Moreover, this thesis highlighted the importance of oral health among older adults when considering health inequalities and that loneliness and social isolation may play an essential role in partially mediating socioeconomic inequalities in subjective oral health.

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Appendices

Appendix 1: Search Terms for systematic review

SEARCH TERMS	
Database	**MeSH terms**
Medline	Socioeconomic Position – socioeconomic factors/ or economic status/ or poverty/ or poverty areas/ or social class/ or educational status/ or employment/ or income/ or occupations/ or career mobility/ or poverty/ or social conditions/
	Social Relationships – interpersonal relations/ or intergenerational relations/ or family relations/ or social capital/ or social environment/ or community networks/ or social support/ or psychosocial support systems/ or social isolation/ or loneliness/ or social alienation/ or social marginalization/ or friendship/
	Health Inequalities – Health Status/ or Health Status Disparities/
Embase Classic + Embase	Socioeconomic Position – socioeconomic factors/ or economic status/ or poverty/ or poverty areas/ or social class/ or educational status/ or employment/ or income/ or occupations/ or career mobility/ or poverty/ or social class/ or social conditions/
	Social Relationships – interpersonal relations/ or intergenerational relations/ or family relations/ or social capital/ or social environment/ or community networks/ or social support/ or psychosocial support systems/ or social isolation/ or loneliness/ or social alienation/ or friendship/ or social marginalization/
	Health Inequalities – Health Status/ or Health Status Disparities/
PsycINFO	Socioeconomic Position – socioeconomic status/ or educational background/ or educational attainment level/ or parent educational background/ or poverty/ or socioeconomic factors/ or family socioeconomic level/ or socioeconomic factors/ or economic inequality/ or disadvantaged/ or family socioeconomic level/ or income level/ or lower class/ or social class/
	Social Relationships – interpersonal relationships/ or social interaction/ or couples/ or caregivers/ or family relations/ or friendship/ or kinship/ or marital relations/ or partners/ or peers/ or social capital/ or social networks/ or social interaction/ or social inclusion/ or social support/ or support groups/ or social exclusion/ or parasocial interaction/ or social exchange/ or online social networks/ or ingroup outgroup/ or social network analysis/ or social deprivation/ or psychosocial factors/ or social acceptance/ or social groups/ or social isolation/

	Health Inequalities – health inequality.mp./ or health disparities/
Free-text search terms	**Medline**
Socioeconomic Position	1. Socioeconomic position MeSH terms 2. socioeconomic position.mp. 3. (socioeconomic* or socio-economic* or SES or SEP or income or depriv* or occupation*).ti,ab,kf. 4. social gradient.mp. 5. 1 OR 2 OR 3 OR 4
Social Relationships	6. Social relationship MeSH terms 7. social relationship.mp. 8. (social relation* or social interaction or social integration or social marginali?ation or social participation or social engagement or social cohesion or social* cohesi*).ti,ab,kf. 9. 6 OR 7 OR 8
Health Inequalities	10. Health inequalities MeSh terms 11. health inequality.mp 12. (health inequ* or health dispar* or health status dispar* or health status dispar* health gradient*).ti,ab,kf. 13. (health adj2 inequ*).mp. 14. 10 OR 11 OR 12 OR 13 15. 5 AND 9 AND 14 16. Limit to Humans
Free-text search terms	**Embase Classic + Embase**
Socioeconomic Position	1. Socioeconomic position MeSH terms 2. socioeconomic position.mp. 3. (socioeconomic* or socio-economic* or SEP or SES or depriv* or income or occupation*).ti,ab,kw. 4. social gradient.mp. 5. 1 OR 2 OR 3 OR 4
Social Relationships	6. Social relationship MeSH terms 7. social relationship.mp. 8. (social relation* or social interaction* or social integration or social cohesion or social engagement or social participation or social marginali?ation).ti,ab,kw. 9. 5 OR 6 OR 7
Health Inequalities	10. Health inequalities MeSh terms 11. Health inequality.mp 12. (health inequ* or health status dispar* or health dispar* or health gradient*).ti,ab,kw. 13. (health adj2 inequ*).mp. 14. 10 OR 11 OR 12 OR 13 15. 5 AND 9 AND 14 16. Limit to Humans
Free-text search terms	**PsycINFO**
	1. Socioeconomic position MeSH terms 2. socioeconomic position.mp. 3. economic security.mp. 4. 1 OR 2 OR 3 5. Social relationship MeSH terms 6. (social relation*).mp. 7. social cohesion.mp. 8. 5 OR 6 OR 7 9. Health inequalities MeSh terms

10. (health inequ* or health dispar* or health gradient).mp.
11. health gradient.mp.
12. health adj2 inequ*
13. 9 OR 10 OR 11 OR 12
14. 4 AND 8 AND 13
15. Limit to Humans

Appendix 2: Search strategy tools and operators

Technique	Command	Example
All known synonyms and acronyms of keyword		socioeconomic position may include socioeconomic status, income, SES, SEP etc.
Truncation – used to find variant word endings	“root word”*	depriv* includes deprivation and deprived
Wildcard – used to replace a character within a word to enable alternative spellings to be included	?	marginali?ed includes marginalised and marginalised
Boolean operators – to combine keywords and subject headings within a key concept, and to combine different key concepts	“OR” “AND”	social position OR social status will identify articles containing either of these terms; social capital AND health status disparities will identify articles with both terms
Searching title, abstract and keyword fields – this will also include current articles to be retrieved that do not yet have MeSH terms assigned	(free-text word search string).ti,ab,kw.	(health inequ* or health status dispar*).ti,ab.kw.

Appendix 3: Newcastle-Ottawa Quality Assessment Form (adapted for cross sectional studies)

Selection: (Maximum 5 stars)

1. Representativeness of the sample:
    a. Truly representative of the average in the target population (all subjects or random sampling)*
    b. Somewhat representative of the average in the target population (non-random sampling)*
    c. Selected group of users
    d. No description of the sampling strategy
2. Sample size:
    a. Justified and satisfactory*
    b. Not justified
3. Non-respondents:
    a. Comparability between respondents and non-respondents' characteristics is established, and the response rate is satisfactory*
    b. The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory
    c. No description of the response rate or the characteristics of the responders and the non-responders
4. Ascertainment of the exposure (risk factor):
    a. Validated measurement tool**
    b. Non-validated measurement tool, but the tool is available or described*
    c. No description of the measurement tool

Comparability: (Maximum 2 stars)

1. The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled
    a. The study controls for the most important factor (select one)*
    b. The study control for any additional factor*

Outcome: (Maximum 3 stars)

1. Assessment of the outcome:
    a. Independent blind assessment**
    b. Record linkage**

c. Self-report⁕
d. No description
2. Statistical test:
   a. The statistical test used to analyse the data is clearly described and appropriate, and the measurement of the association is presented, including
   confidence intervals and the probability level (p value)⁕
   b. The statistical test is not appropriate, not described, or incomplete

This scale has been adapted from the Newcastle-Ottawa Quality Assessment Scale for cohort studies to perform a quality assessment of cross-sectional studies for the systematic review, “*Panethnic Differences in Blood Pressure in Europe: A Systematic Review and Meta-Analysis*”(Modesti *et al.*, 2016).

Appendix 4: Newcastle Ottawa Quality Assessment Form for Cohort Studies

Selection (Maximum 4 stars)

1. Representativeness of the exposed cohort
    a. Truly representative*
    b. Somewhat representative*
    c. Selected group
    d. No description of the derivation of the cohort
2. Selection of the non-exposed cohort
    a. Drawn from the same community as the exposed cohort*
    b. Drawn from a different source
    c. No description of the derivation of the non-exposed cohort
3. Ascertainment of exposure
    a. Secure record (e.g., surgical record)*
    b. Structured interview*
    c. Written self-report
    d. No description
    e. Other
4. Demonstration that outcome of interest was not present at start of study
    a. Yes*
    b. No

Comparability (Maximum 2 stars)

1. Comparability of cohorts on the basis of the design or analysis controlled for confounders
    a. The study controls for age and sex*
    b. Study controls for other factors (list)*
2. Cohorts are not comparable on the basis of the design or analysis controlled for confounders

Outcome (Maximum 3 stars)

1. Assessment of outcome
    a. Independent blind assessment*
    b. Record linkage*
    c. Self-report

d. No description
e. Other

2. Was follow-up long enough for outcomes to occur
   a. Yes*
   b. No
3. Adequacy of follow-up of cohorts
   a. Complete follow up – all subject accounted for*
   b. Subjects lost to follow up unlikely to introduce bias – number lost less than or equal to 20% or description of those lost suggested no different from those followed*
   c. Follow up rate less than 80% and no description of those lost
   d. No statement

Appendix 5: Quality appraisal of included studies

Study	Selection	Comparability	Outcome	Overall rating*
Aartsen et al., 2017	★★★★	★	★★	★★★★★★★
Abel et al., 2011	★★★	★★	★	★★★★★★
Adhikari & Uddin 2022	★★	★	★★★	★★★★★★
Ahnquist et al., 2012	★★	★★	★★	★★★★★★
Aida et al., 2011	★★★	★★	★★	★★★★★★★
Aldabe et al., 2011	★★	★	★★	★★★★★
Andersson, 2016	★★★	★★	★★	★★★★★★★
Antonucci et al., 2003	★★	★	★★	★★★★★
Barber et al., 2016	★★★★	★★	★★★	★★★★★★★★★
Cao et al., 2022	★★★★	★	★★★	★★★★★★★★
Craveiro, 2017	★★	★★	★★	★★★★★★
Cundiff et al., 2016	★★	★★	★★	★★★★★★
Daoud et al., 2009	★★	★★	★★	★★★★★★
De Clercq et al., 2012	★★★★	★★	★★	★★★★★★★★
Drukker et al., 2006	★	★★	★★	★★★★★
Due et al., 2003	★★★★	★★	★★	★★★★★★★★
du Prel et al., 2014	★★★★	★	★★	★★★★★★★
Elgar et al., 2010	★★★	★	★★	★★★★★★
Etman et al., 2015	★★★	★★	★★★	★★★★★★★★
Ferraro & Su, 1999	★★		★★	★★★★
Fone et al., 2007	★★★★	★★	★★	★★★★★★★★
Fone et al., 2014	★★★	★★	★★	★★★★★★★
Gadermann et al., 2016	★★★	★★	★★	★★★★★★★
Green et al., 2022	★★★★	★★	★★★	★★★★★★★★★
Gorman & Sivaganesan, 2007	★★★	★	★	★★★★★
Han et al., 2018	★★	★★	★★	★★★★★★
Haseda et al., 2018	★★★	★★	★	★★★★★★
Hassanzadeh et al., 2016	★★	★	★	★★★★
Hibbard & Pope, 1992	★★★★	★★	★★★	★★★★★★★★★
Huurre et al., 2007	★★★	★	★★★	★★★★★★★
Jin et al, 2020	★★	★★	★★	★★★★★★
Kaur et al., 2018	★★★	★	★	★★★★★
Kim & Kawachi, 2007	★★	★★	★★	★★★★★★
Klein et al., 2012	★★	★★	★★	★★★★★★
Knesebeck & Geyer, 2007	★★★	★	★★	★★★★★★
Kollannoor-Samuel et al., 2011	★★		★	★★★

Lai et al., 2022	★★	★★	★★	★★★★★★
Meisters et al., 2022	★★★	★★	★★	★★★★★★★
Miller & Taylor, 2012	★★	★	★★	★★★★★
Moor et al., 2014	★★★★	★	★★	★★★★★★★
Natamba et al., 2017	★★	★★	★★	★★★★★★
Ng et al., 2014	★★★	★★	★★	★★★★★★★
Nielsen et al., 2015	★★★★★	★★	★★	★★★★★★★★★
Nilsson et al., 2010	★★★	★★	★★	★★★★★★★
O'Brien, 2012	★★★	★	★★	★★★★★★
Olofsson et al., 2018	★★★	★	★	★★★★★
Platts & Gerry 2016	★★	★★	★★	★★★★★★
Rael et al., 1995	★★★	★★	★★★	★★★★★★★★
Rios et al., 2012	★★★	★	★★	★★★★★★
Rodrigues et al., 2021	★★★	★★	★★	★★★★★★★
Roy et al., 2018	★★	★	★★	★★★★★
Rueda, 2012	★★	★★	★★	★★★★★★
Sacker et al., 2011	★★★	★★	★★	★★★★★★★
Salihu et al., 2017	★★	★★	★★	★★★★★★
Salonna et al., 2012	★★★★	★	★★	★★★★★★★
Soskolne & Manor, 2010	★★★★	★★	★★	★★★★★★★★
Stafford et al., 2008	★★★★★	★★	★★	★★★★★★★★★
Stringhini et al., 2012	★★★★	★★	★★★★	★★★★★★★★★
Uebelacker et al.2013	★★★	★	★	★★★★★
Veenstra & Patterson 2012	★★★★	★★	★★	★★★★★★★★
Verhaeghe & Tampubolon, 2012	★★	★★	★★	★★★★★★
Vincens et al., 2018	★★★	★★	★★	★★★★★★★
Vonneilich et al., 2012	★★★	★★	★★★	★★★★★★★★
Vonneilich et al., 2019	★★★★★	★★	★★	★★★★★★★★★
Wang & Hoshi, 2015	★★★	★	★	★★★★★
Wei et al., 2018	★★★★★	★★	★★	★★★★★★★★★
Wu & Rudkin, 2000	★★	★★	★	★★★★★
Zhang et al., 2022	★★★	★★	★★	★★★★★★★
Zhang & Xiang, 2019	★★	★★	★	★★★★★

Appendix 6 Recalculating effect estimates to odds ratios for narrative synthesis

Recalculating multiple regression estimates into odds ratios (OR) and corresponding 95% confidence intervals (CI) for meta-analysis of longitudinal observational cohort studies.

Abbreviations:

OR: odds ratio

PR: Prevalence Ratio

RR: relative risk

HR: hazard ratio

CI: confidence interval

β: standardized regression coefficient

SE: standard error

r: correlation coefficient

*: multiply by

d: standardized mean difference

V: variance

β*: partially standardized (only outcome is standardized, not the determinant) regression coefficient

B: unstandardised regression coefficient

1. <u>In case OR (95% CI) is reported</u>
   1.1. Use the same OR (95% CI) in case the association represents "low socioeconomic position and poor health outcome."
   1.2. Recalculate OR by 1/OR in case the association represents "high socioeconomic position and poor health outcome", or "low socioeconomic position and good/better health outcome". The 95% CI is calculated likewise.

2. <u>In case RR/ PR or HR is reported</u> (Higgins and Green, 2008)
   2.1. Interpret RR, PR, or HR as OR

3. <u>In case β (SE) is reported</u>
   3.1. Step 1 (Peterson and Brown, 2005)

From β (SE) to *r* (SE) → $r = \beta + 0.05\lambda$

where λ equals 1 when β is non-negative and 0 when β is negative.

Or use online calculator: https://www.psychometrica.de/effect_size.html

3.2. Step 2 (Borenstein *et al.*, 2009)

From *r* to *d* →$d = \frac{2*r}{\sqrt{1-r^2}}$

From SE(*r*) to V(*r*) →$V(r) = (SE(r))^2$

From V(r) to V(*d*) → V(*d*)= $\frac{4*V(r)}{(1-r^2)^3}$

3.3. Step 3: Either hand-calculate (Borenstein *et al.*, 2009; da Costa *et al.*, 2012)

From *d* to LogOR →$LogOR = d * \frac{\pi}{\sqrt{3}}$

From V(*d*) to V(LogOR) → $V(LogOR) = V(d) * \frac{\pi^2}{3}$

3.4. Step 4 (Higgins and Green, 2008)

From V(LogOR) to SE(LogOR) →$SE(LogOR) = \sqrt{(}V(\text{LogOR})$

From SE(LogOR) to (95% CI(LogOR)) → $Log(OR) \pm 1.96 * SE(LogOR)$

From LogOR to OR (same for upper and lower limits of 95% CI)

→$OR = \exp{(LogOR)}$

4. or use online calculator for steps 3 and 4:
   https://www.campbellcollaboration.org/escalc/html/EffectSizeCalculator-OR5.php

5. In case β (p-value (2-sided)) is reported

   5.1. Step 1 (Higgins and Green, 2008)

   From p-value (β) to SE (β) →$SE = \frac{\beta}{Z}$

$$Z = abs(normsinv(\frac{pvalue(\beta)}{2})$$

   5.2. Step 2: From β (SE) to OR (95% CI) → Follow the steps 3.1 to 3.4.

6. In case of β* (SE) (the outcome is standardised, the determinant not)

   6.1. Step 1 (Bring, 1994)

   From β* to β → $\beta = (\beta *) * \mathrm{SD}(\text{determinant})$

   From SE(β*) to SE(β) → $SE(\beta) = SE(\beta *) * (SD(deterinant)$

   6.2. Step 2: From β (SE) to OR (95% CI) → Follow the steps 3.1 to 3.4.

7. In case of β* (SE) (the determinant is standardised, the outcome not)

7.1. From β* to β → $\beta = (\beta *) * SD(outcome)$

From SE(β*) to SE(β) → $SE(\beta) = \left(SE(\beta *)\right) * SD(outcome)$

7.2. From β (SE) to OR (95% CI) → Follow the steps 3.1 to 3.4

8. <u>In case B(SE) is reported</u>

8.1. Step 1 (Bring, 1994)

From B to β → $\beta = B * \frac{SD(determinant)}{SD(outcome)}$

From SE(B) to SE(β) → $SE(\beta) = \left(SE(B)\right) * \frac{SD(determinant)}{SD(outcome)}$

8.2. From β (SE) to OR (95% CI) → Follow the steps 3.1 to 3.4

9. <u>In case CI is missing for OR, but p-value is available</u> (Altman and Bland, 2011)

9.1. Step 1: $z \ = \ -0.862 + \ \sqrt{}[0.743 - 2.404 \times log(p - value)]$

9.2. Step 2: Est = LogOR

9.3. Step 3: SE = LogOR/z (ignore the minus signs) and 1.96×SE

9.4. Step 4: 95% CI on log scale = Est –1.96xSE to Est + 1.96xSE

9.5. Step 5: 95% CI on natural scale = exp (LogLCI) and exp (LogUCI)

10. <u>In case SE is missing, but CI is available</u>

10.1. SE= (upper CI – lower CI)/ 3.92

Appendix 7: Data extraction tables - social relationships mediating social inequalities in health

Study characteristics		Study variables			Results		
Author	Country, Population, n, Female (%), Age: mean/SD or range (years)	SEP variable	Social relationship variable	Outcome	Original results from paper (Effect estimate with 95% CI or SE)	OR (95% CI) for narrative synthesis	Conclusion
Aartsen et al., 2017[a]	Norway (♂/♀) Norwegian panel study on Life course, Ageing and Generation (NorLAG) *n* = 9224 50.8 40-80	**Income:** Gross income in 2007 **Education:** Categorical, based on International Standard Classification of Education (ISCED-97) **Occupational status:** Scale (1-9), based on International Standard Classification of Occupations (ISCO-88)	**Structural:** *social activity and network.* Total number (based on 2 parameters: network size and frequency of contact with network members) **Functional:** *social support and loneliness.* Count and continuous (based on 2 items: perceived support, loneliness)	**Physical health:** Self-report (Short-Form Health Survey 12). Continuous, higher scores indicate better health.	<u>High SEP on better health</u> **Men 40-66 years of age:** Indirect via loneliness β 0.013 (95% CI 0.038-0.099) **Men 67-81 years of age:** Indirect via loneliness β 0.011 (95% CI 0.038-0.099) **Women 40-66 years of age:** Indirect via loneliness β 0.023 (95% CI 0.084-0.205) **Women 67-81 years of age:** Indirect via loneliness β 0.016 (95% CI 0.084-0.205)	Coefficients are from SEM Only total indirect effects available	Loneliness accounts for 3.7% and 4.9% of the total effect of SEP and on health for middle-aged and older men respectively, and accounts for 7.2% and 7.8% of the total effect of SEP on health for middle-aged and older women respectively
Adhikari & Uddin, 2022*[b]	Norway (♂/♀) NorLAG *n* = 2856 50.6 ≥55 Follow-up: 10 years	**Income:** Gross income in 2007 **Education:** Categorical, based on International Standard Classification of Education (ISCED-97)	**Structural:** *social network.* Continuous (based on 1 item: frequency of contact with network members) **Functional:** *social support.* Continuous (based on perceived support)	**Physical health:** Self-report (PCS-12 which is the physical health component of the Short-Form Health Survey 12). Continuous, higher scores indicate better health.	<u>Income on physical health</u> **Total effect:** B 0.83 (95% CI 0.67-0.98) **Indirect effect** (social support): B 0.04 (95% CI 0.01-0.07) <u>Education on physical health</u> **Total effect:** B 1.23 (95% CI 0.89-1.57) **Indirect effect** (social support): B 0.12 (95% CI 0.05-0.20)	Coefficients are from SEM	Social support mediated 9.8% of the total effects of education on physical health and 4.8% of the total effect of income on physical health
Aida et al., 2011[a]	Japan (♂/♀)	**Gini coefficient**	**Structural:** *Social activity*. Dichotomous	**SRH:**	<u>SRH:</u>	Original effect estimates from paper	Older Japanese adults had 16% lower odds of

	Aichi Gerontological Evaluation Study Project (the AGES Project) *n* = 3451 46 65-85		(based on participation in voluntary association) **Functional:** *Trust*. Dichotomous (based on perceived trust of others)	Dichotomous, good vs poor **Dental status:** Number of remaining natural teeth. Dichotomous, ≥20 vs ≤19	Model 1: OR 1.25 (95% CI 0.98-1.55) Model 1 + Structural: OR 1.21 (95% CI 0.92-1.57) Model 1 + Functional OR 1.36 (95% CI 1.00-1.89) **Dental status:** Model 1: OR 1.54 (95% CI 1.14-2.14) Model 1 + Structural: OR 1.54 (95% CI 1.17-1.96) Model 1 + Functional: OR 1.67 (95% CI 1.26-2.29)		poor self-rated health when the structural social relationship indicator was added. However, there was no mediation seen for dental status by trust or voluntary membership
Aldabe et al., 2010[b]	28 Europe countries (♂/♀) European Quality of Life Survey (EQLS) *n* = 12 421 51.4 18-50+	**Occupational status:** Quintiles based on ISCO-2008	**Structural:** *Social activity and network.* Categorical (based on 2 items: frequency of contact with friends and family, affiliation with voluntary associations) **Functional:** *Social support, trust, and exclusion.* Dichotomous and categorical (support based on 2 items: emotional support, instrumental support; exclusion based on 4 items: feelings of inferiority, uselessness, lack of recognition or acceptance; social trust based on trust towards people and the state) SS = social support SN = social network SP = social participation SE = social exclusion ST = social trust	**SRH:** Dichotomous, good vs fair/poor	**Men:** Model 1: OR 1.89 (95% CI 1.46-2.46) Model 1 + SS OR 1.78 (95% CI 1.00-3.17) Model 1 + SN OR 1.91 (95% CI 1.00-3.65) Model 1 + SP OR 1.88 (95% CI 1.00-3.54) Model 1 + SE OR 1.61 (95% CI 1.00-2.59) Model 1 + ST: OR 1.74 (95% CI 1.00-3.03) **Women:** Model 1: OR 2.18 (95% CI 1.71-2.77) Model 1 + SS OR 2.04 (95% CI 1.00-4.17) Model 1 + SN OR 2.17 (95% CI 1.00-4.72) Model 1 + SP OR 2.16 (95% CI 1.00-4.67) Model 1 + SE OR 1.78 (95% CI 1.00-3.78)	Original effect estimates from paper	Social support attenuated the SEP-SRH association by 12.4% and 11.9% for men and women, respectively. Social exclusion attenuated the SEP-SRH association by 31.5% and 33.9% for men and women, respectively. Frequency of contact with the social network and participation did not meaningfully contribute to attenuating the SEP-SRH association. Social trust attenuated the SEP-SRH association by 16.9% in men and strengthened the SEP-SRH association in women by 4.85

					Model 1 + ST: OR 2.24 (95% CI 1.48-3.38)		
Antonucci et al., 2003[a]	USA (Detroit) (♂/♀) The Survey of Social Relations *n* = 798 58.6 40-93	**Education:** Continuous, based on highest level of completed education	**Structural:** *Social network*. Count variable (0-20) (based on 2 items: total network size and number of people closest and somewhat close to participant) **Functional:** *Social support*. Continuous (based on 3 items: sick care from child, financial care from child, being able to confide in child)	**SRH:** Health problem Index comprising of a global rating of health + count of chronic illnesses. Standardised scale, positive numbers indicate worse health	Non-significant across all social relationship variables	Non-calculable	No significant mediating effects of SEP on health via social relationships
Cao et al., 2022*[a]	USA (♂/♀) Spina Cord Injury Longitudinal Aging Study *n* = 1540 65 > 18 Follow-up: 1 year	**Income:** Categorical (<$20,000, $20,000 -$49,999, and ≥$50,000) **Employment status:** Categorical (unemployed, part-time job, and full-time job) **Education:** Years of education - continuous	**Structural:** *Social participation* (based on 4 items: marital status, hours out of bed per day, days out of house per week, nights away from home during the past year)	**Survival rate after spinal cord injury:** Based on National Death Index	<u>**Highest income**</u> Model 1: OR 0.70 (95% CI 0.53-0.92) Model 2: OR 0.90 (95% CI 0.67-1.22) <u>**Full-time employment**</u> Model 1: OR 0.61 (95% CI 0.46-0.80) Model 2: OR 0.80 (95% CI 0.60-1.08)	<u>**<$20,000**</u> Model 1: OR 1.43 (95% CI 1.09-1.89) Model 2: OR 1.11 (95% CI 0.82-1.49) <u>**Unemployed**</u> Model 1: OR 1.64 (95% CI 1.25-2.17) Model 2: OR 1.25 (95% CI 0.93-1.67)	Social participation was protective against mortality risk for the most advantaged. Adding social participation measures resulted in a 10% and 20% reduction in mortality risk, when SEP was measured by income and employment status, respectively.
Cundiff et al., 2016[a]	USA (♂/♀) Adult Health and Behaviour Project – Phase 2 (AHAB-II) *n* = 475 52.8 30-54	**Social rank:** Subjective US and community social status	**Functional:** *Social support*. Continuous (based on 2 items: positive and negative interpersonal interactions)	**SRH:** Single item measured on a 5-point Likert scale; lower scores indicate better health	<u>**U.S. social rank:**</u> Direct effect: B -0.08 (-0.07) Indirect effect: B -0.008 (95% CI -0.02, -0.001) <u>**Community social rank:**</u> Direct effect: B -0.06 (-0.05) Indirect effect: B -0.008 (95% CI -0.02, -0.001)	Coefficients are from SEM	Positive social interactions explained 13% of the association between self-reported social rank and poorer self-rated health
Daoud et al., 2009[a]	Israel (♂/♀) *n* = 902 43 30-70	**Education:** Years of completed education. Categorical, ≤8 years/≤11 years/12 years/≥13 years **Land ownership:** Indicator of social prestige **Relative income:** Single question, whether income is similar or higher than	**Structural:** *Social activity and network*. Continuous and categorical (based on 7 items: network structure, social participation, civic engagement, access to healthcare services, neighbourhood problems)	**LLI:** Single item. Dichotomous, yes/no	<u>**Education (≤8 years):**</u> Model 1: OR 2.50 (95% CI 1.46-4.29) Model 1 + Social participation: OR 1.99 (95% CI 1.14-3.48) <u>**Land ownership (No):**</u> Model 1: OR 1.84 (95% CI 1.24-2.73) Model 1 + Social participation: OR 1.66 (95% CI 1.11-2.49)	Original effect estimates from paper	Social participation attenuated 21%-34% of social inequalities in LLI

		average Arab household income	**Functional:** *Social support and trust*. Continuous higher scores represent greater support (based on 3 items: support from others, feelings of trust or being exploited)		**Income (<average):** Model 1: OR 3.55 (1.88-6.71) Model 1 + Social participation: OR 2.81 (95% CI 1.46-5.40)		
De Clercq et al., 2012[a]	Belgium (♂/♀) HBSC-Belgium *n* = 10 915 49.9 9-18	**Family affluence:** Measured using Family Affluence Scale. Continuous, higher scores indicate greater affluence	**Combination:** *Social capital*. Dichotomous and continuous (based on 5 items: affiliation with voluntary association, interaction with neighbours, support from neighbours, trust in neighbourhood community)	**Health and well-being:** 10-item question. Continuous. Higher scores indicate better health and well-being except for loneliness and feeling sad where higher scores indicate greater loneliness/sadness	**Model 1:** B 0.023 (0.003) p <0.01 **Model 1 + SR:** B 0.020 (0.003) p <0.01	Model 1: OR 1.54 (95% CI 1.44-1.66) Model 1 + SR: OR 1.49 (95% CI 1.39-1.60)	Individual and community level social capital mediated the association between SEP and perceived health and well-being among adolescents – a reduction in the odds by 9.3%
Due et al., 2003[a]	Denmark (♂/♀) HBSC-Denmark *n* = 5202 50.4 11-15	**Social class:** Parental occupation measured using the Danish Social Class Classification. Dichotomous, high vs low	**Structural:** *Social activity and network*. Continuous and categorical (based on 2 items: network structure, frequency of social contact) **Functional:** *Social support*. Continuous (based on 5 items: emotional support, instrumental support, informational support, feeling safe at school, experience of being bullied)	**Health status:** **Physical symptoms** include headache, stomach-ache, backache, feeling dizzy, sleep difficulties **Psychological symptoms** include sadness, nervousness, loneliness, irritable, helplessness	**Physical symptoms:** **Boys** Model 1: OR 1.59 (95% CI 1.09-2.31) Model 2: OR 1.13 (95% CI 0.74-1.73) **Girls** Model 1: OR 1.43 (95% CI 1.07-1.91) Model 2: OR 1.17 (95% CI 0.85-1.61) **Psychological symptoms:** **Boys** Model 1: OR 1.94 (95% CI 1.39-2.70) Model 2: OR 1.33 (95% CI 0.90-1.96) **Girls** Model 1: OR 1.47 (95% CI 1.14-1.89) Model 2: OR 1.21 (95% CI 0.91-1.62)	Original effect estimates from paper	Structural and functional social relationship indicators reduced the social gradient in health between 55.3% and 60.5% in girls and 64.9% and 78% in boys for psychological and physical symptoms, respectively
du Prel et al., 2014[a]	Germany (♂/♀) German lidA-study *n* = 6339 53.8 44+	**Education:** Combination of education + vocational training	**Combination:** *Social isolation*. Continuous (based of 5 items: network structure, instrumental support, financial support, frequency of contact with network)	**Depression:** Measured using Beck's Depression Inventory (BDI-V)	**1959 birth year:** Direct effect: β 0.09 (95% CI -0.23, 0.41) Indirect effect: β -0.07 (95% CI -0.12, -0.04) *p*<0.001 **1965 birth year:**	Coefficients are from SEM	Social isolation accounted for 18.4% of the total effect of education on depressive symptoms

					Direct effect: β -0.26 (95% CI -0.48, -0.04) *p*<0.05 Indirect effect: β -0.07 (95% CI -0.11, -0.04) *p*<0.001		
Etman et al., 2015*[a]	11 Europe countries (♂/♀) SHARE *n* = 14 082 54.3 ≥55 Follow-up: 2 years	**Education:** Measured using ISCED-97. Dichotomous, lower education vs higher education	**Structural.** *Social activity*. Dichotomous (based on 3 items of social participation: affiliation with voluntary association, delivering care for sick person, taking part in leisure activities)	**Frailty:** Measured using updated Frieds Frailty Scale. Categorical (pre-frail, frail, non-frail)	**All countries:** Model 1: OR 1.39 (95% CI 1.26-1.53) Model 1 + Social participation: OR 1.36 (95% CI 1.23-1.50)	Original effect estimates from paper	Social participation attenuated social inequalities in frailty worsening by 7.7% for all countries combined
Gadermann et al., 2016[b]	Canada (♂/♀) 4168 49 9.7 (0.3)	**Income:** Based on median equivalized disposable income	**Functional.** *Social support*. Continuous, higher scores indicate greater support/connectedness (based on 2 items: emotional support from parents, neighbourhood, teachers, and connectedness to peers)	**SRH:** Single item. Continuous, higher scores indicate better health	**Direct effect:** β 0.01 p 0.58 **Indirect effect via adult connectedness at home:** β 0.01 (95% CI 0.01-0.02) **Indirect effect via adult connectedness at school:** β 0.003 (95% CI 0.00-0.01) **Indirect effect via adult connectedness in neighbourhood:** β 0.005 (95% CI 0.00-0.01) **Indirect effect via peer belonging:** β 0.01 (95% CI 0.01-0.02)	Coefficients are from SEM	The direct effect of income on health was not statistically significant. Peer connectedness explained 36% of the variance in perceived health, connectedness with adults at home and at school explained 23% and 11% of the variance in perceived health, respectively.
Gorman & Sivaganesan, 2007[b]	USA (♂/♀) National health Interview Survey (NHHIS) *n* = 29 816 52.3 48.7 (16.0)	**Education:** Quartiles, highest level achieved **Occupational status:** Quartiles, ranging from never worked to currently working **Medical care** **Health insurance** **Income-to-poverty ratio**	**Structural:** *Social activity and network*. Continuous and categorical (based on 4 items: network structure, frequency of social contact, affiliation with voluntary association, attend place of worship) **Functional:** *Social support*. Continuous, higher scores indicate greater support (based on emotional support)	**Hypertension:** Single item. Dichotomous, yes/no **SRH:** Single item. Continuous, with higher scores indicating better health	**Hypertension:** **Education (some college)** Model 1: OR 0.70 *p*<0.001 Model 1 + SR: OR 0.72 *p*<0.001 **Occupational (unemployed):** Model 1: OR 1.57 *p*<0.001 Model 1 + SR: OR 1.55 *p*<0.001 **SRH:** **Education (high school)** Model 1: B 0.24 (0.02) *p*<0.001	SRH: non-calculable, unstandardised beta coefficients presented – author no longer has data	Social relationships did not mediate the SEP-SRH and the SEP-hypertension association.

					Model 1 + SR: B 0.21 (0.02) *p*<0.001 **Occupational (unemployed):** Model 1: B -0.52 (0.03) *p*<0.001 Model 1 + SR: B -0.50 (0.02) p<0.001 SR: B 0.23 (0.02) *p*<0.001		
Han et al., 2018[b]	Korea Welfare Panel Study (KOWEPS) (♂/♀) *n* = 5969 74.5 60+	**Education:** Categorical, ranges from non-regular education to college or above **Household income:** Quartiles of income	**Functional:** *Social support*. Dichotomous (based on 2 items: reciprocity, trust)	**Depressive Symptoms:** Measured using Centre for Epidemiologic Studies Depression (CES-D-11) Scale	**<u>High household income on depressive symptoms</u>** **Direct effect:** β -0.176 *p*<0.001 **Indirect effect via reciprocity:** β -0.020 (95% CI -0.030, -0.012)	Coefficients are from SEM	Reciprocity partially mediated income inequalities in depressive symptoms
Hassanzadeh et al., 2016[a]	Iran (♂/♀) Urban Health Equity Assessment and Response Tool-2 (Urban HEART-2) *n* = 31 519 64.9 44.5 (15.9)	**Education:** Categorical, ranges from illiterate to university level **Material goods:** Dichotomous, yes/no. Ownership of car, computer, dishwasher, freezer, and microwave	**Combination:** *Social support, trust*. Continuous (measured using the Social Capital Questionnaire, based on 3 items: individual trust, social support/cohesion, social trust)	**Mental health:** Measured using General Health Questionnaire (GHQ-28). Continuous, score >23 indicates mental health disorders	**Direct effect:** β 0.32 (0.08) **Indirect via SR:** β 0.11	Coefficients are from SEM	Social support and trust mediated social inequalities in mental health
Jin et al., 2020*[a]	China (♂/♀) China Health and Retirement Longitudinal Studies (CHARLS) *n* = 17,250 51.3 59.1 (9.9) Follow-up: 2-years and 4-years	**Poverty:** Total household consumption based on World Bank absolute poverty	**Combination:** *Social participation*. Continuous, higher scores indicate greater participation (based on 11 items: interaction with friends, affiliated with a community club, providing social support to friends, family, neighbours, playing sports at sports club, taking part in community activity, volunteering, looking after sick or disabled person, attending educational or vocational training, using internet, making investments, other)	**Depressive symptoms:** Measured using the Centre for Epidemiologic Studies Depression Scale. Continuous (0-30), higher scores indicate more depressive symptoms	**<u>Baseline</u>** **Total effect:** β 0.468 (95% CI 0.235-0.701) **Direct effect:** β -0.061 (95% CI -0.284, 0.162) **Indirect effect:** β 0.03 *p* <0.001 **<u>2-year follow-up</u>** **Total effect:** β -0.023 (95% CI -0.282, 0.236) **Direct effect:** β -0.034 (95% CI -0.287, 0.219) **Indirect effect:** β -0.005 **<u>4-year follow-up</u>** **Total effect:** β -0.032 (95% CI -0.310, 0.246) **Direct effect:** β 0.087 (95% CI -0.185, 0.359) **Indirect effect:** β -0.001	Coefficients are from SEM	Significant total effects and indirect effects of poverty on depressive symptoms at baseline. Social participation mediated 6.4% of the total effects of poverty on depression at baseline. Social participation did not mediate the effect of poverty on depressive symptoms at the 2-year and 4-year follow-up
Kaur et al., 2018[a]	India (♂/♀) *n* = 1563	**Composite SEP:** Education +	**Combination:** *Social capital*. Continuous,	**SRH:**	**<u>SRH:</u>**	Coefficients are from SEM	Social capital was a significant mediator of

	49.3 40.1 (15.6)	Occupational status + Caste	higher scores indicate higher levels of social capital (based on 6 items: group characteristics, generalised norms, togetherness, sociability, neighbourhood connection and trust)	Measured via Short-Form (SF-36) health survey questionnaire **Mental health:** As above	**Total effect:** β 0.094 (95% CI 0.062-0.127) **Direct effect:** β 0.092 (95% CI 0.058-0.126) **Indirect effect:** β 0.003 (95% CI -0.005, 0.007) **Mental health:** **Men** **Total effect:** β 0.026 (95% CI -0.032, 0.082) **Direct effect:** β 0.017 (95% CI -0.041, 0.074) **Indirect effect:** β 0.009 (95% CI 0.002-0.020) **Women** **Total effect:** β 0.063 (95% CI 0.007-0.120) **Direct effect:** β 0.036 (95% CI -0.022, 0.095) **Indirect effect:** β 0.027 (95% CI 0.011-0.046)		the effect of socioeconomic position on mental health, but not physical health. Social capital mediated 34.7% of the total effect of SEP on mental health for the total sample. When stratified by sex, social capital mediated 42.9% of the total effect of SEP on mental health in women only. No difference was found when stratified by sex for SRH
Kim and Kawachi, 2007[b]	USA (♂/♀) Behavioural Risk Factor Surveillance System survey (BRFSS) *n* = 173 236 57.3 18-65+	**Gini coefficient:** continuous measure of income inequality	**Combination:** *Social capital*. Continuous, higher values indicate higher levels of state social capital (based on 5 items: trust, social engagement, affiliation with voluntary association, civic and political participation)	**SRH:** Measured using items from BRFSS survey + Centres for Disease Control and Prevention HRQOL-4 instrument. Dichotomous, excellent/very good/good health vs fair/poor health **Physical health/Mental health/Activity limitation:** Recent days of poor physical/mental health or activity limitation, continuous scale with higher values indicated poor health or days of activity limitation	**SRH:** Main model: OR 1.26 (95% CI 1.13-1.41) Main model + social capital: OR 1.16 (95% CI 1.04-1.30) **Activity limitation:** Main model β 0.39 (95% CI 0.17-0.60) Main model + social capital: β 0.28 (95% CI 0.03-0.54) **Mental health:** Main model β 0.38 (95% CI 0.03-0.73) Main model + social capital: β 0.18 (95% CI -0.20, 0.57)	**SRH:** Original effect estimates from paper **Activity limitation:** OR: 5.92 (95% CI 2.04-17.18) OR + SR: 3.56 (95% CI 1.09-11.57) **Mental health:** OR: 5.58 (95% CI 1.11-29.96) OR + SR: 2.35 (95% CI 0.62-8.87)	Social capital attenuated 38.5% of the SEP-SRH association, 50% or the SEP-activity limitation association and 70.5% of the SEP-mental health association (calculated from ORs)
Klein et al., 2012*[a]	Germany (♂/♀) Longitudinal Study of Health in Pomerania (SHIP) *n* = 3300 51.8 49.2 (15.4) Follow-up: 5 years	**Education:** No/low level; Medium level; High level **Household income:** Equivalent household income based on disposable income and household size	**Structural:** *Social activity and network.* Dichotomous (low vs higher integration based on 3 items: marital status, contact frequency with friends and family, affiliation	**SRH:** Dichotomous, good/poor	**Education (low):** Model 1: OR 1.61 (95% CI 1.13-2.30) Model 1 + SII: OR 1.48 (95% CI 1.01–2.16) Model 1 + Support: OR 1.53 (95% CI 1.06–2.20	Original effect estimates from paper	Structural + functional social relationships explain 31% of the educational inequalities in SRH Structural + functional social relationships

		Occupational status: Tertiles based on Standard Occupational Prestige Scale	with voluntary associations) **Functional:** *Instrumental and emotional social support*. Dichotomous (based on 2 items: material aid and availability of a trustworthy person to talk to)		Model 1 + All SR: OR 1.42 (95% CI 0.97-2.10) <u>**Household income (very low):**</u> Model 1: OR 1.84 (95% CI 1.33-2.53) Model 1 + SR: OR 1.55 (95% CI 1.08-2.21) <u>**Occupational status (lower tertile):**</u> Model 1: OR 1.51 (95% CI 1.16-1.96) Model 1 + SR: OR 1.36 (95% CI 1.02-1.82		explain 34.5% of the income inequalities in SRH Structural + functional social relationships explain 29% of the occupational inequalities in SRH
Knesebeck and Geyer, 2007[a]	Europe (♂/♀) European Social Survey *n* = 36 263 52.5 ≥25	**Education:** Measured by ISCED-97. Dichotomous, low vs high	**Functional:** *Social support*. Dichotomous (based on emotional support)	**SRH:** Single item. Dichotomous, good/very good vs bad	<u>**High SEP on better health**</u> **Men (France)** Model 1: OR 1.65 (95% CI 1.15–2.35) Model 1+ SR OR 1.54 (95% CI 1.08–2.21) **Men (Italy):** Model 1: OR 1.56 (95% CI 1.01–2.41) Model 1 + SR: OR 1.43 (95% CI 0.92–2.20) **Men (Luxembourg)** Model 1 OR 2.11 (95% CI 1.42–3.15) Model 1 + SR OR 1.97 (95% CI 1.31–2.95) **Women (Belgium)** Model 1 OR 2.09 (95% CI 1.43–3.04) Model 1 OR 1.97 (95% CI 1.35–2.90) **Women (Czech Rep.)** Model 1 OR 2.55 (95% CI 1.43–4.53) Model 1 OR 2.39 (95% CI 1.33–4.29) **Women (Ireland):** Model 1: OR 1.48 (95% CI 1.03–2.15) Model 1 + SR: OR 1.43 (95% CI 0.98–2.07) **Women (Israel):** Model 1: OR 1.56 (95% CI 1.05–2.32)	Study looks at high SEP on better health	**Men:** Only in France, Italy, and Luxembourg does emotional support attenuate the association between education and good SRH by ≥10% among men from higher vs lower SEP and it was fully attenuated in Italy **Women:** Emotional support attenuates the association between education and good SRH by ≥10% in Belgium, Czech Republic, Israel, and Ireland among women from higher vs lower SEP, and was fully attenuated in Israel and Ireland

					Model 1 + SR: OR 1.45 (95% CI 0.97–2.19)		
Lai et al., 2022*[a]	China (♂/♀) *n* = 1590 45.6 78.1 (6.5) Follow-up: 18 months and 3 years	**Education:** Categorical: highest education attained (tertiary or above, secondary, primary or no schooling) **Income:** Categorical: monthly baseline income (<HKD$500, $500 to $999, $1000 to $1499, $1500 to $1999, ≥$2000) **Occupation:** Categorical: longest held occupation during lifetime (managers/professionals/associate professionals; clerks/service workers; semi-skilled/unskilled occupations, and economically inactive/unemployed persons)	**Structural:** *Social isolation.* Continuous, higher scores indicate greater social isolation (based on 6 items: unmarried, living alone, not contacted children at least for a month, <monthly contact with family, <monthly contact with friends, and not participated in any social club or religious group)	**ADL:** measured by the modified Barthel Index (0-20), lower score indicates increased disability	Non-significant results for ADL across all models by education, income, and occupation		No evidence for mediation of SEP on ADL by social isolation
Meisters et al., 2021[a]	The Netherlands (♂/♀) The Dutch Health Survey *n* = 445,748 56.0 59.4 (16.9)	**Quartile of SEP** Based on a combination of education, household income quartile, and self-reported income adequacy	**Functional:** *Loneliness*. Continuous, based on 11-item de Jong-Gierveld scale	**Chronic disease:** Single item question. Dichotomous (at least one vs none) **SRH:** Single item. Dichotomous, excellent/very good/good vs fair/poor **Psychological distress:** Measured by the Kessler psychological distress scale (K10). Dichotomous (none/low/moderate vs high)	**Chronic Disease:** Model 1: OR 1.75 (95% CI 1.72–1.79) Model 2: OR 1.59 (95% CI 1.55–1.62) **SRH:** Model 1: OR 3.26 (95% CI 3.17–3.35) Model 2: OR 2.64 (95% CI 2.57–2.72) **Psychological distress:** Model 1: OR 8.93 (95% CI 8.16–9.77) Model 2: OR 4.87 (95% CI 4.43–5.34)	Original effect estimates from paper	Loneliness explained 21% of socioeconomic health inequalities in self-reported chronic disease prevalence, 27% in poorer self-rated health, and 51% in psychological distress
Miller & Taylor, 2012[b]	USA (♂/♀) Miami-Dade County public schools *n* = 875 45 19-21	**Composite:** Parental education + income + occupational prestige	**Structural:** *Social network.* Categorical and count (based on 3 items: family structure, household size and extended kin network)	**Depression:** Measured by CES-D. Continuous, higher scores indicate higher levels of depressive symptoms	**Increasing SEP:** Model 1: B -0.55 (0.16) $p<0.01$ Fully adjusted model: B -0.05 (0.15) p<0.10	**Low vs high SEP:** Model 1: OR 1.89 (95% CI 1.43-2.50) Fully adjusted model: 0.81 (95% CI 0.64-1.01)	**From coefficients:** Including family support and family structure was protective against depression.

			Functional: *Social support*. Continuous, with higher scores indicating higher levels of support (based on emotional family support)				
Moor et al., 2014[a]	Europe, Canada and Israel (♂/♀) HBSC *n* = 117 460 53.2 11-15	**Family Affluence:** material assets and conditions of household (measured by the Family affluence Scale)	**Combination:** *Social activity, network, and social support.* Dichotomous (based on 4 items: emotional and instrumental support, network structure, contact frequency with friends, school satisfaction academic success)	**SRH:** Single item. Dichotomous, excellent/good vs fair/poor	**Model 1:** OR 1.76 (95% CI 1.69-1.84) **Model 1 + SR:** OR 1.46 (95% CI 1.40-1.52)	Original effect estimates from paper	Social relationship indicators combined attenuated the social gradient in SRH by 39.5% in children from low affluent families compared to high affluent families
Nilsson et al., 2010*[a]	Demark (♂/♀) Danish Intervention Study on Preventive Home Visits *n* = 2825 54.9 74-80 Follow-up: 3 years	**Financial assets:** Deciles, composite measure based on bonds, stocks, mortgage, debt	**Structural:** *Social activity and network*. Categorical and dichotomous (based on 4 items: cohabitation status, network structure, social participation)	**Mobility disability:** Measured by the Mobility-Help Scale. Dichotomous, manage all activities/need help in one or more activities	**Model 1:** OR 1.11 (95% CI 1.07-1.15) **Model 1 + SR:** OR 1.10 (95% CI 1.06-1.14)	Original effect estimates from paper	Social relationships did not mediate the effect of financial assets on onset of mobility disability
Platts & Gerry, 2016[b]	Ukraine (♂/♀) Ukrainian Longitudinal Monitoring Survey (ULMS) *n* = 5451 56.7 25-73	**Education:** Tertiles (up to lower secondary, upper secondary, tertiary) defined by the International Standard Classification of Education (ISCED)	**Combination:** *Social network structure and trust.* Categorical and continuous (based on 3 items: marital status, living alone and trust in friends and family)	**SRH:** Single item. Dichotomous, very good/good vs poor/very poor	**Education ISCED 0-2: Men** Model 1: OR 2.46 (95% CI 1.51-4.01) Model 1 + social support: OR 2.44 (95% CI 1.49-3.98) **Women** Model 1: OR 2.84 (95% CI 1.93-4.17) Model 1 + social support: OR 2.84 (95% CI 1.93-4.17)	Original effect estimates from paper	Social network and trust did not meaningfully attenuate educational inequalities in SRH when comparing the lowest to highest SEP
Rios et al., 2012[a]	USA (♂/♀) 2008 Arizona Health Survey *n* = 3098 63 18+	**Neighbourhood SEP:** % with a bachelor's degree or higher + median household income + % Hispanic residents	**Combination:** *Social cohesion* (neighbourhood and individual level). No description NSC = neighbourhood social cohesion	**SRH:** A single-item assessed self-rated global health from the SF-36 **Psychological distress:** Measured using the Kessler Psychological Distress Scale	<u>SRH</u> **Total effect:** β 0.62, *p* <0.001 **Indirect effect via individual level NSC:** β 0.03 *p*<0.05 **Indirect effect via mean NSC:** β 0.08 (0.04) *p*<0.01 <u>Psychological distress</u>	Coefficients are from SEM	Individual social cohesion accounted for 7% of the variance in SRH and 11% of the variance in psychological distress Neighbourhood social cohesion accounted for 11% of the variance in SRH and 6% of the

					Total effect: β -0.43 (*p* = 0.01) **Indirect effect via individual level NSC:** β -0.03 *p*<0.05 **Indirect effect via mean NSC:** β -0.09 (0.04) *p*<0.05		variance in psychological distress
Rodrigues et al., 2021[a]	Brazil (♂/♀) *n* = 4046 59.0 44.4 (17.0)	**Neighbourhood SEP:** Measured by property value	**Functional:** *Social cohesion.* Continuous, higher score indicates greater social cohesion (based on 5 items: emotional support from neighbours, financial support from neighbours, informational support from neighbours, trust in neighbourhood, sense of belonging)	**SRH:** Assessed through a single question. Dichotomous, very good/good vs fair/poor/very poor	<u>Affluent neighbourhood</u> OR 1.00 (95% CI 0.99-1.00)	<u>Poor neighbourhood</u> OR 1.00 (95% CI 1.00-1.01)	Social cohesion did not mediate the association between neighbourhood disadvantage and SRH
Rueda, 2012[b]	Spain (♂/♀) Spanish National Health Interview Survey *n* = 1602 66.6 65-85	**Regional Inequality:** four regions of different socioeconomic development (Basque Country is the most developed)	**Functional:** *Social support*. Continuous, a higher score represents greater levels of support (based on 2 items: confidant and affective social support)	**SRH:** Assessed through a single question. Dichotomous, good/poor **Mental health:** Measured using 12-item Goldberg's general health questionnaire, scoring ≥3 denotes poor mental health	<u>**SRH:**</u> **Andalusia** **Women** Model 1: OR 1.60 (95% CI 1.07-2.40) Model 1 + support: OR 1.53 (95% CI 1.01-2.31) **The Region of Murcia** **Women** Model 1: OR 2.75 (95% CI 1.77-4.29) Model 1 + support: OR 2.49 (95% CI 1.59-3.93) <u>**Mental health:**</u> **Navarra** **Men** Model 1: OR 3.04 (95% CI 1.45-6.39) Model 1 + support: OR 2.92 (95% CI 1.37-6.25) **Andalusia** **Women** Model 1: OR 1.59 (95% CI 1.02-2.49)	Original effect estimates from paper	**SRH:** Social support attenuated the social gradient in SRH by 11.6% and 14.9% for women in Andalusia and Murcia respectively when comparing women from an area of low vs high socioeconomic development (Andalusia/Murcia vs the Basque Country). **Mental health:** Social support attenuated social inequalities in mental health by 5.9% in men from Navarra when compared to The Basque Country. For women in Andalusia, adjusting for social support explained 3.3% of the SEP-mental health association, and this was no longer significant after adjusting for support.

					Model 1 + support: OR 1.57 (95% CI 0.99-2.51)		
Sacker et al., 2001[b]	UK (♀) Health Survey for England *n* = 5391 20-59	**Material deprivation:** A summed score related to adverse material circumstances **Cambridge Scale:** A measure of social advantage and prestige. Continuous scale with higher scores indicated more social advantage **Erikson-Goldthorpe schema:** Social class based on occupation	**Functional:** *Social support*. Continuous, a higher score represents greater social support (based on 2 items: emotional and instrumental support)	**SRH:** Continuous, with higher values representing worse health	**Material deprivation:** Direct effect: β 0.09 (0.004) Indirect effect: β -0.0013 (-0.1) **Cambridge Scale:** Direct effect: β 0.06 Indirect effect: β 0.0056	Coefficients are from SEM	Higher levels of material deprivation and lower social advantage resulted in greater ill-health partly via lower levels of social support. No indirect pathways found via E-G Schema. All psychosocial and behavioural factors combined explained 25% of the variance in SRH
Salonna et al., 2012[b]	Slovakia (♂/♀) *n* = 1863 53.4 16.85 (1.1)	**Education:** parental education categorised (elementary school, Secondary high school, university) **Financial Affluence:** Measured using financial affluence scale. Tertiles, low, medium, high **Financial Strain:** Perceived strain. Dichotomous, sometimes/rarely/never vs very often/often	**Functional:** *Social support*. Continuous, a higher score represents greater support from parents or friends (based on 3 items: emotional support, instrumental support, feeling a worthwhile person)	**SRH:** Single item. Dichotomous, excellent/very good/good vs bad	**Family affluence (low):** **Boys** Model 1: OR 2.01 (95% CI 1.12-3.59) Model 1 + social support (father): OR 1.88 (95% CI 1.04-3.38) **Girls** Model 1: OR 1.94 (95% CI 1.08-3.50) Model 1 + support (father): OR 1.74 (95% CI 0.96–3.16) **Financial strain (high):** **Boys** Model 1: OR 1.96 (95% CI 1.18-3.25) Model 1 + social support (father): OR 1.66 (95% CI 0.99-2.85)	Original effect estimates from paper	**Family affluence:** Social support from the father attenuated the social gradient in SRH by 12.9% among boys and 21.3% among girls from low affluent families compared to those form high affluent backgrounds **Financial strain:** Social support from the father attenuated the social gradient in SRH by 31.1% among boys from families with high vs low financial strain
Soskolne & Manor, 2010[a]	Israel (♂/♀) LLI *n* = 1256 SRH *n* = 1258 55 48.2 (11.9)	**Education:** Categorical (number of years: 0-8, 9-12, 13-15, 16+) **Financial assets:** Measured by number of cars. Categorical, 0/1/2+	**Structural:** *Social activity*. Continuous (based on 2 items: social participation and civic engagement) **Functional:** *Social trust*. Dichotomous (based on 3 items: perceived lack of fairness, social trust,	**SRH:** Single item. Dichotomous, good vs poor **LLI:** Measure of functional limitation. Dichotomous, yes vs no	**SRH:** **Education (≤ 8 years)** Model 1: OR 4.38 (95% CI 2.72-7.05) Model 1 + SR: OR 2.38 (95% CI 1.45-3.89) **Number of cars (0)** Model 1: OR 5.24 (95% CI 3.23-8.51)	Original effect estimates from paper	All structural and functional social relationships explained between 57.5% 59.1% of the social inequalities in SRH for lowest vs highest levels of SEP All structural and functional social

			and perceived helpfulness)		Model 1 + SR: OR 2.80 (95% CI 1.68-4.64) LLI: **Education (≤ 8 years)** Model 1: OR 1.98 (95% CI 1.24-3.17) Model 1 + SR: OR 1.36 (95% CI 0.84-2.22) **Number of cars (0)** Model 1: OR 3.13 (95% CI 1.91-5.14) Model 1 + SR: OR 2.27 (95% CI 1.34-3.83)		relationships combined explained 40.3% and 63.2% of the social inequalities in LLI for the lowest vs highest levels of SEP
Stringhini et al., 2012*[b]	UK (♂/♀) British Whitehall II Study *n* = 9333 35-55 Follow-up: 24 years	**Occupational position:** Civil service grade. Categorical, high/intermediate/low	**Structural:** *Social activity and network*. Quartiles (based on 3 items: marital status, contact frequency with network, social participation) **Functional:** *Social support*. Quartiles (based on 3 items: emotional support, practical support, negative aspects of close relationships)	**Mortality:** Assessed through National Health Services Central Registry. All-cause mortality, cancer mortality, CVD mortality	All-cause mortality: Model 1: HR 1.59 (95% CI 1.21-2.08) Model 1 + SR: HR 1.40 (95% CI 1.07-1.85) CVD mortality: Model 1: HR 2.48 (95% CI 1.98-4.92) Model 1 + SR: HR 1.86 (95% CI 1.16-2.98)	Original effect estimates from paper	Structural social relationship indictors attenuated SEP gradient in all-cause mortality by 27% and for CVD mortality by 29% The sample was restricted to men as no significant association found between women and mortality, and further restricted to all-cause and CVD mortality as no social gradients found in cancer mortality
Veenstra & Patterson, 2012*[a]	USA (♂/♀) Alameda County Study *n* = 6157 54.2 21+ Follow-up: 35 years	**Education:** Number of years **Income:** Median income	**Structural:** *Social activity and network*. Categorical (based on 3 items: number of close friends, affiliation with voluntary association, church attendance)	**Mortality:** Mortality information via survey data	**Education:** Model 1: OR 0.97 (95% CI 0.96-0.99) Model 1 + SR: OR 0.98 (95% CI 0.97-0.99) **Income:** Model 1: OR 0.98 (95% CI 0.7-0.98) Model 1 + SR: OR 0.98 (95% CI 0.97-0.98)	Original effect estimates from paper	Although education and income had a protective effect on mortality risk, having three or more close friends, regular church attendance and participation in recreational/social activities did not meaningfully contribute to this association
Verhaeghe & Tampubolon, 2012[a]	UK (♂/♀) Taking Part Surveys of England (Wave 2 & 3) *n* = 11 875 56.1 50.6 (18.20)	**Neighbourhood deprivation:** Measured using the Index of Multiple Deprivation of Local Super Output Areas in England (LSOAs)	**Combination**: *Social activity and network*. Dichotomous and categorical. (Based on 3 items: generalised trust, social participation, and network resources)	**SRH:** Single question. Dichotomous, poor health vs good health	**Neighbourhood deprivation on good SRH** Model 1: OR 0.98 (95% CI 0.98-0.98) Model 1 + SR: OR 0.99 (0.98-0.99)	**Neighbourhood deprivation on poor SRH** Model 1: OR 1.02 (95% CI 1.02-1.02) Model 1 + SR: OR 1.01 (95% CI 1.01-1.02)	Social relationship measures attenuated the association between neighbourhood deprivation and self-rated health and explained 2.51% of the variance in good self-rated health.

Vonneilich et al., 2012*[b]	Germany (♂/♀) Heinz Nixdorf Recall cohort study *n* = 4146 50.5 58.8 (7.7) Follow-up: 5 years	**Education:** categorical, measured by years of education (ISCED) **Household income:** disposable income + household size (OECD) **Occupational status:** tertiles, measured by the international Standard Classification of Occupation Scale (ISCO-88)	**Structural:** *Social activity and network*. Categorical, measured using Social integration Index (based on 3 items: marital status, number of close ties, affiliation with voluntary association) **Functional:** *Social support*. Categorical (based on 2 items: emotional and instrumental social support)	**SRH:** Single question. Dichotomous, poor/very poor vs very good/good/moderate	**Education (≤10 years):** Model 1: OR 1.79 (95% CI 1.19-2.69) Model 1 + SR: OR 1.64 (95% CI 1.08-2.49) **Income (very low):** Model 1: OR 1.64 (95% CI 1.23-2.17) Model 1 + SR: OR 1.47 (95% CI 1.10-1.96) **Occupation (Unskilled):** Model 1: OR 1.90 (95% CI 1.34-2.69) Model 1 + SR: OR 1.71 (95% CI 1.20-2.44)	Original effect estimates from paper	Structural and functional social relationships combined contributed to 18.9% of the educational inequalities in SRH, 26.5% of the income inequalities in self-rated health and 21% of the occupational inequalities in SRH
Vonneilich et al., 2019[a]	Europe (♂/♀) European Social Survey (ESS) *n* = 289 979 52.4 15+	**Educational level:** Quartiles, categorised according to ISCED scale, ≤ISCED 2/ISCED 3/ISCED 4/ISCED 5-6	**Structural:** *Social activity and network*. Dichotomous/ Continuous (based on 3 items: living with a partner, frequency of contact with network and social participation) **Functional:** *Social support*. Dichotomous, (based on emotional support)	**SRH:** Measured by a single question. Continuous, with higher values indicating better health	**<u>Social participation:</u>** Direct effect: β 0.123 (95% CI 0.120-0.126) Indirect effect: β 0.016 (95% CI 0.15-0.16) **<u>Social network:</u>** Direct effect: β 0.140 (95% CI 0.137-0.143) Indirect effect: β 0.000 (95% CI 0.000-0.000) **<u>Living with partner:</u>** Direct effect: β 0.133 (95% CI 0.129-0.135) Indirect effect: β 0.007 (95% CI 0.006-0.008) **<u>Emotional support:</u>** Direct effect: β 0.134 (95% CI 0.131-0.137) Indirect effect: β 0.005 (95% CI 0.005-0.006)	Coefficients are from SEM	**From coefficients:** Social participation explained 11.2% of the total effects of education on SRH, living with a partner mediated 5.1% of these total effects, and emotional support mediated 3.7% of the total effects of education on SRH. The social network did not contribute to educational inequalities in SRH
Wang et al., 2015[a]	Japan (♂/♀) *n* = 7904 52.5 65-84	**Education:** Tertiles by highest level achieved (≤junior high school, high school, ≥university) **Income:** Quintiles, ranging from <$10000 - >$90000	**Structural:** *Social activity*. Continuous and categorical (based on 3 items: frequency of social contact, affiliation with voluntary association, taking part in community leisure activity)	**Health Status:** Measured by SRH, BADL, IADL Continuous, with higher scores indicating better perceived health, better basic living experience and better instrumental activity competence	**<u>Men:</u>** **Total effect:** β 0.28 **Direct effect:** β 0.14 **Indirect effect:** β 0.13 **<u>Women:</u>** **Total effect:** β 0.44 **Direct effect:** β 0.21 **Indirect effect:** β 0.23	Coefficients are from SEM	Social interaction partly explained socioeconomic inequalities in health status for men and women. SEP and social interaction explained 32% and 46% of the variance in health status for elderly men and women, respectively.
Wei et al., 2018[b]	China (♀) Born in Guangzhou Cohort Study *n* = 12 382	**Composite SEP:** Quartiles. Parental education + monthly income + maternal	**Functional:** *Social support*. Continuous, higher scores indicate greater levels of	**Depressive symptoms in pregnant women:**	Crude OR presented: 1.63 (95% CI 1.43-1.86)	Crude: original estimate from paper Indirect: coefficients are from SEM	Social support attenuated 56.2% of the association between SEP and depressive

	29.4 (3.5)	employment status + car ownership + crowding + floor of residence + first language	support (based on perceived support from family and friends)	Measured by Zhang's Self-Rated Depression Scale Continuous, presence of depressive symptoms if score ≥53	Indirect effect: β 0.033 (95% CI 0.028–0.038)		symptoms among pregnant women in in Guangzhou, China when comparing those in the lowest SEP quartile to the highest SEP quartile
Zhang et al., 2022[a]	China Chinese Longitudinal Healthy Longevity Survey (CLHLS) *n* = 10,197 57.6 > 75	**Income** Categorical measured in Yuan (< 10,000, 10,000-30,000, 30,000-9000, >90,000) **Education** Categorical (no schooling to senior) **Occupation** Categorical (agriculture, professional, commercial)	**Structural:** *Social participation.* Continuous, higher scores indicated greater participation (based on 3 items: including group exercise, organised social activities and interacting with friends) GE = group exercise IF = interacting with friends SA = social activities	**ADL:** Based on Instrumental Activities of Daily Living Scale **Mental Health:** Based on Minimum Mental State Examination	**ADL** **Income/GE** B 0.06 (95% CI 0.01-0.12) **Education/GE** B 0.17 (95% CI 0.12-0.22) **Education/IF** B 0.24 (95% CI 0.16-0.32) **Mental health** **Income/GE** B 0.05 (95% CI 0.01-0.1) **Education/GE** B 0.14 (95% CI 0.09-0.18) **Occupation/GE** B 0.19 (95% CI 0.13-0.25) **Education/IF** B 0.23 (95% CI 0.16-0.31) **Occupation/SA** B 0.09 (95% CI 0.06-0.12)	Coefficients are from SEM	Group exercise explained 5.4% and 17.1% of the association between education and mental health and ADL, respectively, for those with primary education. Interaction with friends explained 24.7% and 9.2% of the association between education and ADL and mental health, respectively, for those with primary education
Zhang & Xiang, 2019[a]	USA (♂/♀) General Social Survey *n* = 3330 51.8 42.9 (13.3)	**Family Income:** Total income earned by household	**Structural:** *Social activity*. Continuous, higher scores indicate higher social networking time (based on frequency of contact with someone in the neighbourhood)	**HRQoL:** Measured by number of days of poor physical health, mental health, days of activity limitation and self-rated health – Likert scale	**Poor mental health:** Direct effect: β -0.127 *p*<0.001 Indirect effect: β -0.118 *p*<0.001	Coefficients are from SEM	Social networking time mediated income inequalities in mental health only

[a]Adjusted or stratified by at least age and sex; [b]Adjusted or stratified by at least age or sex; *Longitudinal study

Appendix 8: Data extraction tables - social relationships moderating social inequalities in health

Study characteristics		Study variables			Results		
Author	**Country, Population, n, Female (%), Age: mean/SD or range (years)**	**SEP variable**	**Social relationship variable**	**Outcome**	**Original results from paper**	**OR (95% CI) for narrative synthesis**	**Conclusion**
Abel et al., 2011[a]	Netherlands, Hungary, UK (♂/♀) KIDSCREEN Survey *n* = 3979 55.7 12-14	**Parental education:** ISCED. Dichotomous, high vs low	**Functional:** *Social support.* Dichotomous (based on 3 items: emotional support, instrumental support, trust)	**SRH:** Single item. Dichotomous, fair vs poor	**SEP*support by country** The Netherlands $\beta = -0.018$ p >0.05 Hungary $\beta = 0.020$ p >0.05 UK $\beta = -0.030$ p >0.05	Non-calculable – could not get in touch with author	No statistically significant interactions seen between SEP and social support
Ahnquist et al., 2012[b]	Sweden (♂/♀) Swedish National Survey of Public Health *n* = 51 414 54.9 16-84	**Economic hardship:** Household income + inability to meet expenses + lack of cash reserves	**Structural:** *Social activity.* Dichotomous, <2 activities indicate low social participation (based on 7 items: attendance of religious service, affiliation with voluntary/professional association, arts/culture participation, recreational/social participation) **Functional:** *Trust.* Dichotomous, high/low (based on 2 items: interpersonal trust and political trust) SP = social participation IT = interpersonal trust PT = political trust	**SRH:** Single item. Dichotomous, very good/good vs fair/bad/very bad **Psychological distress:** GHQ-12, $\geq$3 symptoms indicate psychological distress **Musculoskeletal problems:** Dichotomous, no vs yes(mild)/yes(severe)	<u>**SRH:**</u> **Main model (Men)** OR 3.07 (95% CI 2.82-3.35) **Men (hardship/low SP)** OR 5.04 (95% CI 4.36-5.81) **Men (hardship/not low SP)** OR 2.78 (95% CI 2.49-3.10) **Men (hardship/low IT)** OR 5.41 (95% CI 4.74-6.17) **Men (hardship/not low IT)** OR 2.64 (95% CI 2.35-2.97) **Men (hardship/low PT)** OR 3.97 (95% CI 3.54-4.46) **Men (hardship/not low PT)** OR 2.05 (95% CI 1.71-2.47) **Main model (Women)** OR 2.89 (95% CI 2.70-3.10) **Women (hardship/low SP)** OR 5.09 (95% CI 4.51-5.74) **Women (hardship/not low SP)** OR 2.68 (95% CI 2.47-2.91) **Women (hardship/low IT)** OR 5.72 (95% CI 5.15-6.35) **Women (hardship/not low IT)** OR 2.46 (95% CI 2.25-2.68) **Women (hardship/low PT)** OR 3.08 (95% CI 2.79-3.39)	Original estimates from paper	Among those suffering economic hardship, higher social participation, and interpersonal and political trust buffered the negative effect of economic hardship on SRH and psychological distress. No interaction effects were found between social participation and economic hardship when looking at musculoskeletal problems. However, higher interpersonal and political trust buffered the negative effect of economic hardship on musculoskeletal problems.

Women (hardship/not low PT) OR 1.95 (95% CI 1.70-2.24)

Psychological distress:
Main model (Men) OR 3.36 (95% CI 3.06-3.69)
Men (hardship/low SP) OR 4.54 (95% CI 3.92-5.26)
Men (hardship/not low SP) OR 3.07 (95% CI 2.74-3.45)
Men (hardship/low IT) OR 5.81 (95% CI 5.10-6.63)
Men (hardship/not low IT) OR 2.84 (95% CI 2.50-3.24)
Men (hardship/low PT) OR 3.30 (95% CI 2.92-3.73)
Men (hardship/not low PT) OR 2.48 (95% CI 2.04-3.01)

Main model (Women) OR 2.47 (95% CI 2.31-2.64)
Women (hardship/low SP) OR 3.31 (95% CI 2.94-3.73)
Women (hardship/not low SP) OR 2.23 (95% CI 2.04-2.42)
Women (hardship/low IT) OR 4.44 (95% CI 4.01-4.91)
Women (hardship/not low IT) OR 2.07 (95% CI 1.89-2.28)
Women (hardship/low PT) OR 2.41 (95% CI 2.18-2.66)
Women (hardship/not low PT) OR 1.94 (95% CI 1.69-2.26)

Main model (Men) OR 2.08 (95% CI 1.91-2.26)
Musculoskeletal problems:
Men (hardship/low IT) OR 3.10 (95% CI 2.73-3.52)
Men (hardship/not low IT) OR 1.81 (95% CI 1.62-2.02)
Men (hardship/low PT) OR 2.81 (95% CI 2.52-3.15)
Men (hardship/not low PT) OR 1.57 (95% CI 1.32-1.87)

Main model (Women) OR 2.06 (95% CI 1.93-2.20)

					Women (hardship/low IT) OR 3.07 (95% CI 2.77-3.41) **Women (hardship/not low IT)** OR 1.80 (95% CI 1.66-1.96) **Women (hardship/low PT)** OR 2.42 (95% CI 2.20-2.67) **Women (hardship/not low PT)** OR 1.43 (95% CI 1.26-1.63)		
Andersson et al., 2016*[a]	USA (♂/♀) MIDUS Survey *n* = 1632 25-75 Follow-up: 10 years	**Childhood parental SEP:** Parental education + occupation + welfare support	**Functional:** *Social support*. Dichotomous, low warmth vs high warmth; no abuse vs physical abuse (based on emotional social support from parent during childhood: warmth and abuse)	**Disease burden:** International Classification of Diseases-9 (ICD-9). Total number of chronic conditions	<u>High SEP on poor chronic health</u> **Baseline (1995)** Model 1: B -0.242 (0.089) p <0.01 Fully adjusted B -0.207 (0.088) p<0.05 **Follow-up (2005)** Model 1: B -0.252 (0.110) Fully adjusted B -0.242 (0.109) p<0.05 Interaction effect non-significant *p* = 0.28	<u>Low SEP on chronic disease</u> **Baseline (1995):** Model 1 OR 1.28 (95% CI 1.20-1.38) Fully adjusted OR 1.28 (95% CI 1.20-1.38 **Follow-up (2005):** Model 1 OR 1.28 (95% CI 1.20-1.38) Model 1 + negative support OR 1.38 (95% CI 1.30-1.49) Stratified results by levels of warmth and abuse are only presented in plots	At baseline, warmth from the parent does not buffer the negative effect of low parental SEP on chronic disease. Warmth strengthens the association between low parental SEP and chronic disease. At follow-up experiencing no abuse strengthened the association between low parental SEP and chronic disease and was only protective against chronic disease for those with moderate or higher levels of SEP.
Antonucci et al., 2003[a]	USA (Detroit) (♂/♀) The Survey of Social Relations *n* = 798 58.6 40-93	**Education:** Continuous, based on highest level of completed education	**Structural:** *network*. Count variable (0-20) (based on 2 items: total network size and number of people closest and somewhat close to participant) **Functional:** *Social support*. Continuous (based on 3 items: sick care from child, financial care from child, being able to confide in child)	**SRH:** Health problem Index comprising of a global rating of health + count of chronic illnesses. Standardised scale, positive numbers indicate worse health	**Men** **Education*network size** Model 1: B -0.08 (0.03) p <0.01 Model 1 + interaction: B -0.07 (0.03) p <0.05 **Education*financial support** Model 1: B = -0.09 (0.30) p <0.01 Model 1 + interaction: B -0.11 (0.03) p <0.001 **Education*emotional support** Model 1: B -0.10 (0.03) p <0.01 Model 1 + interaction: B -0.11 (0.03) p <0.001 **Education*instrumental support** Model 1: B -0.09 (0.03) p <0.01 Model 1 + interaction: B -0.11 (0.03) p <0.001	Non-calculable	Lower health rating scores were reported for men with less education but had social support available form their adult children (*p* ≤0.001). Less educated men with smaller networks had a higher health problem score (*p* ≤0.05). However, no buffering effects were seen in women.

Barber et al., 2016[a]	USA (♂/♀) Jackson Heart Study *n* = 4408 63.5 21-85	**Neighbourhood disadvantage:** % of households below poverty, receiving public assistance, <HS education, crowding, female headed households, no car. Dichotomous, most disadvantaged vs least disadvantaged	**Functional:** *Social cohesion*. Dichotomous (based on 4 items: closeness of neighbourhood community, social support, trust)	**Cumulative Biological Risk:** Biomarkers: metabolic, cardiovascular, neuroendocrine, inflammatory	**Men/low social cohesion:** Model 1: β 0.46 (0.23) *p* = 0.06 Model 2: β = 0.39 (0.24) **Men/high social cohesion:** Model 1: β -0.004 (0.12) *p* = 0.97 Model 2: β -0.03 (0.12) **Women/low social cohesion:** Model 1: β 0.16 (0.19) Model 2: β 0.15 (0.19) **Women/high social cohesion:** Model 1: β 0.16 (0.11) Model 2: β 0.12 (0.11)	**Men/low social cohesion:** OR 8.66 (95% CI 0.91-82.27) **Men/high social cohesion:** OR 0.82 (95% CI 0.34-1.96) **Women/low social cohesion:** OR 2.18 (95% CI 0.31-15.29) **Women/high social cohesion:** OR 2.18 (95% CI 0.85-5.59)	Interaction between SEP, social cohesion was marginally statistically significant for men (*p*=0.05), however it was not statistically significant for women (*p*=0.50). Results revealed no buffering of neighbourhood disadvantage for men or women with high social cohesion
Craveiro et al., 2017[a]	Europe (♂/♀) SHARE *n* = 33 489 53.9 66.31 (10.04)	**SEP Factor:** Education + household income + wealth	**Structural:** *Social activity, network*. (based on 5 items: size of network, living with partner, number of children, frequency of contact, social participation) **Functional:** *Social support*. (based on 4 items: satisfaction with network, emotional support, instrumental support, financial support)	**Health factor:** Composite variable: SRH + ADL + chronic conditions. Higher values indicate worse health	<u>High Sep on poor health</u> <u>Northern Europe:</u> **Main effects:** B -0.22 (0.02) *p* <0.001 <u>Southern Europe</u> **Main effects:** B -0.22 (0.01) *p* <0.001 **Interaction effect (partner):** B = 0.07 (0.01) **Interaction effect (social participation):** B 0.05 (0.01) p <0.001 **Interaction effect (satisfaction):** B -0.01 (0.01) p <0.05 **Interaction effect (financial support):** B -0.01 (0.01) p <0.05 <u>Central Europe</u> **Main effects:** B -0.22 (0.01) p <0.001 **Interaction effect (having children):** B -0.10 (0.03) p <0.001 **Interaction effect (daily contact):** B -0.09 (0.02) p <0.001 **Interaction effect (emotional support):** B -0.08 (0.02) p <0.001 **Interaction effect (network satisfaction):** B -0.02 (0.01) p <0.05	<u>Low SEP on poor health</u> <u>Northern Europe:</u> **Main effects:** OR 2.63 (95% CI 2.50-2.86) **Interaction effects:** NS <u>Central Europe</u> **Main effects:** OR 2.63 (95% CI 2.50-2.86) **Interaction effect (partner):** OR 0.65 (95% CI 0.60-0.70) **Interaction effect (social participation):** OR 0.69 (95% CI 0.65-0.75) **Interaction effect (satisfaction):** OR 1.25 (95% CI 1.16-1.33) **Interaction effect (financial support):** OR 1.25 (95% CI 1.16-1.33) <u>Southern Europe</u> **Main effects:** OR 2.63 (95% CI 2.50-2.86) **Interaction effect (having children):** OR 1.79 (95% CI 1.47-2.17) **Interaction effect (daily contact):** OR	**Northern:** no statistically significant interactions **Central:** social participation and having a partner are beneficial for those in lower SEPs; however, financial support and satisfaction with the network were more beneficial to individuals as the socioeconomic position increases (*p* <0.001) **Southern:** with increasing SEP there was an increase in health enhancing effect of having a child, daily contact, emotional close ties, being satisfied with network (*p* <0.05)

					Interaction effect (social participation): B 0.09 (0.04) *p* <0.05	1.72 (95% CI 1.28-2.33) **Interaction effect (emotional support):** OR 1.67 (95% CI 1.41-1.96) **Interaction effect (network satisfaction):** OR 1.28 (95% CI 1.20-1.39) **Interaction effect (social participation):** OR 0.58 (95% CI 0.50-0.68)	
De Clercq et al., 2012[a]	Belgium (♂/♀) HBSC-Belgium *n* = 10 915 49.9 9-18	**Family affluence:** Measured using Family Affluence Scale. Continuous, higher scores indicate greater affluence	**Structural:** *Social activity and social engagement*. Dichotomous and continuous (based on 3 items: affiliation with voluntary association, interaction with neighbours) **Functional:** *Social support and trust*. Continuous, higher score indicates greater trust and support (based on 2 items: support from neighbours, trust in neighbourhood community)	**Health and well-being:** 10-item question. Continuous. Higher scores indicate better health and well-being except for loneliness and feeling sad where higher scores indicate greater loneliness/sadness	**Perceived health and well-being** **Model 1:** β 0.023 (0.003) *p* <0.01 **Model 1 + family affluence*community SR:** β 0.021 (0.003) *p* <0.01	**Model 1:** OR 1.54 (95% CI 1.44-1.66) **Model + interaction:** OR 1.49 (95% CI 1.39-1.60)	High levels of functional support and trust were protective against poor health among those with low levels of family affluence
Drukker et al., 2006*[b]	The Netherlands (♂/♀) *n* = 475 52 11-15 Follow-up: 2 years	**Neighbourhood social disadvantage:** Maastricht Statistics Department and Statistics Netherlands % single parent families + ethnicity + non-voters + unemployment + social security + mean income + & high and low incomes + economically inactive	**Functional:** *Social cohesion, trust*. Continuous, higher scores indicate lower levels of social capital (based on 3 items: informal social control, social cohesion, trust in neighbourhood residents)	**HRQoL:** Child Health Questionnaire (CHQ) child form (general health + mental health + satisfaction + self-esteem)	No data presented for general or mental health	Non-calculable - could not get in touch with author	No statistically significant associations between neighbourhood factors and changes in general or mental health
Elgar et al., 2010[b]	Canada (♂/♀) HBSC-Canada *n* = 9717 52.61 11-15	**Family affluence:** Family Affluence Scale	**Functional:** *Social capital (Social support, trust)* Continuous, higher scores indicate greater levels of support/trust (based on 3 items: emotional support, informational support, trust in residents)	**Psychosomatic symptoms:** Continuous, higher scores indicate more symptoms Physical health: **Number of injuries**	**Low SEP/Low SR:** **Psychological symptoms** B -1.72 p <0.01 **Somatic Symptoms:** B -1.80 p <0.01 **Injuries:** B -0.38 p <0.05 **Low SEP/High SR:**	Non-calculable – author no longer has data	For all health outcomes, social capital either partly or completely buffered the negative effect of low family affluence on psychosomatic

					Psychological symptoms B 0.02 p ≥0.05 **Somatic Symptoms:** B 0.21 p <0.05 **Injuries:** B 0.15 p <0.05		symptoms and physical injuries
Ferraro & Su, 1999[d]	Fiji, Korea, Malaysia, Philippines (♂/♀) Social and Health Aspects of Ageing Survey *n* = 3277 50+	**Financial strain:** Continuous, higher scores indicate greater strain	**Structural:** *Social activity, network*. Continuous (based on 4 items: affiliation with voluntary association, social participation, number of friends/family, frequency of contact) **Functional:** *Social support*. Continuous (based on 3 items: informational support, instrumental support, financial support)	**Psychological distress:** CES-D scale	**Korea** **Main effect:** β 0.26 (0.05) p <0.01 **Interaction effect (strain*family/friends):** β 0.21 (0.06) p <0.01 **Philippines** **Main effect:** β 0.14 (0.06) p <0.01 **Interaction effect (strain*family/friends):** β 0.21 (0.06) p <0.01 **Malaysia** **Main effect:** β 0.01 (0.05) p >0.05 **Interaction (strain*childcare):** β 0.11 (0.07) p >0.05 **Fiji** **Main effect:** β 0.32 (0.07) p <0.01 **Interaction (strain*financial):** β 0.18 (0.09) p >0.05		**Korea & Philippines:** Financial strain increases psychological distress, but integration in family and friend networks served as a buffer **Malaysia:** The main effect of financial strain was not significantly associated with psychological distress, however, childcare support given by the elder buffered the negative effect of financial strain on psychological distress. **Fiji:** no interaction found
Fone et al., 2007[a]	UK (♂/♀) Wales Caerphilly Health and Social Needs Cohort Study *n* = 10,653 55.2 18-74	**Area income deprivation:** Validated gross household income estimates. Based on UK poverty definition, deprivation defined as % households with household income ≤£10000/year	**Combination:** *Social cohesion*. Categorical (based on 4 items: frequency of contact with neighbours, perceived support availability, trust, sense of belonging)	**Mental health:** Mental Health Inventory (MHI-5) subscale of the SF-36. Continuous, lower scores represent lower mental health status	**Main effect:** B -1.58 (0.35) Interaction effect (low **SEP*medium SR):** B 0.54 (o.51) p = 0.03 **Interaction effect (low SEP*high SR):** B 1.13 (0.52) p = 0.03	Non-calculable - could not get in touch with author	Medium and high social cohesion buffered the negative effect of low-income households on low mental health scores
Fone et al., 2014*[a]	UK (♂/♀) Wales Caerphilly Health and Social Needs Cohort Study *n* = 4426 18-74 (baseline) Follow-up: 7 years	**Neighbourhood deprivation:** Dichotomous, high deprivation vs deprivation (% households ≤£5000/year vs % households ≤£10000/year)	**Combination:** *Social cohesion*. Categorical (based on 3 items: frequency of contact with neighbours, perceived support availability, trust)	**Mental health:** SF-36. Continuous, higher scores indicated better mental health (a positive change indicated better mental health)	**<u>High deprivation:</u>** **Main effect:** B -0.79 (95% CI -1.45, -0.13) **Interaction SEP*high cohesion:** B 1.72 (95% CI 0.26-3.18) **<u>Deprivation:</u>** **Main effect:** B -0.51 (95% CI -1.17, 0.15) **Interaction*high cohesion:** B 1.49 (95% CI 0.08-2.90	Non-calculable - could not get in touch with author	Social cohesion at baseline buffered the negative effect of baseline neighbourhood deprivation on change in mental health 7 years later
Gorman & Sivaganesan, 2007[b]	USA (♂/♀)	**Education:** Quartiles, highest level achieved	**Structural:** *Social activity and network*. Continuous and categorical (based on 5	**Hypertension:** Single item. Dichotomous yes/no	No effect estimated presented	Non-calculable – author no longer has data	Among the lowest SEP groups, social integration and family network size

	National health Interview Survey (NHHIS) *n* = 29,816 52.3 48.7(16.0)	**Occupational status:** Quartiles, ranging from never worked to currently working **Medical care** **Health insurance** **Income-to-poverty ratio**	items: family size, marital status, frequency of social contact, affiliation with voluntary association, attend place of worship) **Functional:** *Social support*. Continuous, higher scores indicate greater support (based on: emotional support)	**SRH:** Single item. Continuous, with higher scores indicating better health			was associated with higher probability of hypertension Family network size and attending a group event buffered the effect of low SEP on poor SRH. However, network size strengthened the association between SEP and SRH for those who were retired.
Green et al., 2022*[b]	USA (♂/♀) Woodlawn cohort *n* = 1159 53.9 6-58 Follow-up: life course	**Life course poverty:** Categorical (never poor, early poverty, late poverty, persistent poverty)	**Structural:** *Social integration.* Count (based on 5 items: currently married, currently employed, parent living with children, affiliation with social organisation, member of church)	**Mortality:** indicator based on National Death Index	**No poverty*midlife social integration** HR 0.54 (95% CI 0.39-0.73) **Early poverty*midlife social integration** HR 0.84 (95% CI 0.72-0.99)	Original estimates from paper	Social integration at midlife buffered the negative effect of early poverty on mortality risk. No significant interactions were found between early poverty and social integration during young adulthood.
Haseda et al., 2018[b]	Japan (♂/♀) Japan Gerontological Evaluation Study (JAGES) N = 87 656 51.8 ≥65	**Income:** Tertiles, low/middle/high	**Structural:** *Social activity*. Continuous (based on 2 items: social participation and social cohesion) **Functional:** *Social support*. Continuous, measured using Health-Related Social Capital Scale (based on 2 items: social support and social cohesion)	**Depressive symptoms:** Geriatric Depression Scale (GDS-15). Continuous, ≥4/5 indicated depressive symptoms	<u>Men (participation)</u> **Model 1:** PR 2.24 (95% CI 2.14-2.35) **Model 3 + interaction terms:** PR 1.81 (95% CI 1.71-1.93) **Individual level SR** Income*SR: PR 1.14 (95% CI 1.01-1.27) **Community level SR** Income*SR: PR 1.14 (95% CI 1.01-1.28) <u>Women (participation)</u> **Model 1:** PR 1.95 (95% CI 1.86-2.05) **Model 3 + interaction terms:** PR 1.50 (95% CI 1.41-1.61) **Individual level SR** Income*SR: PR 1.26 (95% CI 1.13-1.40) **Community level SR** Income*SR: PR 1.04 (95% CI 0.99-1.10)	Original estimates from paper – PR taken as OR Effect modification by social relationship measures only presented in plots	Higher depressive symptoms in those with low income but high levels of civic participation (p = 0.016 in men, p = 0.080 in women). The difference in predicted prevalence of depressive symptoms between the highest and lowest SEP where community-level social participation was at 1+SD level was 18.8% and 15.4% for men and women respectively
Hibbard & Pope, 1992*[b]	USA (♀) Centre for Health Research Household Survey	**Employment status:** Dichotomous, employed vs unemployed	**Structural:** *Community involvement*. Dichotomous (based on 2 items: affiliation with voluntary	**Mortality:** National and State Death Index Records	**Unemployed/no CI vs employed/high SS:** HR 2.1 (95% CI 1.1-3.8)	Original from paper	Community involvement may moderate the effect of employment status on mortality risk – an 18%

	n = 1140 18-65 Follow-up: 10 years		association and frequency of social contact with colleagues) **Functional:** *Social support* (based *on* perceived support from work) CI = community involvement SS = social support		**Unemployed/CI vs employed/ high SS:** HR 1.9 (95% CI 1.0-3.5) **Unemployed/no CI vs employed/low SS:** HR 2.0 (95% CI 1.1-3.5) **Unemployed/CI vs employed/ low SS:** HR 1.8 (95% CI 0.9-3.3)		to 20% difference in magnitude of employment inequality between those with better versus poorer community involvement
Huurre et al., 2007*[b]	Finland (♂/♀) *n* = 1262 56.5 16-32 Follow-up: 16 years	**Parental SEP:** At baseline **Education:** Years of completed education at age 22 **Occupation:** By type at age 32	**Combination:** *Social support, network*. Continuous (based on 4 items: existence of social relationships, network size, perceived quality of social support, satisfaction of social support)	**Depression:** 13-item Beck Depression Inventory (S-BDI). Dichotomous, ≥5 indicates depression	<u>**Low SEP + low social support at 16, 22 & 32 years of age on depression**</u> **Men** **Main effect:** OR 2.93 (95% CI 1.73-4.96) **Adjusted:** OR 2.39 (95% CI 1.22-4.70) **Women** **Main effect:** OR 1.97 (95% CI 1.30-2.98) **Adjusted:** OR 0.96 (95% CI 0.53-1.76)	<u>**Low SEP + high social support**</u> **Men** **Main effect:** OR 2.93 (95% CI 1.73-4.96) **Adjusted:** OR 0.42 (95% CI 0.20-0.82) **Women** **Main effect:** OR 1.97 (95% CI 1.30-2.98) **Adjusted:** OR 1.04 ((5% CI 0.57-1.89)	There was some evidence that low level of social support had a greater impact on depression among the most disadvantaged
Kim & Kawachi, 2007[b]	USA (♂/♀) Behavioural Risk Factor Surveillance System survey (BRFSS) *n* = 173 236 57.3 18-65+	**Mean household income:** $50001	**Combination:** *Social activity and trust (social capital).* Continuous, higher values indicate higher levels of state social capital (based on 5 items: trust, social engagement, affiliation with voluntary association, civic and political participation) SC = social capital	**SRH:** BRFSS survey + Centres for Disease Control and Prevention HRQOL-4 instrument. Dichotomous, excellent/very good/good health vs fair/poor health **Physical health/Mental health/Activity limitation:** Recent days of poor physical/mental health or activity limitation, continuous scale with higher values indicated poor health or days of activity limitation	<u>**Poor SRH:**</u> Model 1: OR 0.98 (95% CI 0.93-1.03) Model 2: OR 0.86 (95% CI 0.76-0.97) <u>**Poor mental health:**</u> Model 1: β 0.17 (0.02-0.32) Model 2: β -0.20 (-0.62, 0.21) <u>**Activity limitation:**</u> Model 1: β 0.05 (-0.04, 0.14) Model 2: β -0.36 (-0.61, -0.10)	**Poor SRH:** original estimates from paper Activity limitation and mental health: 95% CIs for interaction effects non-calculable	Social capital buffered against poor health in states with a lower state-level mean income.
Kollannoor-Samuel et al., 2011[a]	USA (♂/♀) DIALBEST *n* = 211 73.5	**Food insecurity (FI):** Measured by US household food security supplement module (US-	**Functional:** *Social support*. Continuous, higher scores indicate higher support levels (based on social	**Depressive symptoms:** CES-D Scale. Continuous, ≥20	No effect estimates presented	Non-calculable	Medium and high social support buffered against the negative influence of household food

	56.4 (11.8)	HFSSM). Score 0-5, 5 indicates extreme food insecurity	support availability from family and friends)	indicates elevated depressive symptoms			insecurity on depression risk. For those with higher levels of food insecurity, high and medium social support reduced depression probability by 10% and 2% respectively
Natamba et al., 2017[b]	Uganda (♀) Prenatal Nutrition and Psychosocial Health Outcomes (PreNAPs) *n* = 403 24.7 (5.0)	**Food insecurity:** Measured by individually focused FI access scale (IFIAS). Continuous, higher scores indicate greater food insecurity	**Functional:** *Social support*. Continuous, measured using Duke-UNC functional SS instrument, higher scores indicate higher levels of support (based on 3 items: emotional, informational, and instrumental support)	**Depressive symptoms:** CES-D scale. Continuous, ≥17 indicates depressive symptoms	**FI/Low SS:** Model 2: B 0.91 (95% CI 0.55-1.27) p<0.001 **FI/High SS:** Model 2: B 0.53 (95% CI 0.28-0.78)	Non-calculable – could not get in touch with author	Social support buffered the negative effect of food insecurity on depressive symptoms
Ng et al., 2014[a]	Singapore (♂/♀) Marine Parade Elderly Needs Survey 2011 *n* = 2447 59.6 ≥60	**Education:** Dichotomous, primary/lower vs secondary/higher **Housing type:** Number of rooms	**Combination:** *Social support, social isolation*. Categorical (based on 4 items: people you live with, frequency of contact with family, perceived isolation)	**Depressive symptoms:** GDS scale. Continuous, ≥5 indicates depressive symptoms	**Low Sep on depression** OR 3.06 (95% CI 1.52-6.16) **Low SEP*Alone or domestic helper** OR 0.47 (95% CI 0.18-1.25) **Low SEP*Others:** OR 0.29 (95% CI 0.09-0.93) **Low SEP*Children/ Grandchildren** OR 0.93 (95% CI 0.28-3.16) **Low SEP*Spouse** OR 1.06 (95% CI 0.42-2.68) **Low SEP*Spouse & Grandchildren:** OR 3.06 (95% CI 1.52-6.16)	Original estimates from paper	Inconsistent buffering effects of social support on the negative effect of low SEP on depression. Those with low SEP living with others (relatives, friends, tenants) had 70% lower odds of experiencing depressive symptoms compared to their more affluent peers. However, support from immediate family did not buffer the negative effects of low SEP on depressive symptoms
Nielson et al., 2015[c]	Denmark (♂/♀) HBSC-Denmark *n* = 3549 51.3 11-15	**Parental occupational class:** Dichotomous, high vs low	**Functional:** *Trust*. Categorical (based on 3 items: students enjoying being with one another, acceptance of each other, kind and caring)	**Mental health:** HBSC Symptom Check List (HBSC-SCL). Dichotomous daily vs less often (experiencing symptoms)	**Low SEP + High trust:** OR 1.47 (95% CI 0.86-2.52) **Low SEP + Moderate trust:** OR 1.31 (95% CI 0.95-1.81) **Low SEP + Low trust:** OR 1.89 (95% CI 1.25-2.86)	Original estimates from paper	In school classes with low level of trust, there was 89% greater odds of experiencing daily emotional symptoms in the low vs high socioeconomic group compared. Higher social trust buffered the negative effect of low SEP on emotional symptoms
O'Brien, 2012*[a]	USA (♂/♀) MIDUS I/II Survey *n* = 3775 52.4	**Education:** Number of years of education. Continuous,	**Functional:** *Social support*. Continuous, higher scores indicate greater support or greater strain (based on 2	**Chronic health:** Continuous, higher scores indicate	**Chronic health:** Education*social strain B -0.06 (95% CI -0.12, -0.01)	Non-calculable – could not get in touch with author	Low social strain buffered the negative effect of low education on chronic health and

	≥24 Follow-up: 10 years	higher value indicates higher educational level	items: emotional support and emotional strain)	greater frequency of chronic conditions **Functional limitations:** Modified SF-36 health survey. Continuous, higher scores indicate greater limitations **Depressive symptoms:** Continuous, higher scores indicate greater depressive symptoms	**Functional limitations:** Education*social strain B -0.03 (95% CI -0.30, -0.03) **Depressive symptoms:** Education*support B -0.02 (95% CI -0.03, -0.01)		functional limitations. However, social support did not buffer the negative effect of low education on depression and was only protective for those with higher education
Olofsson et al., 2018[b]	Europe (♂/♀) SHARE *n* = 54,741 ≥50	**Education:** Measured using ISCED-97 and used to derive a Relative Index of Inequality in education	**Combination:** *Social network and social support*. Dichotomous, (based on 3 items: number of network ties, emotional support, satisfaction with network)	**SRH:** Five items. Dichotomous, good/very good vs bad	No effect estimated presented	Non-calculable – author does not have beta coefficients, only probability plots	Among those with a low educational level, poor SRH was reported by those with greater satisfaction from their social network for both men and women in Northern Europe only.
Rael et al., 1995*[b]	UK (♂/♀) Whitehall II *n* = 6081 33.1 35-55 Follow-up: 5 years	**Material problems:** Financial difficulties in each employment grade. Tertile, low/medium/high	**Structural:** *Social activity, network*. *Continuous* (based on 2 items: network size, frequency of contact) **Functional:** *Social support*. Continuous (based on 4 items: emotional, instrumental support, first close person, isolation)	**Sickness absence:** Sickness absence records. Dichotomous, short spells (<7 days) vs long spells (>7 days)	<u>**Men: Long spells of sickness absence**</u> RR 1.01 (95% CI 0.88-1.17) <u>**Long spells of illness**</u> <u>**Men (Low SEP/confiding)**</u> **Low confiding** RR 0.92 (95% CI 0.71-1.20) **Medium confiding** RR 1.19 (95% CI 0.95-1.50) **High confiding** RR 0.90 (95% CI 0.71-1.16) <u>**Men (Low SEP/practical support)**</u> **Low practical** RR 1.10 (95% CI 0.86-1.41) **Medium practical** RR 1.13 (95% CI 0.88-1.47) **High practical** RR 0.86 (95% CI 0.68-1.08) <u>**Women: Long spells of sickness absence**</u> RR 1.15 (95% CI 0.99-1.34) <u>**Women (Low SEP/confiding)**</u> **Low confiding** RR 1.09 (95% CI 0.82-1.40) **Medium confiding** RR 1.58 (95% CI 1.23-2.00) **High confiding** RR 0.85 (95% CI 0.66-1.10)	Original estimates from paper: RR taken as OR	Interaction between the lowest tertile of material problems and social support showed some patterns–for women, high negative support and medium levels of emotional support led to high rate of long spells of illness. No interactions were found between material factors and the network structure. For men with low levels of SEP, high confiding and practical support appeared protective against long spells of illness, although these results were not significant.

					<u>Women (Low SEP/negative support)</u> **Low negative** RR 0.83 (95% CI 0.65-1.05) **Medium negative** RR 1.23 (0.94-1.62) **High negative** RR 1.68 (95% CI 1.26-2.25)		
Roy et al., 2018[b]	Canada (♂/♀) Eastern township Population Health Survey (ETPHS) *n* = 8737 52.8 54.3 (15.3)	**Educational level:** Highest level completed **Household income:** <$30000 vs >$30000 **Housing status:** Home ownership vs renter **Working status:** Full time or part-time vs other	**Structural:** *Social activity*. Quartiles (based on 3 items: frequency of contact with friends, affiliation with church/place of worship, leisure/sports participation) Q1SR = Quartile 1 of Social Relationships Q2SR = Quartile 2 of Social Relationships Q3SR = Quartile 3 of Social Relationships Q4SR = Quartile 4 of Social Relationships	**SRH:** Single item. Dichotomous, excellent/very good/good vs fair/poor **Psychological distress:** Kessler Scale, score ≥7 indicates psychological distress	**Men/SRH (<$30000/poor SRH):** OR 3.85 (95% CI 3.19-4.65) **(Q1SR)** OR 2.25 (95% CI 1.49-3.40) **(Q2SR)** OR 2.25 (95% CI 1.44-4.53) **(Q3SR)** OR 2.21 (95% CI 1.82-5.31) **(Q4SR)** OR 2.27 (95% CI 1.15-4.46) **Women/SRH (<$30000/poor SRH):** OR 4.51 (95% CI 3.79-5.37) **(Q1SR)** OR 3.51 (95% CI 2.04-6.04) **(Q2SR)** OR 3.85 (95% CI 2.83-8.33) **(Q3SR)** OR 2.82 (95% CI 1.72-4.64) **(Q4SR)** OR 2.90 (95% CI 1.89-4.46) **Men/Psychological distress (<$30000/yes):** OR 1.93 (95% CI 1.63-2.28) **(Q1SR)** OR 1.12 (95% CI 1.01-1.76) **(Q2SR)** OR 1.19 (95% CI 0.65-2.19) **(Q3SR)** OR 1.22 (95% CI 0.63-2.38) **(Q4SR)** OR 1.23 (95% CI 0.63-2.40) **Women/Psychological distress (<$30000/yes):** OR 2.06 (95% CI 1.79-2.37) **(Q1SR)** OR 1.93 (95% CI 1.25-2.97) **(Q2SR)** OR 1.57 (95% CI 0.93-2.35)	Original estimates from paper	Moderating effects of social participation found in the relationships between SEP and health. Generally, odds of poor SRH and psychological distress among low-income men and women were lower in people with the highest levels of social participation compared to those who have lower levels of social participation

					(Q3SR) OR 1.71 (95% CI 1.12-2.60) **(Q4SR)** OR 1.82 (95% CI 1.20-2.77)		
Salihu et al, 2017[b]	USA (♀) *n* = 132 45.6 (14.4)	**Income:** Dichotomous, ≤$20000 vs ≥$20000 **Employment:** Dichotomous, employed vs unemployed	**Functional:** *Social support*. Dichotomous, low/adequate. Measured using MOS scale (based on 2 items: emotional and instrumental support) SS = social support	**HRQoL:** Global, physical, and mental HRQoL. Dichotomous, low/adequate	<u>**Income (low physical health):**</u> **Low SS*>$20000** OR 1.06 (95% CI 0.37–2.17) **Low SS*≤$20000** OR 0.94 (95% CI 0.46-2.70) **Adequate SS*≤$20000** OR 2.24 (95% CI 1.52–3.41) **Adequate SS*>$20000** OR 1.03 (95% CI 0.53–1.84) <u>**Income (low mental health):**</u> **Low SS*>$20000** OR 0.52 (95% CI 0.18–1.06) **Low SS*≤$20000** OR 1.92 (95% CI 0.94-5.50) **Adequate SS*≤$20000** OR 0.59 (95% CI 0.38-0.87) **Adequate SS*>$20000** OR 0.37 995% CI 0.19-0.63) <u>**Employment (low physical health):**</u> **Low SS*unemployed** OR 0.43 (95% CI 0.28-0.66) **Low SS*employed** OR 2.31 (95% CI 1.51–3.59) **Adequate SS*unemployed** OR 0.46 (95% CI 0.22-0.85) **Adequate SS*employed** 0.53 (95% CI 0.26-0.96) <u>**Employment (low mental health):**</u> **Low SS*unemployed** OR 0.92 (95% CI 0.57-1.51) **Low SS*employed** OR 1.09 (95% CI 0.66–1.74) **Adequate SS*unemployed** OR 0.59 (95% CI 0.36-0.93) **Adequate SS*employed** OR 0.68 (95% CI 0.40–1.11)	**Low income-poor health:** OR 1.78 (95% CI 1.10-3.03) **Low income-poor mental health:** OR 1.69 (95% CI 1.04-3.03) **Unemployed-poor health:** OR 3.22 (95% CI 2.63-5.26) **Unemployed-poor mental health:** OR 0.89 (95% CI 0.63-1.28)	Inconsistent results found. Adequate social support buffered the negative effect of: 1. low-income low mental health 2. unemployment on mental health 3. unemployment on physical health Adequate social support did not buffer the negative effect of low income on physical health
Salonna et al., 2012[b]	Slovakia (♂/♀) *n* = 1863 53.4 16.85 (1.1)	**Education:** parental education categorised (elementary school, Secondary high school, university) **Family Affluence:** Measured using financial affluence scale. Tertiles, low, medium, high	**Functional:** *Social support*. Continuous, a higher score represents greater support from parents or friends (based on 3 items: emotional support, instrumental support, feeling a worthwhile person)	**SRH:** Single item. Dichotomous, excellent/very good/good vs bad	**Boys** Model 1 (Education): OR 1.7 (95% CI 1.1-2.7) Model 2: Education*SS: OR 1.0 (95% CI 0.9-1.1) Model 1 (Affluence): OR 2.0 (95% CI 1.1-3.6) Model 2: Affluence*SS: OR 1.0 (95% CI 0.9-1.1)	Original estimates from paper	Social support from the mother, father, and friends did not moderate the relation between SEP and SRH

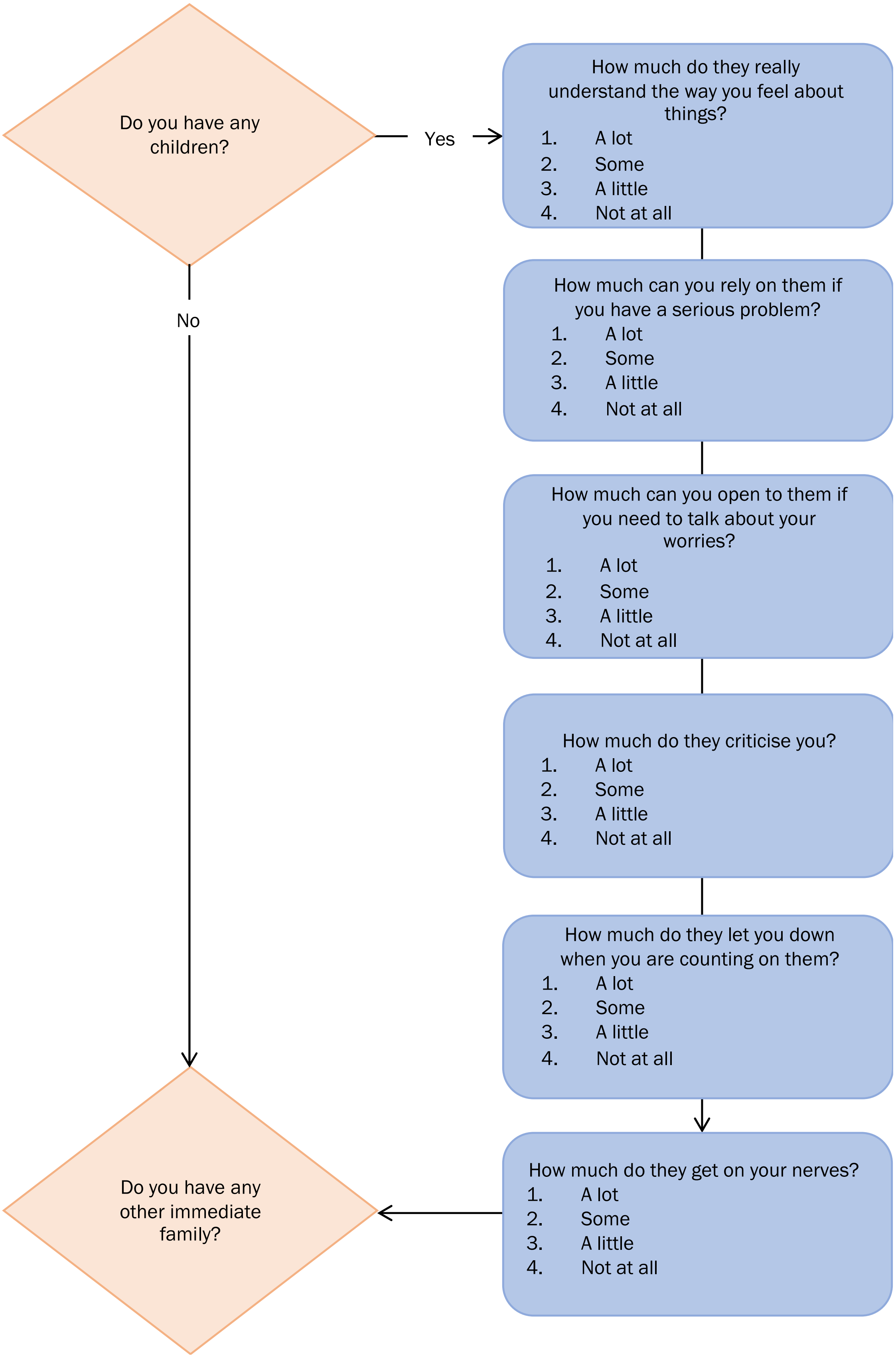
		Financial Strain: Perceived strain. Dichotomous, sometimes/rarely/never vs very often/often	SS= social support		Model 1 (Strain): OR 2.0 (95% CI 1.2-3.3) Model 2: Strain*SS: OR 1.1 (95% CI 0.9-1.2) **Girls** Model 1 (Education): OR 1.4 (95% CI 0.9-2.0) Model 2: Education*SS: OR 1.0 (95% CI 0.9-1.1) Model 1 (Affluence): OR 2.3 (95% CI 1.2-4.4) Model 2: Affluence*SS: OR 1.1 (95% CI 0.9-1.3) Model 1 (Strain): OR 1.2 (95% CI 0.8-1.7) Model 2: Strain*SS: OR 1.0 (95% CI 0.9-1.1)		
Stafford et al, 2008[a]	UK (♂/♀) Health Surveys for England and Scotland + data from postal questionnaire for social capital *n* = 9082 55 16+	**Household deprivation:** 12 items capturing deprivation. Continuous, ≥2 indicates living in deprived household **Neighbourhood deprivation:** Measured using Carstairs deprivation scores from the Manchester Information and Associated Services (MIMAS). Areas with a Carstairs score in the top third were classified as deprived	**Structural:** *Social activity and network*. Continuous, higher scores indicate greater support/bigger network (based on 3 items: number of social ties, affiliation with voluntary association, integration with community) **Functional:** *Social support and trust*. Continuous, higher scores indicate greater support/trust (based on 4 items: reciprocity, attachment to neighbourhood, tolerance of others, trust)	**Common mental disorders (CMD):** 12-item General Health Questionnaire (GHQ)	<u>Household deprivation & CMD:</u> **Deprived/low friend ties:** OR 2.53 (95% CI 1.34-4.79) **Deprived/medium friend ties:** OR 3.04 (95% CI 1.67-5.56) **Deprived/high friend ties:** OR 1.74 (95% CI 1.08-2.79) **Deprived/low attachment:** OR 0.89 (95% CI 0.41-1.95) **Deprived/medium attachment:** OR 1.04 (95% CI 0.55-1.97) **Deprived/high attachment:** OR 1.74 (95% CI 1.08-2.79) **Deprived/low tolerance:** OR 2.96 (95% CI 1.45-6.04) **Deprived/medium tolerance:** OR 3.41 (95% CI 1.80-6.45) **Deprived/high tolerance:** OR 1.74 (95% CI 1.08-2.79) <u>Neighbourhood deprivation & CMD:</u> **Deprived/low attachment:** OR 0.88 (95% CI 0.32-2.37) **Deprived/medium attachment:** OR 1.11 (95% CI 0.45-2.74)	Original estimates from paper	Living in a deprived household was strongly associated with CMD (OR 1.74 95% CI 1.08–2.79) High friend ties and high tolerance buffered some of the negative effect of household deprivation on CMD. Higher levels of neighbourhood attachment were associated with increased odds of CMD for people living in deprived vs non-deprived neighbourhoods and for people with higher vs lower household deprivation
Uebelacker et al., 2013*[b]	USA (♀)	**Household income:** Tertiles, low (<$20000), medium ($20000-	**Combination:** *Social support, social activity*. Continuous, higher scores	**Depression:** Modified CES-D. Dichotomous, higher	**Baseline depression** **Low Income:** OR 2.42 (95% CI 2.28-2.57)	<u>**Baseline depression**</u> **Low income*Low support:**	Higher levels of social support at baseline and follow-up increased the

	Women's Health Initiative *n* = 67 972 50-79 Follow-up: 3 years	$49000), high (>$50000) **Acute financial stress:** Dichotomous, yes vs no	indicate greater levels of support (based on 4 items: emotional support, informational support, tangible support, positive social interactions	(≥5) vs lower (<5) depression levels	**Low income*Low support:** OR 1.43 **Low income*High support:** OR 1.81 **Depression 3-year follow-up** **Low Income:** OR 1.88 (95% CI 1.73-2.05) **Low income*Low support:** OR 1.30 **Low income*High support:** OR 1.57	OR 1.43 (95% CI 1.01-2.04) **Low income*High support:** OR 1.81 (95% CI 1.00-3.25) Follow-up **Low income*Low support:** OR 1.30 (95% CI 1.01-1.67) **Low income*High support:** OR 1.57 (95% CI 1.00-2.46)	association between financial stress/income and new-onset depression 3 years later
Veenstra & Patterson 2012*[a]	USA (♂/♀) Alameda County Study *n* = 6157 54.2 21+ Follow-up: 35 years	**Education:** Number of years **Income:** Median income	**Structural:** *Social activity and network*. Categorical (based on 6 items: number of close friends, affiliation with social group, or occupational group, or child-orientated group, or community group, church attendance)	**Mortality:** Mortality information via survey data	**Income:** Model 1 + low income*church OR 0.936 (95% CI 0.910-0.963) Model 1 + low income*social participation: OR 0.815 (95% CI 0.678-0.980)	Original from paper	There was a protective effect of church attendance and community participation only on mortality among non-wealthy people
Vincens et al., 2018[a]	South America (Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay) (♂/♀) World Values Survey *n* = 10 426 68.58 15-65+	**Education:** Categorical, lower (secondary school incomplete), middle (complete secondary school), higher (college/university) **Gini index:** Mean Gini index 2000/2001 to 2013/2014	**Structural:** *Social activity*. Continuous (based on 2 items: associational membership, civic participation) **Functional:** *Trust*. Continuous (based on 2 items (generalised trust, neighbourhood trust)	**SRH:** Single item. Dichotomous, very good/good vs fair/poor	**Membership** **Generalised trust (good SRH):** **Lower education*SR** OR 1.07 (95% CI 1.04-1.10) **Neighbourhood trust (good SRH):** **Lower education*SR** OR 1.03 (95% CI 1.01-1.04)	**Outcome: low education on poor SRH** **Generalised trust:** **Lower education*SR** OR 0.93 (95% CI 0.90-0.96) **Neighbourhood trust:** **Lower education*SR** OR 0.97 (95% CI 0.96-0.99)	No significant moderating effect for associational membership and civic participation were identified. Generalised trust had a greater impact on the social gradient in health when compared to neighbourhood trust
Wu & Rudkin, 2000[a]	Malaysia (♂/♀) Malaysian Family Life Survey-2 N = 1346 50+	**Literacy status:** Dichotomous, literate vs illiterate **Occupation:** Categorical, professional/manageria, clerical, agricultural, labour/manual, unemployed/missing	**Functional:** *Social support*. Dichotomous, daily contact/no contact (based on daily contact from adult children)	**SRH:** Single item. Dichotomous	**Worse Health Status:** **Malay (agricultural worker/less SS)** OR 5.16 p<0.01 **Malay (agricultural worker/daily SS)** OR 0.98 p<0.05 **Malay (unemployed/less SS)** OR 5.25 p<0.05 **Malay (unemployed/daily SS)** OR 0.25 p<0;05 **Chinese (illiterate/less contact)** OR 3.08 p<0.001	**Malay (agricultural worker/less SS)** OR 5.16 (95% CI 1.48-17.99) **Malay (agricultural worker/daily SS)** OR 0.98 (95% CI 0.96-0.99) **Chinese (illiterate/less contact)** OR 3.08 (95% CI 1.57-5.99)	Social support buffered against the negative effect of low SEP on poor SRH in Malay and Chinese older people

			Chinese (illiterate/daily contact) OR 1.17 p<0.05	**Chinese (illiterate/daily contact)** OR 1.17 (95% CI 1.00-6.05)	

*= longitudinal design; [a]adjusted or stratified by at least age and sex; [b]Adjusted or stratified by at least age or sex; [c]Adjusted by school grade and migration status; [d]Stratified by country

Appendix 9: Flow diagram for ELSA social support questions



Appendix 10: Distribution of missingness in items used to construct loneliness, social isolation, positive and negative social support measures

Variables	Wave 2 (n = 8688)		Wave 3 (n = 8624)	
	Missing[1]		Missing[1]	
	n	%	*n*	%
Loneliness[2]				
Item 1	1001	11.5	1221	14.2
Item 2	1040	12.0	1240	14.4
Item 3	1047	12.1	1241	14.4
Social isolation[3]				
Item 1	1330	15.3	1552	18.0
Item 2	1100	12.7	1313	15.2
Item 3	1053	12.1	1274	14.8
Item 4	0	0	0	0
Item 5	1456	16.8	1568	18.2
Item 6	4	0.05	5	0.06
Positive support[4]				
Item 1	1160	13.4	1314	15.2
Item 2	1190	13.7	1304	15.1
Item 3	1208	13.9	1374	15.9
Item 4	1123	12.9	1318	15.3
Negative support[5]				
Item 1	1163	13.4	1332	15.5
Item 2	1231	14.2	1331	15.4
Item 3	1387	16.0	1533	17.8
Item 4	1295	14.9	1466	17.0

[1]Unweighted

[2]Loneliness:	Item 1 = How often respondent feels lacking in companionship Item 2 = How often respondent feels left out Item 3 = How often respondent feels isolated from others
[3]Social isolation:	Item 1 = Frequency of contact with children Item 2 = Frequency of contact relatives Item 3 = Frequency of contact friends Item 4 = Married/cohabiting or neither Item 5 = Respondent is NOT a member of any organisations, clubs or societies Item 6 = Frequency of voluntary work
[4]Positive support:	Item 1 = Positive support from partner (understanding feelings, opening up to, relying upon) Item 2 = Positive support from children (understanding feelings, opening up to, relying upon) Item 3 = Positive support from relatives (understanding feelings, opening up to, relying upon) Item 4 = Positive support from friends (understanding feelings, opening up to, relying upon)
[5]Negative support	Item 1 = Negative support from partner (criticism, letting respondent down, getting on nerves) Item 2 = Negative support from children (criticism, letting respondent down, getting on nerves) Item 3 = Negative support from relatives (criticism, letting respondent down, getting on nerves) Item 4 = Negative support from friends (criticism, letting respondent down, getting on nerves)

Appendix 11: Distribution of blood pressure at wave 2 and age at waves 2 and 3

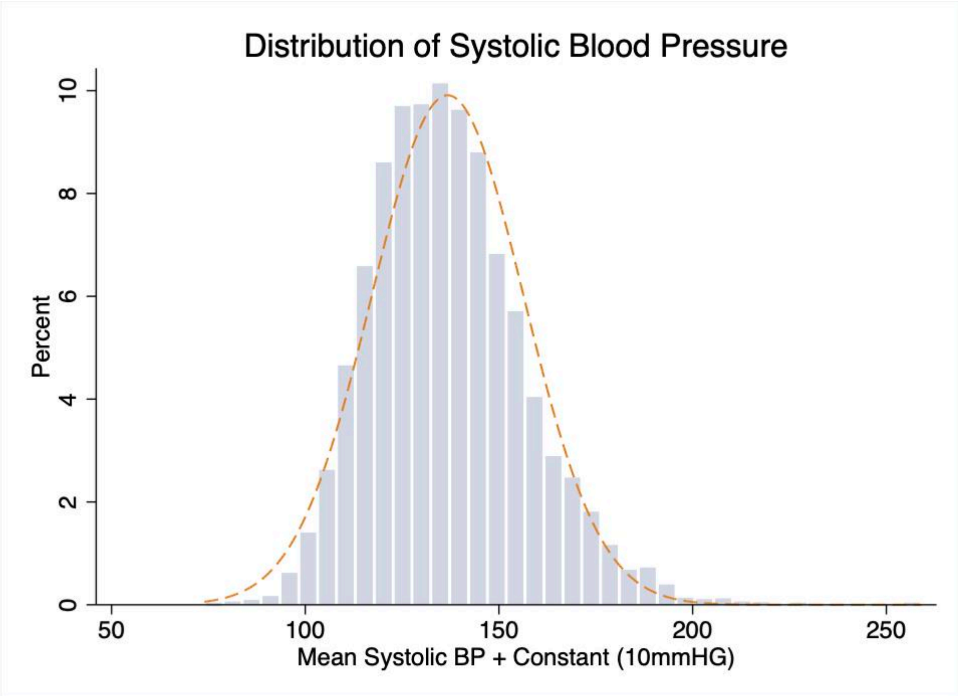


Figure A.11.1 Distribution of mean systolic blood pressure at wave 2

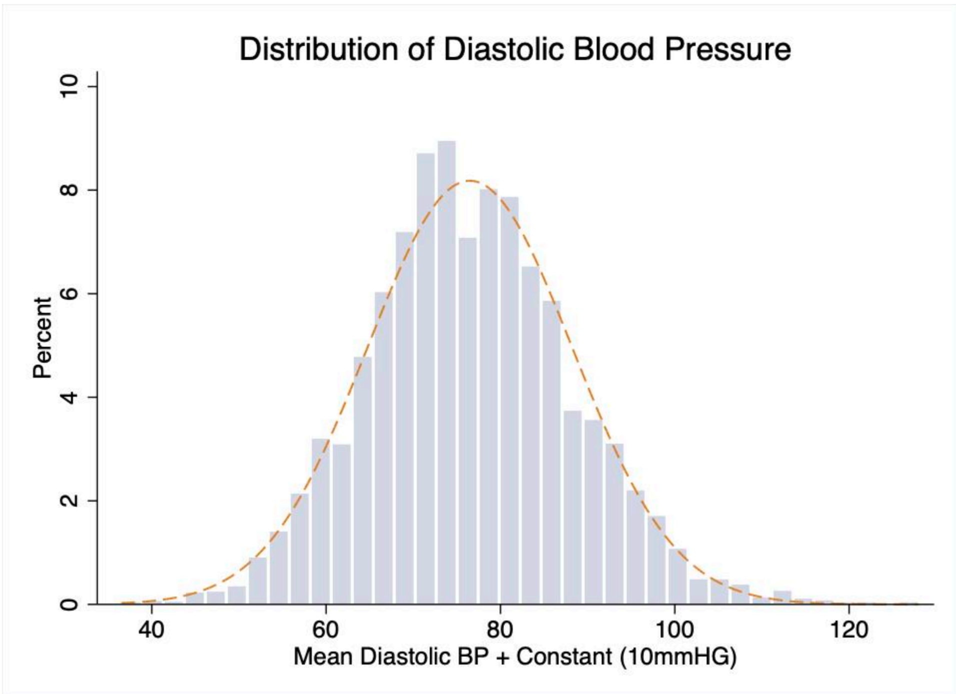


Figure A.11.2 Distribution of mean diastolic blood pressure at wave 2

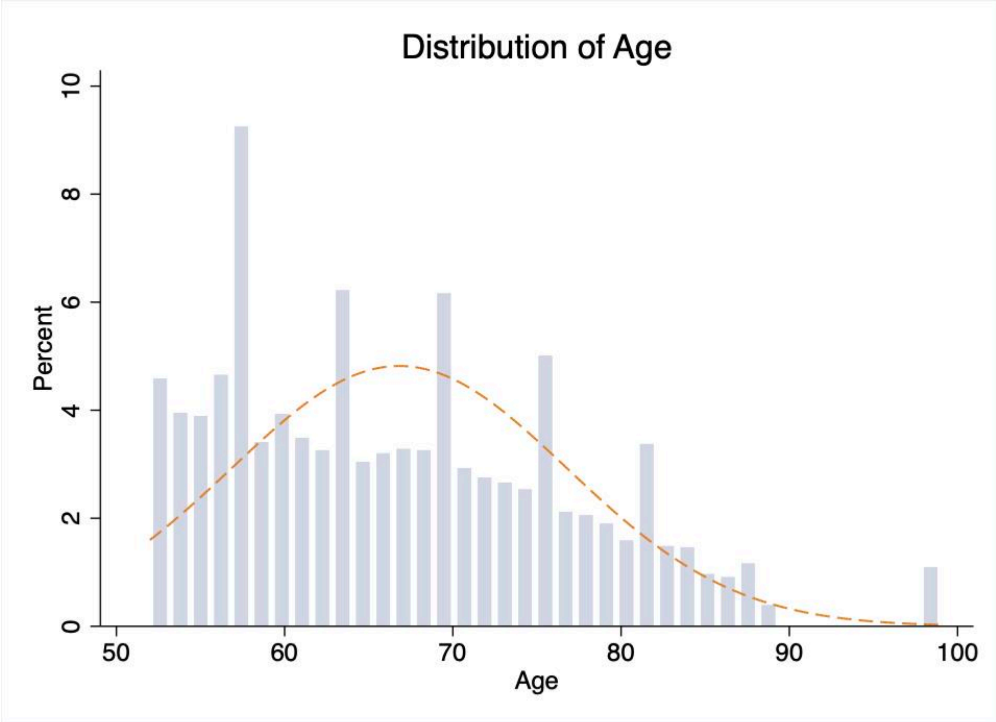


Figure A.11.3 Distribution of age at wave 2

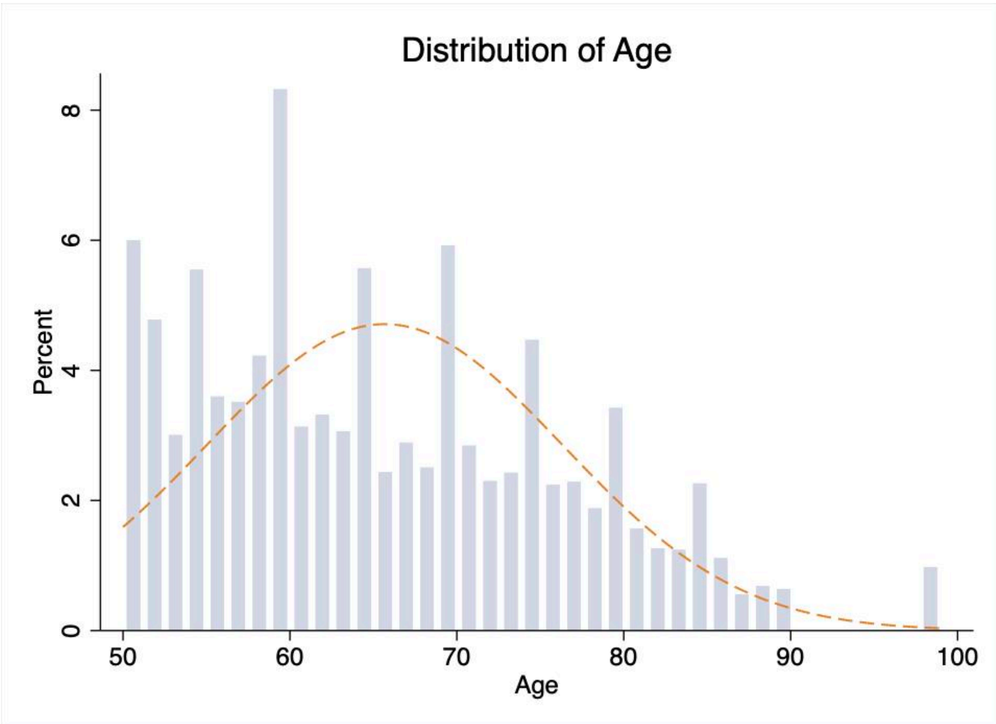


Figure A.11.4 Distribution of age at wave 3

Table A.11.1: Skewness and kurtosis values for systolic and diastolic blood pressure at wave 2

Variables	Observations (n)	Mean (mm HG) (SD)	Skewness	Kurtosis
Systolic blood pressure	6639	136.8 (19.6)	0.55	3.67
Diastolic blood pressure	6639	76.5 (11.7)	0.22	3.25

Table A.11.2: Skewness and kurtosis values for age at waves 2 and 3

Variables	Observation (n)	Mean (years) (SD)	Skewness	Kurtosis
Age (wave 2)	8681	66.8 (10.0)	0.64	2.95
Age (wave 3)	8617	65.7 (10.6)	0.56	2.68

Appendix 12: Distribution of loneliness, social isolation, and positive and negative social support at waves 2 and 3 on observed data

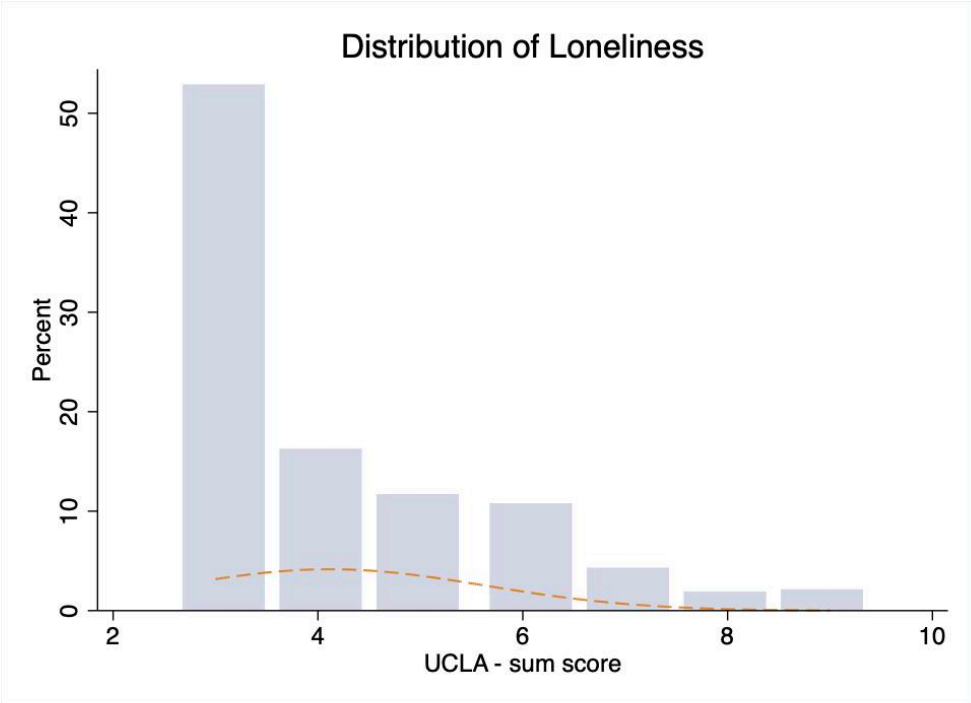


Figure A.12.1 UCLA loneliness sum score among individuals at wave 2

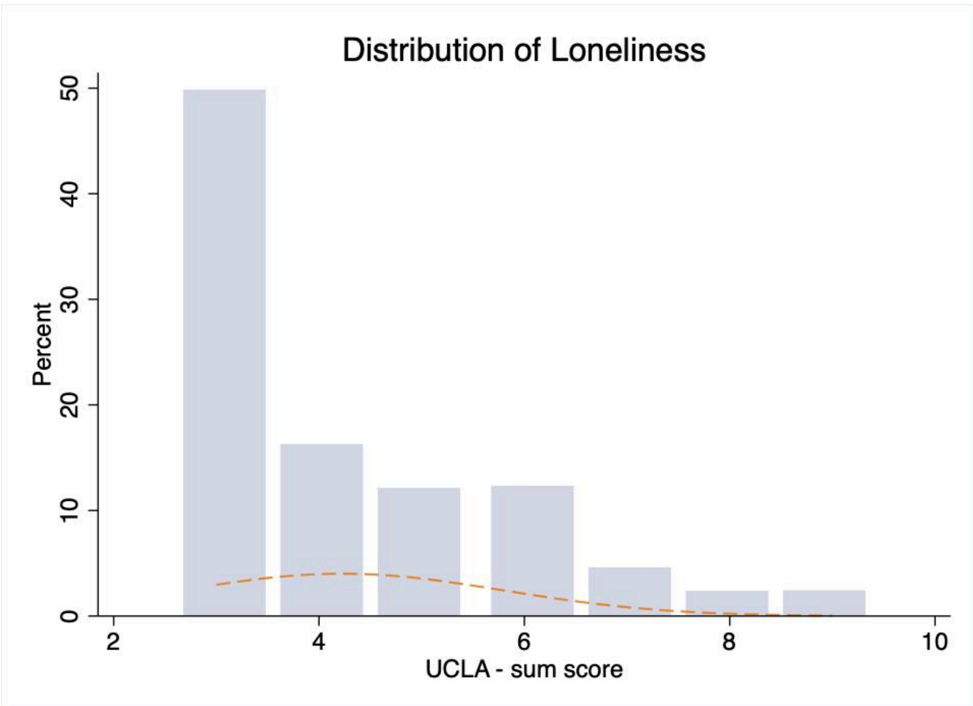


Figure A.12.2 UCLA loneliness sum score among individuals at wave 3

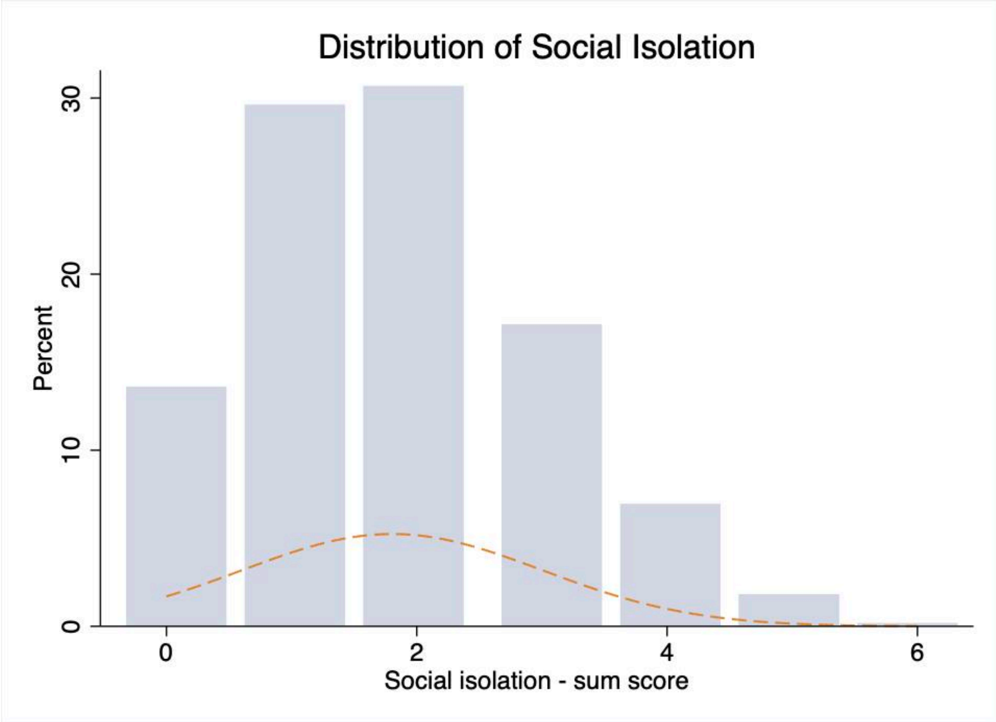


Figure A.12.3 Social isolation sum score among older adults at wave 2

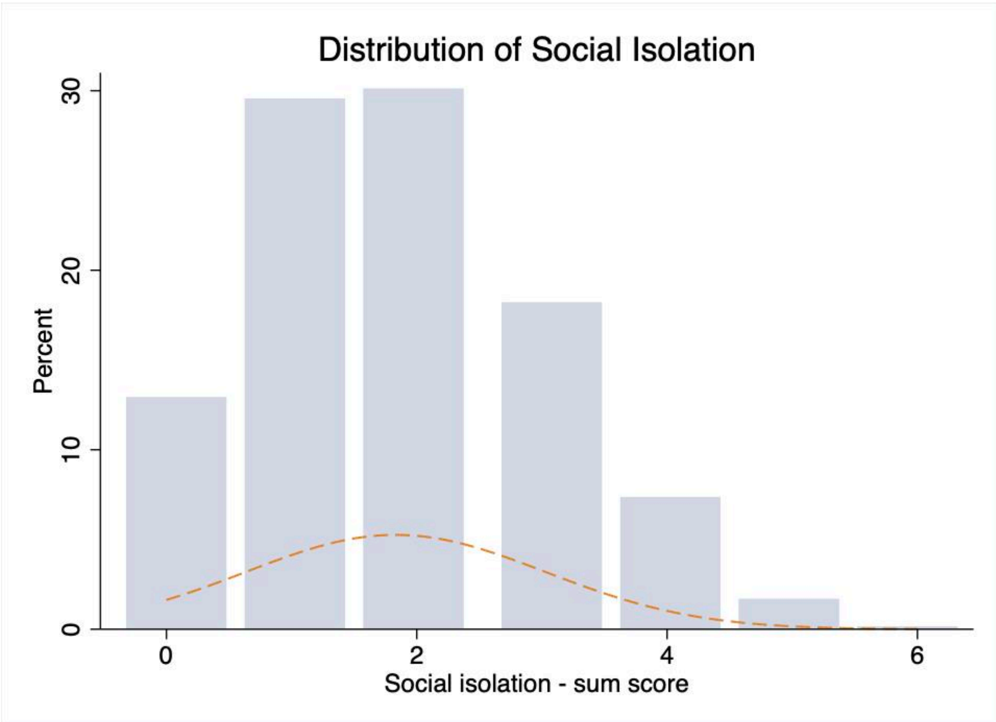


Figure A.12.4 Social isolation sum score among older adults at wave 3

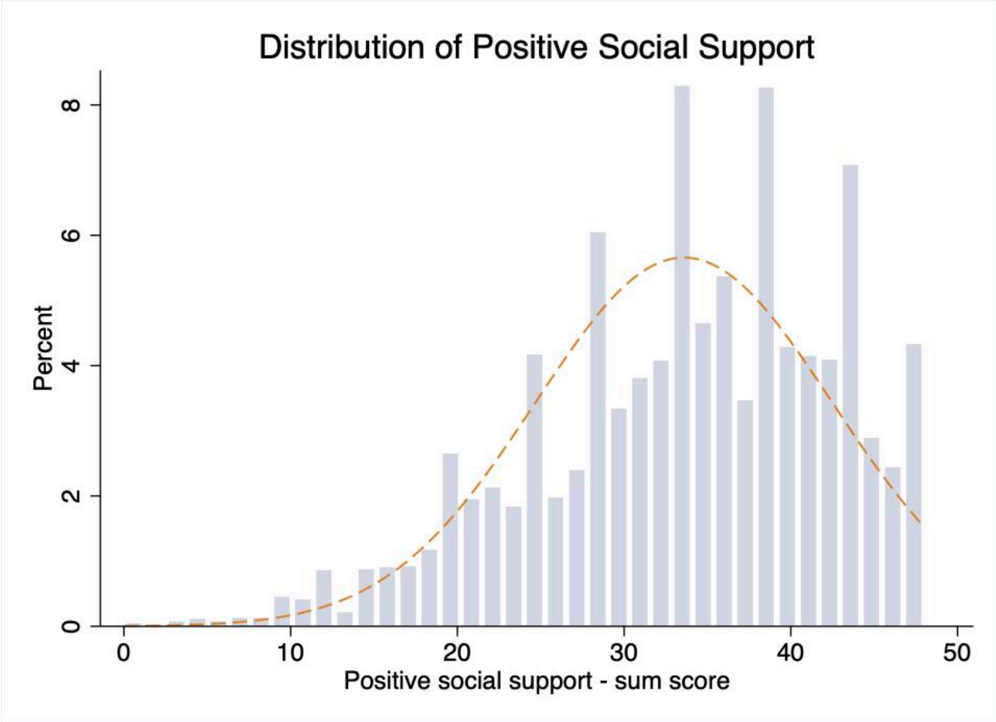


Figure A.12.5 Positive social support score among older adults at wave 2

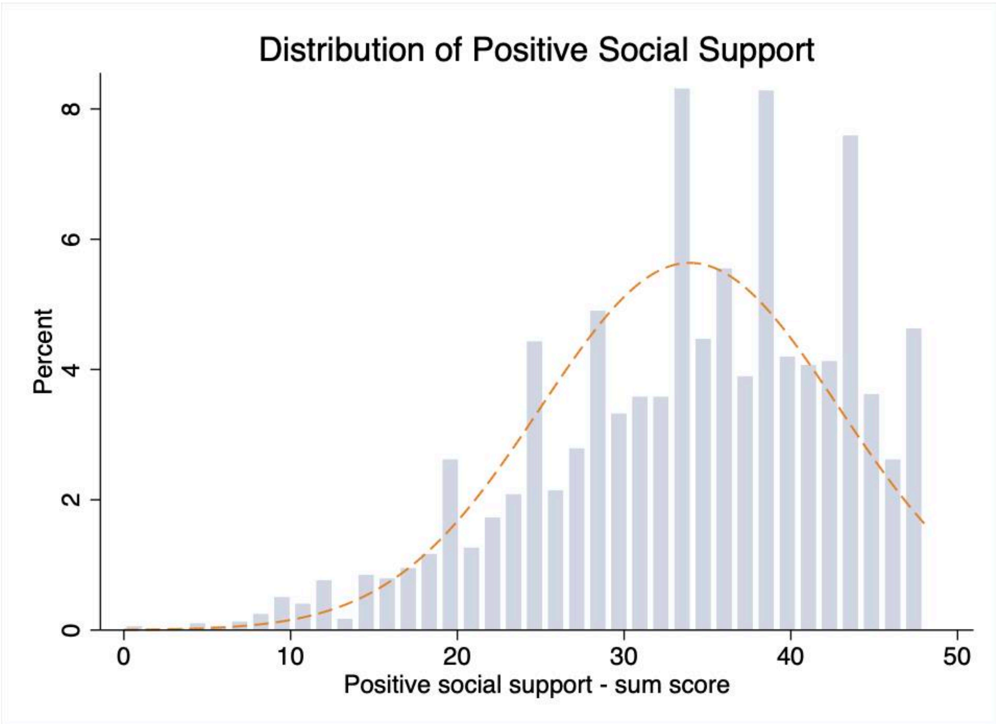


Figure A.12.6 Positive social support score among older adults at wave 3

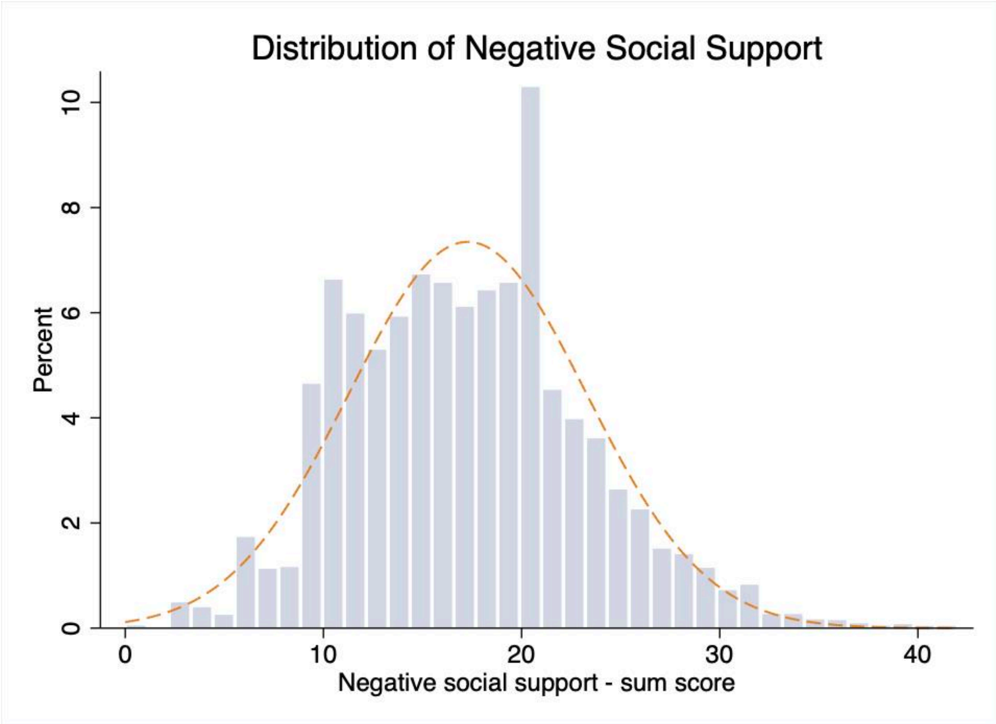


Figure A.12.7 Negative social support score among older adults at wave 2

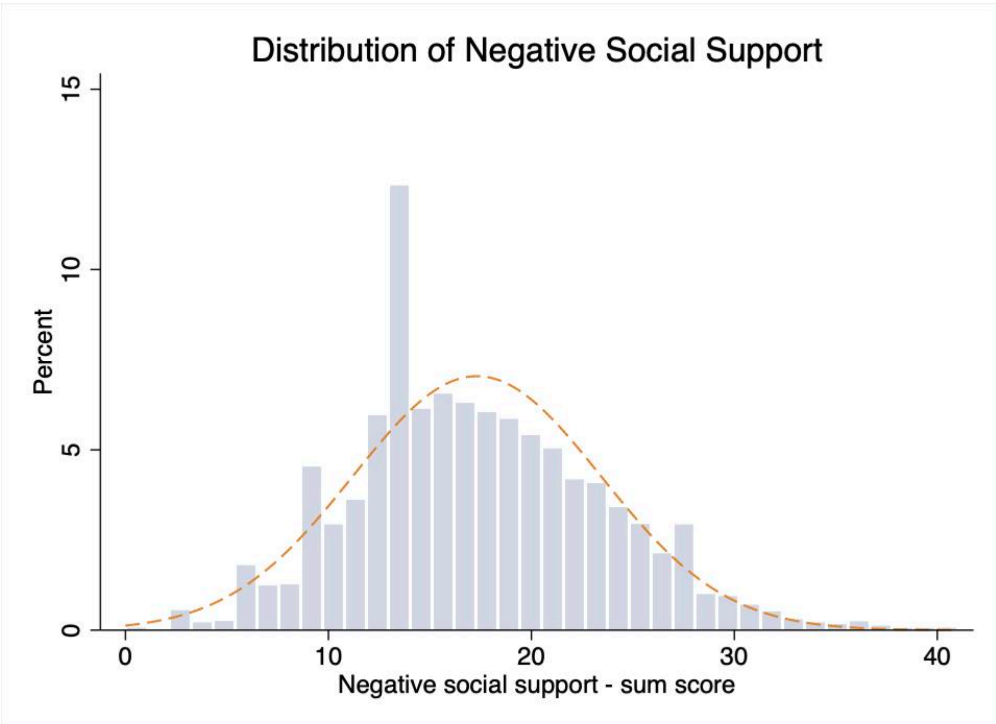


Figure A.12.8 Negative social support score among older adults at wave 3

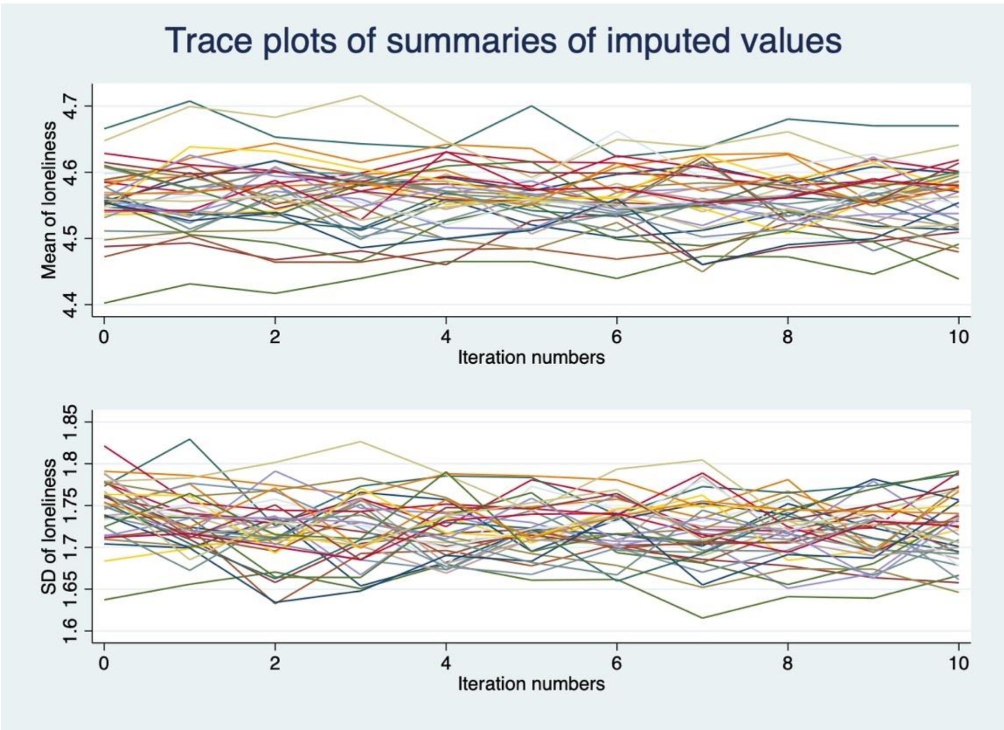
Table A.12.1: Skewness and kurtosis values for loneliness, social isolation, and positive and negative social support at waves 2 and 3

Variables	Observations (*n*)	Mean (SD)	Skewness	Kurtosis
Wave 2				
Loneliness	7583	4.1 (1.5)	1.36	4.14
Social isolation	6679	1.8 (1.2)	0.46	2.87
Positive support	7094	33.6 (8.9)	-0.59	2.90
Negative support	6823	17.3 (6.0)	0.30	3.06
Wave 3				
Loneliness	7342	4.2 (1.6)	1.22	3.72
Social isolation	6515	1.8 (1.2)	0.42	2.77
Positive support	6956	33.9 (8.9)	-0.63	2.96
Negative support	6732	17.3 (6.1)	0.36	3.07

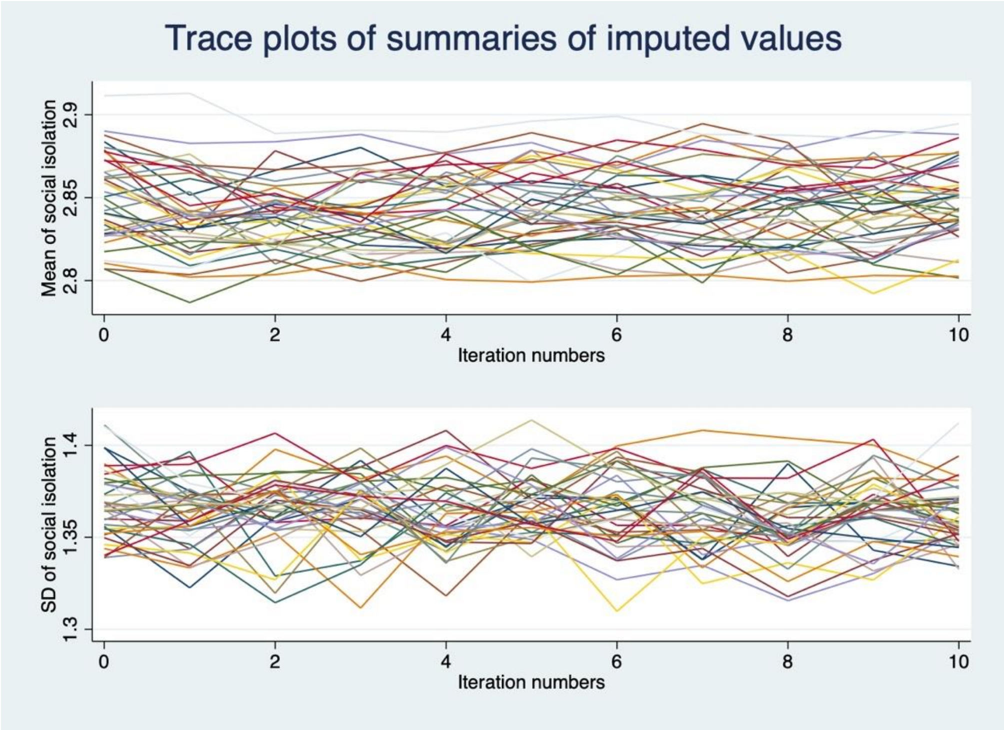
Appendix 13: Diagnostics for multiple imputation

Multiple imputation diagnostics was performed using trace plots. Figures presented below show the trace plots for the predicted mean values and standard deviations for loneliness, social isolation, and positive and negative social support for the analytical samples at waves 2 and 3. There were three analytical samples for the imputed datasets, one each for: self-rated health (wave 2), blood pressure (wave 2), and oral health measures (self-rated oral health, OHRQoL and edentulousness at wave 3). The trace plots were generated during imputations undertaken on these samples. The trace plots indicate that the imputations varied randomly. In addition to the trace plots

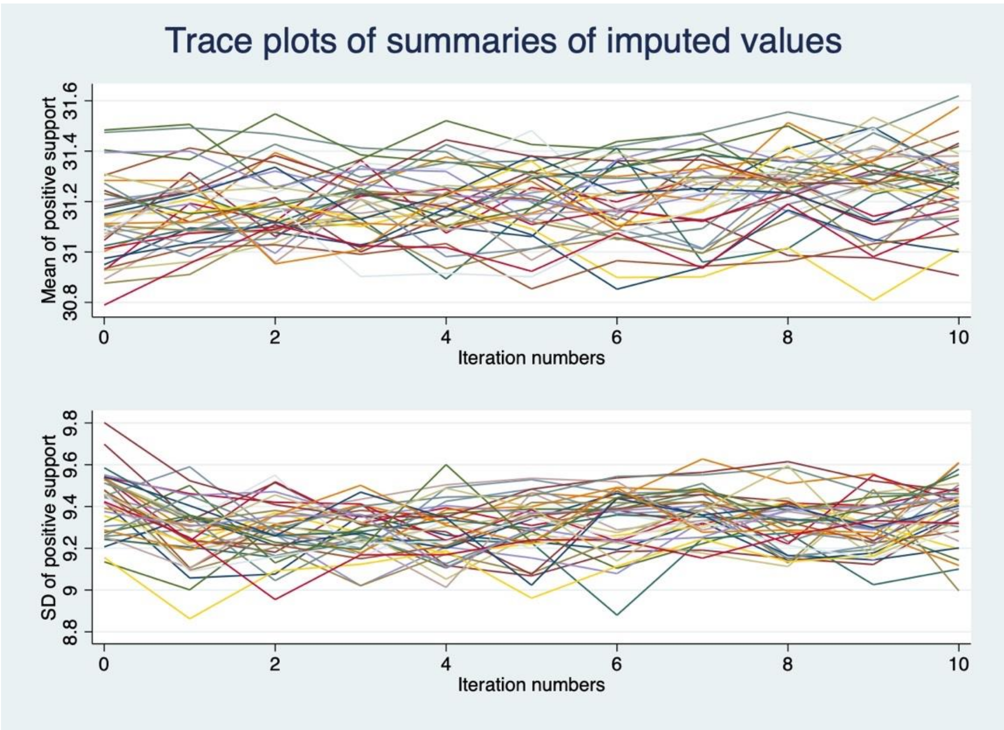
Imputed dataset of self-rated health (wave 2)



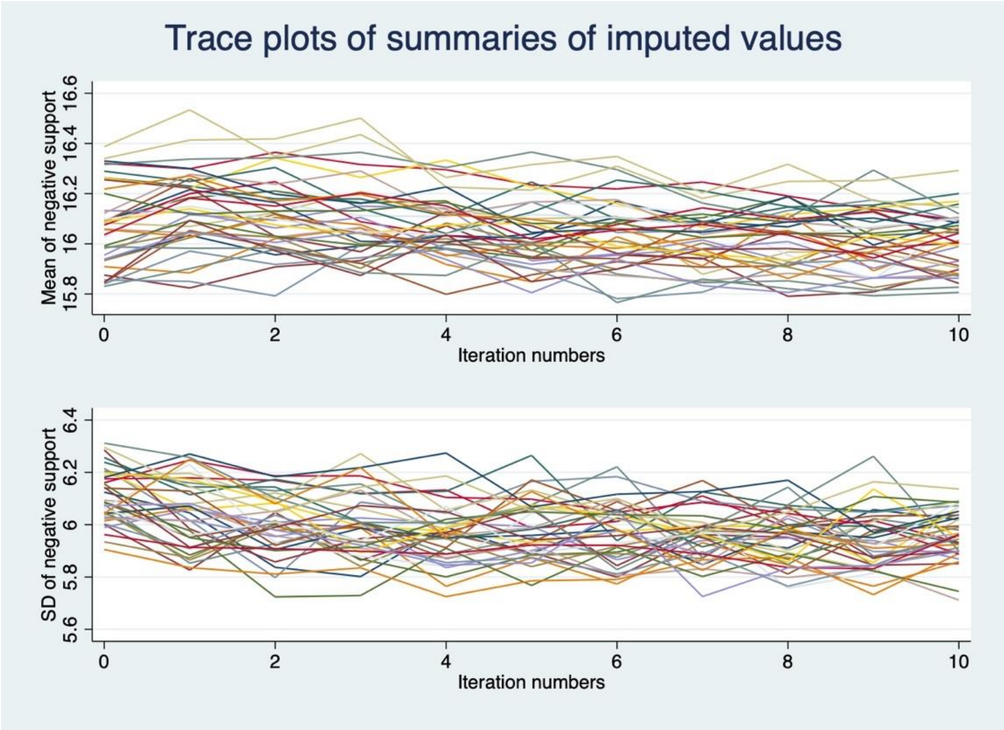
A.13.1 Trace plots for loneliness



A.13.2 Trace plots from imputed data for social isolation

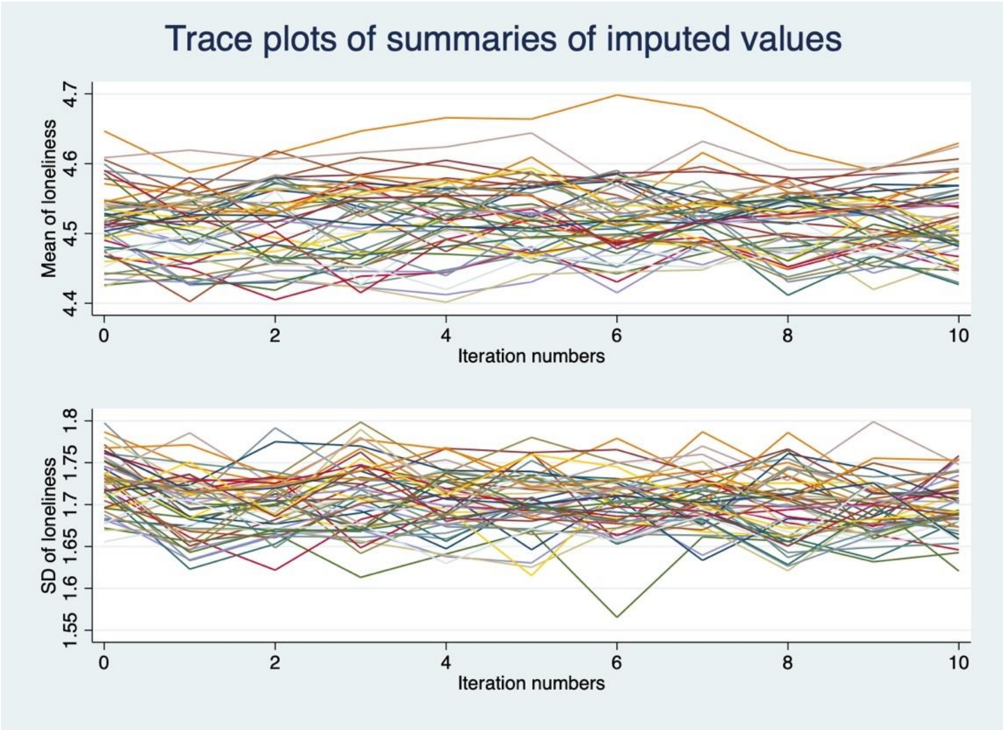


A.13.3 Trace plots from imputed data for positive social support

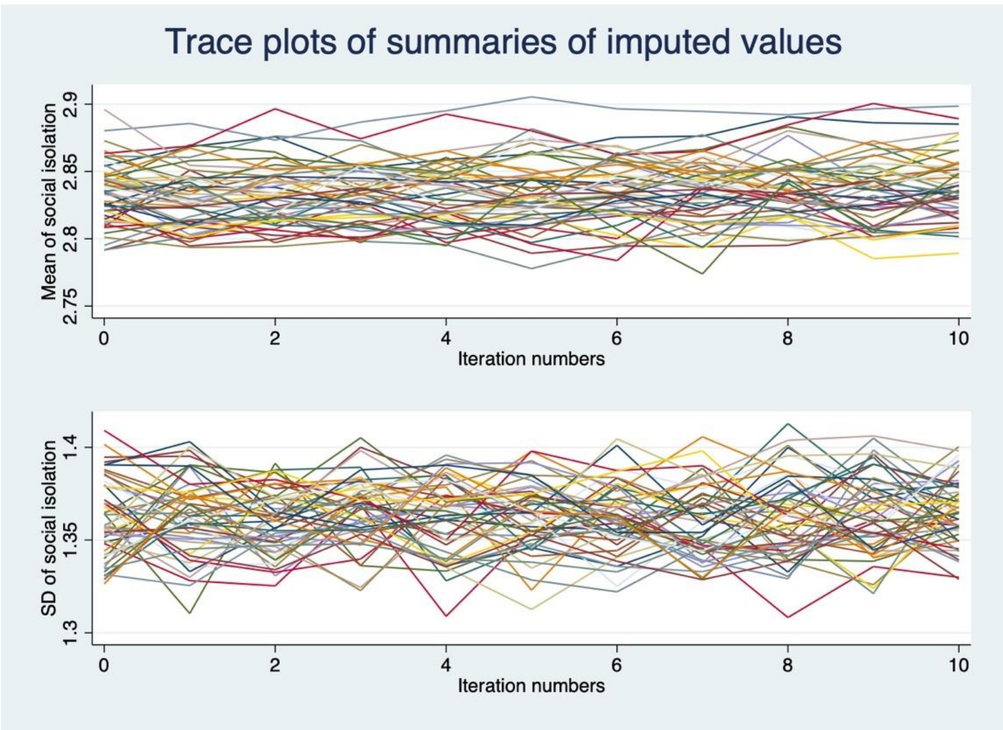


A.13.4 Trace plots from imputed data for negative social support

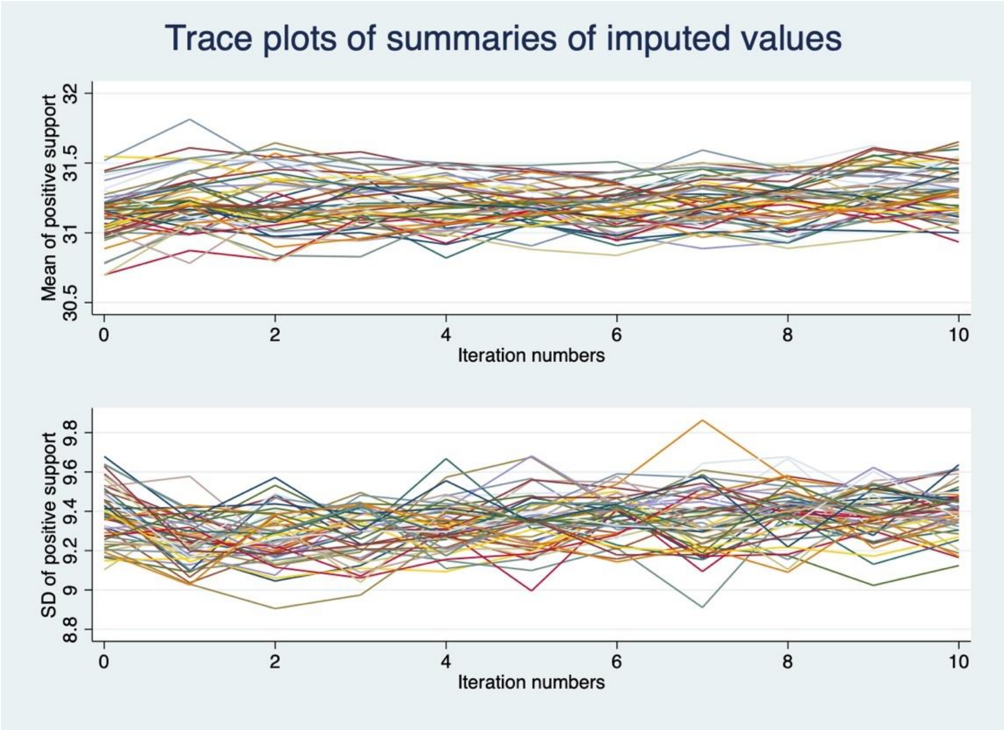
Imputed dataset of blood pressure (wave 2)



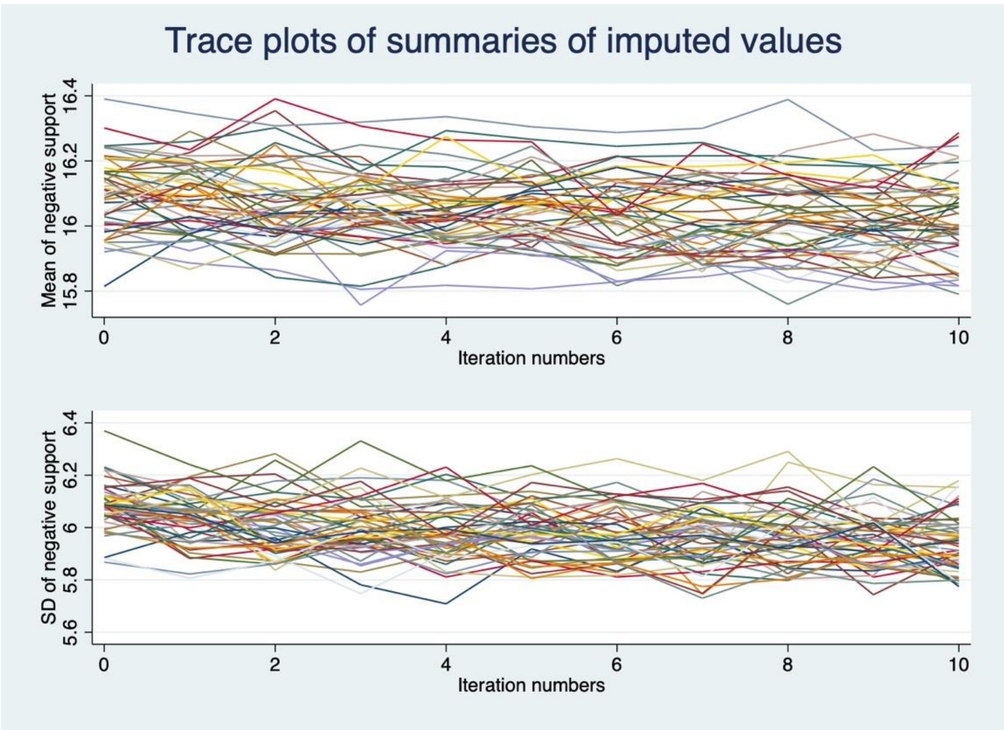
A.13.5 Trace plots for loneliness



A.13.6 Trace plots from imputed data for social isolation

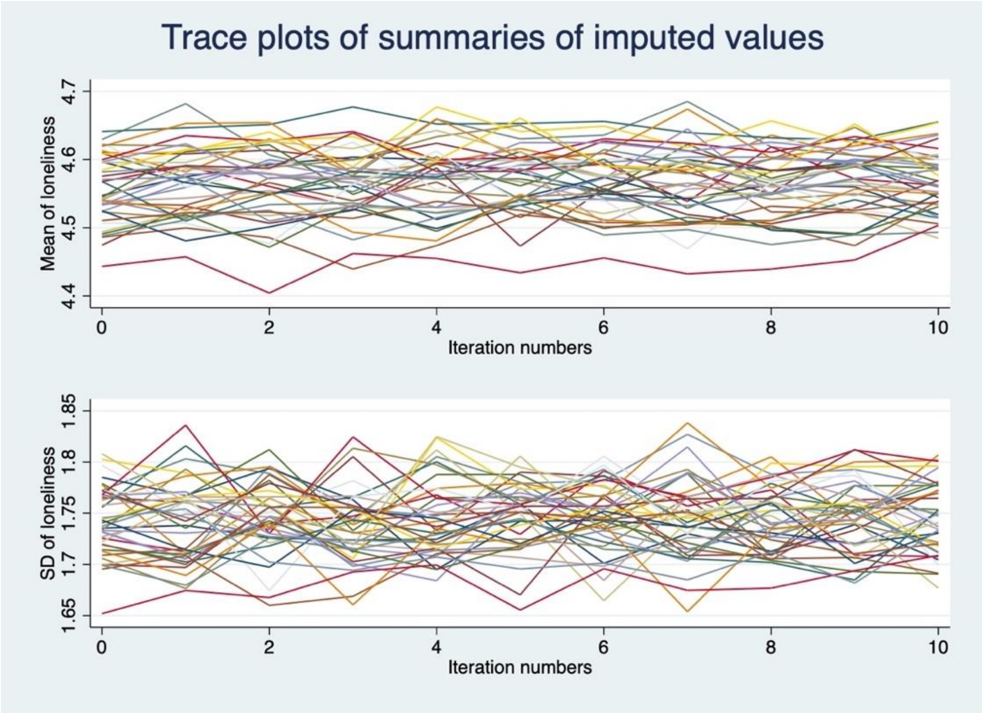


A.13.7 Trace plots from imputed data for positive social support

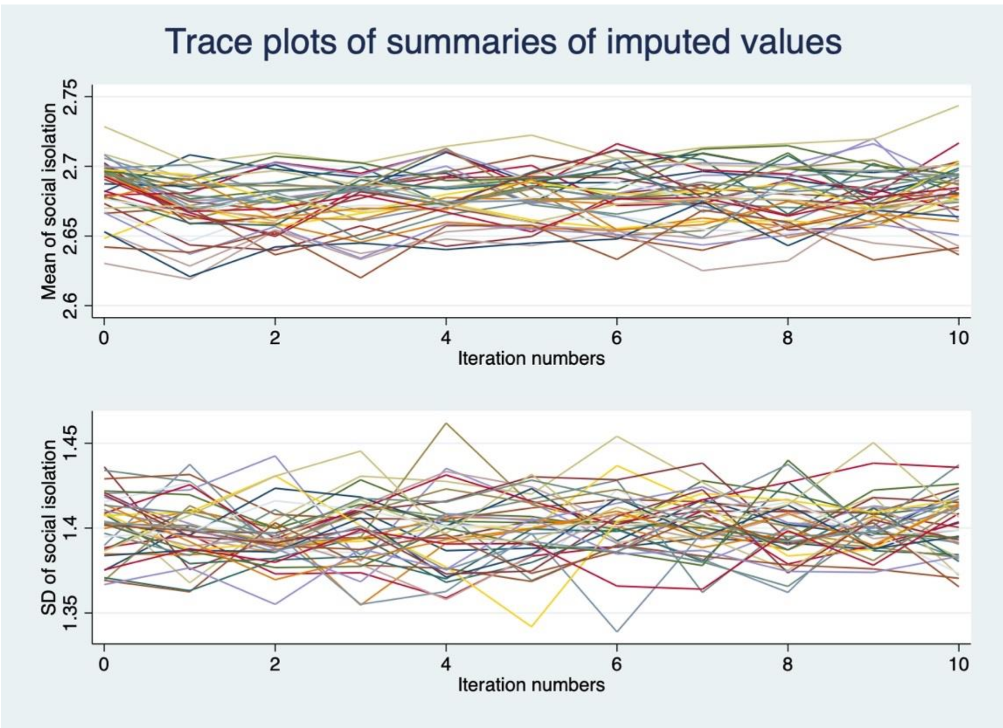


A.13.8 Trace plots from imputed data for negative social support

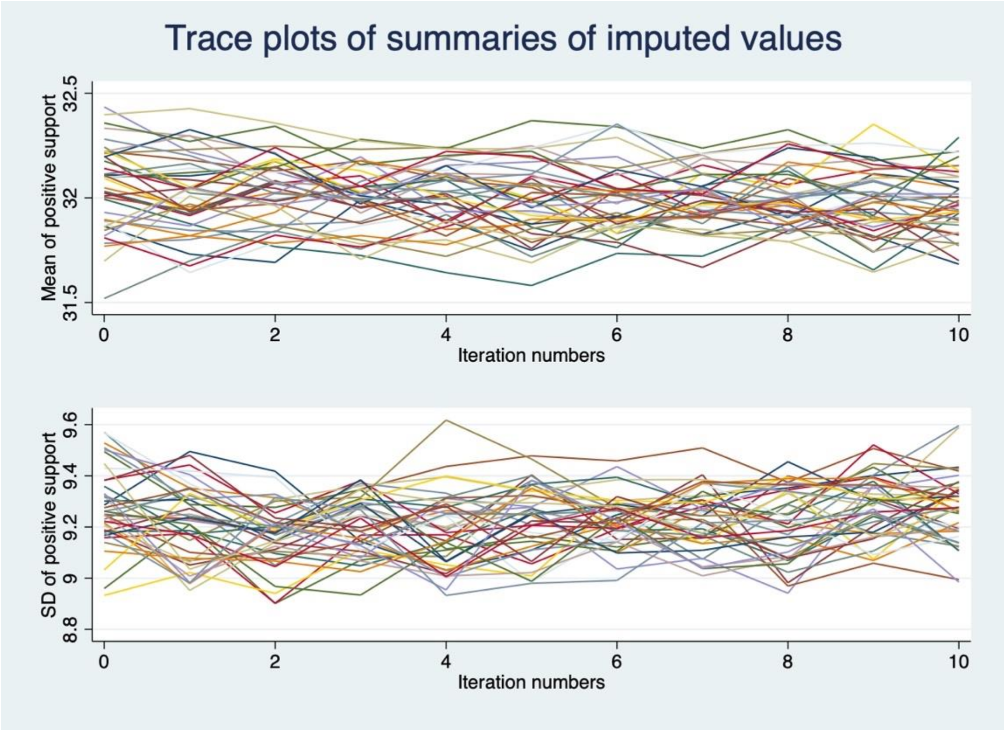
Imputed dataset of oral health outcomes: self-rated oral health, oral health-related quality of life and edentulousness (wave 3)



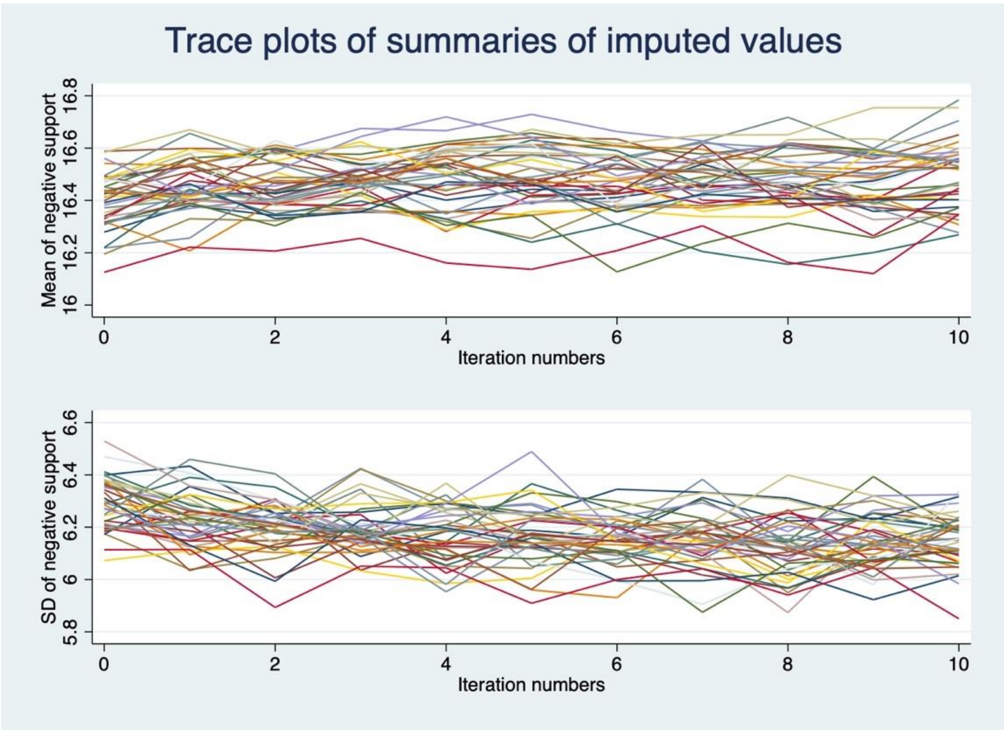
A.13.9 Trace plots from imputed data for loneliness



A.13.10 Trace plots from imputed data for social isolation



A.13.11 Trace plots from imputed data for positive social support



A.13.12 Trace plots from imputed data for negative social support

Appendix 14: Sensitivity analysis: distribution of outcomes by SEP, sex, and age at waves 2 and 3 (observed data)

A complete case analysis on the distribution of outcomes by explanatory measures was conducted to compare the results to analysis of imputed datasets. The methodological approach used in bivariate analysis of the complete cases was the same as with the imputed dataset (see Section 5.2) – logistic and linear regression was implemented to examine associations between all outcomes and SEP markers, social relationship measures, age, and sex. Additionally, bivariate associations were also examined between social relationship measures and SEP markers, age, and sex. There were three analytical samples for the complete cases analysis for each of the following outcomes: SRH (*n* = 5908), SBP/DBP (*n* = 4666) and oral health (*n* = 5768).

Overall, similar trends in prevalence were seen in the complete case analysis to the imputed data at both waves 2 and 3, these are summarised below.

Prevalence of less favourable health outcomes was higher among the least affluent individuals across all measures of health at waves 2 and 3. For SBP and SRH, prevalence of less favourable health was also higher among those with less satisfactory social relationships. For DBP, the highest mean DBP was among those who experienced the highest level of negative support and the lowest level of social isolation. DBP was not associated with loneliness or positive social support at wave 2. Poorer health was more prevalent among the oldest age group, i.e., 80+ years for SRH, SBP and DBP. As expected, men more than women had a higher mean SBP and DBP. SRH was not associated with sex at wave 2 (Table A.14.1).

Prevalence of poorer oral health was higher among the most disadvantaged groups. (Table A.14.2). Similarly, the prevalence of poorer health was higher among those with less satisfactory social relationships. With one exception: the prevalence of total tooth loss was higher among those with the lowest levels of negative social support. Age was also related to poorer oral health, such that the oldest group had the highest prevalence of poor oral health; except for poor SROH whereby prevalence was highest in the youngest age group (50–59-year-olds). The prevalence of poor SROH was higher among men than women, whereas the prevalence of total tooth loss was higher among women than men. OHRQoL was not related to sex at wave 3.

The distribution of less favourable social relationships by explanatory measures at waves 2 and 3 show similar patterns to those seen in the imputed datasets (A.14.3 and A.14.4). Generally, the prevalence of less favourable social relationships was higher among the most disadvantaged groups. With one exception: prevalence of the highest level of negative social support was lowest for those with less than O-level or equivalent education at waves 2 and 3. The prevalence of less satisfactory social relationships was also highest among the older age group at both waves 2 and 3. Social isolation and positive social support were not related to sex at both waves. However, loneliness and negative social support were significantly associated with sex – being lonely was higher among females than males, and the prevalence of the highest level of negative social support was higher among men than women at both waves 2 and 3.

A.14.1 Description of exposures, sex, age, and outcome characteristics of participants at wave 2

Variables	ELSA wave 2 (n = 5908)			
	n	%[1]	Mean	SD
Wealth[2]				
Wealthiest	1385	22.2	N/A	N/A
4th quintile	1285	21.4		
3rd quintile	1230	20.8		
2nd quintile	1110	18.9		
Least wealthy	898	16.7		
Occupation				
Managerial/Professional	1982	31.4	N/A	N/A
Intermediate occupations	1478	24.5		
Routine/manual	2381	42.5		
Never worked/unemployed/other	67	1.6		
Education				
>A level	1588	22.3	N/A	N/A
O level-A level	1530	22.2		
<O level	2790	49.5		
Age				
50-59 years	1919	34.3	66.8	10.0
60-69 years	2101	33.9		
70-79 years	1349	21.9		
≥80 years	539	9.9		
Sex				
Female	3202	52.9	N/A	N/A
Male	2706	47.1		
Loneliness				
Not lonely	4827	81.6	4.1	1.5
Lonely	1081	18.4		
Social isolation				
Lower tertile	2590	43.2	1.8	1.2
Middle tertile	1791	30.3		
Upper tertile	1527	26.5		
Positive social support				
Lower tertile	2141	36.2	33.6	8.9
Middle tertile	1993	33.8		
Upper tertile	1774	30.0		
Negative social support				
Lower tertile	2022	34.0	17.3	6.0
Middle tertile	2225	37.3		
Upper tertile	1661	28.7		
Self-rated health				
Excellent to good	4456	75.1	N/A	N/A
Fair or poor	1452	24.9		
Systolic blood pressure[3]				
<140 mm HG	2807	59.9	136.8 mm HG	19.6
≥140 mm HG	1859	40.1		
Diastolic blood pressure[3]				
<70 mm HG	4061	86.9	76.5 mm HG	11.7
≥70 mm HG	605	13.1		

[1]Weighted for non-response at wave 2; [2]Wealth = household non-pension wealth; [3]Systolic and Diastolic blood pressure *n* = 4666

Table A.14.2 Distribution of SRH and, SBP and DBP by age, sex, and explanatory variables among participants at wave 2

Variables	Total: (n = 4666) n (%)[1]	Systolic blood pressure[2]		Diastolic blood pressure[2]		Total: (n = 5908) n (%)[1]	Fair to poor self-rated health (n = 1452)	
		Mean SBP mm HG (95%CI)[1]	p-value[3]	Mean DBP mm HG (95%CI)[1]	p-value[3]		% (95%CI)[1]	p-value[3]
Wealth[4]								
Wealthiest	1141 (23.1)	134.2 (133.0-135.3)	<0.001	76.7 (76.1-77.5)	0.753	1385 (21.2)	12.7 (10.8-14.8)	<0.001
4th quintile	1045 (21.8)	135.5 (134.3-136.7)		76.6 (75.9-77.3)		1285 (21.4)	18.2 (16.1-20.6)	
3rd quintile	1010 (21.7)	136.9 (135.6-138.3)		76.6 (75.9-77.4)		1230 (20.8)	20.4 (18.1-23.0)	
2nd quintile	843 (18.3)	137.4 (136.1-138.7)		77.1 (76.3-78.9)		1110 (18.9)	33.4 (30.6-36.4)	
Least wealthy	627 (15.1)	139.4 (137.8-141.1)		76.3 (75.2-77.3)		898 (16.7)	46.0 (42.6-49.4)	
Occupation[5]								
Managerial	1619 (32.3)	135.0 (134.0-135.9)	<0.001	76.7 (76.2-77.4)	0.191	1982 (31.4)	17.5 (15.8-19.3)	<0.001
Intermediate	1171 (24.3)	136.4 (135.2-137.5)		77.2 (76.5-77.8)		1478 (24.5)	22.5 (20.4-24.8)	
Routine	1831 (42.0)	137.6 (136.7-138.6)		76.5 (75.9-77.0)		2381 (42.5)	31.3 (29.4-33.3)	
Other	45 (1.4)	136.5 (130.6-142.4)		73.1 (68.7-77.5)		67 (1.6)	38.7 (27.0-51.8)	
Education								
>A level	1288 (25.8)	133.8 (132.9-134.9)	<0.001	77.2 (76.5-77.8)	<0.001	1588 (25.3)	15.7 (13.9-17.7)	<0.001
O level-A level	1231 (25.4)	135.0 (133.9-136.0)		77.4 (76.8-78.0)		1530 (25.2)	19.9 (17.8-22.1)	
<O level	2147 (48.8)	138.6 (137.7-139.5)		76.1 (75.5-76.6)		2790 (49.5)	32.3 (30.5-34.0)	
Age								
50-59 years	1499 (33.3)	131.8 (130.8-132.7)	<0.001	79.0 (78.4-79.6)	<0.001	1919 (34.3)	20.6 (18.7-22.7)	<0.001
60-69 years	1702 (34.4)	135.7 (134.8-136.6)		77.3 (76.8-77.9)		2101 (33.9)	22.8 (20.9-24.8)	
70-79 years	1065 (22.4)	142.2 (141.0-143.4)		75.3 (74.6-76.0)		1349 (21.9)	29.9 (27.4-32.6)	
≥80 years	400 (9.8)	141.9 (139.7-144.1)		69.7 (68.4-71.0)		539 (9.9)	36.1 (32.0-40.4)	
Sex								
Male	2111 (46.6)	137.3 (136.5-138.1)	0.007	77.5 (75.6-76.5)	<0.001	2706 (47.1)	25.6 (23.9-27.3)	0.284
Female	2555 (53.4)	135.7 (134.9-136.5)		76.0 (75.6-78.0)		3202 (52.9)	24.4 (22.9-26.0)	
Loneliness								
Not lonely	3841 (81.9)	136.3 (135.7-137.0)	0.372	76.8 (76.4-77.2)	0.254	4827 (81.6)	21.3 (20.1-22.6)	<0.001
Lonely	825 (18.1)	137.0 (135.6-138.4)		76.2 (75.4-77.1)		1081 (18.4)	40.9 (37.9-44.0)	
Social isolation								
Lower tertile	2117 (44.3)	134.8 (133.9-135.6)	<0.001	76.8 (76.3-77.3)	<0.458	2590 (43.2)	17.8 (16.2-19.4)	<0.001

Middle tertile	1411 (30.2)	137.2 (136.1-138.3)		76.7 (76.1-77.4)		1791 (30.3)	26.9 (24.8-29.1)	
Upper tertile	1138 (25.5)	138.4 (137.3-139.6)		76.5 (75.7-77.2)		1527 (26.5)	34.4 (31.9-37.0)	
Positive support								
Lower tertile	1645 (35.6)	138.2 (137.2-139.1)		76.7 (76.1-77.3)		2141 (36.2)	30.8 (28.7-32.9)	
Middle tertile	1570 (33.4)	135.9 (134.9-136.9)	<0.001	76.5 (75.9-77.1)	0.706	1993 (33.8)	23.2 (21.3-25.2)	<0.001
Upper tertile	1451 (31.0)	135.0 (134.0-136.1)		76.9 (76.3-77.5)		1774 (30.0)	19.9 (18.0-22.0)	
Negative support								
Lower tertile	1582 (33.9)	138.7 (137.6-139.7)		75.5 (74.9-76.2)		2022 (34.0)	25.5 (23.5-27.6)	
Middle tertile	1804 (38.2)	135.4 (134.5-136.3)	<0.001	77.0 (76.4-77.6)	<0.001	2225 (37.3)	23.2 (21.4-25.2)	0.571
Upper tertile	1280 (27.9)	135.2 (134.1-136.2)		77.7 (77.1-78.4)		1661 (28.7)	26.5 (24.4-28.8)	

[1]Percentages for SRH and SBP/DBP, and mean SBP/DBP weighted for non-response at wave 2; [2]Bivariate associations between mean SBP, DBP and exposures; [3]p-values calculated using linear regression for blood pressure and logistic regression for SRH; [4]Wealth = household non-pension wealth; [5]Occupation: Managerial = managerial/professional, Routine = routine/manual, Other = never worked/unemployed/other

A.14.3 Description of exposures, sex, age, and outcome characteristics of participants at wave 3 (*n* = 5768)

Variables	ELSA wave 3 (n = 5768)			
	n	%[1]	Mean	SD
Wealth[2]				
Wealthiest	1365	22.5	N/A	N/A
4th quintile	1259	21.5		
3rd quintile	1160	20.0		
2nd quintile	1107	19.6		
1st quintile	877	16.4		
Occupation				
Managerial/Professional	1977	31.7	N/A	N/A
Intermediate occupations	1484	25.1		
Routine/manual occupations	2243	41.7		
Never worked/unemployed/other	64	1.5		
Education				
>A level	1992	32.4	N/A	N/A
O level-A level	1539	26.0		
<O level	2237	41.6		
Age				
50-59 years	1966	35.6	65.7	10.6
60-69 years	1926	33.8		
70-79 years	1329	21.0		
≥80 years	547	9.6		
Sex				
Female	3143	52.3	N/A	N/A
Male	2625	47.7		
Loneliness				
Not lonely	4576	79.5	4.2	1.6
Lonely	1192	20.5		
Social isolation				
Lower tertile	2451	41.9	1.8	1.2
Middle tertile	1723	29.9		
Upper tertile	1594	28.2		
Positive social support				
Lower tertile	2026	34.6	33.9	8.9
Middle tertile	1976	34.3		
Upper tertile	1766	31.1		
Negative social support				
Lower tertile	2074	35.4	17.3	6.1
Middle tertile	2087	36.3		
Upper tertile	1607	28.3		
Self-rated oral health				
Excellent to good	4801	82.8	N/A	N/A
Fair to poor	967	17.2		
Edentulousness				
Dentate	4908	84.6	N/A	N/A
Edentate	860	15.4		
OHRQoL[3]				
No impact	5338	92.4	N/A	N/A
≥1 impact	430	7.6		

[1]Weighted for non-response at wave 3; [2]Wealth = household non-pension wealth; [3]OHRQoL = oral health-related quality of life: no impact = no oral impact on daily performance, ≥1 = at least one oral impact on daily performance

A.14.4 Distribution of oral health outcomes by age, sex, and explanatory variables among participants at wave 3 (*n* = 5768)

Variables	Total: n (%)[1]	Fair or poor SROH (n = 967)		Total tooth loss (n = 860)		At least one impact (n = 430)	
		% (95%CI)[1]	p-value[2]	% (95%CI)[1]	p-value[2]	% (95%CI)[1]	p-value[2]
Wealth[3]							
Wealthiest	1365 (22.5)	12.4 (10.7-14.4)	<0.001	4.6 (3.6-5.9)	<0.001	4.8 (3.8-6.1)	<0.001
4th quintile	1259 (21.5)	14.3 (12.3-16.6)		9.8 (8.2-11.8)		7.9 (6.4-9.7)	
3rd quintile	1160 (20.0)	15.1 (13.1-17.3)		14.2 (12.2-16.4)		6.0 (4.8-7.6)	
2nd quintile	1107 (19.6)	21.1 (18.8-23.7)		22.8 (20.2-25.6)		9.2 (7.6-11.1)	
Least wealthy	877 (16.4)	25.4 (22.4-28.6)		30.1 (26.9-33.4)		11.0 (8.9-13.5)	
Occupation[4]							
Managerial	1977 (31.7)	14.9 (13.4-16.6)	<0.001	8.0 (6.9-9.3)	<0.001	6.1 (5.1-7.3)	0.001
Intermediate	1484 (25.1)	16.4 (14.5-18.4)		12.2 (10.6-14.0)		7.1 (5.8-8.6)	
Routine	2243 (41.7)	19.2 (17.6-21.0)		22.2 (20.4-24.1)		8.8 (7.6-10.1)	
Other	64 (1.5)	21.2 (11.6-35.6)		36.2 (24.4-50.0)		13.7 (5.8-29.0)	
Education							
>A-level	1992 (32.4)	15.0 (13.4-16.7)	<0.001	6.3 (5.3-7.5)	<0.001	6.1 (5.1-7.3)	<0.001
O level-A level	1539 (26.0)	16.4 (14.5-18.4)		10.4 (8.9-12.0)		6.9 (5.7-8.3)	
<Less than O level	2237 (41.6)	19.4 (17.7-21.2)		25.7 (23.8-27.6)		9.2 (8.0-10.5)	
Age							
50-59 years	1966 (35.6)	18.9 (17.1-20.8)	0.04	5.0 (4.1-6.1)	<0.001	6.6 (5.6-7.8)	0.008
60-69 years	1926 (33.8)	16.7 (15.0-18.5)		12.4 (10.9-14.1)		7.3 (6.2-8.6)	
70-79 years	1329 (21.0)	15.3 (13.4-17.5)		25.6 (23.1-28.2)		8.8 (7.3-10.6)	
≥80 years	547 (9.6)	16.7 (13.6-20.3)		42.1 (37.8-46.5)		9.4 (7.0-12.6)	
Sex							
Male	2625 (47.7)	19.0 (17.5-20.6)	0.001	13.7 (12.4-15.1)	0.001	7.8 (6.8-9.0)	0.507
Female	3143 (52.3)	15.5 (14.3-16.9)		17.0 (15.6-18.4)		7.4 (6.5-8.4)	
Loneliness							
Not lonely	4576 (79.5)	15.4 (14.3-16.5)	<0.001	14.2 (13.1-15.3)	<0.001	6.1 (5.4-6.9)	<0.001
Lonely	1192 (20.5)	24.3 (21.8-26.9)		20.1 (17.8-22.6)		13.2 (11.3-15.4)	
Social isolation							
Lower tertile	2451 (41.9)	13.4 (12.0-14.9)	<0.001	9.6 (8.4-10.9)	<0.001	6.3 (5.4-7.3)	<0.001
Middle tertile	1723 (29.9)	17.4 (15.6-19.4)		14.8 (13.1-16.7)		7.7 (6.5-9.1)	

Upper tertile	1594 (28.2)	22.6 (20.5-24.8)		24.7 (22.6-27.1)		9.4 (8.0-11.0)	
Positive support							
Lower tertile	2026 (34.6)	22.3 (20.5-24.3)		19.7 (17.9-21.6)		9.5 (8.2-10.9)	
Middle tertile	1976 (34.3)	15.4 (13.8-17.1)	<0.001	14.0 (12.5-15.7)	<0.001	8.1 (7.0-9.5)	<0.001
Upper tertile	1766 (31.1)	13.4 (11.8-15.2)		12.1 (10.5-13.9)		4.9 (3.9-6.0)	
Negative support							
Lower tertile	2074 (35.4)	15.3 (13.7-17.0)		21.3 (19.5-23.2)		7.2 (6.1-8.5)	
Middle tertile	2087 (36.3)	17.8 (16.1-19.6)	0.006	13.0 (11.5-14.6)	<0.001	6.7 (5.6-7.9)	0.04
Upper tertile	1607 (28.3)	18.8 (16.9-20.8)		11.1 (9.6-12.8)		9.3 (7.9-10.8)	

[1]Weighted for non-response at wave 3; [2]*p*-values calculated using logistic regression for SROH, OHRQoL and edentulousness; [3]Wealth = household non-pension wealth; [4]Occupation: Managerial = managerial/professional, Routine = routine/manual, Other = never worked/unemployed/other

Table A.14.5 Distribution of social relationships by age, sex, and explanatory variables among participants at wave 2 (*n* = 5908)

Variables	Loneliness	Social isolation	Positive support	Negative support
	Lonely (n = 1081)	Upper tertile (n = 1527)	Lower tertile (n = 2141)	Upper tertile (n = 1661)
	% (95%CI)[4,5]	% (95%CI)[4,5]	% (95%CI)[4,5]	% (95%CI)[4,5]
Wealth[1]				
Wealthiest	11.0 (9.3-12.8)	16.2 (14.2-18.5)	25.0 (22.6-27.5)	29.9 (27.5-32.5)
4th quintile	14.7 (12.7-16.8)	19.2 (17.0-21.7)	31.0 (28.4-33.6)	29.2 (26.7-31.7)
3rd quintile	16.4 (14.3-18.7)	23.1 (20.5-25.9)	33.4 (30.6-36.4)	29.4 (26.7-32.3)
2nd quintile	21.7 (19.3-24.3)	32.0 (29.1-35.1)	40.4 (37.2-43.6)	29.4 (26.6-32.4)
Least wealthy	32.2 (29.0-35.5)	47.8 (44.3-51.4)	56.6 (53.0-60.1)	24.7 (21.8-27.8)
Occupation				
Managerial/professional	12.5 (11.0-14.2)	19.6 (17.8-21.5)	32.3 (30.2-34.5)	28.3 (26.3-30.4)
Intermediate occupations	18.0 (16.1-20.1)	24.9 (22.7-27.3)	34.8 (32.4-37.4)	28.4 (26.1-30.8)
Routine/manual	22.6 (20.9-24.4)	32.0 (30.0-34.1)	39.6 (37.4-41.8)	29.5 (27.7-31.5)
Other[2]	30.3 (20.0-43.0)	43.1 (30.8-56.3)	44.1 (32.1-56.9)	17.5 (10.3-28.0)
Education[3]				
>A level	12.9 (11.3-14.7)	16.6 (14.8-18.5)	31.6 (29.3-34.0)	29.3 (27.1-31.6)
O level to A level	17.5 (15.6-19.5)	25.4 (23.1-27.7)	34.7 (32.2-37.2)	30.9 (28.5-33.4)
<O level	21.8 (20.2-23.4)	32.3 (30.4-34.2)	39.3 (37.3-41.4)	27.2 (25.6-29.0)
Age				
50-59 years	17.7 (15.9-19.5)	24.3 (22.3-14.7)	32.2 (30.0-34.5)	37.2 (34.9-39.5)
60-69 years	15.2 (13.6-16.9)	22.1 (20.2-24.0)	32.0 (30.0-34.2)	30.4 (28.4-32.4)
70-79 years	19.3 (17.3-21.5)	27.7 (25.3-30.3)	40.2 (37.5-43.0)	20.4 (18.3-22.8)
≥80 years	30.3 (26.4-34.5)	47.1 (42.7-51.6)	55.3 (50.9-59.5)	11.8 (9.3-14.9)
Sex				
Male	15.2 (13.8-16.7)	28.0 (26.2-29.9)[NS]	35.4 (33.6-37.4)[NS]	30.6 (28.8-32.5)
Female	21.4 (20.0-22.8)	25.3 (23.7-26.9)	36.9 (35.1-38.6)	26.9 (25.4-28.5)

[1]Household non-pension wealth; [2]Other = never worked/unemployed/other; [3]Educational levels are those specified or equivalent in level; [4]Weighted for non-response at wave 2; [5]Associations between social relationships and explanatory markers significant at *p*<0.05, *p*-values calculated using logistic regression; NS = non-significant

A.14.4 Distribution of social relationships by age, sex, and explanatory variables among participants at wave 3 (n = 5768)

Variables	Loneliness: Lonely (n = 1192)	Social isolation: Upper tertile (n = 1594)	Positive support: Lower tertile (n = 2026)	Negative support: Upper tertile (n = 1607)
	% (95%CI)[4,5]	% (95%CI)[4,5]	% (95%CI)[4,5]	% (95%CI)[4,5]
Wealth[1]				
Wealthiest	12.7 (10.9-14.7)	14.6 (12.8-16.7)	25.6 (23.1-28.2)	27.6 (25.2-30.2)
4th quintile	15.6 (13.6-17.8)	21.2 (18.8-23.7)	27.4 (24.8-30.1)	29.9 (27.3-32.7)
3rd quintile	20.2 (17.9-22.7)	26.5 (23.9-29.2)	32.4 (29.5-35.4)	30.1 (27.4-33.0)
2nd quintile	24.4 (21.8-27.1)	35.3 (32.3-38.4)	40.9 (37.8-44.1)	29.4 (26.6-32.3)
Least wealthy	33.5 (30.3-36.9)	49.4 (45.8-53.0)	51.9 (48.2-55.5)	23.3 (20.4-26.5)
Occupation				
Managerial/professional	17.2 (15.6-19.0)	20.6 (18.8-22.5)	33.4 (31.3-35.6)	28.1 (26.0-30.2)[NS]
Intermediate occupations	19.4 (17.4-21.6)	26.9 (24.6-29.4)	34.0 (31.5-36.6)	28.2 (25.9-30.7)
Routine/manual	23.4 (21.6-25.2)	34.2 (32.2-36.4)	35.5 (33.4-37.6)	28.7 (26.8-30.7)
Other[2]	29.7 (19.6-42.4)	39.7 (27.4-53.4)	47.4 (34.7-60.5)	20.2 (12.1-31.7)
Education[3]				
>A level	16.7 (15.1-18.5)	19.1 (17.3-21.0)	32.4 (30.3-34.7)	30.6 (28.5-32.7)
O level to A level	20.1 (18.1-22.2)	27.3 (25.1-29.6)	33.9 (31.5-36.4)	28.2 (26.0-30.6)
<O level	23.8 (22.3-25.7)	35.8 (33.7-37.9)	36.8 (34.7-39.0)	26.5 (24.6-28.5)
Age				
50-59 years	20.3 (18.5-22.2)	26.3 (24.3-28.4)	32.2 (30.0-34.4)	35.2 (33.0-37.4)
60-69 years	19.3 (17.5-21.3)	25.1 (23.1-27.3)	30.7 (28.6-33.0)	30.4 (28.3-32.6)
70-79 years	19.8 (17.6-22.1)	28.5 (26.0-31.2)	35.9 (33.2-38.7)	21.6 (19.3-24.0)
≥80 years	27.1 (23.4-31.2)	45.1 (40.6-49.5)	54.8 (50.2-59.4)	9.9 (7.6-12.8)
Sex				
Male	17.3 (15.9-18.9)	27.1 (25.6-28.8)[NS]	35.1 (33.2-37.0)[NS]	29.6 (27.8-31.4)
Female	23.5 (22.0-25.0)	29.3 (27.5-31.1)	34.3 (32.6-36.0)	27.0 (25.5-28.7)

[1]Household non-pension wealth; [2]Other = never worked/unemployed/other; [3]Educational levels are those specified or equivalent in level; [4]Weighted for non-response at wave 3; [5]Associations between social relationships and explanatory markers significant at p<0.05, p-values calculated using logistic regression; NS = non-significant

Appendix 15: Sensitivity analysis: logistic and linear regression tables on observed data

Tables A.15.1 to A15.6 show results from cross-sectional logistic and linear multiple regression analyses carried out on the complete cases. This was performed as a sensitivity analysis exercise to compare results from complete cases to those with the imputed datasets. The methodology implemented was identical to that utilised for the imputed datasets (see Chapter 5, Section 5.7.2). There were three analytical samples for complete case multiple regression analysis: SRH (n = 5908, SBP/DBP (n = 4666), oral health measures (n = 5768).

Overall, the complete cases analysis showed a similar effect estimates across most models and a similar direction of association for all outcomes. However, there was some exceptions to be noted. The complete cases analysis underestimated associations in models by occupation for SRH (Table A.15.1), SBP (Table A.15.2) and edentulousness (Table A.15.6). There was an overestimation of the effect estimates in models by wealth for SBP and in models by education for edentulousness.

Table A.15.1 Logistic regression models predicting fair/poor SRH among participants at wave 2 (*n* = 5902)

Models	Household non-pension wealth[1] OR (95% CI)		Occupation[2] OR (95% CI)		Education[3] OR (95% CI)	
Model 1						
Crude association	4th quintile	1.54 (1.22-1.94)***	Intermediate	1.37 (1.16-1.62)***	O-level to A-level or equivalent	1.33 (1.10-1.61)**
	3rd quintile	1.77 (1.41-2.22)***	Routine/manual	2.14 (1.86-2.50)***		
	2nd quintile	3.46 (2.78-4.31)***	Never worked/unemployed	2.97 (1.73-5.12)***	Less than O-level or equivalent	2.55 (2.17-3.00)***
	Least wealthy	5.86 (4.68-7.35)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.52 (1.21-1.92)***	Intermediate	1.40 (1.17-1.66)***	O-level to A-level or equivalent	1.37 (1.14-1.66)**
	3rd quintile	1.74 (1.39-2.19)***	Routine/manual	2.12 (1.83-2.46)***		
	2nd quintile	3.40 (2.73-4.24)***	Never worked/unemployed	2.42 (1.38-4.22)**	Less than O-level or equivalent	2.41 (2.04-2.84)***
	Least wealthy	5.52 (4.39-6.93)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.45 (1.15-1.83)**	Intermediate	1.32 (1.10-1.58)**	O-level to A-level or equivalent	1.31 (1.08-1.58)**
	3rd quintile	1.61 (1.28-2.02)***	Routine/manual	1.88 (1.62-2.19)***		
	2nd quintile	3.00 (2.40-3.75)***	Never worked/unemployed	2.03 (1.11-3.71)*	Less than O-level or equivalent	2.22 (1.87-2.64)***
	Least wealthy	4.39 (3.47-5.56)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.47 (1.17-1.86)**	Intermediate	1.32 (1.11-1.57)**	O-level to A-level or equivalent	1.27 (1.06-1.54)*
	3rd quintile	1.64 (1.30-2.06)***	Routine/manual	1.89 (1.63-2.20)***		
	2nd quintile	3.07 (2.46-3.84)***	Never worked/unemployed	2.08 (1.17-3.71)*	Less than O-level or equivalent	2.11 (1.78-2.50)***
	Least wealthy	4.64 (3.67-5.86)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.51 (1.19-1.90)**	Intermediate	1.38 (1.16-1.64)***	O-level to A-level or equivalent	1.35 (1.11-1.62)**
	3rd quintile	1.70 (1.36-2.14)***	Routine/manual	2.07 (1.78-2.40)***		
	2nd quintile	3.27 (2.62-4.09)***	Never worked/unemployed	2.34 (1.34-4.09)**	Less than O-level or equivalent	2.37 (2.00-2.80)***
	Least wealthy	5.06 (4.01-6.39)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.54 (1.22-1.94)***	Intermediate	1.40 (1.17-1.66)***	O-level to A-level or equivalent	1.38 (1.14-1.66)**
	3rd quintile	1.76 (1.40-2.21)***	Routine/manual	2.13 (1.83-2.47)***		
	2nd quintile	3.46 (2.78-4.32)***	Never worked/unemployed	2.43 (1.37-4.29)**	Less than O-level or equivalent	2.41 (2.04-2.85)***
	Least wealthy	5.79 (4.59-7.29)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.43 (1.13-1.80)**	Intermediate	1.26 (1.06-1.51)*	O-level to A-level or equivalent	1.24 (1.02-1.50)*
	3rd quintile	1.54 (1.22-1.94)***	Routine/manual	1.72 (1.47-2.00)***		
	2nd quintile	2.81 (2.25-3.53)***	Never worked/unemployed	1.82 (0.96-3.45)[NS]	Less than O-level or equivalent	2.00 (1.68-2.38)***
	Least wealthy	4.08 (3.21-5.18)***				

[1]Reference category: 5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Reference category: managerial/professional; [3]Reference category: higher than A-level; NS = non-significant; *p <0.05; **p <0.01; ***p <0.001

Table A.15.2 Linear regression models predicting SBP among participants at wave 2 (*n* = 4666)

Models	Household non-pension wealth B (95% CI)[1]		Occupation B (95% CI)[2]		Education B (95% CI)[3]	
Model 1						
Crude association	4th quintile	1.31 (-0.33, 2.96)NS	Intermediate	1.41 (-0.002, 2.82)NS	O-level to A-level or equivalent	1.09 (-0.36, 2.54)NS
	3rd quintile	2.77 (1.00-4.53)**	Routine/manual	2.59 (1.29-3.90)***		
	2nd quintile	3.25 (1.53-4.98)***	Never worked/unemployed	1.42 (-4.51, 7.36)NS	Less than O-level or equivalent	4.65 (3.31-6.00)***
	Least wealthy	5.33 (3.38-7.28)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.00 (-0.60, 2.61)NS	Intermediate	1.58 (0.19-2.97)*	O-level to A-level or equivalent	1.47 (0.06-2.89)*
	3rd quintile	2.32 (0.62-4.02)**	Routine/manual	2.07 (0.79-3.36)**		
	2nd quintile	2.69 (0.99-4.38)**	Never worked/unemployed	-2.51 (-8.48, 3.46)NS	Less than O-level or equivalent	2.91 (1.54-4.27)***
	Least wealthy	3.44 (1.51-5.36)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.03 (-0.57, 2.63)NS	Intermediate	1.61 (0.21-3.00)*	O-level to A-level or equivalent	1.49 (0.08-2.91)*
	3rd quintile	2.37 (0.66-4.08)**	Routine/manual	2.12 (0.83-3.42)**		
	2nd quintile	2.79 (1.08-4.51)**	Never worked/unemployed	-2.40 (-8.42, 3.62)NS	Less than O-level or equivalent	2.95 (158-4.32)***
	Least wealthy	3.63 (1.69-5.57)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	0.93 (-0.68, 2.53)NS	Intermediate	1.46 (0.06-2.85)*	O-level to A-level or equivalent	1.34 (-0.09, 2.76)NS
	3rd quintile	2.18 (0.48-3.89)*	Routine/manual	1.82 (0.51-3.13)**		
	2nd quintile	2.44 (0.73-4.16)**	Never worked/unemployed	-2.85 (-8.75, 3.04)NS	Less than O-level or equivalent	2.65 (1.27-4.04)***
	Least wealthy	3.04 (1.03-5.05)**				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	0.98 (-0.62, 2.59)NS	Intermediate	1.55 (0.15-2.94)*	O-level to A-level or equivalent	1.43 (0.01-2.84)*
	3rd quintile	2.27 (0.57-3.97)**	Routine/manual	2.01 (0.72-3.29)**		
	2nd quintile	2.57 (0.87-4.26)**	Never worked/unemployed	-2.65 (-8.58, 3.27)NS	Less than O-level or equivalent	2.86 (1.50-4.23)***
	Least wealthy	3.18 (1.22-5.14)**				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	0.99 (-0.61, 2.60)NS	Intermediate	1.59 (0.19-2.98)*	O-level to A-level or equivalent	1.47 (0.06-2.89)*
	3rd quintile	2.31 (0.61-4.01)**	Routine/manual	2.08 (0.79-3.37)**		
	2nd quintile	2.67 (0.98-4.37)**	Never worked/unemployed	-2.50 (-8.47, 3.48)NS	Less than O-level or equivalent	2.91 (1.54-4.28)***
	Least wealthy	3.40 (1.46-5.33)**				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	0.99 (-0.62, 2.59)NS	Intermediate	1.52 (0.12-2.93)*	O-level to A-level or equivalent	1.39 (-0.06, 2.82)NS
	3rd quintile	2.26 (0.55-3.97)*	Routine/manual	1.96 (0.64-3.29)**		
	2nd quintile	2.58 (0.85-4.30)**	Never worked/unemployed	-2.58 (-8.53, 3.37)NS	Less than O-level or equivalent	2.83 (1.42-4.23)***
	Least wealthy	3.23 (1.21-5.25)**				

[1]Reference category: 5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Reference category: managerial/professional; [3]Reference category: higher than A-level; [4]Unstandardised beta coefficients; NS = non-significant; *p <0.05; **p <0.01; ***p <0.001

Table A.15.3 Linear regression models predicting DBP among participants at wave 2 (*n* = 4666)

Models	Household non-pension wealth B (95% CI)[1]		Occupation B (95% CI)[2]		Education B (95% CI)[3]	
Model 1						
Crude association	4th quintile	-0.18 (-1.22, 0.85)	Intermediate	0.38 (-0.51, 1.27)	O-level to A-level or equivalent	0.22 (-0.68, 1.12)
	3rd quintile	-0.15 (-1.19, 0.90)	Routine/manual	-0.31 (-1.16, 0.53)		
	2nd quintile	0.29 (-0.80, 1.37)	Never worked/unemployed	-3.67 (-8.15, 0.80)	Less than O-level or equivalent	**-1.09 (-1.94, -0.24)***
	Least wealthy	-0.52 (-1.82, 0.78)				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	-0.004 (-1.00, 1.00)	Intermediate	0.79 (-0.08, 1.66)	O-level to A-level or equivalent	0.30 (-0.58, 1.19)
	3rd quintile	0.21 (-0.82, 1.24)	Routine/manual	0.32 (-0.50, 1.15)		
	2nd quintile	0.78 (-0.26, 1.81)	Never worked/unemployed	-0.13 (-4.28, 4.03)	Less than O-level or equivalent	0.56 (-0.29, 1.41)
	Least wealthy	0.90 (-0.34, 2.15)				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	-0.01 (-1.01, 0.99)	Intermediate	0.77 (-0.10, 1.64)	O-level to A-level or equivalent	0.29 (-0.59, 1.18)
	3rd quintile	0.20 (-0.83, 1.24)	Routine/manual	0.29 (-0.54, 1.12)		
	2nd quintile	0.76 (-0.28, 1.80)	Never worked/unemployed	-0.20 (-4.33, 3.94)	Less than O-level or equivalent	0.54 (-0.32, 1.39)
	Least wealthy	0.87 (-0.40, 2.14)				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	-0.04 (-1.04, 0.96)	Intermediate	0.73 (-0.15, 1.61)	O-level to A-level or equivalent	0.23 (-0.66, 1.13)
	3rd quintile	0.15 (-0.89, 1.19)	Routine/manual	0.20 (-0.64, 1.04)		
	2nd quintile	0.66 (-0.39, 1.72)	Never worked/unemployed	-0.29 (-4.39, 3.82)	Less than O-level or equivalent	0.43 (-0.43, 1.30)
	Least wealthy	0.71 (-0.59, 2.02)				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	-0.02 (-1.02, 0.98)	Intermediate	0.77 (-0.11, 1.64)	O-level to A-level or equivalent	0.27 (-0.61, 1.16)
	3rd quintile	0.17 (-0.86, 1.20)	Routine/manual	0.27 (-0.55, 1.10)		
	2nd quintile	0.68 (-0.36, 1.72)	Never worked/unemployed	-0.22 (-4.32, 3.89)	Less than O-level or equivalent	0.53 (-0.32, 1.38)
	Least wealthy	0.69 (-0.58, 1.96)				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	0.004 (-0.99, 1.00)	Intermediate	0.78 (-0.09, 1.66)	O-level to A-level or equivalent	0.31 (-0.58, 1.19)
	3rd quintile	0.22 (-0.81, 1.25)	Routine/manual	0.32 (-0.51, 1.15)		
	2nd quintile	0.79 (-0.25, 1.83)	Never worked/unemployed	-0.14 (-4.29, 4.02)	Less than O-level or equivalent	0.56 (-0.29, 1.41)
	Least wealthy	0.94 (-0.31, 2.20)				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	-0.01 (-1.01, 1.00)	Intermediate	0.74 (-0.14,1.62)	O-level to A-level or equivalent	0.25 (-0.64, 1.15)
	3rd quintile	0.17 (-0.87, 1.21)	Routine/manual	0.23 (-0.61, 1.08)		
	2nd quintile	0.68 (-0.38, 1.73)	Never worked/unemployed	-0.27 (-4.35, 3.81)	Less than O-level or equivalent	0.50 (-0.38, 1.37)
	Least wealthy	0.72 (-0.59, 2.04)				

[1]Reference category: 5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Reference category: managerial/professional; [3]Reference category: higher than A-level; [4]Unstandardised beta coefficients; Bold = significant at p <0.001

Table A.15.4 Logistic regression models predicting fair/poor SROH among participants at wave 3 (*n* = 5768)

Models	Household non-pension wealth OR (95% CI)[1]		Occupation OR (95% CI)[2]		Education OR (95% CI)[3]	
Model 1						
Crude association	4th quintile	1.18 (0.92-1.51)^{NS}	Intermediate	1.12 (0.92-1.35)^{NS}	O-level to A-level or equivalent	1.11 (0.92-1.34)^{NS}
	3rd quintile	1.25 (0.99-1.59)^{NS}	Routine/manual	1.36 (1.15-1.61)***		
	2nd quintile	1.90 (1.51-2.38)***	Never worked/unemployed	1.53 (0.74-3.19)^{NS}	Less than O-level or equivalent	1.37 (1.15-1.62)***
	Least wealthy	2.41 (1.90-3.04)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.20 (0.94-1.53)^{NS}	Intermediate	1.19 (0.98-1.44)^{NS}	O-level to A-level or equivalent	1.17 (0.97-1.42)^{NS}
	3rd quintile	1.29 (1.02-1.64)*	Routine/manual	1.42 (1.20-1.69)***		
	2nd quintile	1.94 (1.55-2.43)***	Never worked/unemployed	1.87 (0.89-3.91)^{NS}	Less than O-level or equivalent	1.56 (1.30-1.88)***
	Least wealthy	2.52 (1.99-3.20)***				
Model 3						
Model 2 additionally adjusted for loneliness	4th quintile	1.17 (0.92-1.50)^{NS}	Intermediate	1.16 (0.95-1.41)^{NS}	O-level to A-level or equivalent	1.13 (0.94-1.38)^{NS}
	3rd quintile	1.21 (0.95-1.54)^{NS}	Routine/manual	1.33 (1.12-1.58)**		
	2nd quintile	1.77 (1.41-2.23)***	Never worked/unemployed	1.65 (0.78-3.50)^{NS}	Less than O-level or equivalent	1.47 (1.22-1.77)***
	Least wealthy	2.14 (1.68-2.23)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.14 (0.89-1.46)^{NS}	Intermediate	1.11 (0.91-1.36)^{NS}	O-level to A-level or equivalent	1.08 (0.89-1.31)^{NS}
	3rd quintile	1.19 (0.94-1.51)^{NS}	Routine/manual	1.26 (1.06-1.50)**		
	2nd quintile	1.70 (1.35-2.14)***	Never worked/unemployed	1.72 (0.84-3.51)^{NS}	Less than O-level or equivalent	1.36 (1.12-1.64)**
	Least wealthy	2.05 (1.60-2.63)***				
Model3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.19 (0.93-1.52)^{NS}	Intermediate	1.18 (0.97-1.44)^{NS}	O-level to A-level or equivalent	1.15 (0.95-1.40)^{NS}
	3rd quintile	1.26 (0.99-1.60)^{NS}	Routine/manual	1.40 (1.18-1.66)***		
	2nd quintile	1.80 (1.43-2.26)***	Never worked/unemployed	1.83 (0.88-3.80)^{NS}	Less than O-level or equivalent	1.54 (1.28-1.85)***
	Least wealthy	2.19 (1.72-2.80)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.19 (0.94-1.53)^{NS}	Intermediate	1.18 (0.97-1.44)^{NS}	O-level to A-level or equivalent	1.17 (0.97-1.42)^{NS}
	3rd quintile	1.29 (1.02-1.64)*	Routine/manual	1.42 (1.19-1.68)***		
	2nd quintile	1.94 (1.55-2.44)***	Never worked/unemployed	1.88 (0.90-3.95)^{NS}	Less than O-level or equivalent	1.56 (1.29-1.88)***
	Least wealthy	2.57 (2.02-3.25)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.12 (0.88-1.44)^{NS}	Intermediate	1.11 (0.91-1.35)^{NS}	O-level to A-level or equivalent	1.08 (0.89-1.31)^{NS}
	3rd quintile	1.15 (0.90-1.47)^{NS}	Routine/manual	1.23 (1.03-1.47)*		
	2nd quintile	1.59 (1.26-2.01)***	Never worked/unemployed	1.63 (0.78-3.42)^{NS}	Less than O-level or equivalent	1.34 (1.11-1.63)**
	Least wealthy	1.85 (1.44-2.38)***				

[1]Reference category: 5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Reference category: managerial/professional; [3]Reference category: higher than A-level; NS = non-significant; *p <0.05; **p <0.01; ***p <0.001

Table A.15.5 Logistic regression models predicting at least one oral impact among participants at wave 3 (*n* = 5768)

Models	Household non-pension wealth OR (95% CI)[1]		Occupation OR (95% CI)[2]		Education OR (95% CI)[3]	
Model 1						
Crude association	4th quintile	1.68 (1.21-2.34)**	Intermediate	1.17 (0.88-1.54)^{NS}	O-level to A-level or equivalent	1.14 (0.86-1.50)^{NS}
	3rd quintile	1.26 (0.89-1.78)^{NS}	Routine/manual	1.48 (1.16-1.88)**		
	2nd quintile	1.99 (1.44-2.74)***	Never worked/unemployed	2.43 (0.93-6.37)^{NS}	Less than O-level or equivalent	1.55 (1.22-1.98)***
	Least wealthy	2.42 (1.73-3.39)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.65 (1.19-2.29)**	Intermediate	1.18 (0.89-1.56)^{NS}	O-level to A-level or equivalent	1.16 (0.88-1.53)^{NS}
	3rd quintile	1.24 (0.88-1.76)^{NS}	Routine/manual	1.47 (1.15-1.87)**		
	2nd quintile	1.98 (1.43-2.73)***	Never worked/unemployed	2.25 (0.88-5.74)^{NS}	Less than O-level or equivalent	1.50 (1.16-1.93)**
	Least wealthy	2.33 (1.65-3.29)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.59 (1.14-2.21)**	Intermediate	1.13 (0.85-1.50)^{NS}	O-level to A-level or equivalent	1.11 (0.84-1.46)^{NS}
	3rd quintile	1.11 (0.78-1.56)^{NS}	Routine/manual	1.32 (1.03-1.69)*		
	2nd quintile	1.67 (1.21-2.32)**	Never worked/unemployed	1.86 (0.68-5.08)^{NS}	Less than O-level or equivalent	1.36 (1.05-1.76)*
	Least wealthy	1.74 (1.23-2.47)**				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.61 (1.16-2.23)**	Intermediate	1.14 (0.86-1.51)^{NS}	O-level to A-level or equivalent	1.11 (0.84-1.47)^{NS}
	3rd quintile	1.19 (0.84-1.69)^{NS}	Routine/manual	1.37 (1.07-1.76)*		
	2nd quintile	1.84 (1.32-2.56)***	Never worked/unemployed	2.14 (0.85-5.40)^{NS}	Less than O-level or equivalent	1.38 (1.07-1.79)*
	Least wealthy	2.10 (1.47-3.00)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.64 (1.18-2.27)**	Intermediate	1.17 (0.88-1.56)^{NS}	O-level to A-level or equivalent	1.14 (0.87-1.51)^{NS}
	3rd quintile	1.21 (0.86-1.71)^{NS}	Routine/manual	1.45 (1.13-1.85)**		
	2nd quintile	1.83 (1.33-2.54)***	Never worked/unemployed	2.21 (0.86-5.67)^{NS}	Less than O-level or equivalent	1.47 (1.14-1.91)**
	Least wealthy	2.05 (1.44-2.91)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.64 (1.18-2.28)**	Intermediate	1.17 (0.88-1.55)^{NS}	O-level to A-level or equivalent	1.16 (0.88-1.53)^{NS}
	3rd quintile	1.25 (0.89-1.76)^{NS}	Routine/manual	1.45 (1.14-1.86)**		
	2nd quintile	1.99 (1.44-2.75)***	Never worked/unemployed	2.28 (0.89-5.88)^{NS}	Less than O-level or equivalent	1.48 (1.15-1.91)**
	Least wealthy	2.42 (1.71-3.41)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.57 (1.12-2.18)**	Intermediate	1.13 (0.84-1.50)^{NS}	O-level to A-level or equivalent	1.10 (0.83-1.45)^{NS}
	3rd quintile	1.10 (0.78-1.57)^{NS}	Routine/manual	1.30 (1.00-1.67)*		
	2nd quintile	1.62 (1.16-2.28)**	Never worked/unemployed	1.93 (0.71-5.25)^{NS}	Less than O-level or equivalent	1.33 (1.02-1.73)*
	Least wealthy	1.71 (1.18-2.47)**				

[1]Reference category: 5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Reference category: managerial/professional; [3]Reference category: higher than A-level; NS = non-significant; **p* <0.05; ***p* <0.01; ****p* <0.001

Table A.15.6 Logistic regression models predicting edentulousness among participants at wave 3 (*n* = 5768)

Models	Household non-pension wealth OR (95% CI)[1]		Occupation OR (95% CI)[2]		Education OR (95% CI)[3]	
Model 1						
Crude association	4th quintile	2.24 (1.61-3.12)***	Intermediate	1.60 (1.27-2.01)***	O-level to A-level or equivalent	1.73 (1.34-2.22)***
	3rd quintile	3.40 (2.49-4.65)***	Routine/manual	3.28 (2.69-3.99)***		
	2nd quintile	6.06 (4.48-8.20)***	Never worked/unemployed	6.52 (3.61-11.77)***	Less than O-level or equivalent	5.17 (4.19-6.38)***
	Least wealthy	8.83 (6.52-11.98)***				
Model 2						
Model 1 additionally adjusted for age and sex	4th quintile	1.99 (1.43-2.79)***	Intermediate	1.48 (1.16-1.89)**	O-level to A-level or equivalent	1.75 (1.35-2.27)***
	3rd quintile	3.15 (2.29-4.34)***	Routine/manual	3.29 (2.68-4.06)***		
	2nd quintile	6.23 (4.57-8.50)***	Never worked/unemployed	3.15 (1.78-5.58)***	Less than O-level or equivalent	3.60 (2.90-4.48)***
	Least wealthy	7.58 (5.54-10.37)***				
Model 3a						
Model 2 additionally adjusted for loneliness	4th quintile	1.98 (1.42-2.78)***	Intermediate	1.47 (1.15-1.88)**	O-level to A-level or equivalent	1.73 (1.33-2.25)***
	3rd quintile	3.11 (2.26-4.29)***	Routine/manual	3.22 (2.61-3.96)***		
	2nd quintile	6.14 (4.49-8.39)***	Never worked/unemployed	3.02 (1.71-5.35)***	Less than O-level or equivalent	3.52 (2.83-4.38)***
	Least wealthy	7.38 (5.36-10.15)***				
Model 3b						
Model 2 additionally adjusted for social isolation	4th quintile	1.90 (1.36-2.66)***	Intermediate	1.41 (1.10-1.81)**	O-level to A-level or equivalent	1.63 (1.26-2.13)***
	3rd quintile	2.94 (2.13-4.06)***	Routine/manual	2.97 (2.40-3.67)***		
	2nd quintile	5.56 (4.05-7.62)***	Never worked/unemployed	2.93 (1.64-5.24)***	Less than O-level or equivalent	3.19 (2.55-3.98)***
	Least wealthy	6.39 (4.64-8.80)***				
Model 3c						
Model 2 additionally adjusted for positive social support	4th quintile	1.99 (1.43-2.79)***	Intermediate	1.48 (1.16-1.90)**	O-level to A-level or equivalent	1.73 (1.34-2.25)***
	3rd quintile	3.15 (2.28-4.34)***	Routine/manual	3.28 (2.66-4.04)***		
	2nd quintile	6.21 (4.54-8.51)***	Never worked/unemployed	3.14 (1.77-5.55)***	Less than O-level or equivalent	3.58 (2.88-4.46)***
	Least wealthy	7.55 (5.49-10.38)***				
Model 3d						
Model 2 additionally adjusted for negative social support	4th quintile	1.99 (1.43-2.79)***	Intermediate	1.48 (1.16-1.89)**	O-level to A-level or equivalent	1.74 (1.34-2.26)***
	3rd quintile	3.15 (2.29-4.34)***	Routine/manual	3.30 (2.68-4.06)***		
	2nd quintile	6.23 (4.57-8.51)***	Never worked/unemployed	3.14 (1.78-5.56)***	Less than O-level or equivalent	3.61 (2.90-4.49)***
	Least wealthy	7.59 (5.55-10.39)***				
Model 4						
Model 2 fully adjusted for all social relationship measures	4th quintile	1.85 (1.33-2.59)***	Intermediate	1.39 (1.08-1.78)*	O-level to A-level or equivalent	1.62 (1.24-2.10)***
	3rd quintile	2.87 (2.08-3.96)***	Routine/manual	2.86 (2.31-3.55)***		
	2nd quintile	5.46 (3.98-7.50)***	Never worked/unemployed	2.82 (1.57-5.05)**	Less than O-level or equivalent	3.07 (2.45-3.83)***
	Least wealthy	6.29 (4.55-8.69)***				

[1]Reference category: 5th quintile = wealthiest; Least wealthy = 1st quintile; [2]Reference category: managerial/professional; [3]Reference category: higher than A-level; NS = non-significant; **p* <0.05; ***p* <0.01; ****p* <0.00

Appendix 16: Sensitivity analysis – comparison of effect estimates (presence of any relationship type vs. presence of all relationships)

A sensitivity analysis was done comparing multiple regression results on individuals with any of the following relationship types: having a child, friends, relatives, and partner, to those who confirmed having all these relationship types.

Figures A.16.1 to A16.3 show results from cross-sectional logistic and linear multiple regression analyses carried out on the imputed cases to compare results. The methodology implemented was identical to that utilised for cross-sectional analyses in Chapter 6 (see Section 6.3 and Section 6.4). There were three analytical samples for multiple regression analysis: SRH (*n* = 5547), SBP (*n* = 4263) and oral health outcomes (SROH, OHRQoL and edentulousness) (*n* = 5535).

Results were based on models fully adjusted for sex, age, and all social relationships (loneliness, social isolation, positive and negative social support). Effect estimates are presented for the lowest SEP group. Overall, effect estimates for analyses on those with all relationship types in models by wealth, occupation and education are very similar in magnitude to regression analyses on participants with any of the four relationship types. There was slight over estimation in odd ratios and beta coefficients in analyses of participants with all relationship types in models by wealth for SBP, SROH, OHRQoL and edentulousness (Figure A.16.1). There was a slight over estimation in models by occupation for SRH and SBP (Figure A.16.2). Results for those with any relationship type were slightly overestimated in models by wealth for SRH and in models by education for SRH, SBP and edentulousness (Figure A.16.3), however, the difference was very small. All effect estimates presented for participants with all relationship types were in the same direction to analyses carried out on participants with any relationship type.

Household non-pension wealth – wave 2 and wave 3

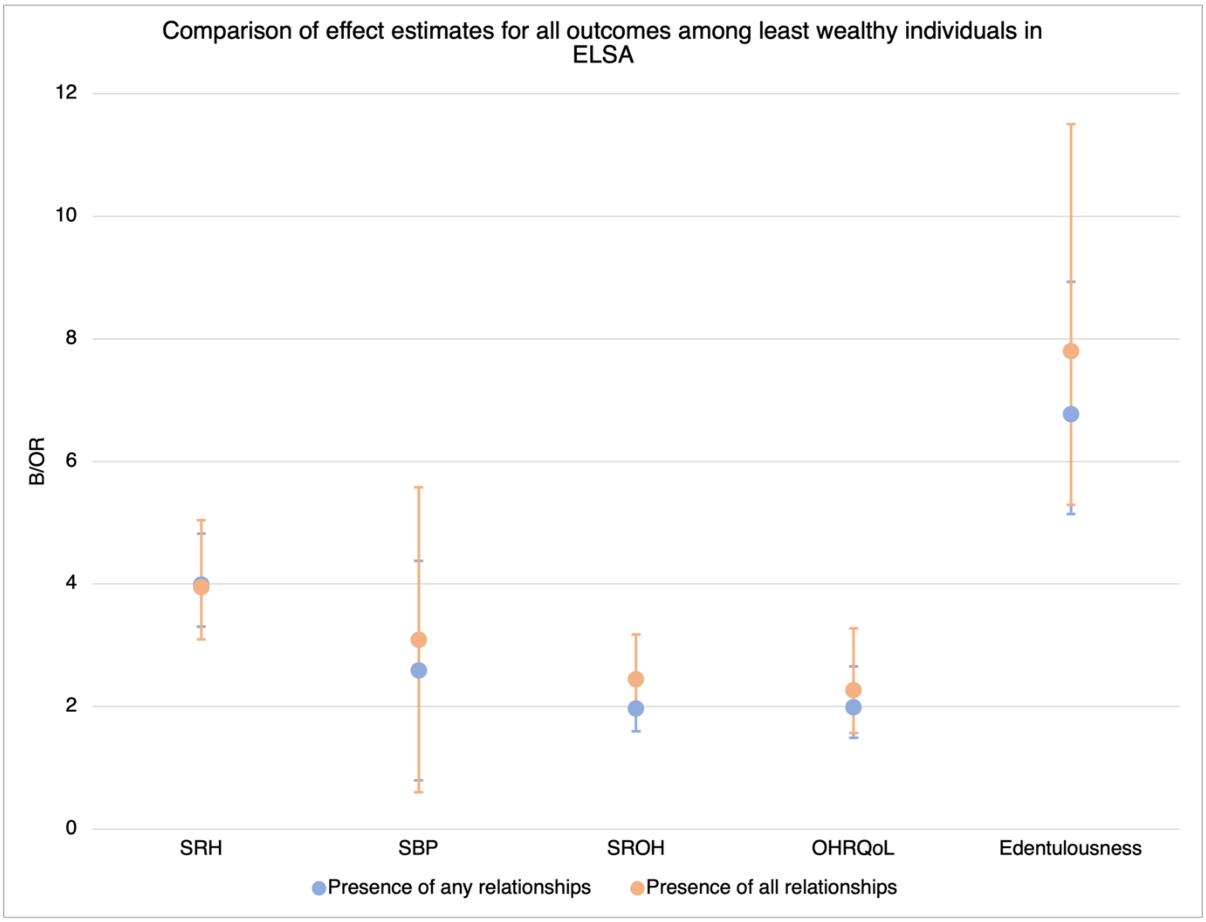


Figure A.16.1 Comparing effect estimates across all health outcomes in participants with any relationship type versus presence of all relationships in models by household non-pension wealth (imputed data)

Occupational class – wave 2 and wave 3

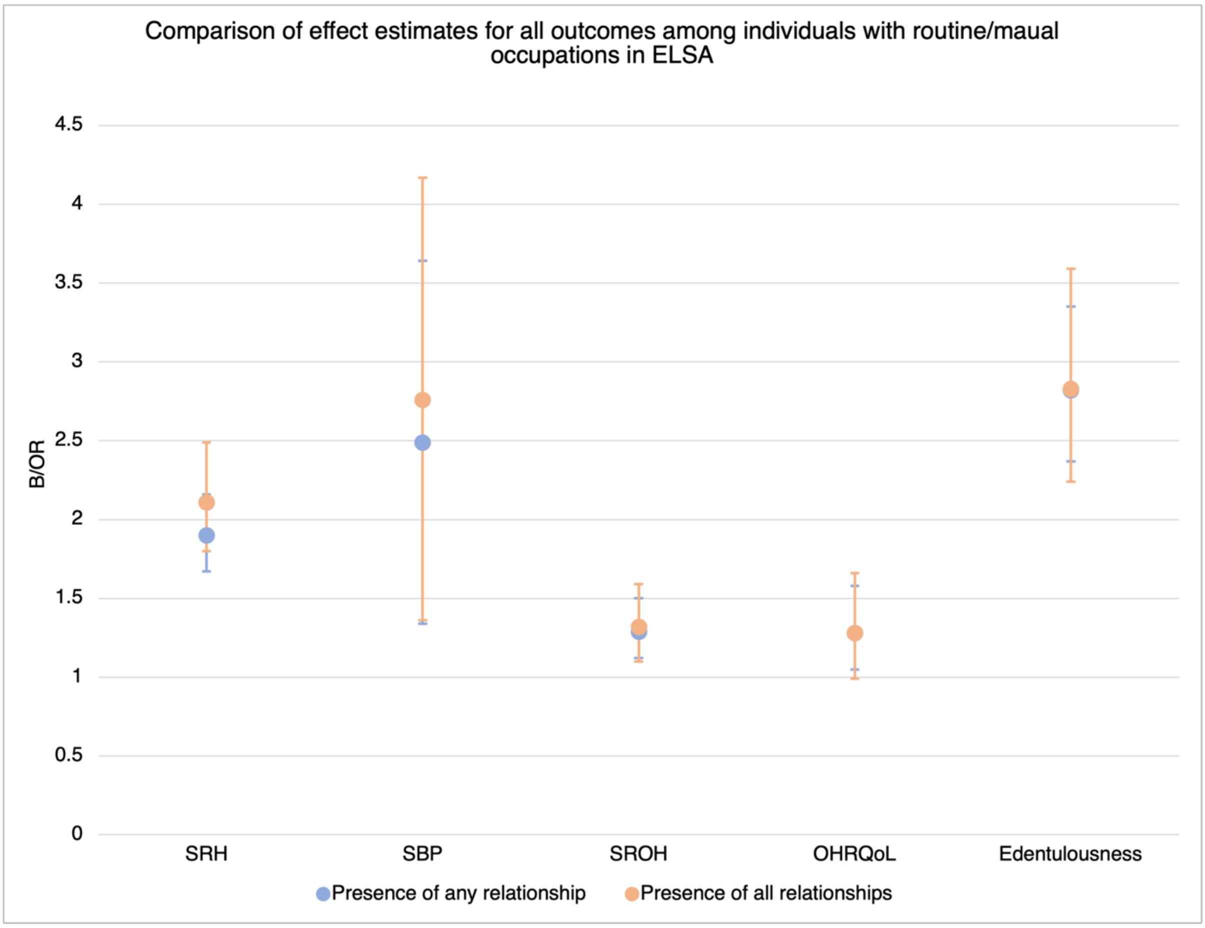


Figure A.16.2 Comparing effect estimates across all health outcomes in participants with any relationship type versus presence of all relationships in models by occupational class (imputed data)

Education – wave 2 and wave 3

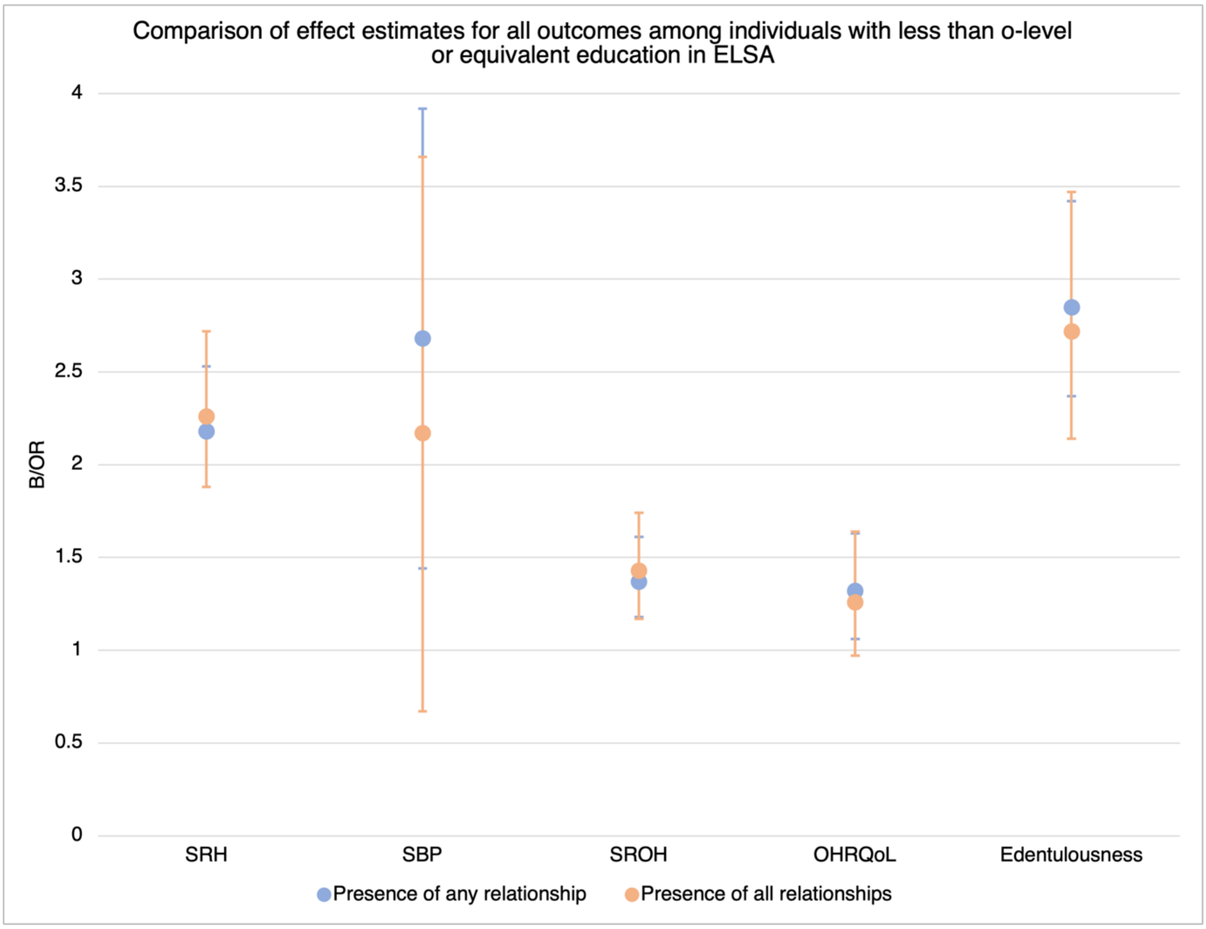


Figure A.16.3 Comparing effect estimates across all health outcomes in participants with any relationship type versus presence of all relationships in models by educational level (imputed data)

Appendix 17: Descriptive tables and figures for longitudinal samples

Table A.17.1 Distribution of missing data at waves 2 to 7

	Wave 2 n = 7990	Wave 3 n = 7885	Wave 4 n = 8921	Wave 5 n = 8157	Wave 6 n = 8344	Wave 7 n = 7626
Variables	Missingness (%)[1]					
Exposure and covariates						
Wealth	2.4	3.4	2.5	2.0	2.1	2.7
Age	0	0	0	0	0	0
Sex	0	0	0	0	0	0
Social relationships						
Loneliness	11.8	14.0	13.2	8.3	10.9	11.6
Social isolation	23.0	23.7	21.6	16.7	18.3	19.5
Positive social support	16.9	18.3	17.6	12.6	14.2	14.9
Negative social support	20.5	20.9	19.6	15.0	16.3	17.4
Outcomes						
SROH	N/A	0.05	N/A	0.06	N/A	0.01
Edentulousness	N/A	0.05	N/A	0.05	N/A	0.09
OHRQoL	N/A	0.04	N/A	0.05	N/A	0.01
SRH	0.09	N/A	0.07	N/A	0.06	N/A
Systolic blood pressure	24.1	N/A	20.5	N/A	17.5	N/A

[1]Unweighted

Table A.17.2 Description of sample from waves 2 to 7 (observed data)

Variables	Wave 2 n = 7990	Wave 3 n = 7885	Wave 4 n = 8921	Wave 5 n = 8157	Wave 6 n = 8344	Wave 7 n = 7626
	n[1] (%)[2]	n[1] (%)[2]	n[1] (%)[2]	n[1] (%)[2]	n[1] (%)[2]	n[1] (%)[2]
Wealth						
Least wealthy	1381 (19.3)	1364 (19.2)	1513 (19.4)	1359 (19.1)	1359 (19.6)	1239 (19.8)
2nd quintile	1542 (19.8)	1489 (19.9)	1699 (20.0)	1599 (20.0)	1559 (19.9)	1355 (20.2)
3rd quintile	1571 (20.1)	1541 (20.1)	1742 (19.9)	1632 (20.3)	1702 (20.0)	1565 (19.9)
4th quintile	1611 (20.3)	1577 (20.4)	1823 (20.2)	1676 (20.3)	1761 (20.1)	1611 (20.0)
Wealthiest	1697 (20.5)	1646 (20.4)	1925 (20.5)	1725 (20.3)	1790 (20.4)	1653 (20.1)
Sex[3]						
Male	4400 (53.4)	4364 (53.1)				
Female	3590 (46.6)	3521 (46.9)				
Loneliness[4]						
Not lonely	5725 (80.9)	5323 (78.5)	6162 (79.2)	5936 (79.0)	5862 (78.5)	5524 (81.7)
Lonely	1326 (19.1)	1458 (21.5)	1578 (20.8)	1544 (21.0)	1575 (21.5)	1214 (18.3)
Social isolation[4]						
Lower tertile	3311(53.5)	3242 (53.3)	3723 (53.0)	3485 (51.8)	3508 (53.1)	3036 (52.3)
Middle tertile	1540 (25.1)	1487 (24.8)	1834 (26.2)	1792 (25.6)	1749 (24.7)	1657 (25.2)
Upper tertile	1299 (21.4)	1285 (21.9)	1436 (20.8)	1519 (22.6)	1556 (22.2)	1447 (22.5)
Positive support[4,5]						
Lower tertile	2385 (35.9)	2224 (34.3)	2451 (33.3)	2555 (35.3)	2651 (36.7)	2207 (33.3)
Middle tertile	2288 (34.5)	2204 (34.3)	2493 (34.0)	2221 (31.3)	2136 (29.7)	2181 (33.80
Upper tertile	1963 (29.6)	2015 (31.4)	2409 (32.7)	2356 (33.4)	2367 (33.6)	2101 932.9)
Negative support[4,5]						
Lower tertile	2508 (39.0)	2109 (33.6)	2427 (33.1)	2831 (39.6)	2519 (34.2)	2276 (33.8)
Middle tertile	2000 (31.1)	2290 (36.7)	2630 (36.2)	2150 (30.6)	2283 (32.2)	2087 (32.7)
Upper tertile	1880 (29.9)	1836 (29.7)	2117 (30.7)	1950 (29.8)	2183 (33.6)	1937 (33.5)
SRH[6]						
Excellent to good	5772 (71.6)		6610 (73.2)		6074 (73.3)	
Fair to poor	2211 (28.4)		2305 (26.8)		2264 (26.7)	
SROH[7]						
Excellent to good		6435 (81.1)		6718 (81.6)		5906 (76.6)
Fair to poor		1446 (18.9)		1434 (18.4)		1719 (23.4)
Edentulousness[7]						
Dentate		6662 (83.4)		7115 (86.9)		4913 (69.1)
Edentate		1219 (16.2)		1038 (13.1)		2706 (30.9)
OHRQoL[7]						
0 impact		7218 (91.4)		7333 (89.7)		6821 (89.3)
≥1 impact		664 (8.6)		820 (10.3)		804 (10.7)

[1]Unweighted; [2]Individual percentages are weighted; [3]Sex at baseline: wave 2 for sample assessing SBP and SRH and wave 3 for oral health outcomes; [4]Categorical social relationship measures used in moderation analyses only; [5]Positive and negative support measures used in moderation analyses only; [6]SRH measured at waves 2, 4 and 6; [7]SROH, OHRQoL and edentulousness measured at waves 3, 5 and 7

Table A.17. 3 Description of sample from waves 2 to 7 (observed data) – Mean (SD) of age, social relationships, and systolic blood pressure

Waves	Age[1]		Loneliness		Social isolation		Positive support[2]		Negative support[2]		SBP[3]	
	n[4]	Mean (SD)	n[4]	Mean (SD)	n[4]	Mean (SD)	n[4]	Mean (SD)	n[4]	Mean (SD)	n[4]	Mean (SD)
Wave 2	7990	65.8 (9.5)	7051	4.1 (1.5)	6150	2.5 (1.3)	6636	33.7 (8.8)	6388	17.4 (6.0)	6066	136.3 (19.4)
Wave 3	7885	64.8 (9.9)	6781	4.2 (1.6)	6014	2.5 (1.3)	6443	34.1 (8.9)	6235	17.4 (6.1)		
Wave 4			7740	4.2 (1.6)	6993	2.5 (1.3)	7353	33.4 (8.9)	7174	17.4 (6.0)	7089	135.7 (18.9)
Wave 5			7480	4.2 (1.5)	6796	2.5 (1.3)	7132	32.8 (8.8)	6931	17.3 (5.9)		
Wave 6			7438	4.2 (1.5)	6814	2.6 (1.3)	7155	32.7 (8.9)	6986	16.9 (5.8)	6883	135.4 (18.6)
Wave 7			6738	4.1 (1.5)	6140	2.6 (1.3)	6489	33.3 (9.0)	6300	16.9 (5.9)		

[1]Age at baseline: wave 2 for sample assessing SBP and SRH and wave 3 for oral health outcomes; [2]Positive and negative support measures used in moderation analyses only; [3]SBP = systolic blood pressure measured at waves 2, 4 and 6; [4]*n* = total observed *n* for variable in given wave

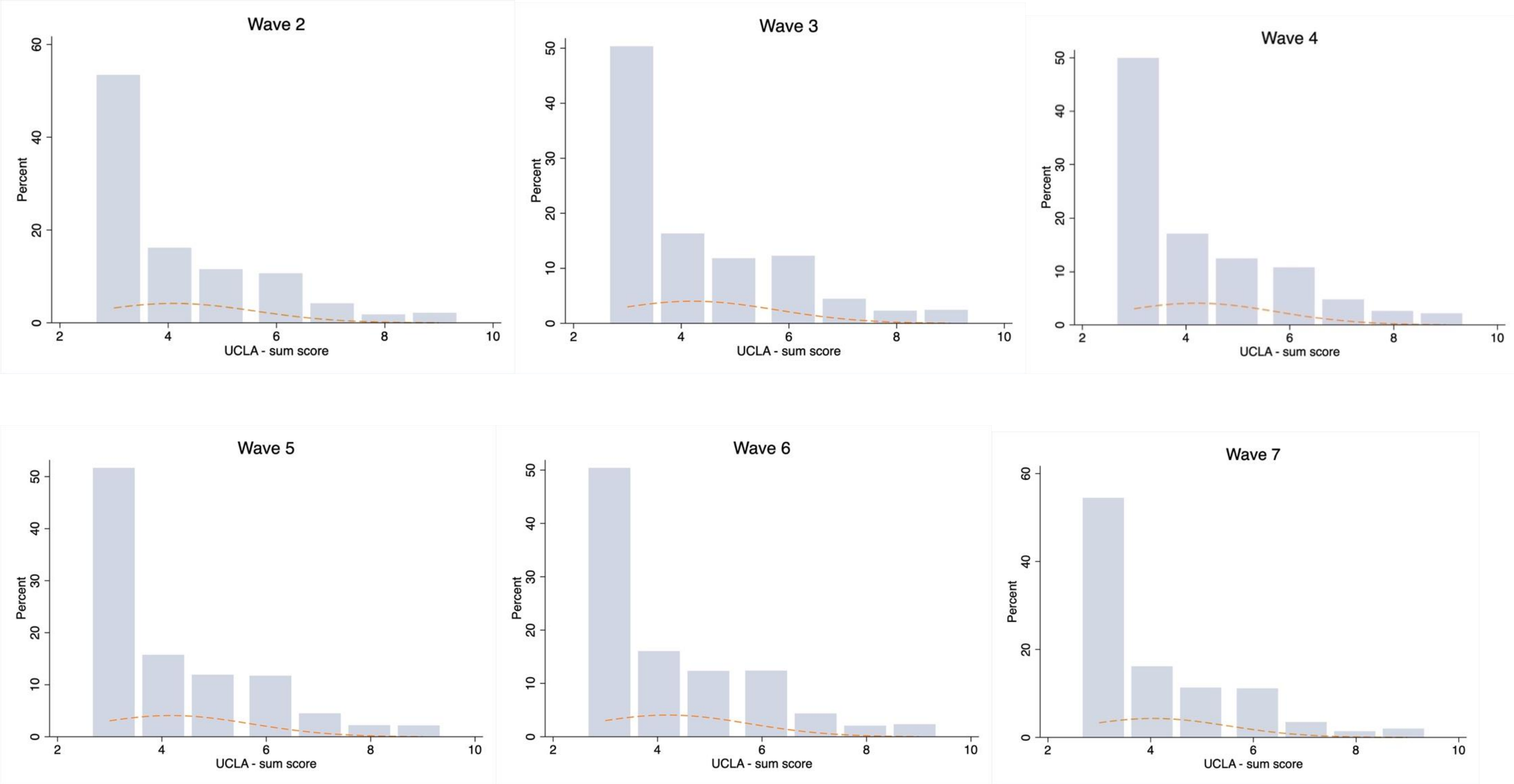


Figure A.16.1 Distribution of loneliness score at waves 3 to 6

UCLA Loneliness: continuous score (3-9); Dashed orange line indicates normal distribution

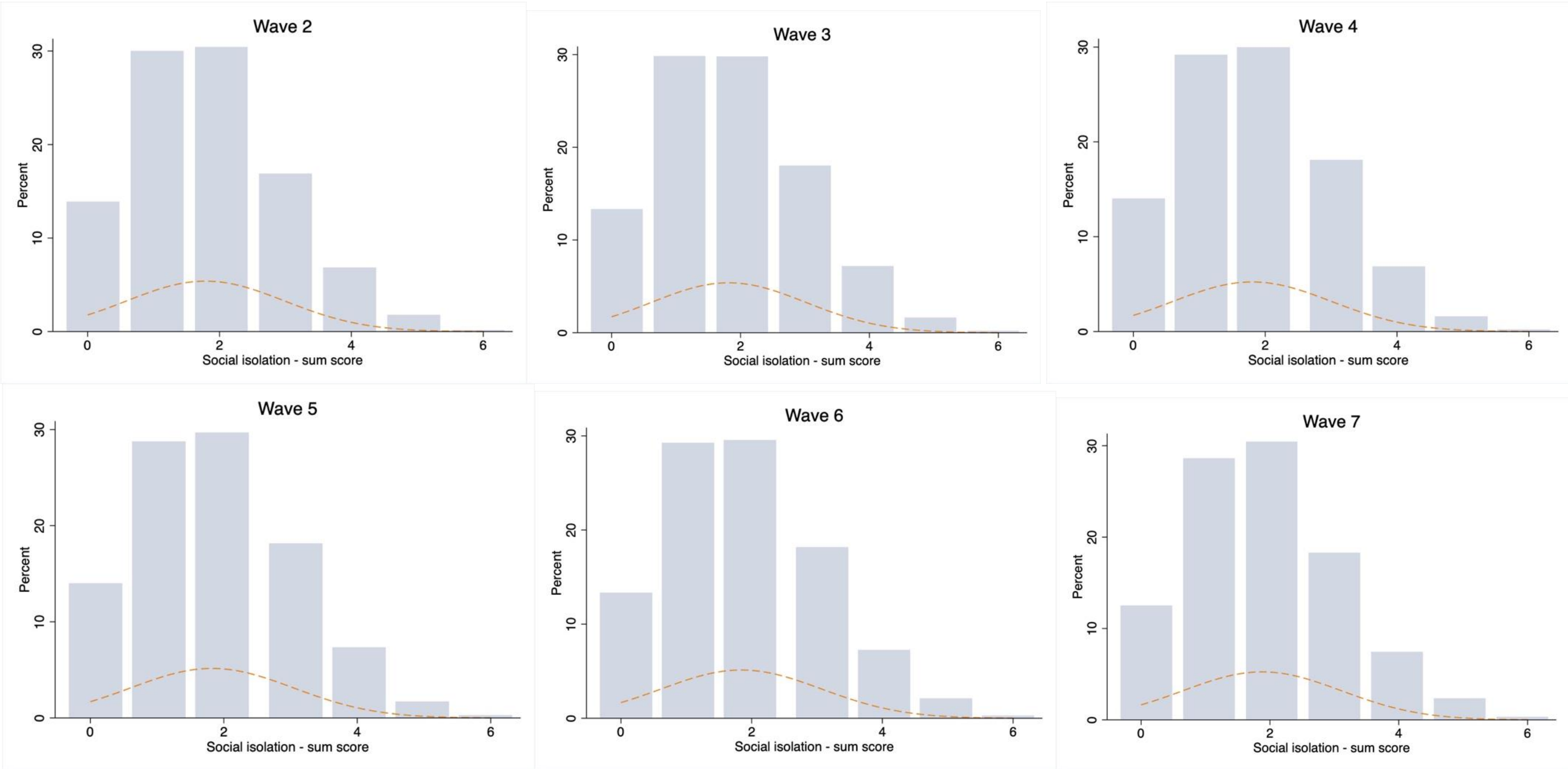


Figure A.16.2 Distribution of social isolation score at waves 3 to 6

UCLA Social isolation: continuous score (0-6); Dashed orange line indicates normal distribution

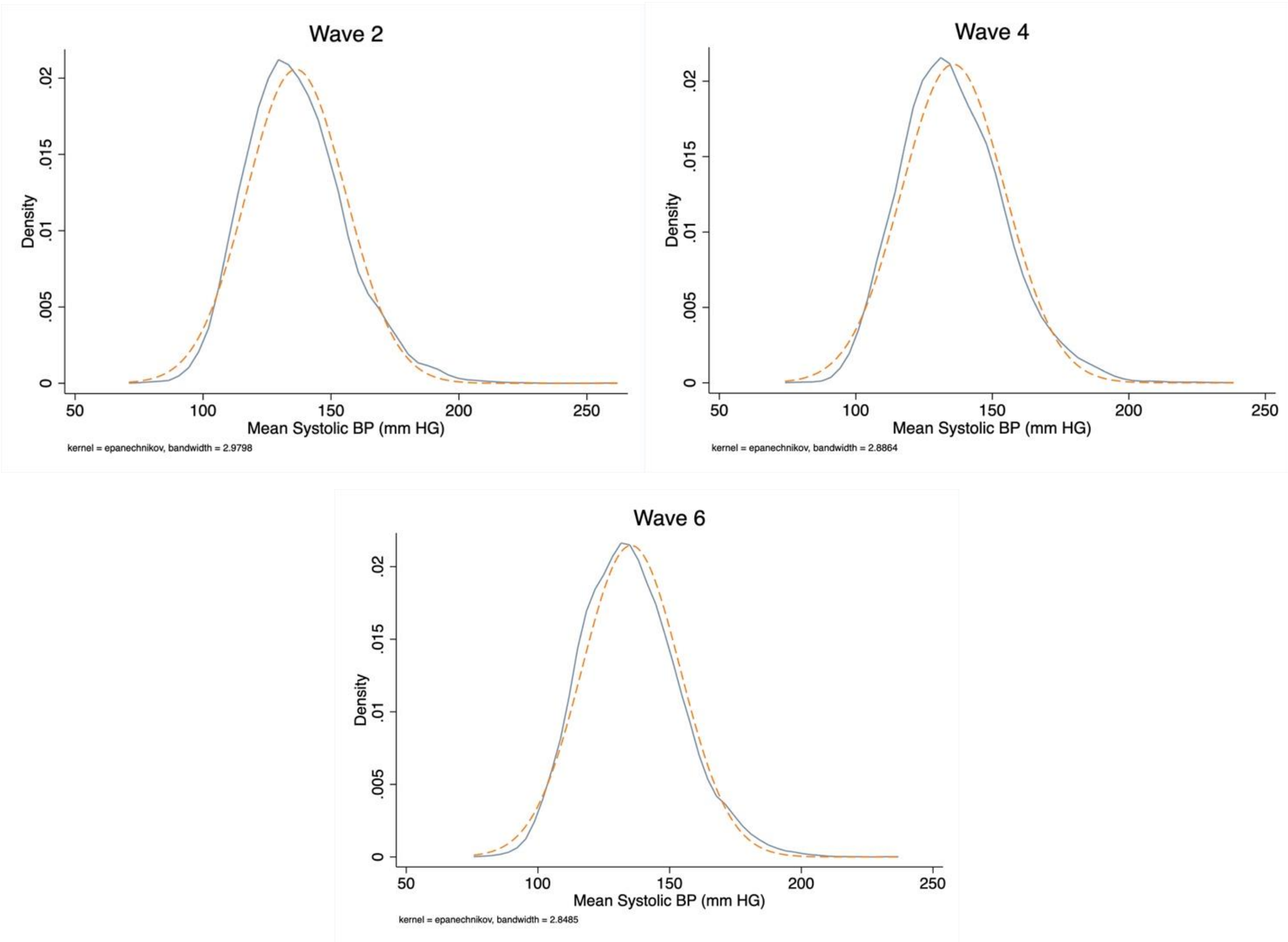


Figure A.1.3 Distribution of mean systolic blood pressure at waves 2, 4 and 6

Blue line indicates distribution of mean systolic blood pressure; Dashed orange line indicates normal distribution

Appendix 18 Unadjusted SEM models

Table A.18.1 Unadjusted auto-regressive pathway model for SRH via loneliness (*n* = 12,618)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[1] → Wealth				
Wealth W2 → Wealth W4	0.864	0.853	0.875	<0.001
Wealth W4 → Wealth W6	0.988	0.922	1.053	<0.001
SRH[2] → SRH				
SRH W2 → SRH W4	2.367	2.220	2.513	<0.001
SRH W4 → SRH W6	2.377	2.244	2.509	<0.001
Loneliness → Loneliness				
Loneliness W3 → Loneliness W5	0.740	0.593	0.886	<0.001
Direct effects				
Wealth → SRH				
Wealth W2 → SRH W4	-0.324	-0.369	-0.279	<0.001
Wealth W4 → SRH W6	-0.236	-0.280	-0.192	<0.001
Wealth → Loneliness				
Wealth W2 → Loneliness W3	-0.200	-0.227	-0.173	<0.001
Wealth W4 → Loneliness W5	-0.024	-0.060	0.012	0.198
Loneliness → SRH				
Loneliness W3 → SRH W4	0.177	0.134	0.220	<0.001
Loneliness W5 → SRH W6	0.166	0.126	0.206	<0.001
SRH → Loneliness				
SRH W2 → Loneliness W3	0.616	0.514	0.718	<0.001
SRH W4 → Loneliness W5	0.250	0.154	0.346	<0.001
SRH → Wealth				
SRH W2 → Wealth W4	-0.114	-0.157	-0.070	0.004
SRH W4 → Wealth W6	-0.250	-0.112	-0.022	<0.001
Indirect effects				
Wealth W2 to SRH W4				
Total effect	-0.360	-0.404	-0.315	<0.001
Total indirect effect	-0.035	-0.045	-0.026	<0.001
Wealth W2 → Loneliness W3 → SRH W4	-0.035	-0.045	-0.026	<0.001
Wealth W4 to SRH W6				
Total effect	-0.240	-0.284	-0.195	<0.001
Total indirect effect	-0.004	-0.010	0.002	0.196
Wealth W4 → Loneliness W5 → SRH W6	-0.004	-0.010	0.002	0.196
Proportion of total effects mediated (%)§				
Wealth W2 → Loneliness W3 → SRH W4	9.7			
Measuring Model Fit				
AIC[3]	146046.997			
BIC[4]	146292.612			
SABIC[5]	146187.741			

[1]Household non-pension wealth; [2]Self-rated health; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; §The proportion of the total effect that is mediated: (ab/(ab+c')) (MacKinnon, Warsi and Dwyer, 1995)

Table A.18.2 Unadjusted auto-regressive pathway model for SRH via social isolation (*n* = 12,573)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[1] → Wealth				
Wealth W2 → Wealth W4	0.864	0.853	0.875	<0.001
Wealth W4 → Wealth W6	0.985	0.919	1.050	<0.001
SRH[2] → SRH				
SRH W2 → SRH W4	2.415	2.270	2.560	<0.001
SRH W4 → SRH W6	2.408	2.276	2.540	<0.001
Social isolation → Social isolation				
Social isolation W3 → Social isolation W5	0.694	0.672	0.715	<0.001
Direct effects				
Wealth → SRH				
Wealth W2 → SRH W4	-0.316	-0.364	-0.269	<0.001
Wealth W4 → SRH W6	-0.214	-0.260	-0.169	<0.001
Wealth → Social isolation				
Wealth W2 → Social isolation W3	-0.280	-0.301	-0.260	<0.001
Wealth W4 → Social isolation W5	-0.078	-0.096	-0.060	<0.001
Social isolation → SRH				
Social isolation W3 → SRH W4	0.141	0.081	0.202	<0.001
Social isolation W5 → SRH W6	0.197	0.142	0.253	<0.001
SRH → Social isolation				
SRH W2 → Social isolation W3	0.235	0.163	0.307	<0.001
SRH W4 → Social isolation W5	0.178	0.117	0.239	<0.001
SRH → Wealth				
SRH W2 → Wealth W4	-0.115	-0.158	-0.071	<0.001
SRH W4 → Wealth W6	-0.068	-0.113	-0.023	0.003
Indirect effects				
Wealth W2 to SRH W4				
Total effect	-0.356	-0.400	-0.312	<0.001
Total indirect effect	-0.040	-0.057	-0.022	<0.001
Wealth W2 → Social isolation W3 → SRH W4	-0.040	-0.057	-0.022	<0.001
Wealth W4 to SRH W6				
Total effect	-0.230	-0.274	-0.186	<0.001
Total indirect effect	-0.015	-0.021	-0.010	<0.001
Wealth W4 → Social isolation W5 → SRH W6	-0.015	-0.021	-0.010	<0.001
Proportion of total effects mediated (%)[§]				
Wealth W2 → Social isolation W3 → SRH W4	11.2			
Wealth W4 → Social isolation W5 → SRH W6	6.5			
Measuring Model Fit				
AIC[3]	133315.383			
BIC[4]	133553.441			
SABIC[5]	133451.748			

[1]Household non-pension wealth; [2]Self-rated health; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (|ab/(ab+c')|) (MacKinnon, Warsi and Dwyer, 1995)

Table A.18.3 Unadjusted auto-regressive pathway model for systolic blood pressure via loneliness (n = 12,591)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[1] → Wealth				
Wealth W2 → Wealth W4	0.869	0.861	0.877	<0.001
Wealth W4 → Wealth W6	1.217	0.972	1.462	<0.001
SBP[2] → SBP				
SBP W2 → SBP W4	0.566	0.543	0.588	<0.001
SBP W4 → SBP W6	0.484	0.455	0.513	<0.001
Loneliness → Loneliness				
Loneliness W3 → Loneliness W5	0.692	0.481	0.902	<0.001
Direct effects (Longitudinal)				
Wealth → SBP				
Wealth W2 → SBP W4	-0.020	-0.043	0.003	0.094
Wealth W4 → SBP W6	-0.016	-0.037	0.005	0.129
Wealth → Loneliness				
Wealth W2 → Loneliness W3	-0.229	-0.252	-0.207	<0.001
Wealth W4 → Loneliness W5	-0.055	-0.102	-0.009	<0.001
Loneliness → SBP				
Loneliness W3 → SBP W4	-0.015	-0.040	0.009	0.216
Loneliness W5 → SBP W6	-0.011	-0.034	0.011	0.318
SBP → Loneliness				
SBP W2 → Loneliness W3	-0.007	-0.035	0.022	0.638
SBP W4 → Loneliness W5	-0.017	-0.038	0.005	0.130
SBP → Wealth				
SBP W2 → Wealth W4	-0.031	-0.045	-0.017	<0.001
SBP W4 → Wealth W6	-0.008	-0.025	0.009	0.331
Indirect effects (Longitudinal)				
Wealth W2 to SBP W4				
Total effect	-0.016	-0.039	0.006	0.160
Total indirect effect	0.004	-0.002	0.009	0.216
Wealth W2 → Loneliness W3 → SBP W4	0.004	-0.002	0.009	0.216
Wealth W4 to SBP W6				
Total effect	-0.016	-0.036	0.005	0.141
Total indirect effect	0.001	-0.001	0.002	0.359
Wealth W4 → Loneliness W5 → SBP W6	0.001	-0.001	0.002	0.359
Measuring Model Fit				
CFI[3]	0.997			
TLI[4]	0.989			
RMSEA[5]	0.025			
SRMR[6]	0.009			

[1]Household non-pension wealth; [2]Systolic blood pressure; [3]Comparative Fit Index; [4]Tucker-Lewis Index; [5]Root Mean Square Error of Approximation; [6]Standardised Root Mean Residual

Table A.18.4 Unadjusted auto-regressive pathway model for systolic blood pressure via social isolation (*n* = 12,542)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[1] → Wealth				
Wealth W2 → Wealth W4	0.869	0.861	0.878	<0.001
Wealth W4 → Wealth W6	1.225	0.982	1.467	<0.001
SBP[2] → SBP				
SBP W2 → SBP W4	0.566	0.543	0.589	<0.001
SBP W4 → SBP W6	0.484	0.455	0.513	<0.001
Social isolation → Social isolation				
Social isolation W3 → Social isolation W5	0.784	0.659	0.908	<0.001
Direct effects (Longitudinal)				
Wealth → SBP				
Wealth W2 → SBP W4	-0.018	-0.042	0.007	0.154
Wealth W4 → SBP W6	-0.018	-0.040	0.003	0.098
Wealth → Social isolation				
Wealth W2 → Social isolation W3	-0.345	-0.367	-0.323	<0.001
Wealth W4 → Social isolation W5	-0.075	-0.118	-0.033	0.001
Social isolation → SBP				
Social isolation W3 → SBP W4	-0.001	-0.027	0.026	0.967
Social isolation W5 → SBP W6	-0.017	-0.040	0.007	0.174
SBP → Social isolation				
SBP W2 → Social isolation W3	0.062	0.035	0.090	<0.001
SBP W4 → Social isolation W5	0.014	-0.007	0.035	0.205
SBP → Wealth				
SBP W2 → Wealth W4	-0.031	-0.045	-0.017	<0.001
SBP W4 → Wealth W6	-0.008	-0.025	0.009	0.371
Indirect effects (Longitudinal)				
Wealth W2 to SBP W4				
Total effect	-0.017	-0.040	0.005	0.131
Total indirect effect	0.000	-0.009	0.009	0.967
Wealth W2 → Social isolation W3 → SBP W4	0.000	-0.009	0.009	0.967
Wealth W4 to SBP W6				
Total effect	-0.017	-0.038	0.004	0.113
Total indirect effect	0.001	-0.001	0.003	0.199
Wealth W4 → Social isolation W5 → SBP W6	0.001	-0.001	0.003	0.199
Measuring Model Fit				
CFI[3]	0.998			
TLI[4]	0.991			
RMSEA[5]	0.023			
SRMR[6]	0.009			

[1]Household non-pension wealth; [2]Systolic blood pressure; [3]Comparative Fit Index; [4]Tucker-Lewis Index; [5]Root Mean Square Error of Approximation; [6]Standardised Root Mean Residual

Table A.18.5 Unadjusted auto-regressive pathway model for SROH via loneliness (*n* = 11,535)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[1] → Wealth				
Wealth W3 → Wealth W5	0.866	0.857	0.879	<0.001
Wealth W5 → Wealth W7	0.891	1.034	1.193	<0.001
SROH[2] → SROH				
SROH W3 → SROH W5	2.109	2.224	2.519	<0.001
SROH W5 → SROH W7	2.125	2.243	2.508	<0.001
Loneliness → Loneliness				
Loneliness W4 → Loneliness W6	0.696	0.575	0.625	<0.001
Direct effects				
Wealth → SROH				
Wealth W3 → SROH W5	-0.092	-0.359	-0.267	<0.001
Wealth W5 → SROH W7	-0.175	-0.281	-0.193	<0.001
Wealth → Loneliness				
Wealth W3 → Loneliness W4	-0.232	-0.217	-0.163	<0.001
Wealth W5 → Loneliness W6	-0.056	-0.074	-0.028	0.011
Loneliness → SROH				
Loneliness W4 → SROH W5	0.154	0.132	0.220	<0.001
Loneliness W6 → SROH W7	0.102	0.125	0.204	<0.001
SROH → Loneliness				
SROH W3 → Loneliness W4	0.419	0.510	0.716	<0.001
SROH W5 → Loneliness W6	0.169	0.208	0.380	0.001
SROH → Wealth				
SROH W3 → Wealth W5	-0.085	-0.122	-0.029	<0.001
SROH W5 → Wealth W7	-0.028	-0.067	0.024	0.209
Indirect effects				
Wealth W3 to SROH W5				
Total effect	-0.128	-0.392	-0.301	<0.001
Total indirect effect	-0.036	-0.043	-0.024	<0.001
Wealth W2 → Loneliness W4 → SROH W4	-0.036	-0.043	-0.024	<0.001
Wealth W5 to SROH W7				
Total effect	-0.181	-0.289	-0.201	<0.001
Total indirect effect	-0.006	-0.013	-0.004	0.018
Wealth W4 → Loneliness W6 → SROH W6	-0.006	-0.013	-0.004	0.018
Proportion of total effects mediated (%)§				
Wealth W3 → Loneliness W4 → SROH W5	28.1			
Wealth W5 → Loneliness W6 → SROH W7	3.3			
Measuring Model Fit				
AIC[3]	137163.273			
BIC[4]	137405.926			
SABIC[5]	137301.056			

[1]Household non-pension wealth; [2]Self-rated oral health; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; §The proportion of the total effect that is mediated: (ab/(ab+c')) (MacKinnon, Warsi and Dwyer, 1995)

Table A.18.6 Unadjusted auto-regressive pathway model for SROH via social isolation (*n* = 11,486)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects				
Wealth[1] → Wealth				
Wealth W2 → Wealth W4	0.865	0.854	0.876	<0.001
Wealth W4 → Wealth W6	0.890	0.786	0.994	<0.001
SRH[2] → SRH				
SRH W2 → SRH W4	2.117	1.963	2.271	<0.001
SRH W4 → SRH W6	2.139	1.994	2.283	<0.001
Social isolation → Social isolation				
Social isolation W3 → Social isolation W5	0.800	0.673	0.927	<0.001
Direct effects				
Wealth → SRH				
Wealth W2 → SRH W4	-0.083	-0.134	-0.033	0.001
Wealth W4 → SRH W6	-0.161	-0.207	-0.114	<0.001
Wealth → Social isolation				
Wealth W2 → Social isolation W3	-0.280	-0.300	-0.261	<0.001
Wealth W4 → Social isolation W5	-0.077	-0.112	-0.041	<0.001
Social isolation → SRH				
Social isolation W3 → SRH W4	0.151	0.092	0.211	<0.001
Social isolation W5 → SRH W6	0.132	0.075	0.189	<0.001
SRH → Social isolation				
SRH W2 → Social isolation W3	0.280	0.180	0.345	<0.001
SRH W4 → Social isolation W5	0.025	-0.039	0.088	0.448
SRH → Wealth				
SRH W2 → Wealth W4	-0.086	-0.132	-0.041	<0.001
SRH W4 → Wealth W6	-0.028	-0.073	0.016	0.210
Indirect effects				
Wealth W2 to SRH W4				
Total effect	-0.126	-0.173	-0.079	<0.001
Total indirect effect	-0.042	-0.059	-0.025	<0.001
Wealth W2 → Social isolation W3 → SRH W4	-0.042	-0.059	-0.025	<0.001
Wealth W4 to SRH W6				
Total effect	-0.171	-0.216	-0.125	<0.001
Total indirect effect	-0.010	-0.016	-0.004	<0.001
Wealth W4 → Social isolation W5 → SRH W6	-0.010	-0.016	-0.004	<0.001
Proportion of total effects mediated (%)[§]				
Wealth W2 → Social isolation W3 → SRH W4	33.3			
Wealth W4 → Social isolation W5 → SRH W6	5.8			
Measuring Model Fit				
AIC[3]	124084.712			
BIC[4]	124327.226			
SABIC[5]	124222.356			

[1]Household non-pension wealth; [2]Self-rated oral health; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (|ab/(ab+c')|) (MacKinnon, Warsi and Dwyer, 1995)

A.18.7 Unadjusted auto-regressive pathway model for OHRQoL via loneliness (*n* = 11,535)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[1] → Wealth				
Wealth W3 → Wealth W5	0.868	0.857	0.879	<0.001
Wealth W5 → Wealth W7	0.961	0.820	1.101	<0.001
OHRQoL[2] → OHRQoL				
OHRQoL W3 → OHRQoL W5	1.830	1.614	2.045	<0.001
OHRQoL W5 → OHRQoL W7	1.695	1.501	1.890	<0.001
Loneliness → Loneliness				
Loneliness W4 → Loneliness W6	0.845	0.681	1.010	<0.001
Direct effects (Longitudinal)				
Wealth → OHRQoL				
Wealth W3 → OHRQoL W5	-0.116	-0.175	-0.056	<0.001
Wealth W5 → OHRQoL W7	-0.220	-0.278	-0.162	<0.001
Wealth → Loneliness				
Wealth W3 → Loneliness W4	-0.235	-0.261	-0.209	<0.001
Wealth W5 → Loneliness W6	-0.024	-0.064	0.016	0.243
Loneliness → OHRQoL				
Loneliness W4 → OHRQoL W5	0.190	0.144	0.237	<0.001
Loneliness W6 → OHRQoL W7	0.149	0.100	0.198	<0.001
OHRQoL → Loneliness				
OHRQoL W3 → Loneliness W4	0.636	0.474	0.798	<0.001
OHRQoL W5 → Loneliness W6	0.271	0.145	0.398	<0.001
OHRQoL → Wealth				
OHRQoL W3 → Wealth W5	-0.072	-0.130	-0.014	0.014
OHRQoL W5 → Wealth W7	-0.009	-0.061	0.044	0.752
Indirect effects (Longitudinal)				
Wealth W3 to OHRQoL W5				
Total effect	-0.160	-0.219	-0.102	<0.001
Total indirect effect	-0.045	-0.057	-0.033	<0.001
Wealth W3 → Loneliness W4 → OHRQoL W5	-0.045	-0.057	-0.033	<0.001
Wealth W5 to OHRQoL W6				
Total effect	-0.223	-0.281	-0.165	<0.001
Total indirect effect	-0.004	-0.010	0.003	0.250
Wealth W5 → Loneliness W6 → OHRQoL W7	-0.004	-0.010	0.003	0.250
Proportion of total effects mediated (%)[§]				
Wealth W3 → Loneliness W4 → OHRQoL W5	28.1			
Measuring Model Fit				
AIC[3]	127813.353			
BIC[4]	128056.007			
SABIC[5]	127951.137			

[1]Household non-pension wealth; [2]Oral health-related quality of life; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (|ab/(ab+c')|) (MacKinnon, Warsi and Dwyer, 1995)

A.18.8 Unadjusted auto-regressive pathway model for OHRQoL via social isolation (*n* = 11,486)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[1] → Wealth				
Wealth W3 → Wealth W5	0.867	0.856	0.878	<0.001
Wealth W5 → Wealth W7	0.962	0.822	1.102	<0.001
OHRQoL[2] → OHRQoL				
OHRQoL W3 → OHRQoL W5	1.917	1.705	2.130	<0.001
OHRQoL W5 → OHRQoL W7	1.772	1.581	1.964	<0.001
Social isolation → Social isolation				
Social isolation W4 → Social isolation W6	0.811	0.678	0.945	<0.001
Direct effects (Longitudinal)				
Wealth → OHRQoL				
Wealth W3 → OHRQoL W5	-0.130	-0.192	-0.068	<0.001
Wealth W5 → OHRQoL W7	-0.233	-0.293	-0.173	<0.001
Wealth → Social isolation				
Wealth W3 → Social isolation W4	-0.287	-0.306	-0.267	<0.001
Wealth W5 → Social isolation W6	-0.075	-0.112	-0.037	<0.001
Social isolation → OHRQoL				
Social isolation W4 → OHRQoL W5	0.115	0.042	0.188	0.002
Social isolation W6 → OHRQoL W7	0.074	0.003	0.146	0.042
OHRQoL → Social isolation				
OHRQoL W3 → Social isolation W4	0.194	0.079	0.309	0.001
OHRQoL W5 → Social isolation W6	-0.002	-0.081	0.076	0.956
OHRQoL → Wealth				
OHRQoL W3 → Wealth W5	-0.072	-0.130	-0.014	0.014
OHRQoL W5 → Wealth W7	-0.007	-0.060	0.046	0.792
Indirect effects (Longitudinal)				
Wealth W3 to OHRQoL W5				
Total effect	-0.163	-0.221	-0.105	<0.001
Total indirect effect	-0.033	-0.054	-0.012	0.002
Wealth W3 → Social isolation W4 → OHRQoL W5	-0.033	-0.054	-0.012	0.002
Wealth W5 to OHRQoL W7				
Total effect	-0.238	-0.297	-0.180	<0.001
Total indirect effect	-0.006	-0.011	0.000	0.066
Wealth W5 → Social isolation W6 → OHRQoL W7	-0.006	-0.011	0.000	0.066
Proportion of total effects mediated (%)§				
Wealth W3 → Social isolation W4 → OHRQoL W5	20.2			
Measuring Model Fit				
AIC[3]	114845.373			
BIC[4]	115087.886			
SABIC[5]	114983.016			

[1]Household non-pension wealth; [2]Oral health-related quality of life; [3]Akaike's Information Criterion; [4]Bayesian Information Criterion; [5]The Sample Size Adjusted BIC; §The proportion of the total effect that is mediated: (|ab/(ab+c')|) (MacKinnon, Warsi and Dwyer, 1995)

A.18.9 Unadjusted auto-regressive pathway model for edentulousness via loneliness (*n* = 11,535)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[1] → Wealth				
Wealth W3 → Wealth W5	0.860	0.849	0.872	<0.001
Wealth W5 → Wealth W7	0.991	0.891	1.092	<0.001
Edentulousness → Edentulousness				
Edentulousness W3 → Edentulousness W5	5.591	5.312	5.871	<0.001
Edentulousness W5 → Edentulousness W7	3.412	3.081	3.742	<0.001
Loneliness → Loneliness				
Loneliness W4 → Loneliness W6	0.799	0.578	1.021	<0.001
Direct effects (Longitudinal)				
Wealth → Edentulousness				
Wealth W3 → Edentulousness W5	-0.276	-0.358	-0.194	<0.001
Wealth W5 → Edentulousness W7	-0.228	-0.267	-0.189	<0.001
Wealth → Loneliness				
Wealth W3 → Loneliness W4	-0.247	-0.274	-0.220	<0.001
Wealth W5 → Loneliness W6	-0.033	-0.085	0.018	0.208
Loneliness → Edentulousness				
Loneliness W4 → Edentulousness W5	0.002	-0.078	0.083	0.954
Loneliness W6 → Edentulousness W7	0.031	-0.006	0.067	0.099
Edentulousness → Loneliness				
Edentulousness W3 → Loneliness W4	0.015	-0.111	0.141	0.811
Edentulousness W5 → Loneliness W6	0.115	0.003	0.227	0.044
Edentulousness → Wealth				
Edentulousness W3 → Wealth W5	-0.163	-0.215	-0.111	<0.001
Edentulousness W5 → Wealth W7	-0.075	-0.165	0.014	0.100
Indirect effects (Longitudinal)				
Wealth W3 to Edentulousness W5				
Total effect	-0.277	-0.358	-0.196	<0.001
Total indirect effect	-0.001	-0.020	0.019	0.954
Wealth W3 → Loneliness W4 → Edentulousness W5	-0.001	-0.020	0.019	0.954
Wealth W5 to Edentulousness W7				
Total effect	-0.229	-0.268	-0.190	<0.001
Total indirect effect	-0.001	-0.003	0.001	0.326
Wealth W5 → Loneliness W6 → Edentulousness W7	-0.001	-0.003	0.001	0.326
Measuring Model Fit				
AIC[2]	133830.875			
BIC[3]	134073.529			
SABIC[4]	133968.658			

[1]Household non-pension wealth; [2]Akaike's Information Criterion; [3]Bayesian Information Criterion; [4]The Sample Size Adjusted BIC

A.18.10 Unadjusted auto-regressive pathway model for edentulousness via social isolation (*n* = 11,486)

	Estimate	95% CI		*p*-value
		Lower	Upper	
Autoregressive effects (Longitudinal)				
Wealth[1] → Wealth				
Wealth W3 → Wealth W5	0.860	0.848	0.872	<0.001
Wealth W5 → Wealth W7	0.988	0.888	1.089	<0.001
Edentulousness → Edentulousness				
Edentulousness W3 → Edentulousness W5	5.601	5.319	5.883	<0.001
Edentulousness W5 → Edentulousness W7	3.405	3.055	3.736	<0.001
Social isolation → Social isolation				
Social isolation W4 → Social isolation W6	0.795	0.656	0.935	<0.001
Direct effects (Longitudinal)				
Wealth → Edentulousness				
Wealth W3 → Edentulousness W5	-0.294	-0.383	-0.204	<0.001
Wealth W5 → Edentulousness W7	-0.219	-0.260	-0.178	<0.001
Wealth → Social isolation				
Wealth W3 → Social isolation W4	-0.281	-0.301	-0.261	<0.001
Wealth W5 → Social isolation W6	-0.072	-0.110	-0.034	<0.001
Social isolation → Edentulousness				
Social isolation W4 → Edentulousness W5	-0.060	-0.170	0.050	0.287
Social isolation W6 → Edentulousness W7	0.055	0.006	0.105	0.028
Edentulousness → Social isolation				
Edentulousness W3 → Social isolation W4	0.167	0.071	0.263	0.001
Edentulousness W5 → Social isolation W6	0.135	0.057	0.213	0.001
Edentulousness → Wealth				
Edentulousness W3 → Wealth W5	-0.164	-0.217	-0.112	<0.001
Edentulousness W5 → Wealth W7	-0.078	-0.168	0.012	0.088
Indirect effects (Longitudinal)				
Wealth W3 to Edentulousness W5				
Total effect	-0.277	-0.358	-0.196	<0.001
Total indirect effect	0.017	-0.014	0.048	0.287
Wealth W3 → Social isolation W4 → Edentulousness W5	0.017	-0.014	0.048	0.287
Wealth W5 to Edentulousness W7				
Total effect	-0.223	-0.263	-0.183	<0.001
Total indirect effect	-0.004	-0.008	0.000	0.055
Wealth W5 → Social isolation W6 → Edentulousness W7	-0.004	-0.008	0.000	0.055
Proportion of total effects mediated (%)[§]				
Wealth W5 → Social isolation W6 → Edentulousness W7	1.8			
Measuring Model Fit				
AIC[2]	120643.425			
BIC[3]	120885.938			
SABIC[4]	120781.068			

[1]Household non-pension wealth; [2]Akaike's Information Criterion; [3]Bayesian Information Criterion; [4]The Sample Size Adjusted BIC; [§]The proportion of the total effect that is mediated: (|ab/(ab+c')|) (MacKinnon, Warsi and Dwyer, 1995)

Appendix 19: Comparison of SEM model fit indices for all outcomes

At present, SEM models that contain categorical variables and implement the MLR estimation method do not have typical fit indices, such as, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Standardised Root Mean Square Residual (SRMR) and Root Mean Square Error of Approximation (RMSEA) available. Instead, statistical information criteria, such as Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) and Sample-Size Adjusted BIC (SABIC). Studies have shown that BIC tends to perform better than AIC with regards to picking the best model, based on the fit of the data (Nylund, Asparouhov and Muthén, 2007; Lin, Huang and Weng, 2017). Therefore, although the final models via loneliness mediating pathways for SRH and OHRQoL had marginally higher AIC compared to Model 2, they were kept due to their lower BIC and SBAIC values. Likewise, the final model via social isolation mediating pathways for SRH was kept due to its lower BIC and SABIC values, despite a slightly higher AIC value when compared to Model 2.

The AIC, BIC and SABIC values for nested models for SRH, SROH, OHRQoL and edentulousness are compared in Tables A19.1 to A.19.8.

A.19.1 Model fit indices for autoregressive cross-lagged loneliness pathways SEM models – SRH

Model	AIC	BIC	SABIC
SRH			
Model 1	216973.397	217338.099	217182.382
Model 2	216973.773	217331.032	217178.493
Final Model	205712.581	206047.350	205904.344

Model 1:
Wealth W2 → Loneliness W3 → SRH W4
Wealth W2 → Loneliness W3 → SRH W6
Wealth W2 → Loneliness W5 → SRH W6
Wealth W4 → Loneliness W5 → SRH W6
Model 2:
Wealth W2 → Loneliness W3 → SRH W4
Wealth W2 → Loneliness W5 → SRH W6
Wealth W4 → Loneliness W5 → SRH W6
Final Model:
Wealth W2 → Loneliness W3 → SRH W4
Wealth W4 → Loneliness W5 → SRH W5

A.19.2 Model fit indices for autoregressive cross-lagged loneliness pathways SEM models – SROH

Model	AIC	BIC	SABIC
SROH			
Model 1	207152.031	207512.334	207356.618
Model 2	207152.833	207505.784	207353.246
Final Model	207148.981	207487.225	207341.043

Model 1:
Wealth W3 → Loneliness W4 → SROH W5
Wealth W3 → Loneliness W4 → SROH W7
Wealth W3 → Loneliness W6 → SROH W7
Wealth W5 → Loneliness W6 → SROH W7
Model 2:
Wealth W3 → Loneliness W4 → SROH W5
Wealth W3 → Loneliness W6 → SROH W7
Wealth W5 → Loneliness W6 → SROH W7
Final Model:
Wealth W3 → Loneliness W4 → SROH W5
Wealth W5 → Loneliness W6 → SROH W7

A.19.3 Model fit indices for autoregressive cross-lagged loneliness pathways SEM models – OHRQoL

Model	AIC	BIC	SABIC
OHRQoL			
Model 1	197831.099	198191.403	198035.686
Model 2	197830.032	198182.983	198030.445
Final Model	197828.999	198167.243	198021.061

Model 1:
Wealth W3 → Loneliness W4 → OHRQoL W5
Wealth W3 → Loneliness W4 → OHRQoL W7
Wealth W3 → Loneliness W6 → OHRQoL W7
Wealth W5 → Loneliness W6 → OHRQoL W7
Model 2:
Wealth W3 → Loneliness W4 → OHRQoL W5
Wealth W3 → Loneliness W6 → OHRQoL W7
Wealth W5 → Loneliness W6 → OHRQoL W7
Final Model:
Wealth W3 → Loneliness W4 → OHRQoL W5
Wealth W5 → Loneliness W6 → OHRQoL W7

A.19.4 Model fit indices for autoregressive cross-lagged loneliness pathways SEM models – Edentulousness

Model	AIC	BIC	SABIC
Edentulousness			
Model 1	202978.792	203339.096	203183.380
Model 2	202977.683	203330.634	203178.096
Final Model	202976.378	203314.623	203168.440

Model 1:
Wealth W3 → Loneliness W4 → Edentulousness W5
Wealth W3 → Loneliness W4 → Edentulousness W7
Wealth W3 → Loneliness W6 → Edentulousness W7
Wealth W5 → Loneliness W6 → Edentulousness W7
Model 2:
Wealth W3 → Loneliness W4 → Edentulousness W5
Wealth W3 → Loneliness W6 → Edentulousness W7
Wealth W5 → Loneliness W6 → Edentulousness W7
Final Model:
Wealth W3 → Loneliness W4 → Edentulousness W5
Wealth W5 → Loneliness W6 → Edentulousness W7

A.19.5 Model fit indices for autoregressive cross-lagged social isolation pathways SEM models – SRH

Model	AIC	BIC	SABIC
SRH			
Model 1			
Model 2			
Final Model			

Model 1:
Wealth W3 → Social isolation W4 → SRH W5
Wealth W3 → Social isolation W4 → SRH W7
Wealth W3 → Social isolation W6 → SRH W7
Wealth W5 → Social isolation W6 → SRH W7
Model 2:
Wealth W3 → Social isolation W4 → SRH W5
Wealth W3 → Social isolation W6 → SRH W7
Wealth W5 → Social isolation W6 → SRH W7
Final Model:
Wealth W3 → Social isolation W4 → Edentulousness W5
Wealth W5 → Social isolation W6 → Edentulousness W7

A.19.6 Model fit indices for autoregressive cross-lagged social isolation pathways SEM models – SROH

Model	AIC	BIC	SABIC
SROH			
Model 1			
Model 2			
Final Model			

Model 1:
Wealth W3 → Social isolation W4 → SROH W5
Wealth W3 → Social isolation W4 → SROH W7
Wealth W3 → Social isolation W6 → SROH W7
Wealth W5 → Social isolation W6 → SROH W7
Model 2:
Wealth W3 → Social isolation W4 → SROH W5
Wealth W3 → Social isolation W6 → SROH W7
Wealth W5 → Social isolation W6 → SROH W7
Final Model:
Wealth W3 → Social isolation W4 → SROH W5
Wealth W5 → Social isolation W6 → SROH W7

A.19.7 Model fit indices for autoregressive cross-lagged social isolation pathways SEM models – OHRQoL

Model	AIC	BIC	SABIC
OHRQoL			
Model 1			
Model 2			
Final Model			

Model 1:
Wealth W3 → Social isolation W4 → OHRQoL W5
Wealth W3 → Social isolation W4 → OHRQoL W7
Wealth W3 → Social isolation W6 → OHRQoL W7
Wealth W5 → Social isolation W6 → OHRQoL W7
Model 2:
Wealth W3 → Social isolation W4 → OHRQoL W5
Wealth W3 → Social isolation W6 → OHRQoL W7
Wealth W5 → Social isolation W6 → OHRQoL W7
Final Model:
Wealth W3 → Social isolation W4 → OHRQoL W5
Wealth W5 → Social isolation W6 → OHRQoL W7

A.19.8 Model fit indices for autoregressive cross-lagged social isolation pathways SEM models – Edentulousness

Model	AIC	BIC	SABIC
Edentulousness			
Model 1			
Model 2			
Final Model			

Model 1:
Wealth W3 → Social isolation W4 → Edentulousness W5
Wealth W3 → Social isolation W4 → Edentulousness W7
Wealth W3 → Social isolation W6 → Edentulousness W7
Wealth W5 → Social isolation W6 → Edentulousness W7
Model 2:
Wealth W3 → Social isolation W4 → Edentulousness W5
Wealth W3 → Social isolation W6 → Edentulousness W7
Wealth W5 → Social isolation W6 → Edentulousness W7
Final Model:
Wealth W3 → Social isolation W4 → Edentulousness W5
Wealth W5 → Social isolation W6 → Edentulousness W7

Appendix 20: Quadrature checks for random effects modelling

Table A.20.1 Table comparing fitted quadrature points to randomly selected 27 and 53 fitted points

	Fitted quadrature 40 points	Comparison quadrature 27 points	Comparison quadrature 53 points	
Log likelihood	-7412.3422	-7412.3478	-7412.342	
		-0.00560171	2.272×10^{-5}	*Difference*
		7.557×10^{-7}	-3.065×10^{-8}	*Relative difference*
Wealth				
2nd Quintile	1.0030844	1.0031712	1.0030629	
		8.678×10^{-5}	-2.152×10^{-5}	*Difference*
		8.651×10^{-5}	-2.145×10^{-5}	*Relative difference*
3rd Quintile	1.7279715	1.7279962	1.7279524	
		2.478×10^{-5}	-1.903×10^{-5}	*Difference*
		1.434×10^{-5}	-1.101×10^{-5}	*Relative difference*
4th Quintile	2.6706668	2.6707157	2.6706449	
		4.89×10^{-5}	-2.191×10^{-5}	*Difference*
		0.00001831	-8.206×10^{-6}	*Relative difference*
5th Quintile	3.7209082	3.7208815	3.7208802	
		-2.669×10^{-5}	-2.798×10^{-5}	*Difference*
		-7.174×10^{-8}	-7.520×10^{-8}	*Relative difference*
Covariates				
Positive support	.00696336	0.00696272	0.00696334	
		-6.428×10^{-7}	-1.480×10^{-8}	*Difference*
		-9.231×10^{-5}	-2.125×10^{-6}	*Relative difference*
Age	0.21118882	0.21117685	0.21118839	
		-1.198×10^{-5}	-4.357×10^{-7}	*Difference*
		-5.671×10^{-5}	-2.063×10^{-6}	*Relative difference*
Sex	-0.13579305	-0.13578874	0.13579308	
		4.309×10^{-6}	-2.342×10^{-8}	*Difference*
		-3.173×10^{-5}	-1.724×10^{-7}	*Relative difference*
Constant	-23.806721	-23.805714	-23.806654	
		0.00100701	6.672×10^{-5}	*Difference*
		-4.23×10^{-5}	-2.803×10^{-6}	*Relative difference*
lnsig2u	2.5270531	2.5269445	2.5270472	
		-1.0853×10^{-5}	-5.895×10^{-6}	*Difference*
		-4.295×10^{-5}	-2.333×10^{-6}	*Relative difference*

Appendix 21 Random effects models predicting edentulousness by positive social support

It is important to note that findings from Section 8.5 do not provide enough evidence for effect modification by positive social support. However, stratified results are presented here for as comparison with the cross-sectional results presented in Table 8.6 (Section 8.4). Similar to the cross-sectional results, results in Table A.21.1 show that positive social support strengthened the association between wealth and edentulousness and did not buffer the negative effect of wealth on edentulousness.

Table A21.1 Random effects models predicting edentulousness: stratified by positive social support (waves 3, 5, 7) (*n* = 9373)

Variables	Lower tertile of positive support (n = 3005) OR (95% CI)	Middle tertile of positive support (n = 3092) OR (95% CI)	Upper tertile of positive support (n = 3276) OR (95% CI)
Constant	2.09×10^{-8} (1.94×10^{-9}, 2.25×10^{-7})	9.69×10^{-8} (8.90×10^{-9}, 1.06×10^{-6})	5.83×10^{-8} (5.68×10^{-9}, 5.99×10^{-7})
Wealth[1]			
4th quintile	2.33 (1.59-3.40)	1.95 (1.28-2.97)	2.41 (1.53-3.80)
3rd quintile	4.15 (2.77-6.22)	2.97 (1.90-4.65)	4.78 (3.01-7.60)
2nd quintile	9.32 (5.95-14.61)	8.85 (5.37-14.58)	7.69 (4.77-12.39)
Least wealthy	13.23 (7.61-23.00)	18.87 (10.71-33.25)	21.08 (12.54-35.42)
Covariates			
Age	1.21 (1.18-1.25)	1.22 (1.18-1.27)	1.21 (1.18-1.24)
Sex (Male)	0.72 (0.55-0.95)	0.83 (0.62-1.11)	0.99 (0.76-1.29)
lnsig2u	1.71 (1.34-2.07)	2.09 (1.72-2.46)	2.13 (1.84-2.42)
Sigma_u	2.35 (1.96-2.82)	2.84 (2.36-3.43)	2.90 (2.51-3.35)
ICC	0.63 (0.54-0.71)	0.71 (0.63-0.78)	0.72 (0.66-0.77)

[1]Wealth = quintiles: 1 = 5th quintile (wealthiest), 5 = 1st quintile (least wealthy); Sigma_u = between person variability; ICC = intraclass correlation