Putting ageism in context: examining the relationship between age discrimination and frailty among older individuals aged 65 years and over.

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ABODUNRIN Q. AMINU

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Putting ageism in context: Examining the relationship between age discrimination and frailty among older individuals aged 65 years and over.

Abodunrin Q. Aminu

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requirements of
Robert Gordon University
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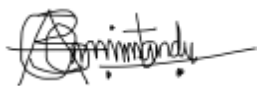
DECLARATION

Statement of declaration:

I declare that this thesis is my original work in partial fulfilment of a Doctor of Philosophy at Robert Gordon University, Aberdeen. All resources utilised during this research work have been properly acknowledged and referenced accordingly.

Name: Abodunrin Quadri, AMINU

Signature:



Date: 16-05-2022.

DEDICATION

I dedicate this research work to my wonderful family, my wife, Mrs Bilikisu Bukola Aminu, and my adorable children, who have been my support system through this amazing journey. My dedication also goes to my dad Alhaji (Engr.) A.S. Aminu, who has offered me the giant shoulder to see further in life and my siblings, who are very supportive. Finally, I dedicate this thesis to Almighty Allah for His infinite mercy and the entire Ummah for the furtherance of knowledge.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude for the EU Horizon 2020 Marie Sklodowska Curie Innovative Training Network funding to support this project. My sincere appreciation goes to my supervisory team for walking this journey with me and offering me all the possible support to become a robust researcher. The appreciation starts from Prof. Angela Kydd, my director of studies, who always ensure I am on track with the relevant task related to my research project and the entire EuroAgeism project, which forms my research journey. Special thanks to Angela for always spending extra time on virtual check up on me and my family, especially during the COVID-19 pandemic, to be sure things are moving on smoothly. I am extending this special gratitude to Dr Nicola Torrance, who offered me technical support in my research analysis and was always willing to support me through the research process. Nicola is critical and as well accommodative. She has allowed me to leap further in my skillset and stretch my capacity in positive ways. I would also like to show my gratitude to Dr Aileen Grant, who guided me critically with my ethics application and data management. Aileen is quite critical as well and always offered alternative perspectives in my critical analysis of previous works. I would like to say I am happy for having you all as my supervisors and hope that our relationship will extend beyond the PhD.

My profound appreciation goes to my wife, Bukola, who kept me motivated throughout the research journey. There were times I felt I would not be able to sustain my interest in the research, but she always believed in my capability and provided the environment for me to ease out my fears and anxiety. She has sacrificed a lot to take care of our children in the last three years, especially at the formative stage of my research that required a lot of time input. I am very grateful to you, and I cannot thank you enough for sharing my dreams and sacrificing to be part of it. My children are amazing and so much joy to be with. Although they are toddlers and may not understand the full extent of commitment required for this work, they always offered me the opportunity to be happy in challenging moments.

My sincere appreciation goes to Robert Gordon University (RGU) for providing the necessary support required during this project. I am grateful to my colleagues Lola Casal-Sanchez and Dr Ghulam Nasir, and many others who have provided peer support in the process of making this research journey worthwhile. I enjoyed the activities of the Research Student Association in RGU and hoped we could have the Edzell Burns retreat again. Special thanks to all my colleagues at the School of Nursing, Midwifery and Paramedic Practice (SNMP), including the administrators, research and teaching staff members. I would like to thank Dr Flora Douglas, who is the research degree coordinator in SNMP, for always keeping the research process smooth. I want to thank the postgraduate school head Professor Andrew Lamb and special thanks to all staff members of the postgraduate school in RGU, including Martin Simpson, Nick Anderson, Andrea Macmillan. They have all worked

hard to ensure that the research culture is preserved and that research students have gotten the right opportunity to excel in the doctoral degree. I would like to mention Paula Sledzinska, who is the research development officer at RGU. I was quite fascinated at the level of dynamism displayed by Paula and her creative ideas to keep research activities going smoothly, especially when things went virtual. I participated in these research activities as much as possible and am proud to say they contributed to the entire experience.

I would like to thank Professor Catherine Gale of the Medical Research Centre at the University of Southampton. At the beginning of firming up my research methodology, I reached out to Professor Catherine Gale because she has expertise in frailty research. I was heavily influenced by her work and felt she would be able to guide me with calculating frailty outcomes. I was quite astonished that she gladly shared her statistical syntax for calculating frailty. This is a very good gesture that I hope to uphold as an independent researcher by enabling others and collaboratively working with colleagues.

I would like to appreciate the entire EuroAgeism members and partners who contributed directly or indirectly to my research journey. Special gratitude to my fellow Early-Stage Researchers in the EuroAgeism projects who worked in other partners institutions across Europe. As a member of Work Package 2, I enjoyed working in a team of high-spirited individuals like Dr Wenqian Xu, Laura Allen, Jovana Brkic and Atiqur Rahman. My profound appreciation as well to Vitalija Gaucaite, who is the Unit Head at the Population Unit, Statistical Division of the United Nations Economic Commission for Europe, for offering me an internship position during this period and Dr Yvonne van Zaalen of the Fontys University of Applied Sciences in Eindhoven, the Netherlands for hosting me as a guest researcher. This experience greatly impacted my entire research journey and broadened my research profile and capacity. I am quite grateful to you all.

I benefited from the spirituality offered by the Muslim Forum of Britain platform and was opportune to work with colleagues and mentors who inspired me into greatness. They believed in my capacity and offered a unique community that kept me close to home. Thank you to all those who make that happen.

Lastly, my deepest gratitude to all those I may not remember to mention; please know that I appreciate you. This is the ending into a new beginning, and I hope that what lies ahead is better and more interesting for myself and everyone.

IMPACT OF COVID-19 PANDEMIC

The SARS-CoV-2 is a coronavirus that emerged in Southeast Asia in December 2019, just a few months into my doctoral study and has spread globally. The disease(s) attributable to this virus is known as the COVID-19. The last 18 months of the pandemic has been very tough; I have shared pains and worries like everyone else and lost loved ones to the dreadful virus. The virus has challenged so many norms and impacted us in ways we could never have imagined. My project was interrupted at some point because I could not access my data remotely. I was restricted to working remotely for a huge part of my postgraduate time with toddlers who would not understand the worries. It was very challenging to cope with this reality when faced with the task of completing doctoral research.

However, I have turned these challenges into positive energies as much as I could. I completed several pieces of training on transferrable skills. I joined a mini writing club with peers who are also in the middle of their postgraduate degrees, which was very helpful to stay focused (even while it was difficult under the pandemic). I learned a new software (R studio) for my statistical analysis and participated in scientific conferences. Although I feel the research journey could have been much more enjoyable, I have developed relevant skills to become a robust and independent researcher.

ABSTRACT

Abodunrin Quadri AMINU

Doctor of Philosophy

"Putting ageism in context: Examining the relationship between age discrimination and frailty among older individuals aged 65 years and over."

Background:

Frailty is the inability of the body's defence system to cope with stressors and it is known to increase the risk of adverse health outcomes such as mortality, falls and hospitalisation among the older population. While the burden of frailty is continuously documented in the literature, there is still an evidence-practice gap in preventing frailty among the ageing population. To develop strategies that may help prevent frailty, there is a need to recognise its modifiable risk factors. In this study, age-based discrimination has been examined as a potential risk factor for frailty. Additionally, this study aimed to examine social relationships among older adults in terms of social isolation and loneliness and how these might influence the association between reported age discrimination and frailty.

Methods:

This quantitative study involved the secondary data analysis of Waves 5 to 9 of the English Longitudinal Study of Ageing (ELSA). ELSA is a national survey exploring the determinants of health among men and women aged 50 years and over. The data collected in the ELSA data started in 2002 and has continued with two years intervals. The main outcomes selected in this study were frailty (Frailty Index score ≥ 0.25), self-reported health status (0= good and 1=poor), social isolation (values ≥2) and loneliness (values ≥5). Reported age discrimination (Yes or No) was the main independent variable and all the outcomes were dichotomised for the statistical analysis. The outcomes were examined as future outcome (Waves 6 to 9) using the baseline (Wave 5) variables as the predictor and covariates. Future frailty outcome was examined additionally as incident-frailty among individuals who were not frail at baseline but developed frailty in the follow-up period. The binomial generalised estimating equation (GEE) was used for the longitudinal analysis. Mediation analysis was conducted using GEE and bootstrapping approaches to explain the potential relationship between reported age discrimination and frailty. Age, gender, long-standing illness, cognition, socioeconomic status (SES) were all included in the analyses to adjust for confounding effects. The results were reported in odds ratio (OR) at 95% confidence interval (CI) and P-value < 0.05.

Results:

Responses from a total of 2,385 individuals aged 65 years and over who participated from Waves 5 through to 9 of ELSA was analysed in this study. Among the study population, 55% (n=1,312) were female and 38.5% of the respondents reported age discrimination. The prevalence of frailty was 12% using the baseline data (Wave 5) but 17% from the pooled average over the eight years analysed. A subset of the study population (n=2,097) was not frail at baseline, that is, individuals with FI <0.25 in Wave 5. Findings from the GEE models after fully adjusting for all the covariates show that reported age discrimination was significantly associated with future frailty/frailty progression (OR 1.49, CI [1.33-1.67]) and incident frailty/frailty development (OR 1.38, CI [1.19-1.60]), future self-reported health (OR 1.19, CI [1.08-1.31]), and future loneliness (OR 1.69, CI [1.53-1.84]). Gender was significantly associated with frailty and women had an increased risk of frailty (OR 1.73) compared to men at P=0.001. The findings from the mediation analysis show that there was a significant indirect effect of reported age discrimination on frailty outcomes. Loneliness accounted for 36% of the association between reported age discrimination and frailty among the respondents in the ELSA data.

Conclusion:

Findings from this study show that reported age discrimination is associated with frailty progression and frailty development among older adults. The findings demonstrate that women are at higher risk of frailty compared to men and thus, frailty intervention should consider this gender disparity in designing and planning frailty prevention strategies. Additionally, the findings also show that future studies would be needed to examine the relationship between reported age discrimination and mental health. Social interventions such as the introduction of legal frameworks and legislation, awareness to combat ageing stereotypes and a review of age-biased protocols in healthcare can help to reduce age discrimination against older adults and to foster healthy ageing among older individuals.

Keywords: Frailty, Ageism, Age discrimination, Ageing, Older adults, 65+ years.

Thesis Word Count: 68, 608 words.

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LIST OF DISSEMINATIONS

(Please see **Appendix VIII** for the list of other planned peer-reviewed publications)

Scientific conferences:

- **Aminu, A.Q.**, Torrance, N., Grant, A., Kydd, A. (2020) Analysis the link between ageism and frailty: a quantitative systematic review. Oral presentation at the Ageing and Social Change Tenth Inter-Disciplinary Conference 2020.

- **Aminu, A.Q.**, Torrance, N., Grant, A., Kydd, A. (2021) Social isolation and loneliness: Association with perceived age discrimination in a prospective analysis of the English Longitudinal Study of Ageing (ELSA). Oral presentation at the Health Studies User Conference July 2021.

- **Aminu, A.Q.**, Torrance, N., Grant, A., Kydd, A. (2021) is age discrimination a risk factor for frailty among older adults? A longitudinal analysis of the English Longitudinal Study of Ageing. Oral presentation at the 15th ESA conference, European Sociological Association. August – September 2021.

Webinar:

- Rahman, A., Brkic, J., **Aminu, A.Q.** (2021) Discussing Ageism in Healthcare: Panellists at the joint webinar between EuroAgeism and University of Third Age.

Policy:

- Xu, W., Allen, L., Brkic, J., **Aminu, A.Q.,** Rahman, A., Kydd, A., Fialova, D. (2021) Implications for policy and planning to foster solidarity between the generations and enhance healthy life among older adults. Available at: www.euroageism.eu

LIST OF ABBREVIATIONS (GLOSSARY)

CI – Confidence Interval

eFI – Electronic Frailty Index

ELSA – English Longitudinal Study of Ageing

ESR – Early-Stage Researcher

EU – European Union

FI – Frailty Index

GEE – Generalised Estimating Equation

GLM – Generalised Linear Model

HRS – Health and Retirement Survey

LMIC – Low-Middle Income Countries

OECD - Organisation for Economic Co-operation and Development

ONS – Office for National Statistics

QATOCCSS – Quality Assessment Tool for Observational Cohort and Cross-sectional Studies

RGU – Robert Gordon University

SERP - School of Nursing & Midwifery Ethical Review Panel

SHARE – Survey of Health, Ageing and Retirement in Europe

UCLA - University of California, Los Angeles

UK – United Kingdom

UN – United Nations

UNECE – United Nations Economic Commission for Europe

US- United States

WHO – World Health Organisation

WP – Work Package

1.0 CHAPTER ONE: INTRODUCTION

This chapter contains the introduction to this doctoral thesis.

1.1 Overview of this chapter

Chapter one is the introductory chapter which sets the tone for the overall thesis direction and provides the background perspectives from the literature concerning the focus of this doctoral study.

1.1.1 About the author

My name is Abodunrin Aminu, and I was recruited in January 2019 as one of the 15 global Early-Stage Researchers in the EuroAgeism project (**Section 1.1.2**). I am a qualified dentist and registered with the medical and dental council of Nigeria. I had postgraduate training in gerontology from the centre for research on ageing at the University of Southampton. I currently volunteer as one of the mentors in the Commonwealth Scholarship Commission programmes for Young Scholars. Owing to my medical statistics and ageing research background, I have developed an interest in population health research using rigorous quantitative methods. Thus, my research philosophy and methodological approach are greatly influenced by my academic background and research interest. I have conducted the present study using the same philosophical perspective.

1.1.2 The EuroAgeism project

The EuroAgeism consortium (2017 – 2022) consists of a group of internationally renowned researchers and 15 global Early-Stage Researchers (ESR) in the United Kingdom (UK), Netherlands, Sweden, Belgium, Czech Republic, Poland and Ireland. The consortium also includes non-governmental partners such as the World Health Organisation (WHO), United Nations Economic Commission for Europe (UNECE), Age Platform Europe, European Centre for Social Welfare Policy and Research and Age Alliance UK. This consortium is funded under the Europe Union (EU) Horizon 2020 funding programme and is set to provide scientific evidence to support policies for combating ageism in the EU and globally by delivering a multi-sectorial and international training programme for early-career researchers. The EuroAgeism research programme focuses on three broad domains: EuroAgeism Work Package 1 (WP1) for technology and ageism, WP2 for research on ageism in access to goods and services (including healthcare), WP3 for research on ageism in the labour market and legislation. Each of the work packages has five ESRs and my project/doctoral study is part of the WP2 focusing on ageism and frailty among older adults.

1.1.3 The outline of this thesis

This thesis examined the association between reported age discrimination and frailty among older adults aged 65 years and over by prospectively analysing data from the

English Longitudinal Study of Ageing (**Section 3.5**). The 65 years cut-off chosen in this study is for statistical purposes and does not suggest the start of old age (ONS 2019a). However, the age of 65 has symbolic representation in policy-relevant documents and demographic data. It is also used by health-promoting organisations such as the United Nations and the World Health Organisation to define older adults (UN 2020; WHO 2021a). The thesis contains eight chapters; the introduction, systematic review of literature, materials and methods, four chapters for the results of the specific analyses and the discussion.

Chapter one focuses on the main outcome (frailty) and includes its concept and definitions. The introduction chapter also defines the burden of frailty and its associated risk factors. The later part of chapter one highlights the gaps in frailty research relating to social determinants of health. The rationale for this study was situated in the lack of adequate evidence exploring the association between reported age discrimination and frailty. This also informed the decision to systematically examine the literature for the relationship between ageism and frailty in chapter two. To retain the narrative on the relationship between age discrimination and frailty throughout the thesis, the chapters (Chapters 2 to 7) included a focus section and an overview section. The focus section was introduced to discuss the link between each of the chapters while the outline section briefly introduces the structure of the chapters.

Chapter two reviews the depth at which the research topic has been previously explored in the literature by examining published evidence on the association between ageism and frailty. The chapter also includes a meta-analysis to examine the pooled statistical results from some of the papers reviewed. The findings from the systematic review, including the meta-analysis, were discussed to buttress the thesis topic's rationale further.

Chapter three is the methods chapter. It starts with a broad introduction to the quantitative research method and survey design. Then there is a discussion on the rationale for the use of secondary data analysis. The research design is discussed in detail in this chapter and the details of all the statistical analyses conducted in this thesis are presented here.

Chapters four, five, six and seven are the results chapters. Chapter four contains the result of the descriptive statistics. It explores the baseline characteristics of the study population and presents the baseline bivariate association between the independent and dependent variables. The remaining chapters (five, six and seven) address the research questions and contain the main findings. The main findings are presented in a structure that includes a brief introduction, the research question being addressed, a brief note on the statistical procedure, concluding with the results and a discussion of findings from the chapter.

Chapter eight is the overall discussion chapter, which summarises the findings from the previous chapters and the discussion of the relevant results. This chapter also includes the section on the strength and limitation of the study design and the implication of the findings in this study for healthy ageing among older adults in the UK who participated in the ELSA study.

1.2 Background into frailty research

This section introduces the discussion on global ageing and how the changing ageing population in many countries influences health and social care. It also provides the connection between ageing and frailty research.

1.2.1 Demography of the ageing population

The world has seen a marked increase in ageing populations in the last few decades, bringing the global population of individuals aged 65 years and over to 727 million in 2020 (UN 2020). Figure 1.1 shows the composition of the regional distribution of the population of individuals aged 65+. Currently, the Eastern and South-Eastern Asia region has 37% (271million) of the world's population of individuals aged 65+ years, followed by Europe and North America, which accounts for 28% (204 million) of the global ageing population. Although the total number of people 65+ years is expected to increase even further for all the regions of the world by 58.7% in 2035 and more than double (1.5 million) in 2050, the largest proportional increase will be seen in Sub-Saharan Africa, Central and Southern Asia. These projections are also reported by the Office for National Statistics for the UK older population, which shows that 18.3% (12 million) of the UK population were 65+ years in mid-2018 and expected to rise to 26% (20 million) in 50 years (ONS 2019b).

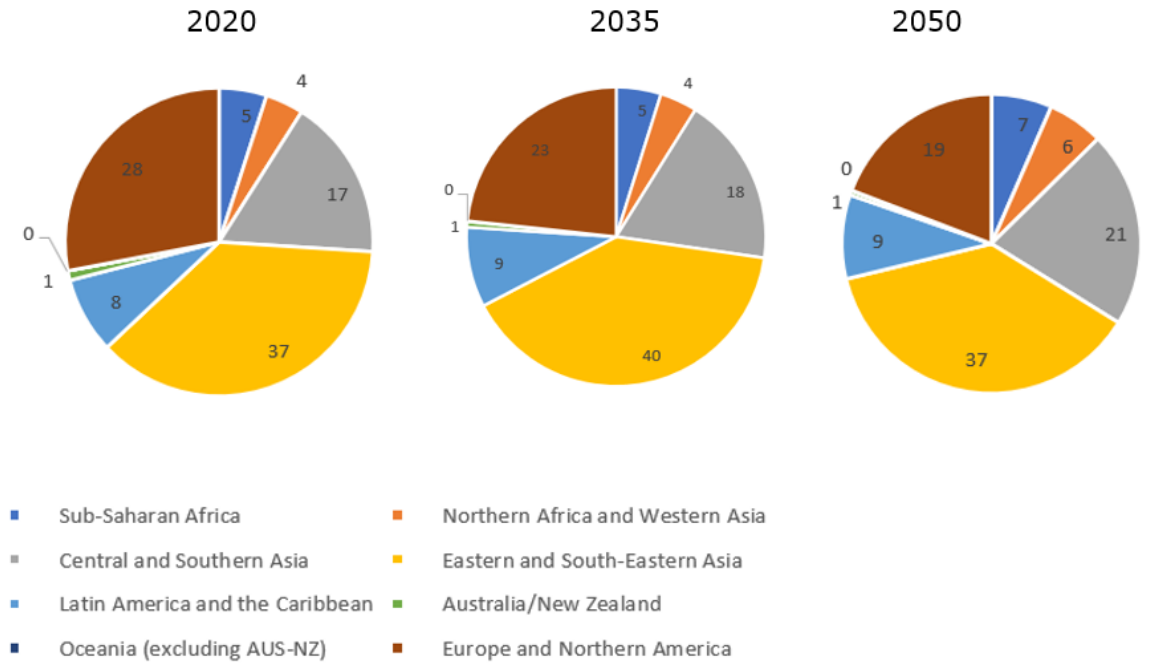

Figure 1.1: Ageing population (percentages of 65+), data from UN World Population Prospects (2020)

The global trend in population ageing has been attributed to the increasing life expectancies in many countries (Lutz et al. 2008) and some countries are experiencing the growth in the ageing population at exponential rates. For instance, Brazil will only have 20 years to adapt to a 15% increase in its 65+ years population compared to the over 140 years it took France to adapt to similar population growth (Pison 2019; UN 2020). The growth in the ageing population is also expected at different rates within the age groups. The UN data in Table 1.1 shows the total number of individuals in the age groups 65-79 years and 80+ years in 2020 and the projected increase in the next three decades. While there will be overall growth in the total population of individuals aged 65+ years, the 80+ years population represents the fastest-growing older population segment. The data shows that the global population of those 80+ will grow by 74% in 2030 and 193% in 2050 compared to the expected 54% and 122% growth among those 65-79 years by 2030 and 2050 respectively.

Table 1.1: Global population of individuals aged 65+ years from 1990 to 2050

Year/Age categories	65-79 years	80+ years	All 65+ years
1990	274,036,000	54,174,000	328, 210,000
2005	389,298,000	85,574,000	474,872,000
2020	582,103,000	145,503,000	727,606,000
2035	900,215,000	254,332,000	1,154,547,000
2050	1,294,522,000	426,368,000	1,548,854,000

Source: Department of Economic and Social Affairs, Population Division, World Population Prospects, United Nations (2020)

The global increase in life expectancies and the consequent increase in the proportion of older people portends some key questions. These questions relate to how much the increasing life expectancy would translate into more healthy years for older individuals (Cosco et al. 2017). It also relates to the impact of population ageing on demand for health and social care. A previous study on population ageing using a care simulation model that involved 300,000 participants in England suggests that the prevalence of multimorbidity

will rise from 45.7% in 2015 to 52.8% in 2035 among individuals aged 65+ and that life expectancy gained will be spent with four additional diseases among this cohort (Kingston et al. 2018). OECD technical report based on the analysis of the Wave 7 of the SHARE data showed that 37% of individuals aged 65 years and over in 22 European countries reported having two or more chronic illnesses and 30% reported having one or more limitations in activities of daily living (OECD 2020). Chronic illness and disability have been associated with an increased risk of frailty among older people (Ferrante et al. 2018; Theou et al. 2012). This means that there will be a potential increase in the total number of frail individuals among the older population. The burden of frailty relating to its prevalence, associated health outcomes and economic impact is discussed in **Section 1.5**. Considering the global scale of ageing, strategies to prevent frailty among the older population will be a key determinant of healthy ageing in future. To prevent frailty, there is a need to recognise its modifiable risk factors. In the following sections, the concept of frailty is briefly introduced and the existing knowledge and potential gaps in frailty research are explored.

1.2.2 The conceptualisation of frailty

Historical background:

The word frailty has its root in the literature in two different contexts. The first is the frailty model (Balan and Putter 2020; Vaupel 1990), mathematical modelling used to explain the distribution of time-to-event in life-course research. The frailty model relates to the individual variabilities in the expected duration before an event will occur and has been used in predicting life events such as mortality (Klein et al. 2016). The frailty model is a concept used in demography and ageing studies and this is where it intersects with the second concept of frailty. The second meaning of frailty is arguably the most popularly cited and refers to the inability of the body defence mechanisms to handle stressors (Rockwood and Mitnitski 2007). This frailty condition has received considerable attention in the last two decades and has shaped the perspectives of population ageing and its implications. This thesis examined the factors that influence the onset of frailty and progression of frailty condition among community-dwelling older individuals (details later). Thus, the mention of frailty further in this thesis refers only to the second frailty meaning, that is, a condition that adversely affects the health and well-being of older adults.

Definition of frailty:

There have been several conceptual and operational definitions to describe frailty among the older population. The conceptual definitions address the description of frailty and the operational definitions provide the empirical criteria for assessing frailty. A previous systematic review by Gobbens et al. (2010a) critically details the sequential development of the conceptual meaning of frailty. Gobbens et al. (2010) reviewed 41 articles that

examined frailty among community-dwelling older adults aged 65 years and over and reported 18 conceptual definitions of frailty and 23 operational definitions from the literature. Some of these definitions are similar, while others are simply updated versions (Gobbens et al. 2010a). An example of a conceptual definition is that frailty refers to the "functional depletion in several domains that results in loss of the body reserve capacity to deal with stressors" (Schuurmans et al. 2004). The operational definitions are discussed in detail in the following section (**Section 1.3**).

The concept of multidimensionality is a major consideration of what an acceptable frailty definition should include. Most conceptual definitions refer to frailty as a physical condition only (Gobbens et al. 2010). However, Gobbens et al. (2010) found that some previous definitions of frailty recognise the need to include deficits in multiple domains of health within a definition of frailty. For instance, Nourhashémi et al. (2001) was found to have included psychosocial and environmental factors in their definition of frailty. This multidimensional concept created two broad ideological categories for assessing frailty among the older population (Walston and Bandeen-Roche 2015). The first group considers only the physical function or performance as the indicator of frailty status. Prominent among this group is Fried's Phenotype Frailty (Fried et al. 2001) that focused on five physical criteria for assessing frailty. The other group considers that frailty is multidimensional, and that frailty assessment should include other determinants of health. The Frailty Index (FI) by Rockwood et al. (2017) is one of the most widely cited examples of the multidimensional frailty model and is based on the theory of accumulated biological deficits (Rockwood et al. 2007) . The frailty definitions have not changed considerably since the findings reported by Gobbens et al. (2010). Rather recently published reviews have focused on analysing the operational definitions used for assessing frailty (Dent et al. 2016; McDonagh et al. 2018).

1.3 **Operational assessment of frailty**

There is a consensus on the concept of frailty (Morley et al. 2013; Van Kan et al. 2008), but there is still a huge divergence on how frailty should be measured (Dent et al. 2016). For clinicians, a good frailty instrument should produce consistent results, assist in diagnosing patients at most risk of frailty, and be concise to fit into the busy clinical environment (Pritchard et al. 2017). Both the Phenotype Frailty instrument (Fried et al. 2001) and the multidimensional Frailty Index (Rockwood et al. 2007) have been adapted for clinical use. For example, general practices in the UK use a multidimensional frailty instrument - the electronic Frailty Index (Boyd et al. 2019). In some other instances, the multidimensional frailty criteria have been derived from the Comprehensive Geriatric Assessment (CGA) used by geriatricians to screen older adults at risk of physical and social vulnerabilities (Dent et al. 2016). All the previously validated frailty assessment criteria used in clinical and research environments have been analysed in previous systematic

reviews (Dent et al. 2016; McDonagh et al. 2018). Some of these assessment criteria are presented further in this section.

1.3.1 Instruments based on physical/biological components

Fried's Frailty Phenotype:

Fried's Phenotype Frailty (Fried et al. 2001) is one of the most widely used frailty assessment instruments validated using the Cardiovascular Health Study (CHS) in the United States. The Phenotype Frailty assesses the physical/phenotype features of older adults aged 65 years and over. The Phenotype Frailty is measured using five criteria: weight loss (unintentional loss of ≥5 kg in the last year), muscle weakness (hand-grip strength), self-reported exhaustion, low physical activity and slow walking speed. The outcome of the Phenotype Frailty assessment is scored from 0 to 5 and categorised into: robust (0), pre-frail (1 to 2) and frail (≥3). The application of Phenotype Frailty requires technical knowledge of the sophisticated instruments for measuring its components.

Fatigue, Resistance, Ambulation, Illness, Loss of Weight (FRAIL) Index:

FRAIL (Morley et al. 2012) is another variant of the physical frailty instrument developed in the US and it is based on five criteria like Fried's Phenotype Frailty. However, unlike Fried's instrument, FRAIL includes the presence of illness and resistance (walking up ten steps unaided) together with self-reported fatigue, slow walking speed (ambulation) and weight loss of ≥5 kg. In a similar way to Fried's instrument, FRAIL produces a score of 0 to 5 and the outcome is categorised as robust (0), pre-frail (1 to 2) and frail (≥3). While FRAIL is much easier to use and requires less technical knowledge than Fried's instrument, it has not been widely validated and thus, its reliability cannot be compared with Fried's Phenotype Frailty.

Gait speed as a frailty instrument:

Aside from the aforementioned frailty instruments that solely screen for physical frailty, gait speeds have been utilised to assess frailty among older people in previous research (Walston et al. 2018). More importantly, gait speed has shown to be significantly associated with adverse health outcomes such as fall and fractures (Kyrdalen et al. 2019). It is also closely linked with the ability to perform some of the activities of daily living and physical activities. Conversely, the downside is that gait speed is not a feasible measure to administer in a clinical setting and has the potential of over estimating frailty prevalence (Dent et al. 2016).

1.3.2 Instruments based on multidimensional domains

Frailty Index (Accumulative Deficits):

The Frailty Index (FI) was developed in Canada and popularly attributed to Kenneth Rockwood. It is arguably the most cited type of multidimensional frailty assessment instrument (Cesari et al. 2014). The FI is based on the theory of accumulated deficits, which suggests that frailty, although often manifest as physical vulnerability, is an aggregation of deficit in the different health domains across the life-course (Rockwood and Mitnitski 2007). As described by Rockwood and Mitnitski (2007), Deficits are a loss of functional capacity in different domains of health that can include symptoms and signs of disease, laboratory markers, or radiographic imaging showing abnormalities. Sometimes termed as "items", these deficits usually include self-reported difficulties with activities of daily living, medically diagnosed conditions, depressive symptoms and social support. Gahbauer Evelyne et al. (2008) suggested that the items utilised for the Frailty Index are usually expected to fulfil five criteria; (i) must be associated with health status (ii) potentially increase in prevalence with age (iii) must be included from different domains of health (iv) same items/deficits must be used for a group of people (v) should not present in everyone. To calculate the FI scores, Rockwood and Mitnitski (2007) proposed that the Frailty Index can be used to assess frailty among older individuals by counting the deficits and assigning a value between 0 and 1. The sum of the deficits should then be divided by the total number of deficits/items included. For example, if 40-items are included in the Frailty Index calculation and a person has a score of 10 from the counted deficits, the score would be divided by the total possible deficits among the cohort (10/40), resulting in a Frailty Index score of 0.25. Although the original calculation from Rockwood's study was based on 72-items (Dent et al. 2016), the FI scores calculated with ≥30 items will yield an accurate and precise outcome as well (Gahbauer Evelyne et al. 2008).

The Frailty Index originally produces a continuous score ranging from 0.0 to 1.0. However, several cut-off points have been suggested to facilitate the categorisation of frailty levels using the FI scores. These cut-off points are usually determined by factors such as the average FI score of a population, age group, correlation with clinical frailty and association with adverse health outcomes (Gahbauer Evelyne et al. 2008). Rockwood and Mitnitski (2007) reported that the maximum FI score that can be tolerated is 0.68, beyond which an additional deficit will likely result in mortality. The Frailty Index has been validated in different studies and adapted to different populations (e.g SHARE-FI in Europe and the electronic FI in the UK). There is also a comprehensive geriatric assessment variant of the Frailty Index (CGA-FI), which involves using information from the comprehensive geriatric assessment (Jones et al. 2004) to calculate the Frailty Index scores.

Edmonton Frailty Scale (EFS):

The Edmonton Frail Scale (EFS) got its name from being developed by researchers in Edmonton, Canada. EFS (Rolfson et al. 2006) is similar to the multidimensional frailty index (FI) as it includes nine items in different domains of health, namely self-reported health status, social support, medication, depressive symptoms, incontinence, hospitalisation, nutrition, health condition and physical performance. With a total score ranging from 0 to 17, EFS is notable for providing different levels of frailty on the multidimensional scale using the following cut-off scores: not frail (0–5); vulnerable (6–7); mildly frail (8–9); moderately frail (10–11) and severe frailty (12-17). Considering that EFS requires nine items, it can be utilised when there are fewer items to calculate the frailty scores compared to Rockwood's FI.

PRISMA-7

PRISMA-7 (Hoogendijk et al. 2013) is another multidimensional frailty assessment instrument developed in Canada and designed to identify frailty amongst the oldest-old individuals. The instrument screens for seven self-reported items, which are age (85 years and over), gender (male), long-standing limiting illness, help with activities of daily living such as help with balancing (cane), walking and sitting (wheelchair) and social support. PRISMA-7 produces a score 0 to 7 with scores ≥3 considered the cut-off point for frailty.

Groningen Frailty Indicator (GFI) and **Tilburg Frailty Indicator (TFI):**

The Groningen Frailty Indicator (GFI) developed by Peters et al. (2012) and Tilburg Frailty Indicator (TFI) developed by Gobbens et al. (2010b) were examples of the multidimensional frailty assessment instrument, both of which are developed in the Netherlands. Unlike the Rockwood's Frailty Index, the GFI has mostly been utilised locally in the Netherlands and contain mostly self-reported items. The GFI includes 15 items covering four health domains: physical (including medication use), cognitive, social and psychological. The GFI produces a score between 0 and 15 and individuals with a score of ≥4 are said to have frailty. The Tilburg Frailty Indicator (TFI) is quite similar to the GFI as it contains 15 self-reported items, only that it includes more social factors (social isolation, loneliness and social support) and confirms frailty at a score of ≥ 5.

Other frailty assessment instruments:

There are other frailty assessment instruments used in previous research. Some of these instruments are modifications of existing instruments adapted to another study population. For instance, an adapted form of Fried's Phenotype Frailty was utilised to examine frailty among older women in the study of osteoporotic fractures (SOF) in the US (Ensrud et al.

2007). Unlike Fried's Phenotype Frailty, the SOF frailty index can be operationalised without the use of special/technical appliances to measure frailty. SOF includes three criteria to assess physical frailty: weight loss of >5% in one year, exhaustion and low mobility. The outcome of the SOF Index is scored from 0 to 3 and categorised into: robust (0), pre-frail (1) and frail (≥2). An example of a tool adapted from the multidimensional instrument is the Gérontopôle Frailty Screening Tool (Subra et al. 2012), developed in France and consists of a 6-item questionnaire followed by a clinical assessment to determine the presence of frailty. The Multidimensional Prognostic Instrument (Pilotto et al. 2008) is like an abridged version of Rockwood's Frailty Index containing only eight items. The Multidimensional Prognostic Instrument (MPI) score adds the deficit in each item and divides the total by eight following the Rockwood's Frailty Index and the final MPI score ranges from 0.0 to 1.0. Similar to the Edmonton Frailty Scale, the MPI also have cut-off points for different severities of frailty, where the score > 0.66 represent frailty, 0.34–0.66 represent pre-frailty and robust is < 0.34.

1.3.3 Choosing the appropriate frailty assessment instrument

To choose the appropriate instrument for frailty assessment, some factors such as the number of items included, time of completion, the technicality of the instrument and the reliability of the instruments are considered (Dent et al. 2016). Based on the aforementioned factors, the limitations of each validated instrument have been reported in previous research (Dent et al. 2016; McDonagh et al. 2018). For instance, Fried's Phenotype Frailty, arguably the most cited type of Physical Frailty instrument, has been criticised for its need for a specialised tool (grip strength dynamometer) to assess frailty (Dent et al. 2016). On the other hand, Rockwood's multidimensional Frailty Index takes a longer time to complete (20 to 30mins) compared to the five-minute Fried's instrument. Other researchers (Morley et al. 2013; Fried et al. 2001) also argued that the prevalence of frailty is usually high when using Rockwood's multidimensional Frailty Index (FI) because it includes disability and diseases. However, when compared to the Phenotype/Physical Frailty instruments, the Frailty Index (FI) is known to provide a more accurate prediction of adverse health outcomes (Cesari et al. 2017). Although the FI can take a longer time to be calculated, it is the chosen method of frailty assessment in the present thesis because it allows the investigation of social and environmental factors on frailty development and progression. Besides, it is a familiar instrument utilised previously in a peer-reviewed article facilitated by Aminu et al. (2021)**– Appendix I**.

1.4 Why disability or comorbidity is not frailty

Despite the vast acceptance of the concept of frailty, it is often the case that frailty is misunderstood for disability or comorbidity because of their shared determinants (Espinoza et al. 2018). It is crucial to untangle the relationships between disability, comorbidity and

frailty to fully understand the precursors of frailty and the concept of frailty development. Disability characterises the difficulty in performing tasks relevant to survival (Tesch-Römer and Wahl 2017). For older adults, this relates to the lack of ability to carry out activities of daily living (Bleijenberg et al. 2017). Comorbidity is used to define a state of having more than one medically diagnosed condition that contributes to an individual's health status simultaneously (Jones et al. 2021). The distinction between frailty, disability, and comorbidity has been established in previous research (Fried et al. 2004). Fried et al. (2004) noted that only 27% and 68% of the 368 frail individuals aged 65 years and over reported a disability or comorbidity respectively, in their previous study (Fried et al. 2001). Another longitudinal study that assessed the overlap between comorbidity, disability and frailty among 2305 participants aged 65+ years in Canada found that 3.6% (15/416) and 8.6% (101/1176) among frail individuals had no comorbidity or disability when assessed with Phenotype Frailty instrument and multidimensional Frailty Index respectively (Theou et al. 2012). This shows that frailty is broader in scope compared to both disability and comorbidity. While frailty, disability and comorbidity are separate concepts, they often overlap and are significantly connected (Wong et al. 2010). Fried et al. (2001) additionally found that 21% of frail individuals had both disability and comorbidity in their study. Other determinants/risk factors of frailty may explain why frailty is different from both disability and comorbidity (**Section 1.5**).

1.5 The burden of frailty

The relevance of frailty research relates to the associated burden of frailty on the health and well-being of older individuals and the consequent impact of frailty on health and social care management. Unlike other known health indicators such as comorbidity and disability, frailty has been shown to predict adverse health outcomes accurately and portends a futuristic area of research for improving healthcare delivery and promoting healthy ageing (Walston et al. 2018). To understand the burden of frailty, it is important to discuss the prevalence of frailty and its associated adverse health outcomes.

1.5.1 The global prevalence of frailty

The accurate global prevalence of frailty is unknown (O'Caoimh et al. 2018), making it challenging for international coordination and collaboration to prevent frailty. This is not unexpected considering the various methods and definitions of frailty that have been adopted in different climes. However, few studies have estimated the global prevalence of frailty and one of those studies is the research by Collard et al. (2012). This was a systematic review of 21 studies that cross-sectionally examined the prevalence of frailty by pooling data of 61,500 community-dwelling older adults aged 65 years and over from high-income countries, mostly in Europe and North America. Collard et al. (2012) suggested that the global prevalence of frailty was 10.7%, which significantly increased with age (P <

.001) and was considerably higher in women (9.6%) compared to men (5.2%). Although Collard's review was a good starting point to appreciate the global scale of frailty, it has been criticised for risk of bias resulting from dropping out many potentially eligible studies that measured frailty prevalence by mean values rather than percentages. Besides, Collard's review only included studies that assessed physical frailty, which only captured the phenotype definition of frailty and did not include studies that used multidimensional frailty instruments. Another systematic review was published recently (O'Caoimh et al. 2021) that addressed some of the limitations of Collard's methodology. O'Caoimh et al. (2021) included all frailty studies published between 1 January 1998 and 1 April 2020. A total of 240 studies were reviewed from 63 countries involving 1,755,497 participants. O'Caoimh et al. (2021) concluded that the pooled prevalence of physical frailty was 12%, which is a little higher than the 10.7% reported by Collard et al. (2012). However, O'Caoimh et al. (2021) reported that when using the multidimensional definition of frailty, the prevalence was significantly higher (24%) than the physical frailty prevalence (12%). This information is vital considering that multidimensional frailty has been suggested to be a stronger predictor of adverse health outcomes than physical frailty (Cesari et al. 2014). The global burden of frailty may not be fully appreciated without considering the development or onset of frailty among non-frail individuals. Previous systematic review and meta-analysis involving 20 000 individuals aged 60 years and over from 28 countries found that the pooled incidence of physical frailty and multidimensional frailty was 40 and 71 new cases per 1000 person-years respectively in three years (Ofori-Asenso et al. 2019). This implies that there are potentially an additional 4-7% new frailty cases to the global number of frail individuals every three years. The combination of the findings, thus, demonstrate the global burden of frailty and why it is important to prioritise initiatives to tackle frailty, which are supported by scientific evidence.

1.5.2 **Prevalence of frailty in the United Kingdom (UK)**

The prevalence of frailty in the UK varies between 2.7% and 3% for severe frailty and 10.7% and 12% for moderate frailty (Clegg et al. 2016), based on the UK electronic Frailty Index (eFI) calculator, which is a variant of the multidimensional Frailty Index (Reeves et al. 2018). These estimates were generated from National Health Service (NHS) records of 207,702 older adults aged 65 years and over and a primary care database (Clinical Practice Research Datalink) that included 964,486 patients aged 65 years and over. Although the reported UK frailty prevalence appears to be similar to the pooled average prevalence of frailty reported from other high-income countries in both O'Caoimh and Collard studies (**Section 1.5.1**), it is challenging to make a direct comparison between these values due to the varying assessment criteria utilised in the different studies. Other studies have compared the prevalence of frailty among low-income and middle-income countries. For instance, the prevalence of physical frailty was reported to be highest in Africa 22%,

followed by the Americas 17%, compared to the 8% in Europe (O'Caoimh et al. 2021). It was reported in another systematic review and meta-analysis that geographically, the prevalence of physical frailty ranged from 3.9% in China to 26% in India (Siriwardhana et al. 2018). Although Siriwardhana et al. (2018) included 56 studies from low-middle income countries, the data published by the authors were not adequate to determine the trend or compare the prevalence of frailty for the countries included in their review.

It is not entirely clear if the burden of frailty is more significant among countries in the high-income level or those in the low/middle-income level. On the one hand, it is arguable that the high-come countries such as the UK and most European and North American countries currently have a large proportion of older people (UN 2020) and could be faced with the challenge of providing long-term care for their population. On the other hand, the growth in the population of individuals aged 65 years and over is expected to be highest in the low- and middle-income countries (LMIC) in the next few decades (UN 2020). Considering the delicate health systems in many LMIC countries (Shamasunder et al. 2020), the burden of frailty may become greater for these countries in the future if the current trend continues. Like other health issues on a global scale, there is a need for local and international collaborations to prevent the burden of frailty. It is essential to discuss how the high prevalence and/or incidence of frailty translates to healthcare burden or adverse health outcomes.

1.5.3 Associated adverse health outcomes

Frailty can be used as an indicator to determine the health status of older people and can provide early signs of declining health and well-being in the ageing society. In this section, there is a demonstration of the impact of frailty on mortality, falls and hospital admissions.

Mortality:

Increased mortality risk among older people has been significantly associated with frailty (Ferrante et al. 2018). Mortality in epidemiological research could be measured as disease-specific mortality or all-cause mortality (Dobbin and Ebell 2018). As the names already suggest, disease-specific mortality relates to the death associated with a specific disease condition, for instance, cancer-related mortality. However, deaths recorded from all events is all-cause mortality. It is broader in scope and gives the details of the total deaths in a population at a given period. A study involving 1,929 older adults aged 65 years and over in Italy found that the risk of all-cause mortality was 48% higher (hazard ratio 1.48; 95% CI [1.03–2.12]) among those with physical frailty compared to those not frail (Castellana et al. 2021). Hoogendijk et al. (2020b) found that the multidimensional Frailty Index (FI) was significantly associated with three- and six-years all-cause mortality and cardiovascular disease mortality among 1,129 individuals aged 65 years and over ($p < 0.001$). Hoogendijk

et al. (2020b) further reported that the mortality risk significantly increased between 3% to 7% per 0.01 increase in the frailty index scores of the participants in their study.

There are inconsistent reports on the association between physical frailty and 30-days mortality among older individuals living with chronic conditions. A previous study examined the impact of frailty on mortality among 5,021 older adults aged 80 years and over during 30-days admission in 311 Intensive Care Units (ICU) admissions from 21 European countries, including the UK (Flaatten et al. 2017). Findings from Flaatten's study showed a significant 53% increase in 30-days mortality risk among frail individuals compared to those who were not frail. Whereas another study from China involving a cohort of 256 individuals aged 65 years and over found out that frailty was not associated with 30-days all-cause mortality (Luo et al. 2020). Flaatten et al. (2017) and Luo et al. (2020) recruited participants from different age cohorts, but the median age of their participants (84 and 86 years, respectively) was similar. Flaatten's study appeared quite robust considering the multicentre approach and the larger study population in their research compared to Luo's study. Thus, it is possible that frailty significantly influence all-cause mortality among critically ill patients in 30-days. However, this is still an area where future studies may be required.

Falls:

Falls represent one of the clinical consequence of frailty and fall-related injury is one of the commonest reasons for emergency admissions among older adults (Hartholt et al. 2010). Previous research that analysed the burden of falls and fall-related injuries among 195 countries and territories found that the global prevalence and incidence of falls were 5.1% (CI [4.6-5.8]) and 2.2% (CI [1.9-2.5]) respectively using 2017 data from the Institute for Health Metrics and Evaluation (James et al. 2020). The findings further showed that falls were significantly associated with an estimated 16 million years of life lost (YLL), 19 million years lived with disabilities (YLDs) and 35 million disability-adjusted life years (DALYs) for all age groups (James et al. 2020). Another study examined the prevalence of falls among 4300 individuals aged 60 years and over in the UK (Gale et al. 2016). The result from Gale et al. (2016) showed that the average prevalence of falls among older adults in the UK was 28.4%, which was significantly higher in women (29.1%) compared to men (23.5%). Aside from being at more risk of frailty compared to men (Corbi et al. 2019), fall-related injury among women could have been linked to the risk of bone weakness (osteoporosis) due to hormonal changes post-menopausal (Morrison et al. 2013). Another study involving an Asian population found that physical frailty was positively correlated with falls (B coefficient = 0.71, 95% CI = 0.42, 1.01) among 356 participants in Thailand. Aside from the immediate risk of falls among frail individuals, there is a future associated risk of falls. A meta-analysis that involved 11 studies reported that frailty was significantly associated with the risk of future falls (pooled OR = 1.84, 95% CI= 1.43–2.38, P < .001). Although most

studies have examined the association between physical frailty and falls, the combined effect of cognitive decline and physical frailty (cognitive frailty) has also been shown to increase the risk of falls among frail individuals (Tsutsumimoto et al. 2018). Tsutsumimoto et al. (2018) found that cognitive frailty significantly increased the risk of falling by 46% (Odds ratio 1.46, CI [1.23 - 1.73]) and the risk of fall-related fracture by 92% (OR 1.92, CI [1.20 - 3.08]) among 10,202 older adults aged ≥ 65 years in Japan.

It is not in all cases that fall in older adults are precipitated by frailty. For instance, falls can sometimes be triggered by a medical syndrome (fainting/syncope) that allows blood recirculation during cardiovascular crises (Brignole and Hamdan 2012). However, for frail individuals, the weak muscles of lower extremities, incompetent postural balance and impaired vision are all determinants of falls (Nowak and Hubbard 2009). This may explain the association between frailty and falls among older adults. For instance, physical frailty is characterised by sarcopenia (muscles loss) or muscle weakness that affects the lower extremities, leading to an increased risk of falling (Chittrakul et al. 2020). This was the case in Gale's study (2016) that showed that the risk of fall significantly increased by three times (OR 3.32, 95% CI 2.09, 5.29) for those with muscle weakness who could not perform a standing balance test. Cognitive frailty can also directly impact maintaining balance, leading to falls (Nowak and Hubbard 2009; Tsutsumimoto et al. 2018). Previous research has reported that maintaining standing balance is difficult during a cognitive task for all age groups (Barra et al. 2006). Barra's study found that multitasking significantly increased the incidence of falling by 50% ($P = 0.0008$) even for healthy subjects.

Hospitalisation:

Hospital admissions, readmissions and length of stay have been significantly associated with frailty among older adults (Hubbard et al. 2017). Hubbard et al. (2017) examined if frailty status during hospital admission could predict adverse health outcomes for 1,418 patients aged 70 years and over from 11 hospitals in Australia using the multidimensional Frailty Index (FI). The result from Hubbard's study showed that frailty significantly increased the length of stay in the hospitals >28 days (OR 1.29, Confidence Interval CI [1.10–1.52]), the likelihood of admission into residential care (OR 1.31, CI [1.10–1.57]), fall incidence during admission (OR 1.29, CI [1.10–1.50]) and inpatient mortality (OR 2.01, CI [1.66–2.42]). Another study examined the association between frailty and hospital admission by analysing emergency admission records of older adults aged ≥ 75 years using electronically generated data of 7,503 patients from the Cambridge Hospital Information Systems in the UK (Wallis et al. 2015). The authors reported that frailty was significantly associated with transfer to Geriatric Wards (Odds Ratio OR = 1.33, 95% CI: [1.24-1.42], $P < 0.001$), in-patient mortality [OR= 1.60, 95% CI: [1.48-1.74], $P < 0.001$] and length of stay ≥ 10 days (OR = 1.19, 95% CI: [1.14-1.23], $P < 0.001$). However, frailty was not significantly associated with 30-days readmission (Wallis et al. 2015). This means that the

changes in the clinical frailty scale (physical frailty only) utilised in Wallis's study did not account for any exacerbation of patients' conditions that could warrant readmission in the short period. Besides, frailty deficits are cumulative, which may not always acutely increase the risk of readmission but are more likely to significantly predict post-hospital discharge mortality in the long term (Ma et al. 2013).

Aside from predicting hospital admission, frailty has also been shown to play a role in the decision to admit older adults into social care. A longitudinal study of 754 adults aged 70 years and over reported a significant increase in nursing home admissions among frail individuals (OR, 3.52; 95% CI [1.23-10.08]) compared to those not frail. A previous meta-analysis of five studies also reported that frailty significantly increased the odds (pooled OR = 5.58, 95% CI = 2.94-10.60, P < .00001) of nursing home admission by five times (Kojima 2018).

While the global prevalence and the associated adverse health outcomes have shown the scale of the frailty burden, there is a need to analyse the economic implications. This is because some of the associated adverse health outcomes have been shown to have a substantial economic impact on healthcare costs. For instance, research that examined the cost of falls and fractures in the Republic of Ireland reported an annual 130,000 cases of falls and fractures, which accounted for an estimated 404 million Euros in healthcare costs (Gannon et al. 2008). Since frailty has been associated with multiple health outcomes, it will be relevant to discuss the economic implication of frailty on healthcare costs.

1.5.4 **Economic burden of frailty**

A review of the literature shows that the economic burden of frailty in the UK has been documented in previous research. Han et al. (2019) examined the financial burden of frailty on the NHS by estimating the associated cost of managing frail patients at 125 general practices using the primary care records of 95,863 patients aged 65 years and over between 2003 and 2014. Han et al. (2019) reported that the length of stay after emergency admission was significantly higher by seven times among older patients with severe frailty than that of non-frail, corresponding to 61.5 million additional days of hospital stay annually following an emergency admission. Their findings suggest that overall frailty could potentially increase healthcare costs by an extra annual amount of £2,108.20 per patient living with severe frailty, estimated at £6 billion per year overall. They also found that frailty was significantly associated with increased general practice consultations (over 29 million visits), increased emergency admissions (1 million) and increased elective admissions (1.1 million) in a period covering ten years.

Evidence suggests that increased health and social care costs have also been associated with frailty in other European countries and the US. A previous review of 21 articles found

an estimated annual rise in healthcare costs per patient ranging from $8,620 to $29,910 (Alkhodary et al. 2020). Overall, Alkhodary et al. (2020) reported that costs of frailty were mainly due to hospitalisation costs, ranging between $806 and $152,726, followed by care transition costs ranging between $804 and $19,728 annual per person among frail older adults. While several studies have analysed frailty costs using a cross-sectional research design, one study analysed longitudinal data from Germany examining frailty costs among 1,636 individuals aged between 57 to 84 years and found that the total annual healthcare costs increased significantly by 101% among frail individuals compared to that of the non-frail (Hajek et al. 2018).

The combination of these findings shows that if frailty is left unaddressed, it could strain healthcare resources and jeopardise the ability to provide adequate healthcare regimes to the older population. Considering that life expectancy has increased markedly in the last decade, many more people will potentially live with some level of frailty. This means that the future economic burden of frailty is likely to be more, if not prevented or reversed. Thus, it is important to analyse and understand the associated risk factors of frailty and the results from this thesis could potentially add to the knowledge of frailty determinants.

1.6 Modifiable risk factors of frailty

Frailty has received considerable attention as an emerging concept in the last two decades and thus, some of the risk factors of frailty have been discussed in previous research (Rockwood and Howlett 2018). Although the risk factors have been mostly associated with physical frailty, evidence suggesting that frailty is multidimensional means that there is still a need for further exploration into factors that influence the mental and social components of frailty. Health behavioural factors such as smoking, nutrition/diet and physical activities have been associated with frailty (Kojima et al. 2015). These health behaviours represent habitual activities that affect health (Conner and Norman 2017; Gochman 1997) and can provide the pathway to restore, maintain or improve health among frail individuals (Conner and Norman 2017).

1.6.1 Physical activity and frailty:

Physical activity interventions have long been used as a strategy to improve the health and well-being of vulnerable individuals, including people living with disabilities and has been indicated to play a significant role in identifying individuals at risk of frailty (Walston et al. 2018). Previous research showed that sedentary individuals are twice more likely to be frail (adjusted OR = 2.80; 95% CI: 0.98–8.02) than those who are physically active in the Health, Aging and Body Composition study (Peterson et al. 2009). Another study that examined the association between frailty and physical activity among 3800 individuals aged 60 years and over found a 39% decrease in all-cause mortality among frail individuals who

are physically active (Higueras-Fresnillo et al. 2018). These findings raise important questions concerning the level of physical activities that could significantly influence health or reduce frailty.

Arguably, not all levels of physical activity would have positive health benefits for frail individuals (Rogers et al. 2017). Rogers et al. (2017) found that only the rigorous level of physical activity (not low or moderate levels) slowed down the frailty progression among individuals of all age groups who participated in the ELSA study. Generally, a larger proportion of the world's population does not meet the WHO guideline of 150 minutes/week of moderate or 75 minutes/ week of vigorous physical activity (WHO 2010) and this is even more prominent among the older population (da Silva et al. 2019). It is not clear if vigorous activity interventions can be realistically achieved for reversing frailty among older individuals, as suggested in Roger's study. Besides, Roger's study has relied on the self-reported physical activity of the participants and may not represent the actual intensity of physical activity as classified by the authors. Research has shown that physical activity interventions such as strength and aerobic fitness and balance exercise could effectively make older individuals more physically active (Heath et al. 2012). These physical activity interventions have been linked to positive health outcomes such as reduced mortality, functional autonomy and cognitive health (Heath et al. 2012). Despite the aforementioned studies suggesting an association between physical activity and frailty, there is a paucity of research on the intensity of physical activity required to reverse frailty or reduce the progression of frailty among older people. Thus, research may need to explore physical activity interventions for frail older individuals to document the intensity levels associated with frailty reduction.

1.6.2 **Nutrition and frailty:**

An adequate level of nutrition is essential for the body's defence mechanism to function optimally (Cooper and Ma 2017). Using the Mini Nutritional Assessment (MNA) scale (Guigoz 2006), a previous study on malnutrition among 2252 community-dwelling American veterans aged 65 years and over indicated that the prevalence of malnutrition was 15% (344/2252) and that a further 40% of the participants were at risk for malnutrition (Win et al. 2017). A similar result was reported from another study among older people aged 65 years in Italy which found that the prevalence of malnutrition was 16% in men and 26% in women and that 35% of men and 41% of women were at risk of malnutrition (Donini et al. 2013). Conversely, previous research including 1186 participants aged 65 years and over found the prevalence of malnutrition to be 4.8% among nursing home residents (Madeira et al. 2019). Although Madeira's study also utilised the MNA scale, the low prevalence of malnutrition obtained by the authors could have been influenced by

their decision to include only healthy participants (not confined to bed and not living with dementia) in their study.

Nutrition has been shown to play a role in the frailty development among the ageing population (Yannakoulia et al. 2017). The lack of adequate body nutrients significantly influences frailty components such as weight loss (Miller and Wolfe 2008), muscle loss/sarcopenia (Cruz-Jentoft et al. 2017), immune deficiency (Burns and Goodwin 2018) and poor cognitive function (Scarmeas et al. 2018). Also, nutritional interventions have been useful in preventing frailty development. For instance, a longitudinal study in Spain involving 1,822 community-dwelling individuals aged 60 years and over indicated that animal proteins and monounsaturated fatty acids are macro-nutrients that significantly reduced the risk of incident frailty (Sandoval-Insausti et al. 2016). Aside from macro-nutrients, micro-nutrients have also been shown to reduce frailty progression. For instance, a 75 nmol/l serum level of 25-hydroxyvitamin D has been suggested to manage and prevent physical frailty among older people (Bruyère et al. 2017). A longitudinal study involving 1100 participants aged 65 years and over who have been followed up for three years found that individuals with higher levels of micro-nutrients (vitamins B6, C, E and folates) were less likely to be frail compared to those with lower levels of these micro-nutrients (Balboa-Castillo et al. 2018).

1.6.3 **Smoking and frailty:**

Smoking has been linked to many diseases in people and shown to be significantly detrimental to health (Hackshaw et al. 2018). Although there are some controversial claims on the benefits of smoking cigarettes (Baron 1996), a meta-analysis of 55 papers by Hackshaw et al. (2018) showed that one cigarette per day significantly increased the risk of cardiovascular heart disease. As early as 1983, a report from the United States Department of Health and Human Services showed that smoking was linked to 30% of coronary heart diseases (CHD) and smokers had a 70% increased risk of mortality compared to non-smokers (CDC 1984; USPHS 1983). Many studies, including cross-sectional and longitudinal designs, have indicated that compared to non-smokers, smokers are significantly more at risk of lung cancer (Tindle et al. 2018), fracture (Hernigou and Schuind 2019), gum diseases (Leite et al. 2018), poor musculoskeletal health (Al-Bashaireh et al. 2018), depression (Wootton et al. 2020), poor cognition (Ott et al. 2004) and poor quality of life (Jia and Lubetkin 2010). The association between the smoking of cigarettes and frailty has also been established in the literature. Current smokers and past smokers aged 65 years and over were significantly more likely to be frail compared to non-smokers in the Women Health Initiative Observational Study (Fugate Woods et al. 2005). A more recent study found that smokers were significantly more likely to be frail (OR = 1.60, 95% CI = 1.02–2.51, P = 0.04) compared to non-smokers among 2,542 individuals aged 60 years and over

who participated in the English Longitudinal Study of Ageing (Kojima et al. 2018). Although many countries, including the UK, have introduced laws to address smoking in public spaces (Gibson 2017; Glahn et al. 2018), the associated burden of tobacco smoking is far from eliminated. Nonetheless, smoking is a modifiable risk factor, which makes smoking cessation interventions a viable opportunity for health promotion and health improvements (Golechha 2016).

1.6.4 Other associated risk factors of frailty

There are some other factors associated with frailty that have been previously examined in the literature. Muscle loss (sarcopenia), polypharmacy (five or more medications), gait impairment, reduced hand-grip strength, chronic inflammation and cardiovascular diseases have all been significantly associated with increased risk of frailty among the older population. While the biological factors associated with frailty have been well documented, there is a paucity of research on the psychosocial components of frailty. This currently represents a potential gap in frailty research and hence, the area of focus in this thesis. The previously examined social determinants of frailty are discussed in the following section.

1.7 Psychosocial determinants of frailty

Broadly, psychosocial factors have been suggested to contribute to the development of frailty research (Rockwood et al. 2007). This may be because the social and psychological factors are relevant in contextualising the development of frailty and how frailty influences overall health outcomes. However, there is a paucity of research that examines the social risk factors of frailty. Some of the social determinants included in the operational definition of frailty have been highlighted in **Section 1.3**. The current thesis examines the social risk factors of frailty in the context of ageism (details in the later chapters).

1.7.1 The cognitive aspect of frailty

One of the key concerns of frailty is associated with cognitive decline among older individuals (Searle and Rockwood 2015). The ability to process executive and memory tasks such as reading, remembering, thinking and attention is used to define the level of cognitive function (Lezak et al. 2004). The relationship between cognitive decline and frailty among older adults has been documented in a previous systematic review (Brigola et al. 2015). All of the 19 studies reviewed by Brigola et al. (2015) indicated that frailty significantly increases the risk of cognitive decline among older individuals. On closer observation, it appears that most of the previous studies reviewed by Brigola et al. (2015) have focused on physical frailty and cognition. The factors facilitating the association between physical frailty and cognition are unclear, considering that physical frailty mainly assesses muscle strength and body stamina (Fried et al. 2001). However, the association

between physical frailty and cognition have been consistent even when the components measured in physical frailty (**Section 1.3**) were individually examined with cognition (Alfaro-Acha et al. 2006).

While agreeing with previous research on the association between frailty and cognitive decline, Canevelli et al. (2015) has indicated the lack of adequate evidence to determine the direction of association between frailty and cognitive decline. This is important because frailty is a multidimensional concept involving multiple health domains and thus, it can manifest the other way round that poor cognitive health increases the risk of frailty among older people. For instance, a previous study that examined 942 older Mexican Americans aged 67 years and over indicated that the risk of frailty was 9% higher among individuals with poor cognitive status (Raji et al. 2010). Besides, reduced performance in the activities of daily living, which is one of the components used for assessing frailty among older adults, has been associated with poor cognitive health (Safak et al. 2019).

In 2013, a Consensus Group facilitated by the International Academy on Nutrition and Aging (I.A.N.A) and the International Association of Gerontology and Geriatrics (IAGG) proposed that beyond physical frailty, there is a new entity "cognitive frailty" that can potentially affect the health and well-being of the older population (Kelaiditi et al. 2013). The International Consensus Group proposed that cognitive frailty can be established in a person with physical frailty and cognitive impairment. Cognitive frailty may explain the mechanism behind the development of neurodegenerative diseases. This is a different approach to frailty research as previous studies have mostly focussed on frailty and cognition separately (Kelaiditi et al. 2013). Given the importance of cognitive health on the overall health and well-being of frail individuals, it will be relevant to further examine the direction of association between poor cognitive health and frailty and the combined effect of cognitive frailty among the older population.

1.7.2 Social isolation, loneliness, and frailty

The lack of social relationships has been considered as one of the psychosocial domains in frailty (**Section 1.3.2**). The social relationship plays a central role in maintaining good health and well-being (Umberson et al. 2010). The strength of individuals' social relationships is defined by their social contact and social participation (Zellweger et al. 2019). The quality of the social relationship is also associated with the social network of a person (Zellweger et al. 2019). Most often, individuals have to maintain regular contacts with members of their social network to maintain good social relationships. Social isolation objectively measures the frequency of social contact with members of the same social network and thus, isolation reflects the lack or absence of frequent contact (Fakoya et al. 2020). Individuals who maintain frequent social contacts may still have the feeling of being isolated. This subjective feeling of isolation is regarded as loneliness and reflects the

psychological interpretation of good social relationships (Berg-Weger and Morley 2020). Social isolation has been conceptually differentiated from loneliness in the literature (Fakoya et al. 2020). Social isolation is usually measured in epidemiological studies through social contacts with children or family members, social engagement in the community or associations and living arrangements (Fakoya et al. 2020). Whereas loneliness status is measured using a validated instrument, for example, the UCLA 3-item loneliness (Hughes et al. 2004).

The prevalence of social isolation among older adults aged 65 years and over was reported to be 24% (7.7 million) in previous research that analysed data from the National Health and Aging Trends Study (Cudjoe et al. 2020). Also, a systematic review of 13 papers reported that the prevalence of loneliness was 35% among 5,115 care home residents with a mean age of 84 years (Gardiner et al. 2020). Both social isolation and loneliness have been linked to different health conditions including poor cognition (Palmer 2019), chronic inflammation (Smith et al. 2020), high blood pressure (Hawkley et al. 2010) and depressive symptoms (Ge et al. 2017). Another systematic review and meta-analysis of 148 studies reported that the risk of mortality is 29% higher among those who are socially isolated and lonely compared to those who maintain good social relationships with others (Holt-Lunstad et al. 2015). Social isolation and loneliness have also been linked to frailty. One study that analysed data from 2,817 people aged 60 years and over in the ELSA study found that the risk of physical frailty significantly increased by 85% (Relative Risk RR 1.85, [CI= 1.14, 2.99]) for those who reported loneliness (Gale et al. 2018). The authors noted that although loneliness played a role in the progression of physical frailty, there was no significant association with social isolation. Another study examined social isolation and loneliness and their association with reversing frailty among 27,468 individuals aged 60 years and over (Jarach et al. 2021). Jarach's study found that a low loneliness score was significantly associated with the reversion of frailty. Nevertheless, another study by Shankar et al. (2017) that longitudinally examined data from the ELSA study reported that social isolation was significantly associated with low gait speeds among older individuals. Overall, studies on the association between social isolation and frailty are sparse and the few studies available present conflicting results. Unlike Shankar's study that only focused on the physical components of frailty, Gale et al. (2018) examined the association between social isolation and frailty using the multidimensional definition of frailty as well as the physical frailty model. Arguably, the result from Shankar's study could have been short of the true picture of frailty. This is because Shankar et al. (2017) have analysed a smaller sample size compared to Gale's study and social isolation may have been associated with the other domains of frailty not considered in Shankar's study. Nevertheless, all these studies provide the relevant background for future studies on social isolation and frailty.

1.7.3 Social support and frailty

PRISMA-7 and the Edmonton Frailty Scale (**Section 1.3**) include social support as a means of assessing the social component of frailty. Social support is one of the well-researched social determinants of health (Taylor 2011) and was described by earlier studies as "the information that leads to the feeling of being valued and cared for" (Cobb 1976) by people belonging to the same social network. Other authors have included emotional support (Schaefer et al. 1981) to define the concept of social support, although this appeared not to be consistently agreed upon (Bloom 1990). More recently, social support has been described as involving non-professional help made available to individuals through their social relationships with others, whether in formal or informal settings (Gottlieb and Bergen 2010). Previous systematic reviews reported that social support had been measured in epidemiological research as positive and negative social support (Al-Dwaikat and Hall 2017). Other measures of social support include social networks, living arrangements, cultural values and social benefits (French et al. 2018). Sometimes, social support scales are designed for specific health parameters being assessed. For instance, an 8-item social support scale is used to measure instrumental assistance and emotional encouragement for physical activity (Moser et al. 2012). Gottlieb and Bergen (2010) also reported that the Inventory of Socially Supportive Behaviours (Barrera Jr and Ainlay 1983), the Social Provisions Scale (Cutrona and Russell 1987) and the Social Support Inventory (Mitchell et al. 2003) are social support scales with good reliability and validity scores and the most commonly used in epidemiological studies.

The influence of social support on health outcomes has been documented in the literature. Social support was linked to a reduced risk of anxiety at 0.356 and 0.330 fixed and random effect sizes respectively, in a meta-analysis of 64 studies that examined the association of social support and mental health (Harandi et al. 2017). The risk of mortality was found to be significantly reduced (HR, 0.83 [95% confidence interval (CI)= 0.80–0.85]) for individuals with a high level of social support, as reported in a study that examined the American National Health Interview Survey (CDC 2020) involving 30,500 participants (Barger 2013). However, another study that analysed the British White Hall Study II (Marmot and Brunner 2005) involving 9,333 middle-aged participants (35-55 years) who were followed-up for 24-years found that low-level of social support significantly increased the risk of mortality in men (HR 1.59, [95% CI=1.21-2.08]) but not women (Stringhini et al. 2012). Generally, gender differences in health outcomes have been explained using the health-sex paradox (**Section 5.2**).

There are reports of the association between social support and frailty. Previous research examined a cohort of 558 patients using a multidimensional Frailty Index and found that the higher level of social support was significantly associated with a reduced odds ratio

(OR = 0.80, 95% [CI=0.64–0.98]) of frailty (Lurie et al. 2015). Another study reported that social support had a significant negative association with frailty (β = −0.128, 95% [CI= −0.198, −0.056]) among 637 individuals aged 65 years and over in China (Liu et al. 2020). Owing to the increased risk of adverse health outcomes among frail patients, these findings may potentially explain why individuals with low social support would be at a higher risk of mortality compared to those with a high level of social support. The combination of previous findings suggests that social determinants may be relevant in understanding the progression of frailty among the older population. Currently, it appears that there is still a knowledge gap in the social dimensions of frailty. There is a lack of adequate information on how social behaviours could put frail individuals at additional risk of adverse health outcomes.

1.7.4 **Ageism and frailty**

Ageing is central to the concept of frailty, and there is a need to understand the normal decline associated with ageing and how society perceives this (Fedarko 2011). Although biologically, the body system tends to respond slower to stimulus later in life (Fedarko 2011), individuals' rates and duration for this decline in the body defence system are different. Despite the theory of ageing decline, the increasing life expectancy shows that other cumulative factors influence how individuals age (Rockwood et al. 2007). The growth in the ageing population could be regarded as one of the achievements of humans since the last half-century. Population ageing can be interpreted as the human ability to adapt to biological changes and the resilience to environmental exposures (Fedarko 2011). Despite this successful emergence in human history, the demographic changes are sometimes perceived negatively by society leading to an increased risk of discrimination towards older individuals (Rychtařiková 2019). This negative social perception or behaviour is often because of the assumption that ageing represents vulnerability, weakness and loss of ability to function independently (Bai 2014). The negative perception of ageing has been shown to increase significantly with older population growth and could become detrimental to older adults (Nieboer et al. 2021).

The negative perception of ageing has been considered one of the origins of ageism and could explain why discrimination against older individuals might become widespread (Swift et al. 2017). Ageism is a form of systemic discrimination or stereotyping against an individual or a group of people solely because of their age (Abrams et al. 2011; Butler 1969). Swift and Abram (2016) proposed a risk of ageism model (RAM), which hypothesised that ageism against older individuals could manifest in three different circumstances, namely internalised/embodied negative ageing perception, ageing stereotype threats and age discrimination. Ageism towards older adults can be resultant from internalised negative perceptions of ageing (Levy 2009). This means that those who

have internalised the negative ageing perceptions could become ageist towards themselves. A previous longitudinal study involving 6095 Irish participants aged 50 years and over found that individuals with a negative perception of ageing were significantly more at risk of depression (Freeman et al. 2016). Older individuals may also face ageing stereotypes threat from others who have internalised negative ageing perceptions (Swift and Abram 2016). The expression of ageism in the form of age discrimination against older adults is the focus of this thesis. Older adults could experience age discrimination from individuals (micro-level), an organisation (meso-level) or a system of government (macro-level) (Iversen et al. 2009). A UK study found that one in three older individuals aged 52 years and over reported being discriminated against due to their age (Rippon et al. 2015). Rippon et al. (2015) also found that the participants in the ELSA study reported age discrimination from places such as grocery shops, recreational centres and even in a hospital setting.

The older population consists of a heterogenous mix of individuals at different spectrums of health and well-being. It may be that those frail individuals who are susceptible to diseases because of their frail state will have the characteristics that fit into the normative belief of older adults' vulnerability, thus, exposing them to a higher risk of age-based discrimination compared to their healthy peers. Age discrimination can lead to a barrier in access to healthcare (Inouye 2021) and could be much more detrimental for frail individuals in greater need of care. For instance, ageism has been reported in stroke diagnostic procedures, which led to disparities in the level of care provided to older adults (Hadbavna and O'Neill 2013). The association between age discrimination and poor health among older people have been reported in previous research (Jackson et al. 2019). There is a reason to consider that age discrimination could be associated with frailty. This is because everyday discrimination has been reported to significantly influence precursors of frailty, such as inflammation measured by increased blood levels of C-Reactive Protein, in a study involving 12,624 Americans aged 51 and older (Zahodne et al. 2019). Although, Zahodne et al. (2019) had examined perceived racial discrimination, their findings suggest that there could be a link between social discrimination (age, gender, racial or other forms of discriminations) and frailty. Additionally, age discrimination could lead to health inequalities that can aggravate frailty among older adults (Krieger 2014; Mikton et al. 2021). However, there is a lack of adequate data on how age discrimination influences frailty development among the older population. Few studies have broadly examined the association between ageism and the health of frail older individuals. The synthesis of these few studies is discussed in chapter two, which include the systematic review and meta-analysis of the existing research on ageism and frailty (**Section 2.2**).

1.8 Research objective

The rationale for this doctoral thesis is presented here after critically examining the literature to understand the concept of frailty, the associated risk factors of frailty and the detrimental effect of ageism on the health and well-being of frail older adults.

1.8.1 Rationale

Frailty is an important indicator of health and wellness in the ageing population, which may be reversible or preventable (Jarach et al. 2021). Modifiable risk factors such as sedentary behaviour and diet have been associated with frailty and used to plan frailty interventions (**Section 1.6**). While reported age discrimination has been shown to negatively influence older individuals' physical and mental health (Jackson et al. 2019), its role as a potential risk factor of frailty has not been previously established. Thus, this thesis focuses on the relationship between reported age discrimination and frailty among older adults aged 65 years and over.

Social isolation and loneliness are among the social determinants of frailty discussed in this chapter (**Section 1.7**). Although social relationships in the form of intergenerational solidarity have effectively reduced ageism (Burnes et al. 2019), there is a paucity of research on the relationship between age discrimination, social isolation and loneliness and how this relationship affects the overall health and well-being of frail older adults. Consequently, the following research questions were examined in this study.

1.8.2 Research questions

- What is the frailty trajectory among older adults aged 65+ years and is there gender disparity in frailty status among these individuals?
- Is there an association between age discrimination, frailty and health status of older adults aged 65+ years?
- Is there an association between age discrimination, social isolation and loneliness among older adults 65+ years?
- What is the role of social isolation and loneliness on the relationship between age discrimination and frailty among older adults 65+ years?

2.0 CHAPTER TWO: LITERATURE REVIEW

This chapter contains a systematic review to examine the relationship between ageism and frailty.

2.1 Chapter overview

Focus: The focus of this PhD study is to examine age discrimination as a potential risk factor of frailty and to examine if health behaviour (physical activity) or social relationship (social isolation and loneliness) play a role in the underlined factors. In the present chapter, the aim is to systematically examine the literature to understand the available knowledge on the wider concept of ageism (including age discrimination and ageing stereotypes) and frailty, specifically focusing on quantitative studies. This would provide useful information on the existing possible associations between age discrimination and frailty and the areas where the findings from this present thesis may be contributory.

Outline/Abstract: This chapter addresses the literature reviews conducted in this doctoral thesis. The section involves three main sections: (1) systematic literature review to examine the association between ageism, frailty and health of older adults (2) the sub-analysis of the review papers (3) the summary of the findings from this chapter.

The first section (2.2) addresses the systematic literature review, which provides a background to the main topic of this doctoral study. The systematic review approach was utilised primarily because of its reproducibility and the reduced risk of bias. The involved literature search mainly in five electronic databases CINAHL, AgeLine, MedLine, Psycharticle and Web of Science were explored for relevant articles. Quality appraisal of the full texts of the reviewed paper (n=14) is reported and the findings from the review are presented in section 2.2.6. Out of the 14 articles reviewed, only five examined frailty outcome and the sub-analysis of these papers were conducted in section 2.2.7. For the systematic review, the findings from all the reviewed papers were descriptively summarised. The findings from the systematic review suggest that there is an association between ageism and health of older adults. A meta-analysis of the papers was planned but could not be achieved due to data limitation. The last section (2.4) is the summary of the systematic review, where the findings are re-presented to reflect on the overall focus of this doctoral study in examining the relationship between age discrimination and the risk of frailty among older adults.

2.2 Analysing the link between ageism and frailty: a quantitative systematic literature review

An early definition by Tranfield et al. (2003), described a systematic review as an "empirical way of reviewing literature that can be reproduced and aims to reduce biases" (Tranfield et al. 2003, p. 209). A systematic review involves the identification and careful examination of all relevant literature that addresses specific objectives. Bryman (2016) further described a systematic review as involving four stages including:

1. Defined aim and scope
2. Systematic search methods

3. Appraisal
4. Analyses and Synthesis

In a systematic review, search strategies are uniquely developed to identify literature that is registered under databases of journals in different fields. Thereafter, relevant literature is extracted based on clearly defined criteria and are then critically appraised for risk of bias. The differences in the extracted literature are usually summarised or analysed to generate relevant evidence. Petticrew (2015) indicated that, in contrast to the conventional narrative review, a systematic review provides an unbiased and acceptable form of evidence from the literature. The present systematic review was deemed the most appropriate method of reviewing the relevant literature on frailty and ageism. It will foster a comprehensive understanding of the topic area and guide towards the potential gaps in the literature on ageism and frailty.

2.2.1 The rationale for a systematic review

In a systematic review, search strategies are uniquely developed to identify literature that is registered under databases of journals in different fields. After that, relevant literature is extracted based on clearly defined criteria and critically appraised for bias risk. The differences in the extracted literature are usually summarised or analysed to generate relevant evidence. Petticrew (2015) indicated that, in contrast to the conventional narrative review, a systematic review provides an unbiased and acceptable form of evidence from the literature. The present systematic review was deemed the most appropriate to review the relevant literature on frailty and ageism. It will foster a comprehensive understanding of the topic area and guide the literature's potential gaps on ageism and frailty.

Advantages and disadvantages of a systematic review

The systemic literature review is regarded as one of the top scientific evidence-based outputs in research. Although the systematic review has several advantages, some of its limitations have also been highlighted in the literature (Table 2.1).

Table 2.1 The advantages and disadvantages of the systematic literature review

Advantages	Disadvantages
Identifies relevant papers in a topic area	Can only rely on available data
Filter's information	Can miss out on important information
It is usually cheap and cost-effective	Can be time-consuming
Highlights the gaps in the literature	May focus mostly on structure rather than the quality of search
Can generate new evidence	There is a risk of missing out on unpublished data
It can be used in the formulation of policies	Quality assessment can vary
It is reproducible	The search strategy can limit output
It reduces the risk of bias	Are still subjected to the reviewer's perspectives

Source: Adapted from Bryman (2016), Haddaway et al. (2015) and Petticrew (2015)

Owing to the inherent advantages in a systematic literature review, as highlighted in Table 2.1, this approach will be utilised to examine the objectives discussed in this chapter. The aim and objectives of this review (**Section 2.2.3**) was carefully constructed to facilitate the understanding of the theoretical background underpinning the link between ageism and frailty.

2.2.2 Context

Ageism is a pervasive social issue that is implicit (self-directed) or explicit towards others (Cruikshank 2013). Robert Butler (1969) referred to ageism as systemic discrimination, prejudice, and stereotypes against an individual or group solely because of their age. Previous studies have shown that ageism is detrimental to the health of older adults (Chang et al. 2020; São José et al. 2019). This systematic review involves the synthesis of findings on the association between ageism and frailty.

2.2.3 Aim and objectives

This review examines ageism and associated health and well-being in frail, older adults in the community and institutional settings. The objectives of this review included the following:

1) To conduct a systematic literature search to identify studies that investigated the association between ageism and frailty, focusing on quantitative studies.
2) To examine the association between ageism and frailty.

2.2.4 **Methods**

This section contains a discussion of the processes conducted to achieve the objectives of the systematic review in this chapter.

Protocol registration:

This review was registered on the longitudinal register of systematic reviews (PROSPERO), and the protocol was published on June 7, 2019, with record number CRD42019135851 (**Appendix II**). This record number can be used to access the review on the PROSPERO register; the purpose of registering the review protocol is to avoid unintentional repetition of reviews, promote transparency and reduce the risk of bias (Stewart et al. 2012). The protocol registration also allows for public inquiry and verification of review details that publishers consider essential to support the integrity of a review (Moher et al. 2015).

Search strategy:

A literature search was conducted on electronic databases hosted on the EBSCO platform, available on the Robert Gordon University (RGU) library resource. The search was conducted on four main databases (AgeLine, CINAHL, MedLine and PsychArticles), and additional databases on EBSCO; namely SocIndex, CAB Abstract, MED - The Allied and Complementary Medicine Database, Business Source Complete, International Pharmaceutical Abstracts and ERIC. This was done to ensure that a comprehensive approach had been employed to retrieve all the relevant studies for the review. The search content included all the search fields: Title TI, Abstract AB, Author AU, All Text TX, Subject Term SU, Source SO, ISSN IS, ISBN IB. No limiter was applied regarding the first date of publication of literature to be included in the study. The literature search initially included all eligible papers published on or before 30 April 2019, which was later updated up until 15 October 2021 to cover recently published articles.

The search strategy was developed by identifying the relevant keywords, search terms and medical subject (mesh) headings with advice from the librarian. The search string used for searching the database is the following:

FRail* AND ("age discrimination" or agi* or age* or "age prejudice" or "self-perception* of ag*" or "age stereotype*" or "age identity") AND ("health*" or "well-being" or "wellbeing" or "well being")

Aside from the search on the EBSCO databases mentioned earlier, a further search was carried out on the Web of Science (WOS). However, additional strings were included in the search strategy on the WOS search to manage the outputs generated. The additional strings were: (NOT TI "Biomaker*" NOT TI "Animal*" NOT TI "molecul*" NOT TI "validat*" NOT TI "Case*" NOT TI "Plant" NOT TI " experiment*").

Eligibility criteria for study selection:

It is important to have clearly defined eligibility criteria when conducting a systematic review because it reduces the chances of bias and increases the validity of the review findings (Bryman 2016). Additionally, having pre-defined eligibility criteria enhances the reproducibility of a review and prevents the risk of false presentation of evidence that could arise from the over-representation of a population in a study.

Inclusion criteria for the review:

- Studies addressing ageism among the frail older population
- Studies that have been written in the English Language
- Journal articles
- Studies with participants from the community and social care settings published in Europe
- Human studies
- Studies with a quantitative measure of ageism (including cross-sectional and longitudinal designs, case-control studies, cohort studies, randomised controlled trials of non - clinical trials of interventional medicinal products (non-CTIMPs).

Exclusion criteria for the review:

- Qualitative studies
- Laboratory or experimental studies, evaluation or assessment protocols
- Case reports and randomised controlled trials of CTIMPs.
- Non-human studies
- Studies validating data collection tools
- Studies conducted outside Europe
- Studies on ageism in population less than 65 years
- All languages other than English

Study selection:

Extraction of data for this review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic review. This guideline provides an evidence-based checklist that facilitates proper execution of the review process and guides how to review the findings that should be presented (McInnes et al. 2018).

Abstract screening and inter-rater reliability:

Abstract screening is an integral part of a systematic review process and an additional level of screening that facilitates the separation of irrelevant materials during a review. This is because sometimes, the authors' title of a research publication may be misleading and may not accurately reflect the content of the study. A previous study that compared "title screening only" to "title and abstract screening" of over 2900 citations in a review found

out that, although the number of rejected citations using both approaches was the same, title and abstract screening yielded more precision overall (Mateen et al. 2013). At this stage, there was an agreement on the inclusion and exclusion criteria for the papers to be included in the review.

During the title screening, 90 articles were extracted from 1,584 outputs from the four main databases (AgeLine, CINAHL, MedLine and PsychArticle) and 40 from 3520 on other databases explored in EBSCO. Additionally, the refine options were applied to accommodate only the relevant articles. Of the 734 articles identified on the Web of Science database, 32 articles were extracted after the title screening. This amounted to a total of 162 extracted articles that were exported into the researcher's EndNote Reference Library.

Duplicate references were eliminated (30 from the EBSCO and five from Web of Science) using the duplicate tool in EndNote, leaving 127 articles. To ensure that all duplicate articles had been eliminated, a manual check was conducted thoroughly to examine the 127 articles; one article was found to have been missed out of the EndNote duplicate tool due to the disparity in the order of authors of the article as published on different databases (Cooper and Gale 2018 instead of Gale and Cooper 2018). This left the total number of articles extracted at the title screening stage at 126. At the next stage, the researcher and two independent reviewers (NT and AG) conducted an abstract screening to determine which full-text papers would be examined to determine if they were suitable to be included in this review.

The 126 articles identified by the title review were exported from the Endnote folder into a Microsoft Excel spreadsheet for abstract screening. Of the 126 abstracts screened by the researcher, eight articles were approved for the full-text review and 118 were rejected. The review team AG and NT also conducted blinded screening of the abstracts of the 126 articles, approving 11 articles for full-text review and rejecting 115 as having not met the inclusion/exclusion criteria. Thus, there was a disparity between the researcher and AG/NT concerning three articles (n=8 vs n=11) to be included in the review. These three studies were later excluded after the review team met and critically examined the focus of the studies concerning the inclusion criteria. Thus, eight studies from the database search were initially selected for review. Three additional articles were included in the review from the updated searches and additional three articles were obtained from the reference lists of the papers identified from the database search. Therefore, a total of 14 articles were eventually selected for review.

The screening of primary studies in a review could be subjective and dependent on the reviewer's perspective and knowledge of the subject area, which could affect the reliability of the review syntheses (Belur et al. 2018). One way to avoid such bias is by having well-structured criteria for retrieving the eligible papers, as done in this doctoral study. Another

way to minimise bias is to check for inter-rater reliability during the screening process (Belur et al. 2018). To assess inter-rater reliability, Cohen's kappa inter-rater reliability test was conducted using the IBM Statistical Package for Social Sciences (SPSS) version 26. Although the Jacob Cohen (kappa) statistical reliability tool has its limitations because of its ability to overestimate the level of agreement between reviewers' ratings (Grant et al. 2017), it has been widely validated and built into statistical packages. This statistical test has been suggested to have comparative advantages compared to other reliability tools such as S coefficient or Aickin's α because Cohen's kappa tool is simple to use, and it can detect marginal variation between reviewers (Zhao et al. 2013). The outcome of Cohen's statistics is reported as a range of values between 0 and 1, the greater the value the better the agreement between the reviewers on the decision to include or exclude a paper. This is also interpreted as the degree of percentage agreement that exists between the reviewers as shown in Table 2.2.

Table 2.2: Interpretation of Kappa's reliability value

Value of Kappa	Level of Agreement	% of Reliable Data
0–.20	None	0–4%
.21–.39	Minimal	4–15%
.40–.59	Weak	15–35%
.60–.79	Moderate	35–63%
.80–.90	Strong	64–81%
Above.90	Almost Perfect	82–100%

Source: McHugh (2012)

To calculate the inter-rater reliability statistic in the present review, all "Yes" values on the citation Microsoft Excel spreadsheet were recoded into "1" and all the "No" values into "0". This is consistent with the approach of conducting the kappa's statistics as reported in a previous study (Mercer et al. 2016). Additionally, this approach was necessary because the SPSS tool could only interpret information in the strings of 0 and 1. Thereafter, the Microsoft Excel spreadsheet was exported into the SPSS and the cross-tabulation analysis was carried out using the kappa statistics (See Table 2.3 & 2.4).

Table 2.3: Summary of cross-tabulation statistics during the inter-reliability test

		AG/NT		Total
		0	1	
AA	0	115	3	118
	1	0	8	8
Total		115	11	126

0 = No 1 = Yes

The kappa statistic measures inter-rater reliability calculated when two raters conduct a single rating of a sample independently or when one rater conducts two different ratings on a selection. As the case is in the present review, AA and NT/AG rated the abstracts of the studies included in the review.

Table 2.4: Kappa's statistics for inter-rater reliability

		Value	Asymptotic Standard Error [a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.830	.096	9.450	.000
N of Valid Cases		126			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The Kappa's statistics result presented in Table 2.4 show that the Kappa value for the inter-rater test in this review is 0.83, which indicates a strong agreement between the reviewers. Thus, the processes that resulted in the 14 full texts included in this systematic review can be assumed to be reliable.

Risk of bias assessment:

Assessing the risk of bias of primary studies included in a review is another critical step that defines the integrity of a systematic review. This is imperative because the risk of bias assessment usually aids the prevention of false negative or false positive outcomes that could occur as a result of inaccuracy in data computation (Viswanathan et al. 2017). Most importantly, the risk of bias assessment of studies in a review encourages critical appraisal by helping to understand the findings from the reviewed studies and guiding the interpretations of the disparities or heterogeneity among the reviewed studies. The NIH Quality Assessment Tool for Observational Cohort and Cross-sectional Studies (NIH 2019) was used for assessing the primary studies in this review, and this tool will be further

referred to as QATOCCSS for the rest of this thesis. The advantage of the QATOCCSS and why it was adopted as the tool for assessing the risk of bias in this review will be discussed in the following section. Table 2.5 also lists other quality assessment tools such as the Critical Appraisal Skill Programme (CASP) and Newcastle-Ottawa Scale that were considered and compared with the QATOCCSS.

Tools for quality appraisal:

The quality appraisal of individual papers included in a systematic review is an advantage of the systematic review over a narrative review. It is vital because the outputs of a systematic review will be largely dependent on the quality assessment and other processes such as inter-rater tests and clear eligibility criteria involved in a review (Haraoui 2016).

The quality assessment of papers in a review is not an absolute shield against bias because the use of different quality appraisal tools may lead to different results (Hoy et al. 2012). For instance, a previous study reported that using different quality assessment tools resulted in varying outcomes in a review of the same set of research articles (Jarde 2013). This emphasises the importance of using the appropriate tool to assess the quality of primary studies in a systematic review (Barkhordarian et al. 2013). Table 2.5 gives a list of quality assessment tools considered during this systematic review's quality assessment stage.

Table 2.5: Examples of Quality Appraisal tools considered in this study

Tools	Initials
Newcastle-Ottawa Scale (Bae 2016)	NOS
Critical Appraisal Skill Programme (CASP 2018)	CASP
Agency for Healthcare Research and Quality (AHRQ 2014)	AHRQ
Risk of Bias for non-randomized (observational) studies or cohorts. (Sterne et al. 2016)	ROBINS-I
Appraisal tool for Cross-Sectional Studies tool (Downes et al. 2016)	AXIS
Quality Assessment Tool for Observational Cohort and Cross-sectional Studies	QATOCCSS

Note: Only quality assessment tools for observational studies were included because all the papers included in this review were observational studies with a quantitative research study design.

The QATOCCSS was utilised for the quality appraisal of the papers in this systematic review because it provides clear guidance to support its use and it is designed to facilitate coherent

understanding of the assessment process. In the next few paragraphs, the development of the QATOCCSS and its benefits will be discussed.

Quality Assessment Tool for Observational Cohort and Cross-sectional Studies:

The National Institute of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-sectional Studies was developed jointly by methodologists from National Heart, Lung and Blood Institute (NHLBI) and Research Triangle Institute International (NIH 2019). It was developed to facilitate critical appraisal and internal validation of the components of a study. Although the NIH appraisal tool was not designed to provide numeric scores for quality rating, it included items for evaluating potential bias in study methods or implementation (NIH 2019).

The rationale for using the QATOCCSS:

The quality assessment tool for observational cohort and cross-sectional studies was developed to guide researchers to identify the potential bias that could be found in a study and contains 14 items. QATOCSS allows for reviewers to select "yes," "no," or "cannot determine/not reported/not applicable" in response to each item on the tool. For each item where "no" was selected, the tool guides the researcher to examine the potential risk of bias that could be introduced by that flaw in the study design or implementation (NIH 2019).

Furthermore, the QATOCCSS has a detailed guidance document, which was developed to assist reviewers with understanding the context of the questions on the tool items. The guidance document provides detailed descriptions and examples of the application of the items and justifications for each item's inclusion. For some items, examples are provided to clarify the intent of the question and the appropriate reviewer's response (NIH 2019). This is a significant benefit of the QATOCCSS, making it a comprehensible tool for appraising observational studies.

Additionally, unlike the NOS that has not been validated for cross-sectional studies (Luchini et al. 2017), the QATOCCSS gives clear instructions on how to use the tool for assessing different types of observational studies. Likewise, while CASP items are mainly focused on cohort studies (CASP 2018), QATOCCSS gives clear guidance on its applicability for both cohort and cross-sectional studies.

Lastly, the QATOCCSS tool was developed through a large collaboration of the Agency for Healthcare Research and Quality (AHRQ) Evidence-Based Practice Centres, the Cochrane Collaboration, the USPSTF, the Scottish Intercollegiate Guidelines Network (SIGN), and the National Health Service Centre for Reviews and Dissemination. Thus, it draws on robust critical appraisal itself and has been used widely in appraising observational studies. Nevertheless, the QATOCCSS may also be limited by the inherent inability to measure quality accurately when used by different researchers.

2.2.5 **Results**

This section contains the synthesised findings from the systematic review.

PRISMA Flow chart

The findings from this study have been reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic review (Page et al. 2021). A PRISMA flow chart representing the diagrammatic expression of the study screening and selection can be seen in Figure 2.1 and the PRISM checklist can be seen in **Appendix III**.

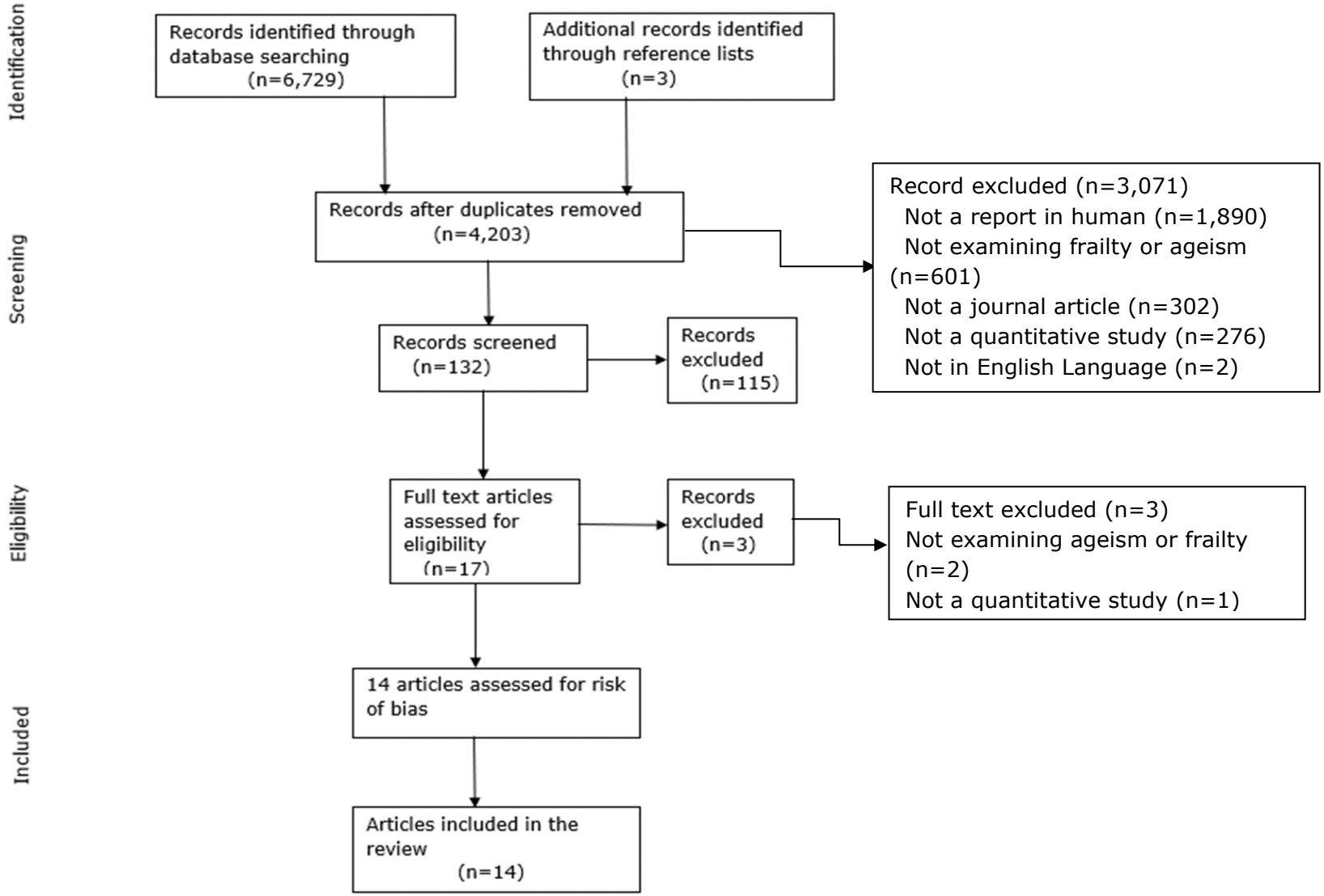

Figure 2.1: Study Selection Flow Chart for this review

The Quality Assessment Report:

Using the QATOCCSS tool, the quality of individual studies included in this study was assessed. The risk of bias was assessed based on the study design of the reviewed papers, clear aims and objectives of these studies, justification for the included population, measures of the dependent and outcome variables and adjustment potential cofounders in the analyses. Figure 2 shows the rating of the papers to the quality assessment questions. The full assessment record of the papers can be seen in **Appendix III(a).**

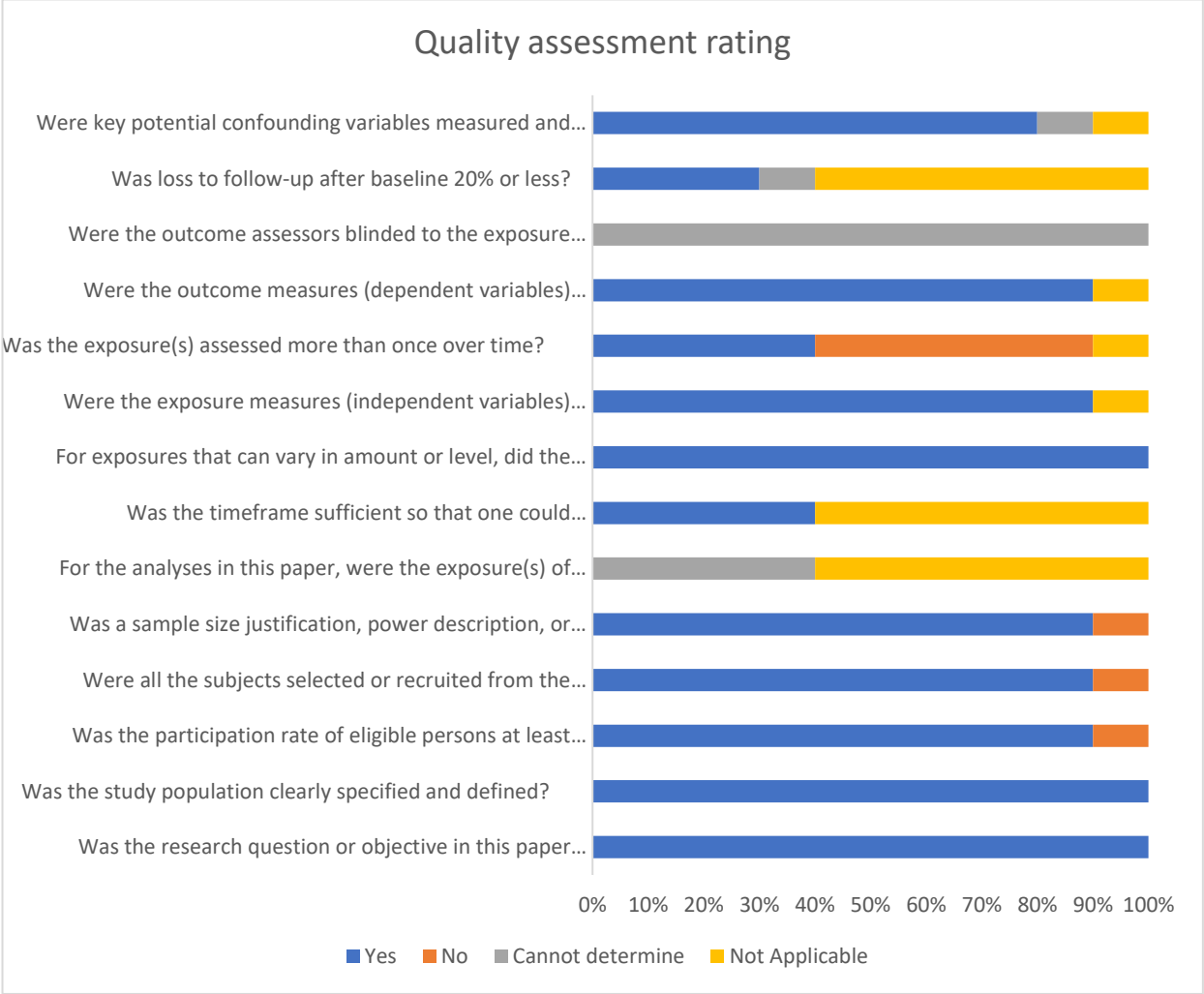

Figure 2.2: The quality assessment chart for the included papers in the review

The quality assessment of the papers was conducted and the rating of each of the papers as related to the quality assessment is visualised using a stacked bar chart (Figure 2.2). Of all the papers assessed, 13 papers were rated good and one of the papers was rated fair (Table 2.6). The summary of each of the included papers is presented in Table 2.7. This summary included the authors, study population, country, age of respondents, study design and main findings reported.

Table 2.6: Summary report of the Quality Assessment of the Full texts

Citations	Rating
Beyer et al. (2015)	Good
Bowling (2008)	Good
Buckinx et al. (2018)	Good
Gale and Cooper (2018)	Good
Kalfoss (2017)	Fair
Kornadt et al. (2021)	Good
Jackson et al. (2019)	Good
Moser et al. (2011b)	Good
Rippon et al. (2015)	Good
Robertson and Kenny (2016)	Good
Salguero et al. (2019)	Good
Vauclair et al. (2015)	Good
Warmoth et al. (2018)	Good
Ye et al. (2020)	Good

Five papers (Ye et al. 2020; Salguero et al. 2019; Buckinx et al. 2018; Gale and Cooper 2018; Warmoth et al. 2018) were found to have used comparable measures to examine the relationship between ageism and frailty outcome, so this will be discussed in detail in the sub-analysis (**Section 2.3**).

The findings from the remaining papers are summarised and discussed in section 2.2.6.

Table 2.7: Summary of participants' characteristics, study design and outcomes from the reviewed papers

Citation	Aim	Study design, Country and data date (years)	Age, data source and Characteristic of Participants	Main findings
Longitudinal design:				
Beyer et al. (2015)	To examine the notion that health behaviour acts as a mediator in the relationship between positive self-perception of ageing and health	Longitudinal, Germany (2009 - 2011)	309 Community-dwellers aged 65–85 years.	After controlling for cofounders, positive self-perception of ageing was associated with self-reported health over 2.5 years.
Gale and Cooper (2018)	To examine the effect of negative attitude to ageing on the risk of the onset or progression of frailty	Longitudinal, England 2004-05; 2006-07; 2008-09; 2010-11	3,505 men and women aged 60 years and over from ELSA.	The positive attitude to ageing (POA) was associated with a decline in the risk of becoming physically frail or pre-frail at follow-up. After adjusting for age and sex, the baseline level of physical frailty was relative risk RR 0.86 (95% CI 0.79, 0.94) for pre-frailty and RR 0.72 (95% CI 0.63, 0.83)
Jackson et al. (2019)	To examine the association between age discrimination and health and wellbeing among older adults in England	Longitudinal, England 2010-11 & 2016-17	7731 participants, aged 50+, 45% men and 55% women from ELSA	Perceived age discrimination was reported by 1943 (25·1%). Respondents who reported age discrimination were more likely to have poorer health (odds ratio [OR] 1·32 [95% CI 1·17–1·48]), coronary heart disease, chronic lung disease, arthritis, limiting long-standing illness and depressive symptoms compared to those who did not report age discrimination. At 6 years follow up, perceived age discrimination was associated with the deterioration of self-reported health (OR 1·32 [95% CI 1·10–1·58]) and incident coronary heart disease, stroke, diabetes, chronic lung disease, limiting long-standing illness and depressive symptoms over 6 years.
Warmoth et al. (2018)	To explore the relationship between older adults' perception of ageing" and frailty cross-sectionally and longitudinally	Longitudinal, England 2004-05 & 2010-11	4163 respondents at baseline, aged 50+ from ELSA	There was association between negative POA and frailty (β = .12, at p < .001). Negative POA also predicted greater frailty 6 years later (β = .03, at p < .05)

Cross-sectional design:

Bowling (2008)	To examine the quality of life of older adults based on their perceptions and self-ratings of active ageing	Cross-sectional, England	1460 older adults aged 65 years and over in the Omnibus survey.	Self-perceived successful ageing was significantly associated with the absence of long-standing illness (β −0.215; 95% CI −0.338−0.093) and good quality of life (β 0.414; 95% CI 0.303–0.525).
Buckinx et al. (2018)	To examine the effect of negative attitudes to ageing among nursing home residents on frailty status	Cross-sectional, Belgium (2013-2015)	Mean age 83.9 ± 8.19 years; 75% women, participants (n = 272).	Frail respondents had a more negative perception of aging (mean score of 80.3 ± 10.2 SD) than pre-frail respondents (83.6 ± 10.8) and robust (non-frail) respondents (86.5 ± 10.5) (p = 0.02).
Kalfoss (2017)	To describe subjective attitudes towards ageing among Norwegian older adults	Cross-sectional, Norway (Not stated)	Mean age of 77 years (60 to 91), 490 Norwegian older adults; 58% women and 41 men.	19% of participants felt both socially isolated and losing physical independence. 95% of the older adults agreed or strongly agreed to the importance of exercise.
Kornadt et al. (2021)	To examine the association between perception of ageism during the COVID-19 pandemic and the health and well-being of older adults.	Cross-sectional, Luxembourg (2020)	611 participants aged 60 to 98 years from the TNS ILRES (Luxembourg)	After controlling for age and life satisfaction before Corona, perceived ageism was negatively related to life satisfaction after the onset of the pandemic (β = − 0.30, p < 0.001) and perceived ageism was negatively related to subjective health (β = − 0.12, p = 0.004).
Moser et al. (2011)	To longitudinally evaluate the hypothesis of a relationship between self-perception of ageing and vulnerability to adverse outcomes	Cross-sectional, Switzerland (2004-2008)	1,422 participants aged 65 to 70 years. 43% of men and 57% of women.	There was a strong association between Basic Activity of Daily Living and self-perception of ageing OR 2.19 (1.43–3.36) at p<0.05.
Rippon et al. (2015)	To examine cross-national differences in perceptions of age discrimination in England and the United States	Cross-sectional, America and England (2010 -11)	4,818 respondents in HRS and 7,478 in the English Longitudinal Study of Ageing (ELSA). Age was 52+ years.	Perceived age discrimination was significantly higher in England 34.8% compared to the United States 29.1% at p<0.05.
Robertson and Kenny (2016)	To examine the effect of negative perceptions of ageing association between frailty and cognitive function.	Cross-sectional, Republic of Ireland (2009)	4135 participants from TILDA, aged 50+ years.	There was a significant association at p<0.05 between negative perceptions of aging and frailty in predicting cognition (B = −0.11, SE = .04), attention

				(B= 0.13, SE= .04) and executive function (B = −0.09, SE = .04).
Salguero et al. (2019)	To examine the association between ageist attitudes and frailty	Cross-sectional, United States (2014-2015)	381 participants from the US Department of Veteran Affairs, aged 50+ years.	There was no significant association between ageist attitudes (explicit or implicit) and frailty with OR = .98 (95% CI = .95–1.01) and OR: =.97 (95% CI = .37–2.53) respectively at p >0.05.
Vauclair et al. (2015)	To examine the association between income inequality and older people's health through reported age discrimination	Cross-sectional, 28 countries, mostly from Europe, including the UK, Israel, and Turkey (2008).	7,819 older adults aged 70 years and over, who participated in the European Social Survey.	There was a correlation between perceived age discrimination and self-rated ill-health, r = .74, p < .01 and between income inequality correlates with self-rated ill-health at r = .40, p < .05.
Ye et al. (2020)	To examine the mechanism of ageism on frailty based on the Stereotype Embodiment Theory	Cross-sectional, Shanghai China	630 community-dwelling participants aged 60 to 94 years.	Experience of ageism (age discrimination) had a significant indirect effect (β' = .360*-.456*-.576 = .095, p < .001) on frailty. Attitudes to Ageing had a direct effect (β = −.576, p < .001) on frailty.

Main findings

The main findings from the reviewed papers are presented in this section. A total of the 14 papers were synthesised in the systematic review.

Association between ageism and frailty:

Findings show that six of the 14 papers in the present systematic review measured frailty (Ye et al. 2020; Salguero et al. 2019; Buckinx et al. 2018; Gale and Cooper 2018; Warmoth et al. 2018; Robertson and Kenny 2016). Five out of these six papers (Ye et al. 2020; Salguero et al. 2019; Buckinx et al. 2018; Gale and Cooper 2018; Warmoth et al. 2018) examined frailty as the main outcome variable (**Section 2.2.6**). Among all the papers that examined frailty, only Buckinx et al. (2018) examined the association with perception of ageing (POA). The remaining five papers examined the association between frailty and attitudes to ageing (ATA).

Most of the papers that measured frailty (n=5/6) concluded that negative ATA/POA was significantly associated with a frailty condition among the older population. Only Salguero et al. (2019) reported that a negative attitude to ageing was not significantly associated with frailty. Furthermore, Buckinx et al. (2018) noted that the relationship between POA and frailty is only significant among participants with poor cognitive function. Two of the papers (Buckinx et al. 2018; Robertson and Kenny 2016) utilised only the Phenotype Frailty instrument to measure the frailty status of the participants. Two papers (Salguero et al. 2019; Warmoth et al. 2018) measured frailty using only the multidimensional frailty index (FI), while Gale and Cooper (2018) used both the Phenotype Frailty instrument and the FI. Ye et al. (2020) measured frailty using the FRAIL instrument (**AppendixIIIb**). Overall, the review findings show that 86% (n=12/14) of the papers reported a significant association between ageism and health outcomes, including poor health status, chronic illnesses and frailty (Table 2.7).

Study design:

The study design was reviewed in terms of the statistical approach and use of covariates. The papers were categorised into those that conducted cross-sectional data analysis (71%, n=10) and those with longitudinal analysis (29%, n=4). Covariates were used in the papers reviewed to examine the effect of cofounders on the relationship between the dependent and independent variables. A total of 12 papers (86%) included in this review adjusted for covariates in their analyses. It was not stated if covariates were considered by Bowling (2008), and Kalfoss (2017) carried out a descriptive analysis. The following covariates were identified in the review:

- Age (n = 10)
- Chronic conditions (n = 3)
- Depressive mood/feelings/symptoms (n = 4)

- Education/Wealth/Income/Socioeconomic Status/Socioeconomic position (n = 9)
- Ethnicity/Race (n=1)
- Gender (n = 8)
- Living arrangements (n = 2)
- Marital Status (n = 3)
- Medications (n = 2)
- Self-reported health (n = 2)
- Smoking status (n = 1)
- Work status (n = 1)

Study settings:

Among the reviewed papers, 93% (n=13, Table 2.7) included participants from community settings and 7% (n=1, Table 2.7) of the papers reviewed involved participants resident in a nursing home. Only Buckinx et al. (2018) examined the relationship between attitude towards ageing and frailty status of 272 nursing home residents. The mean age of participants in the study by Buckinx et al. (2018) was 83.9 ± 8.19 years, and their study population included mostly women, 75% (204). Buckinx et al. (2018) reported that 54 (19.9%) of the participants in their study were frail, 182 (66.9%) were pre-frail, and 36 (13.2%) were robust using the Phenotype Frailty instrument.

Attrition of Data:

Attrition of data was a common finding from the papers in this review, especially among the longitudinal studies (n = 4, Table 2.7). The lack of responses to the relevant variables (self-perception of ageing, frailty, self-reported health) accounted for the missing data in the cross-sectional papers reviewed. Jackson et al. (2019), who conducted longitudinal analyses on the Waves 5 and 8 of ELSA data, indicated that data attrition in the follow-up analyses was highly significant among the oldest old, less healthy, and less wealthy participants from the baseline data. The attrition of data in the follow-up study was 43% for Warmoth et al. (2018), 32% for Beyer et al. (2015), and the least; 28% for Jackson et al. (2019). Gale and Cooper (2018) and Jackson et al. (2019) indicated that missing observations in the analysed data were imputed for the longitudinal analyses using multiple imputation techniques.

Other findings:

There are other relevant findings from the reviewed papers that are worth mentioning. Three frailty measures (FRAIL, Phenotype Frailty and Frailty Index) were identified from the reviewed papers. Also, 11 scales and items measuring ageism components were identified from the review. The list of these measurements has been provided for further information in **Appendix III(b)**.

2.2.6 Sub-analysis of the reviewed papers

A further synthesis of the papers examining the effect of ageism on the risk of frailty was considered using a meta-analysis. A meta-analysis is a preferred method of determining pooled effect estimate and involves the collation and analysis of empirical data from two or three independent studies with similar outcomes to estimate their collective effect (Israel and Richter 2011). In addition to the advantages of a systematic review (Table 2.1), the meta-analysis improves the statistical power in the quantitative analysis of the review outcomes (Israel and Richter 2011). Also, the use of meta-analysis allows for the single estimation of the effect of the exposure variable on the outcome from the different studies or papers reviewed (Bulabula et al. 2020). However, a meta-analysis of the papers in this study was not plausible as discussed below.

Papers examining frailty outcome:

Five papers were found to have examined frailty as an outcome in this review and these papers are Ye et al. (2020), Salguero et al. 2019, Buckinx et al. (2018), Gale and Cooper (2018) and Warmoth et al. (2018). Two of these papers Gale and Cooper 2018; Warmoth et al. 2018) included longitudinal analysis. Warmoth et al. (2018) reported that there was an association between negative POA and frailty (β = .12, at $p < .001$) and Ye et al. (2020) reported that there was a significant association between positive attitude to ageing and frailty ($\beta = -.576$, $p < .001$). Buckinx et al. (2018) reported that frail respondents had lower AAQ scores (mean score of 80.3 ± 10.2 SD) compared to those who are robust (non-frail) respondents (86.5 ± 10.5) at $p = 0.02$. Whereas Salguero et al. (2019) reported that the odds ratio of frailty was 0 .98 (95% CI = .95–1.01) for those with positive attitudes to ageing and Gale and Cooper (2018) reported that the risk ratio of frailty was 0.86 (0.79, 0.94) for individuals with positive attitudes towards ageing. To conduct a meta-analysis, the effect size of the outcome variable reported in the reviewed papers must be comparable. In the case of the five papers included in this meta-analysis, the effect sizes were reported using four different measures (β coefficient, means and standard deviation, odds ratio and risk ratio). Considering the obvious disparities in the methodology of each of the papers, it was likely that there would be high heterogeneity in the result of the meta-analysis. Therefore, the meta-analysis of the papers identified in review could not be reasonably justified in line with suggestions from previous research (Ioannidis et al. 2008). Alternatively, the preliminary analysis of the pooled effect from the papers is presented in **Appendix III(c)** only for illustration.

2.2.7 **Discussion**

This systematic review aimed to identify studies that quantitatively investigated the ageism and frailty among older people, the association between ageism and frailty. After the literature search and abstract screening,14 papers were identified to have met the eligibility criteria set out a priori in this review. Kappa's inter-rater reliability statistics was 0.83, which showed a strong agreement between the main reviewer and the supporting assessors (my supervisors) on the eligibility of the chosen papers. The quality assessment of the full text was done using the NIH quality assessment of cross-sectional and observational studies tool. Findings from the quality assessment show that 93% (13/14) of the reviewed papers were rated good and only one was rated fair. Six of the reviewed papers directly examined frailty but five out the six examined frailty as the outcome of interest (**Section 2.2.6**). The findings from this review also show that 78.6% (n=11) of the papers reported a significant association between ageism (negative perception/attitude to ageing/ reported age discrimination) and the participants' health. However, the result suggests that there is limited information on the relationship between reported age discrimination and frailty.

The result showing that 78.5% (n=11) of the reviewed papers reported a significant association between ageism and poor health is consistent with findings from previous systematic reviews that examined the effect of ageism on health among the older population (Chang et al. 2020; São José et al. 2019). For instance, Chang's review of 422 studies covering a period of 25 years showed that ageism was significantly associated with a poor health outcome in 95% of the study examined (Chang et al. 2020). Although meta-analysis of the five papers that examined frailty in the systematic review was not feasible considering the disparities between the studies, all the papers individually reported significant association between ageing stereotypes (negative perception of ageing/ ageing attitudes) and frailty in older population. However, there was inadequate data on the relationship between age discrimination and frailty. To fully understand the detriment of ageism on the health and well-being of older adults, it is therefore pertinent for further analysis of the of the association between age discrimination frailty. Additionally, there was no adequate information on the mechanism of association between ageism and health. A previous systematic review and meta-analysis of 63 studies on ageism intervention by Burnes et al. (2019) found that awareness/educational training and intergenerational contact had a significant effect on knowledge of ageing (SMD = 0.42; $P < .001$) and attitudes towards ageing (SMD= 0.33; $P < .001$) using standardised mean difference (SMD). By implication, the findings from Burnes et al. (2019) also suggest that social contacts may play a role in understanding the detriment of ageism on health of older adults. Thus, it would be relevant to examine the role of social contacts and other possible covariates linking ageism and frailty.

Overall, the findings from the review show the importance of considering ageism/age discrimination as a risk factor for frailty and consolidates the possible area of contribution of this thesis to the overall body of literature on frailty prevention. While the results of the present review suggest that there could be a significant association between ageism and frailty, the limitations of the review are acknowledged. Weaknesses of the review such as the limited scope and inadequate reporting from the reviewed papers are discussed in the main discussion chapter (**Section 8.6**)

2.3 Chapter summary

This chapter examines the quality of evidence on the association between ageism and frailty. The systematic review included published articles before October 15, 2021, that quantitatively examined ageism with frailty. 14 papers were identified from the systematic review and the findings suggest that there is an association between ageism and health of older adults. Five of the identified papers examined the relationship between perception of ageing/attitude of ageing and frailty. Although the meta-analysis of the papers was not possible, all the papers concluded that there may be an association between ageism and the risk of frailty among older adults. Conversely, the review synthesis shows that there is a paucity of research on how age discrimination may influence frailty among older adults.

Thus, the research questions in this thesis (**Section 1.8**) examines the association between age discrimination and frailty to broaden the scope of previous research. Additionally, there is an analysis of gender disparities in frailty trajectory that has not be covered in the identified literature. Details of the methodology adopted in this thesis, and the data analysed is discussed in the next chapter.

3.0 CHAPTER THREE: MATERIALS AND METHODS

This chapter contains the details of the research design and statistical analyses in this thesis.

3.1 Chapter overview

Focus: The literature discussed in the previous chapter shows that while previous studies have examined the association between ageism and health among older adults, there is lack of adequate data on the mechanism linking ageism and frailty. Also, there was inadequate resources on the longitudinal relationship between age discrimination and frailty from the literature review. The focus in this chapter is to examine the association between age discrimination and frailty among older adults aged 65 years and over by using a longitudinal research design This chapter will describe the methodology adopted to answer the research questions in **Section 1.8**.

Outline: This chapter introduces the scientific processes that underpin the research approach adopted for the present doctoral study. After the chapter overview and the overall research method statement, there are three main sections within this chapter. The first section (3.3) includes a general introduction to quantitative research and the use of secondary data as the choice for the research method. It includes critical discussion on the survey research design (cross-sectional and longitudinal), the protocols involved in quantitative research studies, and secondary data analysis justification. The second section (3.4) is the material section that discusses the process of identifying the relevant secondary data for the research and the description of the English Longitudinal Study of Ageing (ELSA). The last third section is the method section (3.5), which introduces the specific procedures utilised to examine the relationship between reported age discrimination and frailty among older individuals aged 65 years and over. The methods section includes the measurements from the ELSA dataset that are included in the statistical analyses and the details of the statistical analyses conducted. There is a summary at the end of the chapter and the highlights of the next chapter are provided.

3.2 Overall study design

This prospective cohort study examines the longitudinal association between reported age discrimination and frailty among individuals 65+ in the English Longitudinal Study of Ageing (**Section 3.4**).

3.3 The quantitative research methods

Broadly, the quantitative research approach involves using numerical data to monitor or evaluate scientific observations to describe the outcomes or make inferential conclusions. The quantitative research approach can be classified into experimental and non-experimental types (Table 3.1).

Table 3.1: Experimental and Non-experimental Research Design

Non-experimental	Experimental

Descriptive research (observational and Survey design)	True experimental research (pretest/post-test only design, randomised control trials)
Correlational research	Quasi-experimental research (non-equivalent group designs or interrupted time series)
Causal-comparative research	Single-case research

Source: Adapted from (Dimitrov 2008)

Experimental research design is a type of quantitative research that involve empirical calculations generated from scientific processes. The experimental research design includes true experimental research, quasi-experimental research and single-case research (Table 3.1). This type of quantitative research is mostly conducted in natural sciences. Mitchell (2015) argued that experimental research design is the most conclusive type of research because the casual effect can be confirmed or rejected. However, it could be argued that human experiences are more intricate than the perfect or ideal situations usually simulated in experimental studies (Dimitrov 2008).

Non-experimental research is the second broad domain of quantitative research approaches, including descriptive studies, correlational studies and causal-comparative studies. The non-experimental research is also known as observational research and involves data collection from participants without any manipulation or adjustment of the independent/explanatory variables (Reio 2016). This doctoral study will involve the analysis of a survey, which is a non-experimental type of quantitative research approach (see Table 3.1).

3.3.1 **Survey research design**

Survey research design is a non-experimental type of quantitative research utilised to collect data from a sample of individuals through their responses to a set series of questions (Ponto 2015). Although the survey design is commonly categorised under the descriptive type of the quantitative research process, Frankel (2012) argues that the survey research design can be used to achieve more than descriptive characteristics of a population. This is because surveys collect information that allows researchers to examine the associations between variables (Frankel 2012; Ponto 2015). The English Longitudinal

Study of Ageing (ELSA) is an example of a survey research design that allows for inferential analysis. The ELSA study is discussed in detail in **Section 3.5**.

The survey research design can be further classified into cross-sectional studies and longitudinal studies based on the frequency of data collection from the participants (Caruana et al. 2015). In the cross-sectional survey, the data is collected at one point to study the population of interest. A population census is an example of a cross-sectional survey involving the entire population (Dimitrov 2008). One of the limitations of the cross-sectional survey is the low predictive ability of the data (Sedgwick 2014). This is because the data are collected simultaneously, and it may be challenging to establish temporal relationships between variables. Additionally, participants' responses in a cross-sectional survey can be influenced by other prevailing events around the time of the data collection. For instance, there are high chances that the prevalence of a seasonal condition can be underestimated or overestimated depending on the time of the year the data is collected.

On the other hand, longitudinal surveys aim to provide adequate information to study the relationship between variables over time (Caruana et al. 2015). In longitudinal surveys, researchers collect data from participants at different time intervals. The information collected in longitudinal surveys is useful in different ways. For instance, longitudinal surveys can be used to monitor the pattern of observations among a study population/subset of a population over time (descriptive research), or they can be used to establish the relationship between two variables (causal-comparative research). Longitudinal studies may include multiple cross-sectional surveys research designs. This occurs in longitudinal studies when different participants are recruited at successive points for the same survey, termed "repeated cross-sectional survey" (Brady and Johnston 2015). Although the repeated cross-sectional survey allows the observation of population trends like other forms of longitudinal study designs, it has been contested as a true form of longitudinal design because of the difficulty to maintain comparability and representativeness of the sample (Brady and Johnston 2015). An example of this is the Scottish Health Survey (Hamer et al. 2009), which is an annual survey that includes different samples every year among individuals living in private households in Scotland. Despite the differences in the research design under the quantitative approach, there are similarities in the characteristics of studies utilising the quantitative, as illustrated in the following section.

3.3.2 The characteristics of and processes involved in quantitative research methods

Broadly, the quantitative research method usually takes the deductive approach (Soiferman 2010) and usually follows the patterns of identifying known hypotheses through literature review, which can then be tested using collected observations to derive conclusions. Garrard (2016) posited that the research topic should be framed in the form of a question to give a clear direction of interest. After the literature review and the research objectives/questions, the study design takes the critical mass of the research process. The study design section of a quantitative research method provides a structured approach to determining sample selection, data collection, and analysis.

Data collection is a crucial step in the quantitative research procedure. Once the study population has been identified, researchers must decide how the participants' information will be collected. Conventionally in quantitative research, data is collected via questionnaires, inventories, checklists and surveys (Marsden and Wright 2010). When these tools are used to collect information directly from the participants, the information collected is termed 'primary data collection'. It has become common in health and social research for data collected primarily in a study to be re-used in future studies. This re-use of this primary data is termed 'secondary data analysis', and it is known to be effective in population-level scientific enquiry (Johnston 2017). To complete the quantitative research process, the data collected are analysed and conclusions are drawn from the results. In this doctoral study, secondary data analysis was adopted to longitudinally examine the association between reported age discrimination and frailty among older adults. The justification for utilising secondary data is discussed in the next section, which include the advantages and limitations of analysing secondary data.

3.3.3 Justification for secondary data analysis

In recent years, secondary data analysis has been conducted more frequently in health and social care research due to the increasing number of data repositories (Andersen et al. 2011). An example of such data repositories is the UK data archive (UKDS 2021). Modern scientific guidelines and principles for data management have encouraged open access to research data to promote transparency and reproducibility (Stall et al. 2019). These principles emphasise the need to improve the findability (repositories), accessibility, interoperability and reuse of data (secondary analysis).

For researchers studying the trend or development of a condition across a population, secondary analysis is an option to be considered if data already exists that fits with their research questions. This is usually beneficial as it could potentially reduce the research timeframe while achieving quality outputs. The opportunity to analyse data spanning eight

years in this thesis exemplifies the benefit of using secondary data (**Section 3.5**). The secondary data analysis allows for maximum utilisation of data that has already been collected for original studies. It may sometimes also be the only option to assess the prevalence of extreme conditions such as fatal accidents or mortality (death registry). An overview of the advantages and limitations of secondary data analysis has been documented in Table 3.2.

Table 3.2:The advantages and limitations of secondary data analysis

Advantages	Limitations
Maximum utilisation of research resources	Can potentially limit the scope of the study research questions
Foster interdisciplinary collaborations for the collection of data across diverse areas of research	May not be relevant to contemporary events or topics
Provides high-quality data with a large sample size	Although the sample size is usually large, it may contain insufficient samples for specific enquiries
Allows for longitudinal analysis	Could pose the challenge of managing large datasets
Data is usually made available in a statistical-ready format	Tools for collecting data may not have been suitable for researchers' enquiry

Source: Adapted from Vartanian (2010)

3.4 **Materials**

This section describes the processes involved in identifying the data to examine the objective of this study. It also includes a discussion on the ethical consideration and data management protocol to manage the materials utilised.

3.4.1 **Identifying the dataset for this study**

A crucial step in the quantitative research process for utilising secondary data is identifying a suitable data source itself. Researchers planning to use secondary data need to locate a dataset that will be suitable to meet the research aim and objectives. As noted in the earlier section (3.3), one of the potential challenges of secondary data analysis is that the scope of the research question may be limited by the extent and quality of the data available. Besides locating a suitable data source/dataset, another important step is to evaluate the data relevance**.** This involves checking the quality of the data in terms of the

data's initial purpose and study protocol. The data quality can be assessed by reviewing the technical report or previous publications from the data.

As one of the studies under the EuroAgeism project (EuroAgeism 2018) funded by the European Union Horizon 2020, this doctoral study addresses age discrimination and frailty at a population level. An initial effort was made to identify datasets in Scotland suitable to examine the link between frailty and age discrimination. A preliminary literature scoping was carried out in March 2019 to potentially identify suitable datasets across the UK (see Table 3.3). The datasets that were considered for this study include the Healthy Ageing in Scotland – HAGIS (Douglas et al. 2018), Care in the Last Days of Life Dataset (Schneider and Atherton 2018), Cognitive Function and Ageing Studies (CFAS 2019), Scottish Care Resource Utilisation Groups – SCRUGGS data (ISD-Scotland 2019) and the English Longitudinal Study of Ageing (Clemens et al. 2019b).

Of all the datasets considered, the English Longitudinal Study of Ageing (ELSA) is the only study that collected information on age discrimination at the time of selecting the database (November 2019). The HAGIS is currently at the pilot stage, SCRUGGS has been discontinued since 2009 for unspecified reasons, and the remaining datasets did not contain the relevant information required for the study. Likewise, the initial intent for this study was to compare the experience of age discrimination across the population of the 65+ individuals dwelling in the community and those residing in nursing homes. However, there is currently a scarcity of nationally representative data that contain complete sociodemographic and health data of both community-dwelling and nursing home residents in the UK. A study by Burton et al. (2019) that examined data from Scottish Care Home Census (1,299 care home services) between 2006 and 2011 reported that only descriptive analysis is possible with these data on care home residents in Scotland. Thus, this study will be examining the relationship between age discrimination and frailty among community-dwelling individuals aged 65+ who participated in the ELSA study.

Table 3.3: **List of the datasets considered for the proposed study**

Name	Description	Strengths	Weaknesses
HAGIS (Douglas, Rutherford and Bell 2018)	The Healthy Ageing in Scotland study included participants aged 50+ in Scotland. The study aimed to collect data on the health and socioeconomic status of 7000 respondents in Scotland. It is said that the HAGIS is the first Scottish longitudinal study on ageing. http://www.hagis.scot	a) The pilot study has been enacted with 1000 respondents collected already. b) Data linked with HMRC data, Educational data from Scotland and the Scottish Qualifications Authority and SMR data http://www.hagis.scot/media/microsites/hagis/documents/bmjopen-2017-018802.pdf	a) Only 1000 respondents recruited so far. b) No information on care home participants c) Data not publicly available yet d) No questions on discrimination.
Care in the Last days of life dataset Data (Schneider and Atherton 2018)	A dataset containing information on individuals approaching the last days of life and individuals aged 70+ normally resident in the same household in Scotland. This uses data extracted from the 2011 census linked with Death records, Cancer registry, Hospital admission records, Prescription data.	a) Data is readily available b) Could answer questions on health disparities between individuals in the community and long-term care c) Components of frailty could be possibly derived in the data to develop a frailty index for each individual d) Requires little funds to access e) Permission to access data may likely be processed quickly.	a) To use this data, the proposed study has to ans the questions linked to end of life care b) It does not have components to answer questio on age discrimination directly c) Not publicly available.

ELSA (Banks et al. 2019)	The English Longitudinal Study of Ageing (ELSA) is nationally representative data on the health and socioeconomic well-being of individuals aged 50 and older. Wave 9 is the most recent, with data collection covering 15 years. ELSA has been linked to several administrative and health records.	a) Publicly available b) Contains data on frailty, health, unmet needs, age discrimination, social circumstances of older people c) Contains respondents in community and care homes d) Contains harmonised data and is suitable for comparisons e) Very resourceful with a considerable amount of publications and theses.	Few respondents moved to care homes (n=58).
SCRUGGS ISD-Scotland (2019)	The data was collected on (a) Patients on long term admission in hospital wards and (b) Psychiatric patients in older adults' wards. Available on ISD.	Data is publicly available and resourceful for the unmet needs of older individuals residing in care homes.	a) Data available through ISD are mostly aggrega Data collection ceased since 2009 b) Does not contain data on age discrimination.
CFAS (2019)	The CFAS is a nationally representative study of 18,000 people aged over 65 years in the UK.	This dataset provides information on the health and sociodemographic of participants aged 65 years and over living in the community and care homes.	Does not have components to answer questions o age discrimination

3.4.2 Ethical consideration and data management

The ELSA data was accessed (Access date: 4/November/2019) after the ethical approval was granted in October 2019 by Robert Gordon University (RGU) School Ethics Review Panel (SERP) with approval number 19-15 (**Appendix IV**). This ethics application was necessary to ensure that the research was beneficial and minimised the risk of harm to the participants and the researcher. Consequently, the data was managed appropriately in line with the General Data Protection Regulation and the Robert Gordon University Research Governance and Integrity Policy (RGU 2019).

The SERP ethical approval (updated 19-15) was obtained in December 2020 (**Appendix V**) after the ethics application was resubmitted to include the Wave 9 of the ELSA, which became available at the time of the data analysis (November 2020). Wave 9 was included in this study to ensure the most recent information for the participants in the ELSA study were being analysed.

Data access:

The ELSA data is an anonymised dataset publicly available through the UK data archive (UKDS 2020). The ELSA data can only be accessed via registration with the UK data archive. The UK data archive requires that an intending researcher interested in downloading data or requesting data access obtain an End User Licence (EUL) by registering on the UK data archive platform. This registration is facilitated through the UK Access Management Federation (UKAMF) login. Since RGU is a registered institution under the UKAMF, the ELSA data was accessed through institutional login.

The UK data archive End User Licence (EUL) agreement requires that confidentiality is kept, data is not commercialised without prior knowledge and approval of the UK data archive, and that the data is not linked to the HSE for identification of participants or specific geographical location. All of these rules were strictly adhered to in the management of the ELSA data.

Data Confidentiality:

There is no identifiable or potential risk to participants associated with this study as all the data collected was already anonymised. The ELSA data does not contain personal identifiers, so the data outputs cannot be linked to the study participants.

Data Storage and Data Sharing:

The ELSA data file was kept on a highly secured and personalised R drive provided on RGU's secure network. The R drive is a safe and backed up network drive only accessible

via password. Thus, the data storage system can only be accessed by authorised individuals with login details. This is in line with the UK General Data Protection Regulation (GDPR) guidelines.

To prevent the occurrence of unauthorised access, the data will not be shared through any media platform. The results of the data analysis will be shared through RGU personalised R drive to provide an additional level of security for the data.

3.4.3 The English Longitudinal Study of Ageing (ELSA)

ELSA is a longitudinal study that includes participants aged 50 years and over living in England. ELSA is a harmonised dataset because it has been structured along with the Health and Retirement Study (HRS) in the US (Juster and Suzman 1995) and the Survey of Health, Ageing and Retirement in Europe (SHARE) (Börsch-Supan et al. 2013). This gives ELSA the potential to provide comparative findings with the rest of Europe. At the baseline, data collection was conducted in 2002, and participants in the Health Survey for England (HSE 1995) were recruited into the ELSA study. The researchers working on ELSA have continued to collect data from the same participants every two years since the baseline data were collected. The ELSA baseline study population consists of 12,099 participants with a mean age of 65 years (range 50 to 100 years).

ELSA data has been collected at different Waves (Wave 1 to 9) using interviewer-administered questionnaires. There are *refreshment samples* included in the study population at Waves 3, 4, 6 and 7 to maintain the representativeness of the ELSA data. The refreshment samples are individuals recruited from the HSE household who meet the age eligibility criteria of the ELSA study (50 years and over). This is necessary to avoid lack of sample representation due to non-response, mortality or increasing participants age at successive Waves of the ELSA study. ELSA samples include the core members (CM), core partners (CP), new partners (NP), young partners (YP) and old partners (OP) of the core members (Figure 3.1). The ELSA study team also conducted cross-sectional and longitudinal weightings of the data at each wave to ensure that the study maintains its representativeness. The 'system missing' data for the CP is used for the cross-sectional weighting and longitudinal weighting is achieved using the cases that have been involved in all the waves since Wave 4 (Clemens et al. 2019a). Thus, the ELSA provides quality longitudinal data that will be relevant for investigating the research questions in this study.

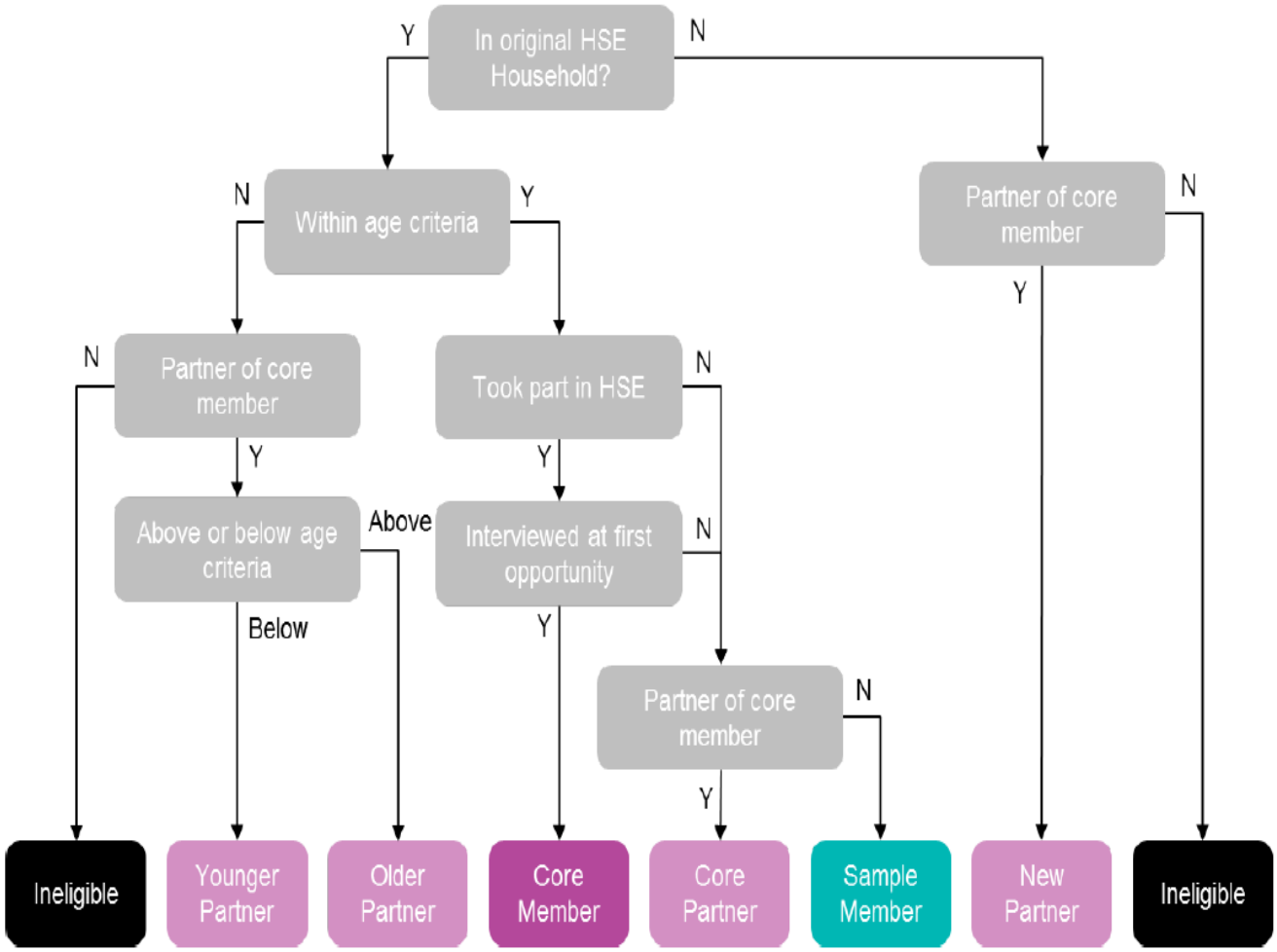

Figure 3.1: Eligible participants in the ELSA study (data user guide 2018)

3.4.4 The relevant data available in the ELSA

The secondary data analysis of ELSA from Waves 5 (2010), 6 (2012), 7 (2014), 8 (2016) and 9 (which became available in 2020) will be conducted. The ELSA study contains 150 main questions across all the Waves (1 – 9), and specific questions such as the questions on discrimination were introduced in Wave 5. Overall, the total information collected in ELSA can be categorised into (1) Demographic data, (2) Economic data, (3) Measures of Health, Disability, and Health Behaviour, (4) Psychosocial Measures, (5) Cognitive function.

This section includes a brief description of the relevant variables in the ELSA data utilised in this doctoral study. In this section, the variables are discussed as they appear in the ELSA dataset. The discussion on how the variables were managed and analysed is reported under the statistical analysis section.

Age discrimination:

The reported age discrimination variable in the ELSA was derived from the questions adopted from the HRS (2006) on perceived discrimination (Smith et al. 2017). The authors of the HRS developed their questions on perceived discrimination through the work on "racial differences in physical and mental health" (Williams et al. 1997). The information on perceived discrimination was grouped under the measures of social participation in the ELSA questionnaire. The item on discrimination was introduced and collected in Wave 5 of ELSA. Five questions on discrimination were introduced in the questionnaire to determine the participants' experiences of discrimination generally, and the subsequent questions examined the reasons for the reported discrimination. Participants were asked the following questions, which were extracted from the ELSA Wave 5 interview questionnaire (Clemens et al. 2019b):

In your daily activities, do you experience any of the following?

- Treated with less courtesy or respect
- Treated in a way to show you are not clever
- Poor service in restaurants and stores as compared to others
- Treated poorly by doctors or in hospital services, as compared to others
- You are threatened or harassed

The participants were prompted to give a response to the question on discrimination based on a 6-level Likert scale ranging from "Almost every day" (score of 1) to "Never" (score of 6). Participants that reported discrimination were further asked: "Have you been discriminated against because of your race, gender, age, financial status, weight, physical appearance, physical disability, sexual orientation or others, please specify?". The reported age discrimination variable was derived from the responses to the above-stated questions in the self-completed questionnaires.

Physical function: Physical Activities (PA), Activities of Daily Living (ADL) and Mobility Status

The physical function of the respondents in the ELSA study was measured in several ways and included variables such as PA level, ADL and Mobility status. The ADL data consists of the basic ADL and the instrumental ADL (IADL) data in the ELSA study. Respondents were asked to indicate through a self-completed questionnaire if they had difficulty with a list of activities including basic activities such as dressing, using the toilet

and eating (basic ADL), and the use of technology or appliances for activities such as preparing meals, paying bills and making calls for the IADL (**Appendix VI**). The responses to the ADL and IADL questions are coded as 0 No and 1 Yes. For the physical activity status, respondents were asked to state whether they consider themselves to be 1= sedentary, 2= low activity, 3= moderate activity or high physical activity. To assess the mobility status, respondents were asked if they experience difficulties as a result of health or physical problem using show cards. For example, respondents were asked if they had difficulties with 'walking a 100 yard'. The response for the mobility status is also coded as Yes/No. Each of the physical function variables was be utilised to calculate the frailty index (**Section 3.5**).

General health conditions:

The general health condition of the respondents was assessed in the ELSA study using self-reported health status (SRH), self-reported long-standing illnesses. Interviewer-administered questions were also used to assess doctor-diagnosed medical conditions (**Appendix VI**). The self-reported health status is widely used, and well-validated questions for examining health status in population health (Bombak 2013). The respondents were asked to rate their health status on a Likert scale of 5=poor 4=fair 3=good 2=very good 1= excellent. The self-reported limiting long term illness was assessed using the question "Do you have any disability, long-standing illness, or infirmity?" and respondents were asked if this "illness or disability" limited their activities in any way. The response was coded Yes/No.

The interviewer asked the respondents if they had been diagnosed with medical conditions such as cancer, respiratory distress or cardiovascular diseases, response coded as Yes/No (**Appendix VI**).

Social isolation and Loneliness:

Social isolation was derived in the ELSA data via respondents' marital status (not married/not cohabiting with a partner), social contacts (less than monthly contact with children, family and friends via face-to-face meetings, telephone or mail contact) and social activities (low participation in community or religious activities). Each activity was scored 0 or 1, and higher scores indicated severe social isolation. The minimum score for the social isolation variable is 0 and the maximum is 5.

Loneliness was measured in the ELSA dataset using a 3-item scale, which included the following questions (Hughes et al. 2004)

1. How often do you feel you lack companionship?
2. How often do you feel left out?

3. How often do you feel isolated from others?

The responses to the questions were 1 Hardly Ever, 2 Some of the Time, 3 Often and the aggregate score for respondents ranged from 3 to 9. Higher scores indicated severe loneliness.

Depressive symptoms and cognitive function:

Depressive symptoms were assessed in the ELSA study via an eight-item Center for Epidemiologic Studies Depression (CES-D) scale (Carleton et al. 2013; Radloff 1977). The CES-D contains questions to examine depressive symptoms such as 'felt sad' or 'unhappy' during the last week. Responses were coded as Yes or No and the total CES-D score ranges from 0 to 8. Higher scores on the CES-D suggests a greater risk of depression.

The cognitive measure included in the ELSA study covers different cognitive domains and focuses on eliciting memory and executive functions. The respondents' numerical ability, self-reported and longitudinal memory, processing speed and word-finding ability were assessed using a combination of methods such as show cards, self-reported questions and the Mini-Mental State Examination-MMSE (Zaninotto et al. 2018). The objective memory test has scores ranging from 0 to 30 and the executive function index also has scores ranging from 0 to 30. The total cognitive index was used as the cognitive variable, which has combined scores ranging from 0 to 60.

Subjective Social Status:

The subjective social status was assessed in the ELSA study was adapted from the 10-scale self-reported social status. The respondents in the ELSA were asked to imagine where they will place themselves on a 10-steps ladder, with the first step representing people worst-off in income, education, job and step 10 representing people who are best-off in the same items. The reliability and the good predictive ability of the ten levels of the SSS on health outcome has been reported in previous research (Operario et al. 2004). The social status variable in the ELSA data has been re-scaled to range between 5-wost off and 100-best off.

Sociodemographic status:

The sociodemographic variables from the ELSA study that are included in this study include age, gender and living arrangement. The ELSA data includes respondents aged 50 years and over and age was entered in the dataset as a continuous variable. The age variable is collapsed at 90 years to avoid disclosing a few individuals above this age in the ELSA study. The gender variable in the ELSA study was coded as 1 Male and 2 Female.

Frailty (derived):

The Frailty Index (FI) is used to assess frailty among ELSA respondents (Rockwood et al. 2017). The other widely published frailty assessment tool (Physical Frailty) has been discussed extensively in Chapter 2. Unlike the Frailty Index, the Physical Frailty tool assesses impairment in muscle functions and typically focuses on the physical health domain only (Gobbens et al. 2010a). The Frailty Index has been selected for evaluating frailty in this study because it is multidimensional and covers additional health domains, including physical, cognitive, and socioenvironmental aspects (Rockwood and Mitnitski 2007).

The Frailty Index scores are calculated by averaging each individual's number of deficits (impairments) in a data sample. Previous research has suggested that a variable that would qualify to be included as a deficit in the Frailty Index should satisfy five criteria (Gahbauer Evelyne et al. 2008), which have been discussed in the introductory chapter (**Section 1.3**).

Although the ELSA dataset does not contain a direct measure of frailty, a 52-item variable comprising self-reported health conditions, disabilities, eyesight, hearing, activities of daily living and depressive symptoms were used to derive the Frailty Index (**Appendix VI**). The 52-items are comparable across other studies (Gahbauer Evelyne et al. 2008; Gale and Cooper 2018) and the FI remains valid even when different types or numbers of deficits are counted (Blodgett et al. 2015).

The deficits were assigned values between 0 and 1 to generate the frailty score. The Frailty Index score was calculated by adding up the total deficits for each respondent and dividing this by 52. The output score is calculated to range between 0.0 and 1.0, where a higher score indicates severe frailty.

3.4.5 Missing data

Missing data is common in survey research due to the large samples that are usually recruited for this type of study (Wang et al. 2019). The researchers who recruit a large number of participants in a longitudinal study are generally faced with the likelihood of having an incomplete dataset. This may be because of the attrition of participants in longitudinal studies or interviewers' input error (Madden et al. 2017). In secondary data analysis, there is a need to consider the effect of missing data on the interpretation of the findings. He (2010) argues that the reuse of data with many missing values could result in inaccurate conclusions. A critical review of the literature suggests that different

mechanisms can be used to address missing data in health research, such as dropping the missing data (complete-case analysis), non-response weighting and multiple imputations (Wang et al. 2019).

In the complete-case analysis, the cases with missing information are dropped out of the analysis altogether. Although the complete-case approach may be acceptable for a small number of missing cases, it could lead to a considerable loss of vital information and false conclusions in extensive sample analysis (Zhang 2016). Sometimes, missing data can be adjusted by weighting. This is achieved by ensuring that the group with the missing data maintain sample representation after dropping the missing cases by adjusting the data with a variable of interest (He 2010). Another method of addressing missing data is through the process known as multiple imputations. In multiple imputations, the estimated values for the missing data can be generated at multiple times/iterations and the pooled average is then used in the analytical model (He 2010; Rubin 1987). Before the multiple imputations, missing cases are analysed to determine if the data are missing at random (MAR), missing completely at random (MCAR) or missing not at random (MNAR) as described by Pedersen et al. (2017). This is important because the mechanism of addressing missing data is dependent on the pattern of the missing data (Graham 2012). For instance, the monotone imputation method is appropriate if the data were missing not at random (Jakobsen et al. 2017).

The authors of ELSA have already assigned values (-9 to -1) to incomplete data to reflect the different reasons why these data were missing (Table 3.4).

Table 3.4: **Missing value codes and description in the ELSA dataset**

Code values	Description
-9	Refusal
-8	Don't Know
-4	Missing by error
-3	No valid answer
-2	Self-completion instrument not completed/Schedule not applicable
-1	Item not applicable

Source: Adapted from the NatCen (2018)

The value -2 in the ELSA data is used to identify respondents who did not return the self-completed questionnaire (SCQ). For instance, 10274 participants were issued the SCQ in Wave 5, but only 9030 returned the questionnaires. The response rate across the other waves included in this doctoral study is presented in chapter 4. The ELSA study allowed for respondents to 'refuse to answer', choose 'don't know' or skip a question as

'item not applicable'. For instance, when a respondent indicated 'no children', subsequence questions on contact with children are filled as items not applicable.

In the present study, only cases with complete participation are considered for analysis. This means that individuals who missed out in any of the five Waves of ELSA (Waves 5 through 9) are not included in the analysis. However, missing values in the complete cases are imputed using multiple imputations (**Section 4.4**). Other missing values already coded as -9 or -8 or -1 for refusal/don't know/item not applicable respectively in the ELSA data are re-coded as a 'No' response where applicable following previous research (Rippon et al. 2015).

3.5 Methods

This section includes a discussion on the procedures followed to analyse the ELSA data. These procedures include transforming variables, computation of new variables, and managing missing data, descriptive statistics and inferential statistics.

3.5.1 Study design

This study involved the secondary data analysis of the English Longitudinal Survey of Ageing (ELSA). The details of the relevant variables from the analysed ELSA data have been discussed in **Section 3.4.8**.

3.5.2 Variables derived from the questionnaire instruments:

Dependent variables

1. **Frailty**

The calculated Frailty Index scores (**Section 3.4.4**) for the respondents in the ELSA study was utilised to define the frailty status. Individuals with scores of ≥0.25 were regarded as frail following previous research (Gahbauer Evelyne et al. 2008).

2. **Social isolation and loneliness:**

The social isolation and loneliness variables will be defined using the top quintile (≥2 for social isolation and ≥5 for loneliness) as done in previous research by Steptoe et al. (2013b).

3. **Health status:**

The health status was grouped and reverse coded in the statistical analysis as 1= Poor/Fair and 2= Good/Very good/Excellent as used in previous research (Steptoe and Jackson 2018).

Independent variable

1. **Reported age discrimination:**

The reported age discrimination variable will be the main predictor in the statistical analysis. The reported age discrimination variable will be coded as 0= Not discriminated 1=Discriminated (Rippon et al. 2014).

Covariates

Age was included in the statistical model as 65 to 69 years, 70 to 74 years, 75 to 79 years and 80+ years categories as used in previous studies (Chamberlain et al. 2016). The gender variable was coded as 1 for Male and 2 = Female. The ethnicity status of the respondents was included in the analysis of this doctoral study as 1= White and 2= Non-White. The long-standing illness variable was included in the analysis and coded as 0= No and 1=Yes. The subjective social status was entered as a categorical variable using the percentile scores, which was coded as Low= $<25^{th}$ percentile; Medium= $\geq 25^{th}$ to $<75^{th}$ percentile; High= $\geq 75^{th}$ percentile following previous research (Goodman et al. 2015). The cognitive variable was derived from the global cognitive index scores of the respondents (memory + executive function) that ranged from 0 to 60 (Steel et al. 2002). The cognitive variable was entered into the statistical model as a categorical variable, where $\leq 25^{th}$ represented poor cognitive performance and $>25^{th}$ percentile represented good cognitive performance. The cognitive variable was coded as 0=Good 1=Poor.

3.5.3 Statistical software

All the analyses were conducted in the R studio. The R studio is open-source with pre-installed (base) functions and allows for installing new applications (packages) to run the desired analyses. The R studio has the function codes (e.g. summary, table and list) for displaying the content of a variable. It also allows for building statistical models to examine the association between variables. The summary function in R gives a specified variable's minimum, median, maximum, and mode values. Other functions like the "*table* or *prop.table"* functions present the counts and proportion of each observation within a variable. The following sections highlight the type of statistics conducted in this study.

3.5.4 Statistical analysis

This section introduces the statistical analyses conducted to explore the sample characteristics and to examine the association between the variables. Descriptive statistics were used to examine the baseline characteristics of the participants, which

include mean and standard deviations of the age, frailty scores, social status, social isolation and loneliness scores of the respondents. The descriptive statistics was further utilised to examine the intersection between the independent variables and the dependent variables using the cross-tabulation function. Reliability and sensitivity tests were conducted using two measures in this study. Firstly, internal consistency between the frailty scores was checked using the Cronbach reliability test as it was done in previous research (Gale and Cooper 2018). This was necessary to ensure that the multidimensional Frailty Index reliably produced consistent results for each respondent across the five Waves of ELSA data analysed. Secondly, the analyses were conducted with the outcome variables in their continuous to ensure that the categorisation of the did not change the direction of association with the independent variables as done in previous research (Steptoe et al. 2013b).

Inferential statistics, including bivariate analyses (Pearson's Chi-squared test), and the generalised estimating equation (GEE), were conducted. The Chi-squared test was used to examine the preliminary association between the variables. This is necessary to determine if there is a potential association between the variables before fitting the generalised linear models. Chi-squared tests are suitable for testing the association between two or more categorical variables. The GLM was used to cross-sectionally examine the association between the variables and GEE was used for the longitudinal analysis. The justification for these statistical methods is discussed in **Section 3.5.5**. A multicollinearity test was conducted to examine if there is a correlation between the independent variables included in the main analyses. Multicollinearity occurs if there is a high correlation between the independent variables (Daoud 2017), leading to overestimation of the effect sizes in a model and reducing the statistical power. Thus, it is relevant to check the collinearity effect to interpret the model results correctly.

3.5.5 The rationale for the GEE

Predicting one variable (outcome/dependent) with another variable (explanatory/independent) can be achieved with multivariate analysis using different statistical methods such as linear regression, logistics regression, generalised linear model and mixed models. Previous research has discussed these statistical methods and their various applications in detail (Diggle et al. 2002; Gardiner et al. 2009). While the linear regression model and the logistic regression can only accept a continuous or categorical outcome respectively, the GLM can allow for ordinal variable, continuous variable and categorical variable (Hubbard et al. 2010). Secondly, unlike the linear regression model, the GLM is flexible with the normality assumption for the outcome

variable (Schluchter 2008). Therefore, the model's parameter estimates can be achieved without emphasis on the normality assumption (Zorn 2001).

The generalised estimating equation (GEE) is a variant of the generalised linear model (GLM) that is suitable for analysing longitudinal data. A longitudinal analysis of the ELSA data was conducted using the GEE. Aside from the GEE, the mixed model and the logistic regression can also be used to examine longitudinal data (Hubbard et al. 2010). The logistic regression is not the preferred option for longitudinal analysis in this study because repeated outcomes in the logistic regression analysis are treated as independent outcomes. Previous research has shown that repeated variables in longitudinal studies are usually correlated and not independent (Hubbard et al. 2010). Thus, using logistic regression for repeated outcomes can lead to false estimation of the effect sizes in the predictive model. Another type of statistical model that can be used for longitudinal analysis is the mixed model. One of the main differences between GEE and mixed models is the level of the association between variables. GEE is a fixed effect model like the regression models, albeit a flexible form of fixed effect (Hubbard et al. 2010). The fixed effect means that the GEE assumes that only the dependent variable changes in response to the changes in the independent variable and that the values of the independent variable are constant (Gardiner et al. 2009; Salkind 2010).

Conversely, in addition to the fixed effect, the mixed model allows for changes in the values of the independent variables (i.e., subject-level variability). While the mixed model can generate information crucial to derive a deeper understanding of the participants' data, the current study was not focused on individual-level variability (Gardiner et al. 2009). Besides, the GEE has been arguably shown to reflect a true estimation of a population-level result with verifiable assumptions compared to the mixed model (Hubbard et al. 2010).

3.5.6 The predictive models with mathematical notations

As in the additive models where ($y = \alpha + \beta1X1 + \beta2X2 + \beta3X3$) represents the mathematical annotations (Ballinger 2004), in the longitudinal analysis using the GEE models, the mathematical annotation is $Yij = \alpha + \beta1X1ij + \beta2X2ij + \beta3X3ij$…. However, the GEE takes into consideration the correlation within-subject data in the outcome variable by using the marginal mean outcome μij, which is $\mu ij = \Sigma(Yij)$.

Thus, the GEE marginal model specifies that a relationship between μij and the covariates Xij is written as $g(\mu ij) = Xij\beta$ or mathematical annotation written as $\mu ij = \alpha + \beta1X1ij + \beta2X2ij + \beta3X3ij$…, where α is the intercept, β is the coefficient, X is the covariate for each subject 'i' at jth number of responses and g is the link function.

Considering that the GEE utilises marginal mean, the variance estimate is a population level estimate (Odueyungbo et al. 2008). There are three main types of known link functions used in GEE and written as g(μij) = μij "Identity link" for continuous outcome, g(μij) =log [μij / (1- μij)] "Logit link" for categorical outcome and g(μij)=log(μij) "Log link" for count outcome variables (Leung et al. 2009).

In this study, the GEE models were conducted for each outcome variable (frailty status, self-reported health status, social isolation and loneliness). The outputs were reported as odds ratio at 95% Confidence Interval and P-value <0.05 representing the significant association. The fitness of the models was determined via the residual variance, which shows the amount of variance in the outcome variables attributable to the independent variables—the lower the residual variance, the better the model. Gender disparities in frailty trajectory was determined firstly by plotting mean frailty scores of the respondents from Waves 5 through to 9 on a line graph and conducting a GEE analysis to examine the association between gender and frailty in the study population.

The association between reported age discrimination and frailty was conducted longitudinally using the GEE models. The GEE analysis involved future frailty (Waves 6 to 9) as the outcome variable. There was further longitudinal analysis to examine the association between reported age discrimination and frailty development among the non-frail population. The non-frail population are those that had <0.25 frailty index scores at baseline (Wave 5). The association between reported age discrimination and self-reported health status of the respondents in the ELSA data was also examined. Just like the frailty outcome, the future risk of poor health status (Waves 6 to 9) was examined using the GEE model. The health status variable was entered into the model as a binary outcome (0=good/very good/excellent; 1=poor/fair).

The association between reported age discrimination and social isolation and reported age discrimination and loneliness was examined separately using the GEE models in a similar method described in the previous paragraph. The outcome variables (social isolation and loneliness) were entered into the model separately as categorical variables. The GEE was used to examine the longitudinal analysis of the future risk of social isolation and loneliness (Waves 6 to 9).

Age, gender, long-standing illness, cognitive status, social status and educational status were included in all the models as covariates to adjust for confounding effects. All the independent variables were introduced into the models in a stepwise approach.

3.5.7 **Mediation analysis**

The role of social isolation and loneliness on the relationship between reported age discrimination and frailty was examined using mediation analyses. Although physical activity was initially planned to be included as a mediator, it was later dropped due to data limitation (**Section 7.4**). The social isolation and loneliness variables were used as potential mediators to examine further the effect of reported age discrimination on the frailty outcomes of the ELSA participants. The potential mediators were conceptualised as shown in the conceptual model (Figure 3.2). A mediator is a type of variable that can be used to explain the indirect effect of an independent on a dependent variable. The mediation analysis can be used to describe the process linking the independent and dependent variables (Baron and Kenny 1986; Hayes 2009). Mediation analysis can be adapted for cross-sectional and longitudinal data to demonstrate the indirect effect between the independent and dependent variables (MacKinnon et al. 2007). Figure 3.2 illustrates the type of mediation analysis suggested by Baron and Kenny (1986).

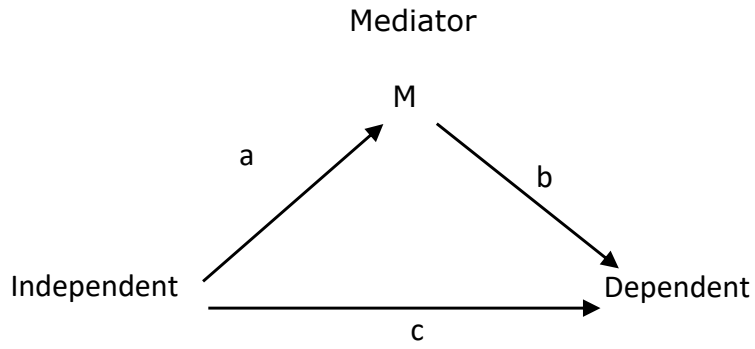

Figure 3.2: The Conceptual Mediation Model (Zhao et al. 2010)

This study hypothesised a priori that respondents who reported age discrimination were likely to become socially isolated or lonely or less physically active, which could then increase their frailty risk (**Section 7.4**). The mediation analysis in this study was conducted using regression analysis and bootstrapping approach in the R software to examine the indirect effect of reported age discrimination on the frailty scores of the respondents via each of the potential mediators (social isolation, loneliness and physical activity). The associations between reported age discrimination at (Wave 5) and the social isolation, loneliness and frailty scores at Waves 6 to 9 were analysed. This was done to examine an exposure/independent variable before the outcome of interest (MacKinnon et al. 2007). The Sobel test was used to examine the significance of the indirect effect of reported age discrimination on frailty. The Sobel test is a form of a t-

test to determine if there is no statistical difference between the *total effect* of an independent variable on the outcome variable and the *direct effect* of the independent variable on the outcome variable after adjusting for the potential mediator (Preacher and Hayes 2008).

3.6 Chapter summary

This chapter started with a broad introduction to quantitative research and the types of quantitative research. There was a focus on the non-experimental type of quantitative research and a discussion on the use of survey research design. The justification for using secondary data was discussed and the process leading to the choice of the ELSA data to examine the research questions in this thesis. Finally, the method section included measurements used in this doctoral study and an explanation of the statistical analyses that were conducted to examine the relationship between reported age discrimination and frailty. Using the longitudinal quantitative design and the mediation analysis, it is expected that this thesis will be able to examine if age discrimination is a potential risk factor of frailty among older adults. Thus, temporal associations would be examined using the reported age discrimination and frailty variables in the ELSA datasets. However, the study design also recognises that the association between age discrimination and frailty can be non-causal and a need to adjust for possible confounders in explaining the narrative all through the thesis

In the next chapter, the results of the statistical analyses conducted using the ELSA data are presented. This includes the baseline sample characteristics and the significant predictors of frailty and social participation between Wave 5 and Wave 9 of the ELSA cohort.

4.0 CHAPTER FOUR: RESULTS OF THE DESCRIPTIVE ANALYSIS

Analysis of the sample characteristics and prevalence of the outcome variables using descriptive and bivariate statistics.

4.1 Chapter overview

Focus: The overarching focus of this thesis is to examine age discrimination as a potential risk factor of frailty. This chapter predominantly presents the descriptive results of the analysis described in chapter three. This is crucial to understand the data pattern, missing values and to test preliminary associations between the variables of interest. The aim is to determine factors that are associated with frailty among the covariates in the ELSA data, based on the prior discussion of frailty determinants identified in the literature review (chapter) and those already established in the literature (chapter one). The expectation is that the findings from the present chapter would show if age discrimination, including other covariate(s), is a potential determinant of frailty that can be analysed further in a multivariate analysis.

Outline: Chapter four presents the results of the analyses conducted to examine characteristics of the older individuals aged 65 years and over in the ELSA data. Section 4.2 describes the participants' response rate from Waves 5 through 9 of the ELSA data. The following section (4.3) contains the total number of responses analysed in this study. The participants in the baseline data (Wave 5 of the ELSA) were followed up for eight years and the corresponding data for the same participants were merged across the Wave 5 to 9 of the ELSA data using the participants' unique identification number. Section 4.4 contains information on the missing values in the cases and variables. The summary of the missing data analysis and the visualisation of the pattern of the missing data is also presented. Section 4.5 contains the result of the reliability and multicollinearity test. Section 4.6 presents the result of the baseline characteristics of the sample study. This includes the percentages and counts of cases in each of the independent and outcome variables analysed. The following section (4.7) consists of the results of the bivariate analyses to test the association between the independent variables and the outcome variables. Pearson's Chi-squared test was utilised to examine the association between categorical variables and the result for each of the outcome variables is reported in separate Tables (4.4 to 4.7). Section 4.8 contains a brief discussion of the findings from the descriptive and bivariate analyses. There is a summary at the end of the chapter and the highlights of the following chapter are presented.

4.2 The response rate in the ELSA study

In the ELSA study, participants were issued self-completed questionnaires as part of the data collection process. Preliminary analysis showed that 9,030 individuals returned the questionnaire in Wave 5, representing 88% of the total sample population (Table 4.1).

In the subsequent Waves of the ELSA included, the response rates were lower than for the baseline data; 85%, 85%, 86% and 86% for the Waves 6, 7, 8 and 9, respectively.

Table 4.1: Overall response rate in the ELSA study Waves 5 to 9

Wave	Computer-Assisted Personal Interview (CAPI) response, N	Self-Completed Questionnaire response rate.
5	10,274	9,030 (88%)
6	10,601	8,997 (85%)
7	9,666	8,197 (85%)
8	8,445	7,222 (86%)
9	8,736	7,502 (86%)

Source: Analysis of the ELSA data Waves 5 to 9

In the ELSA study, individuals who did not return the questionnaires were coded as *schedule not applicable* and identified with the number (-2) in the data frame.

4.3 **The analysed sample**

Data files were merged to capture the same respondents who participated through all five waves of ELSA. This was done by merging the respondents' unique ID through Wave 5 to 9 using the merge function in R studio software. Of the 10,274 individuals who responded to the CAPI in the baseline data (Wave 5), 8999 (87.5%) respondents remained in the ELSA study at Wave 6. There was further attrition of participants in the subsequent data collection points, which included 7,675 (74.7%), 6,575 (64%) and 5,665 (55%) baseline respondents in Waves 7, 8 and 9, respectively. Further analysis to examine the reasons for the attrition was not possible. However, this may have been due to morbidity, mortality or disinclination to continue with the ELSA study.

Among the 5,665 cohort members who participated in the ELSA Waves 5 through to 9, a total of 2,530 (44.6%) individuals aged 65 years and over completed the computer-assisted personal interviews (CAPI). However, only 2,385 participants completed both the CAPI and the self-completed questionnaires (SCQ). This leaves the study population at 2,385, which is equivalent to 94.3% of the selected cases (2,385/2,530).

The study population (n=2,385) also represents 44.4% of the participants aged 65 years and over at Wave 5 of ELSA (n=5,377). A total of 2,992 individuals aged 65+ years at the baseline (Wave 5) were dropped-out for reasons including loss to follow-up, risk of disclosure and incomplete data. Preliminary analyses show that the mean age and standard deviation of the study population and the drop-out group were 71.9±5.27 and 75.3±6.7 respectively. The results show that there was a significant difference in the age of individuals in the drop-out sample compared to those included in this study ($t = 20.159$, $df = 5167.7$, $p\text{-value} < 0.01$). Only a slight difference in gender composition

with 53.4% female in the drop-out group compared to 55.8% female in the study population. A higher percentage of people who dropped out (66.6%) reported long-standing illness compared to the (55.4%) among the study population. Reported age discrimination was reported by 35.9% in the dropped-out group compared to the 38.5% among the study population. **Appendix VI(a)** shows the characteristics of the dropped - out cases, while the remainder of the chapter focuses on the study population included in further data analysis.

4.4 The missing data report

The missing values among the 2,385 responses in the study were examined using the Visualisation and Imputation of Missing Values "VIM" package in the R studio. Figure 4.1 contains the respective pattern of missing values in the selected variables. The independent variables included in this study had missing values of less than 1%. The highest percentage (17 %) of missing values among the outcome variables was in the social isolation and loneliness variables at Waves 9. All missing values were imputed before the main analysis.

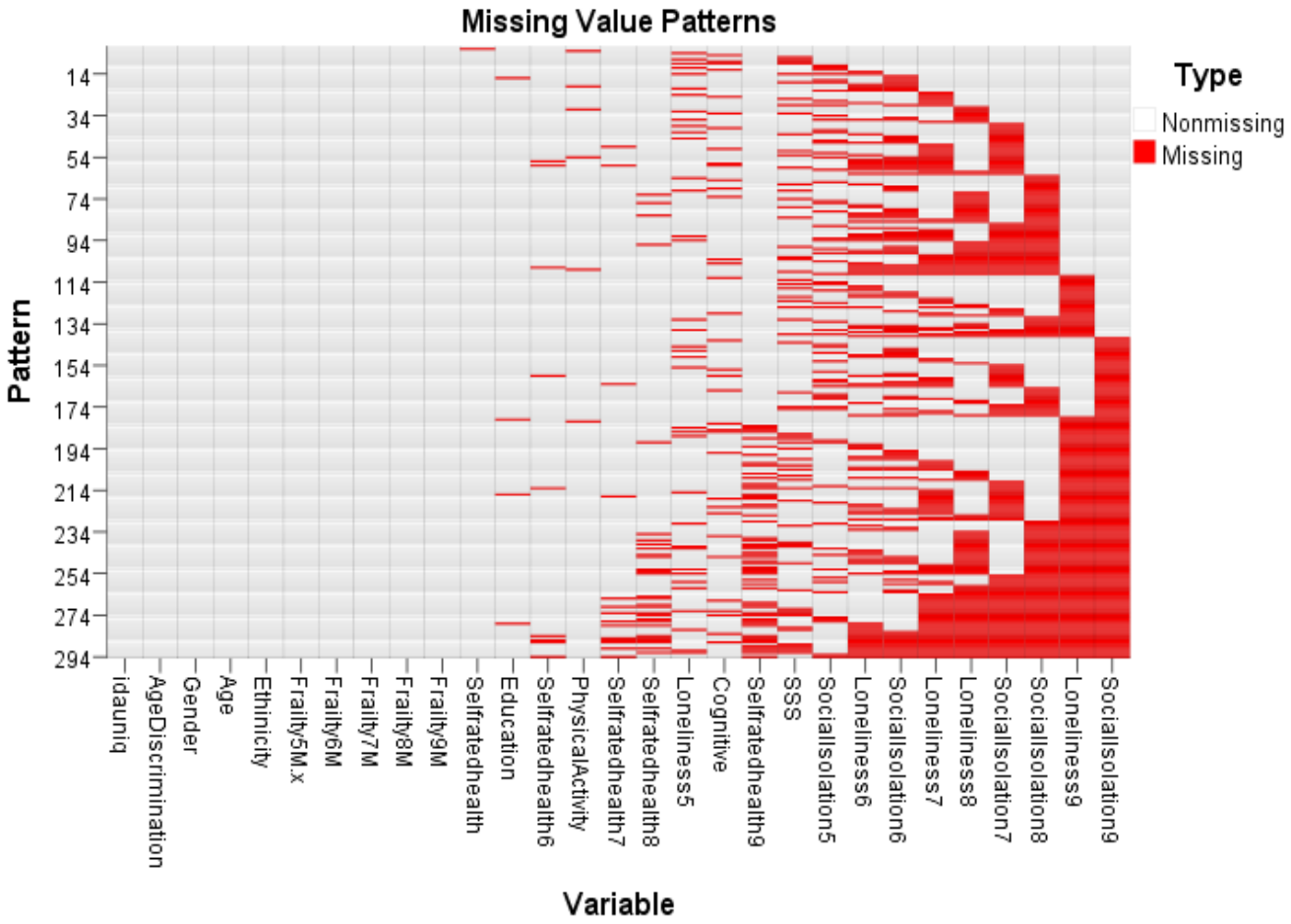

Figure 4.1: Missing value pattern for the study population (n=2385)

Figure 4.1 is a visual representation of the pattern in the missing values across the variables in the study population. The grey area shows the area covered by the variables without any missing values. The red areas represent the missing values in each of the relevant variables. It can be observed that there is no specific structure to the distribution of the missing values in the study population (the missingness does not appear to have affected all the variables in the same way). This type of missing data pattern is referred to as missing not at random (MNAR).

The Frailty Index scores had no missing values and the self-reported health variable had missing values less than 5% all through Waves 5 to 9. Multiple imputations are recommended for MNAR and the missForest package in the R studio was utilised to impute missing values for the study population before the data analysis.

4.5 **Reliability and Multicollinearity results**

The Cronbach reliability test shows a high level of consistency in the frailty index scores of the respondents in the ELSA data (Cronbach alpha = 0.94, 94%). The multicollinearity results in Table 4.2 show that the tolerance values for the independent variables were all above 0.8 and the variance inflation factors were <10, suggesting that there was no collinearity between the independent variables (Alin 2010).

Table 4.2: Multicollinearity tests showing the tolerance values and variance inflation factors for the variables analysed in the ELSA data

Coefficients			
Model		Collinearity Statistics	
		Tolerance	VIF
1	Age Discrimination	.976	1.024
	Gender	.928	1.077
	Cognitive status	.886	1.128
	Education level	.832	1.201
	Age	.930	1.075
	Social status	.902	1.108
	Long-standing illness	.979	1.021

a. Dependent Variable: Frailty

4.6 **The baseline sample characteristics**

The minimum age in the study population is 65 years and the maximum age is 89 years. The mean age and standard deviation (SD) are 71.9 years (SD± 5.27). The results in Table 4.3 show that 55% of the respondents were female, corresponding with sample representation in the overall ELSA study.

Table 4.3: The baseline characteristics of the study population (n=2385)

Variables	N	(%)
Age		
65 to 69	940	(39.4)
70 to 74	742	(31.1)
75 to 79	460	(19.3)
80+	243	(10.2)
Gender		
Female	1331	(55.8)
Male	1054	(44.2)
Age discrimination		
No	1469	(61.5)
Yes	916	(38.5)
Self-reported health		
Poor/Fair	495	(20.8)
Good/V.Good/Excellent	1890	(79.2)
Long-standing illness		
Yes	1322	(55.4)
No	1063	(44.6)
Frail (≥0.25)	288	(12.1)
Social Isolation (≥2)	773	(32.3)
Loneliness (≥5)	695	(29.2)
Cognitive status		
Poor (<26)	482	(20.2)
Good (≥26)	1903	(79.8)
Subjective social status		
Low	413	(17.3)
Medium	1127	(47.3)
High	845	(35.4)
Educational level		
Highly skilled	805	(34)
Skilled	759	(32)
Low skilled	821	(34)
Ethnicity		
White	2342	(98)
Non-white	43	(<2)

Source: Analysis of the ELSA Waves 5 to 9

The result presented in Table 4.3 shows that 38.5% of the respondents reported age discrimination. Most of the respondents (79%) considered their health status good/very good/excellent, although 55% of the sample reported a long-standing illness. Frailty was measured with a cut-off of Frailty Index (FI) score ≥ of 0.25, which found that 12% of the study population were frail at baseline. The mean FI scores for Waves 5 to 9 were 0.15 (SD±0.07), 0.16 (SD±0.08), 0.17(SD±0.08), 0.18 (SD±0.08) and 0.19 (SD±0.09), respectively. The minimum and the maximum FI scores are 0 and 0.65, respectively, in the study population. A greater percentage (32%) of the respondents were categorised

as socially isolated compared to 29% who reported loneliness. The baseline descriptive analyses also show that 17% of the respondents reported poor social status and 20% were considered to have poor cognitive status using the cognitive memory and executive function test. The educational status shows that 34%, 32% and 34% are low skilled, skilled, and highly skilled. The majority of the respondents (~98%) were from a white ethnic background, while the non-white made up less than 2% of the study population. Therefore, the ethnicity variable was not included in the subsequent analysis. This is because the small sample in the non-white group could lead to an inappropriate interpretation of the influence of the ethnic grouping on the outcome variables.

4.7 **Results of the bivariate analyses to test the association between the variables**

The association between the following variables: reported age discrimination, age, gender, subjective social status, education, long-term illness, and cognitive status of the respondents was tested for the frailty status, social isolation status, loneliness status and health status at baseline. Pearson's Chi-squared non-parametric test was conducted for the bivariate analysis, and the results are presented in Tables 4.4 to 4.7.

Table 4.4: Baseline association between the independent variables and frailty outcome (n=2,385)

Variables	Non-Frail n=2,097 (%)	Frail n=288 (%)	P-value
Age			<0.01
65 to 69	859 (40.96)	81 (28.12)	
70 to 74	658 (31.38)	84 (29.17)	
75 to 79	397 (18.75)	67 (23.27)	
80+	187 (8.91)	56 (19.44)	
Gender			<0.01
Male	961 (45.83)	93 (32.29)	
Female	1136 (54.17)	195 (67.71)	
Age Discrimination			<0.01
Yes	780 (37.20)	136 (47.22)	
No	1317 (62.80)	152 (52.78)	
Long-standing illness			<0.01
Yes	1051 (50.12)	271 (94.10)	
No	1046 (49.88)	17 (5.90)	
Cognitive status			<0.01
Poor	391 (18.65)	91 (31.59)	
Good	1706 (81.35)	197 (68.41)	
Subjective social status			<0.01
Low	337 (16.07)	76 (26.39)	
Medium	976 (46.54)	151 (52.43)	
High	784 (37.39)	61 (21.18)	
Educational level			<0.01
Highly skilled	734 (35.00)	71 (24.65)	
Skilled	695 (33.14)	64 (22.22)	
Low skilled	668 (31.86)	153 (53.13)	

Source: Analysis of the ELSA Waves 5 to 9

The result of the Pearson's Chi-squared test in Table 4.4 shows the relationship between the independent variables and the frailty status of the respondents at baseline. The result shows a significant difference in the frailty status by age, gender, social status, educational level, cognitive status, presence of long-standing illness and reported age discrimination at $p < 0.01$. The findings show that the majority (67.7%) of the frail individuals were women. Details concerning the gender disparity in the frailty trajectory across Waves 5 to 9 of ELSA is presented in **Chapter 5**. Within the frail individuals, 94.1% reported long-standing illness. A higher percentage of 52.4% and 26.4% among those who reported medium and low social status were frail compared to the 46.5% and 16.1% who were not frail. The bivariate analysis shows that among those who reported age discrimination, 47.2% were frail compared to the 37.2% who were not frail. Also, amongst those with poor cognitive status, 18.6% were non-frail compared to 31.5% who

were frail. Frailty prevalence was higher among respondents in the 75-79 years and 80+ years categories at baseline.

Table 4.5: Baseline association between the independent variables and social isolation outcome (n=2,385)

Variables	Social isolation No n=1,612 (%)	Yes n=773 (%)	P-value
Age			<0.01
65 to 69	671 (41.63)	269 (34.80)	
70 to 74	492 (30.52)	250 (32.34)	
75 to 79	307 (19.04)	153 (19.79)	
80+	142 (8.81)	101 (13.07)	
Gender			> 0.05
Male	707 (43.86)	347 (44.89)	
Female	905 (56.14)	426 (55.11)	
Age Discrimination			<0.05
Yes	633 (39.27)	283 (36.61)	
No	979 (60.73)	490 (63.39)	
Long-standing illness			<0.01
Yes	877 (54.40)	445 (57.57)	
No	735 (44.60)	328 (42.43)	
Cognitive status			<0.01
Poor	288 (17.87)	194 (25.09)	
Good	1324 (82.13)	579 (74.91)	
Subjective social status			<0.01
Low	249 (15.45)	164 (21.22)	
Medium	729 (45.22)	398 (51.49)	
High	634 (39.33)	211 (27.29)	
Educational level			<0.01
Highly skilled	600 (37.22)	205 (26.52)	
Skilled	495 (30.71)	264 (34.15)	
Low skilled	517 (32.07)	304 (39.33)	

Source: Analysis of the ELSA Waves 5 to 9

The result of the Pearson's Chi-squared test in Table 4.5 shows the association between the independent variables and the social isolation status of the respondents at baseline. There was a significant difference in the social isolation status by age, social status, educational level, cognitive status, presence of long-standing illness at $p < 0.01$ and reported age discrimination at $p < 0.05$. There was no significant difference in the reported social isolation between both genders. Of note, social isolation was higher among respondents who did not report age discrimination at baseline. A higher

percentage of respondents living with long-standing illness (57.6%) and poor cognitive status (25.1%) were socially isolated, compared to 17.9% and 54.4% respectively who did not report social isolation. Also, socioeconomic status was significantly associated with social isolation among individuals with low/medium social status and educational qualifications.

Table 4.6: Baseline association between the independent variables and Loneliness outcome (n=2,385)

Variables	Loneliness No n=1,690 (%)	Yes n=695 (%)	P-value
Age			<0.01
65 to 69	676 (40.00)	264 (38.00)	
70 to 74	544 (32.19)	198 (28.48)	
75 to 79	323 (19.11)	137 (19.71)	
80+	147 (8.70)	96 (13.81)	
Gender			< 0.01
Male	815 (48.22)	239 (34.39)	
Female	875 (51.88)	456 (65.61)	
Age Discrimination			<0.01
Yes	581 (34.38)	335 (48.20)	
No	1109 (65.62)	360 (51.80)	
Long-standing illness			<0.01
Yes	875 (51.88)	447 (64.32)	
No	815 (48.22)	248 (35.68)	
Cognitive status			<0.01
Poor	310 (18.35)	172 (24.75)	
Good	1380 (81.65)	523 (75.25)	
Subjective social status			<0.01
Low	252 (14.91)	161 (23.17)	
Medium	752 (44.50)	375 (53.96)	
High	686 (40.59)	159 (22.87)	
Educational level			<0.01
Highly skilled	599 (35.44)	206 (29.64)	
Skilled	545 (32.25)	264 (37.99)	
Low skilled	546 (32.31)	225 (32.37)	

Source: Analysis of the ELSA Waves 5 to 9

The result of the Pearson's Chi-squared test in Table 4.6 shows the relationship between the independent variables and the loneliness status of the respondents at baseline. There was a significant difference in the loneliness status by age, gender, social status, educational level, cognitive status, presence of long-standing illness and reported age discrimination at $p < 0.01$. A higher percentage of those who reported loneliness were women (65.6%) compared to men (34.4%). Among those who reported loneliness,

64.3% had long-standing illness compared to 35.7% without long-standing illness. Table 4.6 shows that 24.75% among those with poor cognitive status reported loneliness compared to the 18.35% that did not report loneliness. Among those who reported age discrimination, 48.2% reported loneliness compared to the 34.38% who did not. There was also a significant difference in the loneliness status of the respondents based on their subjective social status (Table 4.6).

Table 4.7: Baseline association between the independent variables and self-reported health status (n=2,385)

Variables	Self-reported health Good n=1,891 (%)	Poor n=494 (%)	P-value
Age			<0.01
65 to 69	768 (40.61)	172 (34.82)	
70 to 74	593 (31.36)	149 (30.16)	
75 to 79	351 (18.56)	109 (20.06)	
80+	179 (9.47)	64 (12.96)	
Gender			< 0.01
Male	862 (45.58)	192 (38.87)	
Female	1029 (54.42)	302 (61.13)	
Age Discrimination			<0.01
Yes	700 (37.02)	216 (43.72)	
No	1191 (62.98)	278 (56.28)	
Long-standing illness			<0.01
Yes	893 (47.49)	429 (86.84)	
No	998 (52.51)	65 (13.16)	
Cognitive status			<0.01
Poor	329 (17.40)	153 (30.97)	
Good	1562 (82.60)	341 (69.03)	
Subjective social status			<0.01
Low	285 (15.07)	128 (25.91)	
Medium	871 (46.06)	256 (51.82)	
High	735 (38.87)	110 (22.27)	
Educational level			<0.01
Highly skilled	700 (37.02)	105 (21.26)	
Skilled	608 (32.15)	151 (30.57)	
Low skilled	583 (30.83)	238 (48.17)	

Source: Analysis of the ELSA Waves 5 to 9

The result of the Pearson's Chi-squared test in Table 4.7 shows the relationship between the independent variables and the self-reported health status of the respondents at baseline. There was a significant difference in the self-reported status by age, gender, social status, educational level, cognitive status, presence of long-standing illness and

reported age discrimination at $p < 0.01$. The prevalence of poor self-reported health among the respondents in the baseline study population was 20.7%. Among the respondents that reported age discrimination, 43.7% reported poor health status compared to the 37.0% that reported good health status. There was a significant association between long-standing illness and report of poor health at $P<0.01$. Individuals with poor cognitive status were found to have reported a higher percentage of poor health (30.9%) compared with good health status (17.4%). The result also shows that low educational qualifications and poor social status were significantly associated with poor health status at $P<0.01$.

4.8 Discussion

This chapter examines the baseline characteristics of the study population, and it also includes the bivariate analysis of the relationship between the independent variables and the outcome variables using the Wave 5 of ELSA data (Sections 4.3 and 4.4). The main findings from this chapter show that the prevalence of reported age discrimination among individuals aged 65 years and over in this study was 38.5%. The baseline prevalence of loneliness was 29.2% and 32.3% of the respondents reported social isolation at baseline. Frailty prevalence was 12% among the study population at baseline (Wave 5). The findings from the bivariate analyses suggest that there is a significant association between age discrimination and the outcome variables (frailty, self-reported health, loneliness and social isolation).

Previous studies have compared the prevalence of age discrimination among countries (Bratt et al. 2018; Han and Richardson 2015; Rippon et al. 2015; Vauclair et al. 2015). For example, Rippon et al. (2015) indicated that reported age discrimination is higher among older adults aged 50 years and over in England (34%) compared to those in the US (29%). Another study that analysed age discrimination among the participants of the ELSA study indicated that the prevalence of age discrimination was 27% (Jackson et al. 2019). This is lower compared to the prevalence of age discrimination (38.5%) found in this study. While Rippon et al. (2015) and Jackson et al. (2019) both analysed the ELSA data, their study involved a younger population (52 years and over). Considering that age discrimination was mostly reported by individuals aged 65 years and over in the ELSA study (Jackson et al. 2019), it is expected that the prevalence of age discrimination in the present study should be higher. Although findings from this chapter already show an association between age discrimination and all the outcome variables (frailty, self-reported health status, social isolation and loneliness), further analysis is undertaken in chapters 5, 6 and 7, where the variables are examined extensively.

The prevalence of frailty has become a major factor in describing the susceptibility of an ageing population to poor health outcomes. Previous research suggests that frailty prevalence can be determined using the mean frailty index scores as well as cut-off points (Theou et al. 2014). The findings from this study show that the mean frailty score (0.15) at baseline for individuals who participated in the ELSA study was lower compared to the average mean (0.17) reported in 11 European countries from a previous study that analysed the 2004 SHARE data (Hoogendijk et al. 2020b). Previous research was found to have examined the prevalence of frailty in the British population (Gale et al. 2014; Pradhananga et al. 2019). Pradhananga et al. (2019) examined the prevalence of frailty among older adults aged 65 years and over in London. The authors extracted over 13,000 electronic health records from the National Health Service (NHS) and analysed the prevalence of frailty using the electronic Frailty Index (eFI) scores of their sample. Pradhananga et al. (2019) reported that the frailty prevalence among older residents in London was approximately 18%. Another study involving the UK population found that the prevalence of frailty was 14% among 5,450 individuals aged 60 years and over who participated (Gale et al. 2014). The findings from this study show that the baseline prevalence of frailty was 12% using the 0.25 cut-off point for the frailty scores for the respondents in the ELSA. This is lower than the values reported by both Pradhananga et al. (2019) and Gale et al. (2019). However, the combined frailty prevalence across the five Waves of ELSA analysed in this study was found to be 17%. Cross-sectional analysis of prevalence can be misleading due to the possibility of measurement error or bias related to the time of the event. Thus, it is plausible to assume that the average frailty prevalence in the present study will be around 17%, which is consistent with findings from Pradhananga's study. This further strengthens the argument for the longitudinal approach utilised in this study. Although Gale et al. (2014) also employed a longitudinal research design and reported that frailty prevalence was 14% in the ELSA study, they have measured frailty among a younger population (60+ years) compared to the present study (65+ years), using the Phenotype Frailty instrument (Fried et al. 2001) which only accounts for physical frailty. Besides, the Phenotype Frailty instrument is known to generate a lower prevalence of frailty compared to the multidimensional Frailty Index used in this study (Blodgett et al. 2015). Generally, the prevalence of frailty is challenging to compare across studies due to the methodological differences in the way frailty is assessed (**Section 1.3**). Nonetheless, Gale et al. (2014) acknowledged that the prevalence of frailty in their study increased with age. Further analysis of frailty trajectory across the five waves of ELSA analysed in this study is presented in Chapter 5, including gender disparity in frailty outcome.

The prevalence of social isolation and loneliness was also examined in this chapter. The findings show that 25.3% and 32.3% of older adults aged 65 years and over reported social isolation and loneliness in the ELSA data. A report of social isolation and loneliness from the analysis of 2010, 2012 and 2014 European Social Survey showed that the average prevalence of social isolation was 18% (75 million) and loneliness was 7% (30 million) among adults in 24 European countries (Barjakovà et al. 2018). The report further showed that the prevalence of social isolation was highest in Greece (43%) compared to Portugal (9%). Data from the NHS Scotland and the 2017-18 Welsh National Survey respectively showed that 11% of Scottish adults often feel lonely and 16% of Welsh adults reported loneliness (Griffin 2010; Welsh-Gov 2018). The findings suggest that the social isolation and loneliness prevalence is higher among the respondents in the ELSA data compared to data reported from both Scotland and Wales. Older individuals are at risk of social isolation and loneliness because of factors such as living alone, chronic illness and the loss of their social networks (Fakoya et al. 2020). This may explain why individuals in the ELSA reported a higher prevalence of social isolation and loneliness compared to the average prevalence reported for the total adult population (18+ years) in Scotland and Wales. The disparity in social isolation and loneliness prevalence could also be due to social desirability bias, which happens when people only report a favourable social condition for themselves (Grimm 2010). This is often the case in large studies using direct self-rating measurement for social isolation and loneliness (Victor et al. 2005). The risk factors of social isolation and loneliness, such as chronic illnesses, social status and living arrangements, have been documented in the literature (Grenade and Boldy 2008; Klinenberg 2016). Social isolation and loneliness have been associated with poor physical and mental health among the older population (Holt-Lunstad et al. 2015). In this study, the result of the Chi-squared test found a significant association between reported age discrimination and loneliness/social isolation. Further discussion on the relationship between age discrimination and loneliness/social isolation is available in the next chapter.

Lastly, this chapter includes the baseline analysis of the reported health status of the study population. This study found that four out of every five respondents in the ELSA study rated their health as good/very good or excellent. The baseline prevalence of poor/fair self-reported health in this study (20.8%) is lower compared to the 40% prevalence reported in a previous cross-sectional study that examined the association between poor self-reported health and depression among a primary care population involving 2555 participants from Finland (Rantanen et al. 2019). The higher prevalence reported in Rantanen's study could have been because the participants in their study were living with chronic conditions (Type 2 diabetes and cardiovascular diseases). This is the case with findings from this study, which showed that 86% of those who reported

poor health were those who reported long-standing illness. Rantanen et al. (2019) also found that individuals who reported poor/fair self-reported health were significantly at risk of depression. However, another study suggested that physical functioning compared to mental or social function is a greater determinant of self-reported health status among 20,000 adults after analysing the European Prospective Investigation of Cancer study (Mavaddat et al. 2011). The predictors of poor self-reported health among older adults aged 65 years and over who participated in the ELSA data are discussed further in **Section 5.4**. However, the result of the bivariate analyses in this chapter suggests a significant association between reported age discrimination and poor self-reported health status at baseline (Wave 5).

4.9 **Chapter summary**

This chapter includes the results of the descriptive statistics to describe the baseline characteristics of the study population. The prevalence of frailty among the ELSA participants is consistent with the findings from previous literature, confirming the burden of frailty on the older population as described in the introduction chapter and the reason it is important to examine the modifiable risk factors of frailty. The bivariate analyses showed significant associations exist between reported age discrimination and frailty among the ELSA participants. While this is suggestive of a relationship between age discrimination and frailty, there is no indication that the association is temporal or causal. Thus, there is a need for further analysis to the determine the level of association. This provides the basis for the multivariate analyses in the next chapter. The next section is chapter 5, and it the generalised estimating equations conducted to examine the frailty trajectory of the sample and the influence of reported age discrimination on the frailty status of the respondents.

5.0 CHAPTER FIVE

Analysis of the relationship between age discrimination, frailty and health status

5.1 Chapter overview

Focus: While findings from the previous chapter suggest that there is a significant difference in frailty outcome among those who reported age discrimination and those who did not, there is a need to examine if the association is confounded by other known determinants of frailty. The present chapter focusses on addressing the research questions to determine if reported age discrimination and gender are risk factors of frailty among those who participated in the ELSA study using multivariate analysis. This will be potentially relevant for understanding frailty burden and to recognise the detrimental effect of age discrimination for the older population.

Outline: This chapter details the data analyses and findings on the relationship between reported age discrimination and frailty. There are four main sections in this chapter addressing the research questions, and each of these sections is presented in a format to include a brief background to the research question, the analyses conducted, the results generated and discussion of the findings. There is an overall introduction to the content of this chapter, which is immediately followed by the investigation of gender differences in frailty trajectory in section 5.2. The frailty trajectory was visualised on a line graph using the mean frailty scores for both genders from baseline through the follow-up period. Section 5.3 addresses the relationship between age discrimination and frailty. The frailty outcome was split into future frailty and incident frailty. The relationship between age discrimination and self-reported health status is discussed in Section 5.4. This chapter ends with a summary of the findings and the highlight of the next chapter.

5.2 Gender disparity in frailty trajectory

The objective here is to examine if there are significant gender differences in the Frailty Index scores of the respondents. Gender disparities have been suggested to influence health outcomes (Hubbard and Rockwood 2011) and thus, it is crucial to understand the trajectory of frailty outcomes for both genders (Male and Female).

5.2.1 Research question

- Is there gender disparity in the frailty trajectory among older adults 65 years and over in the ELSA study?

5.2.2 Procedure

A line graph was utilised to visualise the mean frailty scores by gender across the five time-points (T1 to T5) corresponding to the ELSA data from Waves 5 through to 9. The

GEE model was used to examine the effect of gender on frailty outcomes. The frailty outcome across the five Waves of ELSA was pooled into a single variable in the GEE analysis as repeated data. The outcome variable was dichotomised into 0= Not-Frail and 1= Frail, which was entered into the model formula as a factor variable. The GEE model was built as following binomial regression and exchangeable correlational structure.

GEE Logit Model specified as:

Logit (μ ij) = α + β1 Gender

μ ij = marginal mean frailty outcome for each subject 'i' at jth time-points, j= Waves 5 through 9.

The summary function in the R software was used to print the results of the fitted model.

5.2.3 **Results**

The trajectory in frailty across the time points in the study population is shown in Figure 5.1. The graph showed that the mean frailty scores for both genders increased continuously from baseline (T1) throughout the 8years follow-up period.

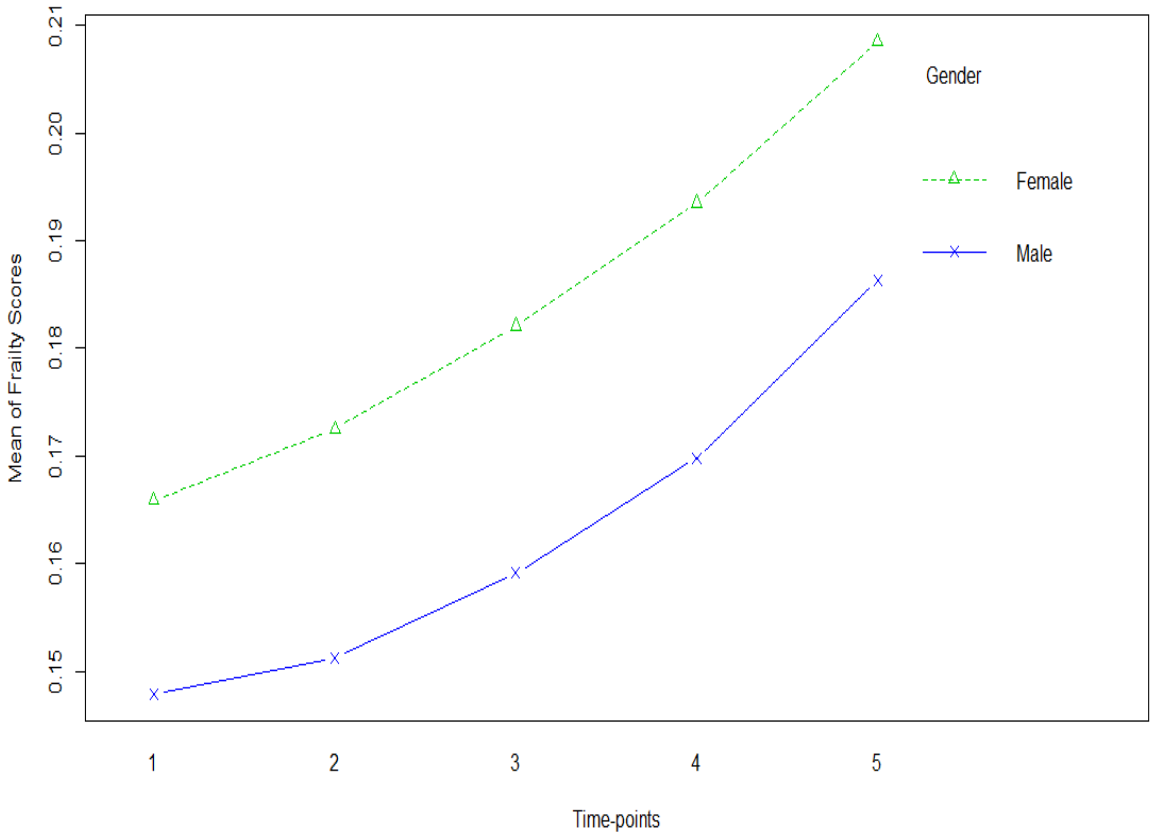

Figure 5.1: Frailty trajectory in the study population (n=2,385) from Waves 5 through to 9.

It can be observed from the frailty trajectory lines in Figure 5.1 that women had higher mean frailty scores than men from baseline to time-point five. The result of the binomial GEE model to examine gender association with frailty outcome is shown in Table 5.1. The result demonstrates gender difference in the frailty outcome covering the 8years follow-up period. The findings from the GLM model suggest that women were significantly at higher compared to men at $P < 0.01$ for the period combined.

Table 5.1: Multivariate analysis using the generalised linear model to examine the relationship between gender and frailty using the pooled observations across the five time-points

Variables	Odd Ratio (OR)	95% CI Lower	95% CI Upper	P-value
(Frailty)				
Female	1.73	1.57	1.91	<0.01

Source: Analysis of the ELSA Waves 5 to 9

Reference group: Male

The male gender was the reference group in the GLM model. The result (Table 5.1) showed that there was a 73% increase in the odds of frailty outcome for the female population in the study population compared to men. This means that women were significantly more likely to be frail compared to men in the eight years follow-up period. The association between gender and frailty outcomes has been further examined in the presence of other probable predictors of frailty (**Section 5.3**).

5.2.4 Discussion of findings in Section 5.2

There is a need to understand the specific health needs of each gender to plan health and social care delivery appropriately. The results from the analysis in this section depict the risk of frailty progression among male and female English older adults aged 65 years and over.

The overall mean Frailty Index (FI) score for women (0.18) is significantly higher compared to the mean FI score for men (0.16) from the pooled data in this study in the eight years analysed. The findings from this study suggest that women are at higher risk of frailty compared to men. The result of the analysis from this study is consistent with the findings from previous studies (Gordon et al. 2017). There are possible reasons suggestive of the pattern of frailty outcome in both genders and one potential explanation is the women-men "health-survival paradox" (Gordon et al. 2017). It has

been documented in the literature that women have a higher life expectancy compared to men. For instance, the Office for National Statistics data showed that the 2017-2019 average life expectancy at birth for men and women in the UK is 79.4 years and 83.1 years, respectively. Although globally, there are few exceptions to this, women in South Asia have been shown to have lower life expectancies compared to their male counterparts owing to maternal mortality and excess mortality in female children (Kennedy et al. 2020). While women generally have a longer life span, paradoxically, men tend to have better health status later in life than women (Kingston et al. 2014). A previous study suggested gender differences in health and well-being among older adults by comparing data from 11 European countries, the UK and the United States (Crimmins et al. 2011). The authors reported that, compared to men, women were more likely to have poor health such as depression, chronic illnesses, conditions limiting functionalities and arthritis. It is thus possible that the cumulative effect of morbidities in women has contributed to their overall frailty scores in this study.

Gender disparities in health and well-being among older adults have also been linked to life-course socioeconomic inequalities. Previous studies have reported that wealth gaps exist between both genders, with women earning lesser than men due to underrepresentation in the labour market (Sierminska et al. 2010) and reduced access to resources that can ensure financial security (Denton and Boos 2007). Similarly, other studies have suggested that individuals with poor SES are more likely to be frail compared to those with high SES when the educational status is used as a proxy for SES (Franse et al. 2017; Hoogendijk et al. 2014). This is consistent with the findings from the present study, suggesting that there is an association between frailty and the educational status of older adults aged 65 years and over (**Section 4.7**). Despite the relatively high prevalence of frailty among the female gender, it has been argued by Hubbard and Rockwood (2011) that women are more resilient and likely to cope longer with frailty compared to men due to their genetic makeup.

To explain the higher risk of frailty in women, Hubbard and Rockwood (2011) also proposed that the physiological reserve needed to tackle the deleterious effect of ageing could have depleted over the life course due to childbearing. Previous studies have reported that fertility can negatively impact the health and well-being of women later in life. This means that women in countries with higher fertility rates would be expected to have higher frailty prevalence. Although it would be interesting to examine the claim by Hubbard and Rockwood (2011) even further, it is currently outside the scope of this study.

In conclusion, the findings from this study suggest that there is a significant difference in the frailty trajectory between men and women. The result showed that older women in

the ELSA study were more likely to be frail compared to men. Factors such as the health-survival paradox, fertility and inherent genetic makeup have been attributed to the variability in the frailty outcome in both genders, but the higher frailty experienced by women could be an interaction between these factors.

5.3 Age discrimination as a predictor of frailty

5.3.1 Introduction

This section aims to examine reported age discrimination and frailty outcomes in the study population. This section involves three major data analyses:

1) Multivariate analysis of the association between reported age discrimination and future-frailty outcome (Waves 6 to 9)
2) Multivariate analysis of the association between reported age discrimination and incident-frailty (Waves 6 to 9)

The incident-frail is the future-frailty outcome but among a subset of the study population who were not frail at baseline. The non-frail population are defined by the Frailty Index cut-off point of <0.25.

5.3.2 Research question

- Is there an association between reported age discrimination and frailty?

5.3.3 Procedure

The generalised estimating equation (GEE) models were utilised to examine the relationship between age discrimination and the outcome variables (incident-frailty and future-frailty). The main analysis in all the models was between reported age discrimination and frailty outcome. The covariates (age, gender, cognitive status, long-standing illness, social status and educational level) were included in the model to adjust for possible confounding effects. The frailty outcomes were included in the GLM and the GEE models as categorical variables (Frail or Non-Frail). For the GEE, the data frame was structured in a long format and thus, the dependent variables were analysed as a repeated outcome in a single variable. The result is reported for both the unadjusted and adjusted models, including all the confounding variables.

The GEE models were fitted using exchangeable correlation structure:

Logit (μ ij) = α + β1 Age Discrimination ---------- (Unadjusted model)

Logit (μ ij) = α + β1 Age Discrimination + β2 Gender + β3 Long standing illness + β4 Cognitive Status + β5 Social Status + β6 Educational level ----------(Adjusted Model)

μ ij = marginal mean frailty outcome for each subject 'i' at jth time-points, j=4 (Waves 6 through 9).

The summary function in the R software was used to generate the results of the fitted model. The logit coefficient estimates generated in the model were converted into odd values using the exponential function *(exp (coefficients (Modelfit)*. The confidence intervals were generated using the *confint* function in R.

5.3.4 **Results**

This section includes the results of the binomial GEE models to determine the influence of age discrimination on the frailty outcomes; future-frailty and incident-frailty. The odds ratio (OR) at 95% confidence interval from the GEE analyses are presented in Tables 5.2 and 5.3.

Future frailty (frailty progression):

In the GEE model, a total of 2,385 cases were analysed to examine the relationship between the age discrimination at (Wave 5) and the future-frailty outcome (Wave 6 to 9). The predictor and confounding variables were also entered into the model in a stepwise approach for the GEE. The results of the adjusted and the adjusted model of the GEE are presented in Table 5.2.

Table 5.2: Multivariate analysis using the generalised estimating equation to longitudinally examine the relationship between age discrimination and frailty (future-frailty)

Variables	OR [95% CI] Unadjusted	P-value	OR [95% CI] Adjusted	P-value
Age discrimination	1.62[1.46-1.80]	<0.01	1.49[1.33-1.67]	<0.01
Age categories (70-74)			1.15[1.00-1.33]	<0.01
(75-79)			1.71[1.46-1.99]	<0.01
(80+)			3.71[3.09-4.44]	<0.01
Gender (Female)			1.52[1.34-1.71]	<0.01
Long-standing illness (Yes)			5.44[4.74-6.27]	<0.01
Cognitive status (Poor)			1.42[1.24-1.62]	<0.01
Social Status (Medium)			1.51[1.31-1.74]	<0.01
(Low)			1.93[1.63-2.28]	<0.01
Education (Skilled)			1.19[1.02-1.39]	<0.01
(Low-skilled)			1.89[1.62-2.19]	<0.01

Source: Analysis of the ELSA Waves 5 to 9

*Reference group: Age discrimination (No), Age (65-69), Gender (Male), Long-standing illness (No), Cognitive status (Good), Social status (High), Education (Highly skilled).

The unadjusted and adjusted GEE results in Table 5.3 show that reported age discrimination significantly predicted frailty outcomes over the eight years analysed in this study. The predicted frailty outcome in the GEE represents the average frailty scores of the respondents across the eight years. The findings from the GEE showed that all the baseline predictors were significantly associated with future frailty outcomes at P <0.01. The group that reported age discrimination at baseline were significantly more likely to be frail compared to those that did not report age discrimination. Unlike the baseline frailty, the older group of respondents were significantly frailer compared to the reference group (65-69). Long-standing illness was significantly associated with future frailty outcomes of the respondents, OR 5.44[4.74-6.27] at 95% CI. The odds of frailty outcome in the group with long-standing illness was five times higher compared to the group without long-standing illness. Women had a higher risk of future-frailty outcome (OR, 1.52[1.34-1.71]) compared to men and the group that had poor cognitive status were more likely to be frail in future compared to those with good cognition add ORs. Respondents with low social or educational status were significantly more at risk of frailty compared to those in the high socioeconomic groups.

Incident frailty (frailty development):

The last GEE model conducted for the frailty outcome is the analysis of the incident frailty as shown in Table 5.3. A total of 2,097 cases were analysed in this section, representing the population of the non-frail individuals at baseline using Frailty Index score <0.2. The objective here is to examine the influence of reported age discrimination on future frailty development among individuals who were not frail at baseline. The incident frailty outcome represents the development of frailty between Waves 5 to 9.

Table 5.3: Multivariate analysis using the generalised estimating equation to longitudinally examine the relationship between age discrimination and new frailty development (incident-frailty)

Variables	OR [95% CI] Unadjusted	P-value	OR [95% CI] Adjusted	P-value
Age discrimination	1.50[1.31-1.72]	<0.01	1.38[1.19-1.60]	<0.01
Age categories (70-74)			1.15[0.95-1.39]	0.13
(75-79)			1.76[1.44-2.15]	<0.01
(80+)			3.96[3.16-4.95]	<0.01
Gender (Female)			1.34[1.15-1.56]	<0.01
Long-standing illness (Yes)			3.34[2.85-3.93]	<0.01
Cognitive status (Poor)			1.20[1.01-1.44]	0.03
Social Status (Medium)			1.53[1.28-1.83]	<0.01
(Low)			1.65[1.33-2.06]	<0.01
Education (Skilled)			1.45[1.19-1.77]	<0.01
(Low-skilled)			1.84[1.51-2.25]	<0.01

Source: Analysis of the ELSA Waves 5 to 9

*Reference group: Age discrimination (No), Age (65-69), Gender (Male), Long-standing illness (No), Cognitive status (Good), Social status (High), Education (Highly skilled).

Despite being the less vulnerable group at baseline, the result of the GEE analysis showed that reported age discrimination remained significantly associated with frailty outcome in the non-frail population at P<0.05 over the eight years analysed. After adjusting for confounders, the result shows that the odds of developing frailty within eight years was 1.38[1.19-1.60]. The risk of incident frailty was significantly higher (38%) among those who reported age discrimination compared to those that did not report it at baseline. Age was associated with the risk of frailty development, with the

older group significantly more likely to develop frailty compared to the younger group. Women had significantly higher odds (OR, 1.34[1.15-1.56]) of becoming frail in the follow-up period compared to men while holding other covariates constant. Long-standing illness significantly increased the risk of frailty development by three folds and the odds of frailty development (OR, 2.66[2.33-3.03]) was higher among those with poor cognition compared to those with good cognition. The odds of frailty development among respondents with low social and educational status were 1.53[1.26-1.85] and 1.52[1.28-1.80] at 95% CI, respectively, compared to those in the high social and educational status.

In summary, the findings show that reported age discrimination was significantly associated with frailty outcomes in the study population. The conclusions of the GLM and GEE analyses in this study suggest that respondents who reported age discrimination were significantly at higher risk of frailty overall. In the later part of this thesis (**Chapter 7**), there is further analysis examining the effect of other variables on the relationship between age discrimination and frailty.

5.3.5 Discussion of findings in Section 5.3

The relationship between reported age discrimination and frailty among older individuals aged 65 years and over was examined in this section. A total of 2,385 responses were analysed, except for the incident-frailty outcome that was analysed in a subset of the sample population (n=2,097; individuals who were non-frail at baseline). The main findings from the analyses in this section (5.3) show that individuals who reported age discrimination were significantly at risk of being frail compared to those who did not report age discrimination. In the longitudinal analysis of the study population using the GEE, individuals that reported age discrimination at baseline had 62% higher odds (OR, 1.62[1.46-1.80]) of future frailty in eight years compared to those without reported age discrimination in the unadjusted model. After adjusting for the confounders in the GEE analysis, the odd of future frailty was 1.49[1.33-1.67] among those who reported age discrimination compared to those without reported age discrimination. Also, there was a longitudinal analysis to examine the influence of reported age discrimination on the development of frailty (incident-frailty) among individuals who were not frail at baseline (n=2,097). In eight years, the odds of frailty development were 1.50[1.31-1.72] and 1.38[1.19-1.60] for the group that reported age discrimination at baseline compared to those without reported age discrimination. The findings from this study also show that the covariates included in the GEE models accounted for the risk of frailty in the study population. Of note, long-standing illness was significantly associated with the future frailty (OR, 5.44[4.74-6.27]) and incident frailty (OR, 3.34[2.85-3.93]) in the study

population. Women were significantly more likely to be frail or develop frailty in future compared to men. Poor cognition and low socioeconomic status increased the risk of frailty as well. The risk of frailty was increasingly higher in the age groups 70-74 years, 75-79 years and 80+ years respectively compared to age 65-69. The strengths and limitations of the analyses and approach utilised in this section are discussed in the main chapter (**Sections 8.5 and 8.6**).

Few studies have examined the relationship between frailty and ageism in the broader context (see chapter 2). There are three components of ageism (age discrimination, prejudice and age stereotypes) described by Robert Butler (1969). These studies have focused on the relationship between attitudes to ageing/ageing stereotypes and frailty (Gale and Cooper 2018; Moser et al. 2011a; Salguero et al. 2019). Only one study was found to have examined the relationship between age discrimination and frailty (Ye et al. 2020). Ye et al. (2020) reported a significant indirect relationship between age discrimination (AD) and frailty outcome that is mediated through ageing stereotypes (AS) in a sample of Korean older adults aged 60 years and over. Similar to Ye et al. (2020), findings from the present study showed that reported age discrimination significantly predicted frailty outcomes among older adults aged 65 years and over in the ELSA study. The design of the present study is different when compared to previous studies that examined ageism and frailty. Firstly, no previous study was found to have examined the relationship between age discrimination and frailty in the English population. Secondly, unlike Ye et al. (2020), this doctoral study analysed the direct and indirect effects of reported age discrimination on frailty outcomes using different mediators (**Section 7.4**).

The covariates included in this study have been examined as predictors of frailty in previous studies (Gale et al. 2014; Hajek et al. 2018). The findings from this study suggest that age is significantly associated with frailty. Individuals in the age group (80+ years) were significantly at risk of frailty compared to those <80 years. This is consistent with the examined predictors of frailty among older adults. Clegg et al. (2013) indicated that the risk of frailty increased with age in their study and Hubbard and Rockwood (2011) reported that women were significantly more at risk of frailty compared to men in the older population. While the present study's findings suggest a significant association between age and frailty, the fact that 88% of the study population are considered not frail at baseline suggests that frailty is possibly avoidable, reversible or preventable (Travers et al. 2019).

The findings from this study show that the presence of long-standing illness played a significant role in the frailty outcome among older adults aged 65 years and over living in England. From the GEE analysis, individuals with long-standing illness were five times

more likely to be frail compared to those without long-standing illness. Previous research has shown a correlation between disability, morbidity and frailty (Theou et al. 2012). Theou et al. (2012) compared frailty measures with and without disability and co-morbidity and found that the prevalence of frailty was highest in the frailty measure that included disability and co-morbidity. The frailty index used in this study to measure frailty outcome included disability in respect to the activities of daily living and diagnosed chronic conditions (**Appendix VI**). This may explain the significant association between long-standing illness and frailty outcome in this study. However, the frailty index measure used in this study has been shown to reliably predict adverse health outcomes and life expectancy in other previous epidemiological studies (Cesari et al. 2014). The primary purpose of including the long-standing illness in the multivariate analyses in this study was to adjust for its possible confounding effect on the relationship between the main predictor (reported age discrimination) and frailty.

Psychosocial risk factors of frailty were also examined in this study. The findings showed that the socioeconomic status and cognitive status of the respondents significantly predicted frailty outcomes. Respondents with low/moderate social status or educational qualification were more likely to be frail or develop frailty in eight years compared to those with high social status or highly skilled educational qualification. This is consistent with findings from previous research that examined socioeconomic risk factors of frailty among older adults 65 years and over in Italy (Poli et al. 2017). It is essential to consider psychosocial factors because they may reflect the deficits or inequalities that would have accumulated through the life course (Ding et al. 2017). The cognitive function of the respondents also played a significant role in the frailty outcome, as older individuals with poor cognitive status were more likely to be frail or become frail in eight years compared to those with good cognition. The cognitive measure utilised in this doctoral study comprises the memory and executive functions of the respondents (Steel et al. 2002). Previous studies have shown that cognition plays a significant role in frailty outcomes (Fougère et al. 2017; Sleight and Holtzer 2020). For example, Sleight and Holtzer (2020) analysed data from 450 older adults in New York and found that individuals with poor verbal memory and cognitive functioning were more likely to be prefrail or frail compared to those with good cognition.

In summary, this section (5.3) contains the results of the longitudinal analyses to examine the relationship between reported age discrimination and frailty. The findings showed that reported age discrimination significantly predicted frailty before and after adjusting for potential confounding factors. Conversely, there is a paucity of information on the mechanism by which age discrimination influences frailty among older individuals. It is proposed in this study that individuals who reported age discrimination may become

socially isolated or experience loneliness that can negatively impact their health. Details of the role of social isolation and loneliness on the relationship between age discrimination and frailty are available in chapter 7.

5.4 Age discrimination as a predictor of poor health status

5.4.1 Introduction

This section aims to longitudinally examine the relationship between reported age discrimination and the health status of the respondents in the ELSA study.

5.4.2 Research question

- Is there an association between reported age discrimination and the health status of older adults aged 65 years and over?

5.4.3 Procedure

The generalised linear models and the generalised estimating equation were utilised to examine the relationship between age discrimination and the health status of the respondents in the study population. The main predictor in all the models was age discrimination and the adjusted models included the covariates (age, gender, cognitive status, long-standing illness, social status and educational level) to examine for confounding effects. The outcome variable was self-reported health status categorised into 0= Good and 1= Poor. The model was fitted for the self-reported health status as a repeated outcome from Waves 6 through to 9 using the GEE.

The GEE models were fitted using exchangeable correlation structure:

Logit (μ_{ij}) = α + β1 Age Discrimination ---------- (Unadjusted model)

Logit (μ_{ij}) = α + β1 Age Discrimination + β2 Gender + β3 Long standing illness + β4 Cognitive Status + β5 Social Status + β6 Educational level ----------(Adjusted Model)

μ_{ij} = marginal mean self-reported health outcome for each subject 'i' at jth time-points, j=4 (Waves 6 through 9).

5.4.4 **Results**

A total of 2,385 responses were analysed in the multivariate analyses in this section. The result of the binomial GEE models show that age discrimination significantly predicted future health status of respondents in the ELSA study at P <0.05 (Table 5.4).

Future health status:

The result in Table 5.4 showed that respondents that reported age discrimination had 31% higher odds (OR, 1.31[1.20-1.44]) of poor health status in eight years in the unadjusted model compared to those who did not report age discrimination. After adjusting for the confounders, the odds ratio of poor health status among individuals that reported age discrimination was 1.19[1.08-1.31]. Only the individuals aged 80+ years at baseline differ significantly in the risk of poor health status in eight years. The respondents with long-standing illness were four times (OR, 4.01[3.61-4.46]) more likely to have poor health status at baseline and in future respectively compared to those without long-standing illness. The odds of poor health in individuals with poor cognitive health was 1.70[1.51-1.91] and respondents in the low/medium socioeconomic status (SES) were more likely to have poor health compared to those with high SES.

Table 5.4: Multivariate analysis using the generalised estimating equation to longitudinally examine the relationship between age discrimination and future poor health status

Variables	OR [95% CI] Unadjusted	P-value	OR [95% CI] Adjusted	P-value
Age discrimination	1.31[1.20-1.44]	<0.01	1.19[1.08-1.31]	<0.01
Age categories (70-74)			1.01[0.89-1.13]	0.83
(75-79)			1.13[0.99-1.30]	0.05
(80+)			1.29[1.09-1.53]	<0.01
Gender (Female)			1.00[0.90-1.10]	0.96
Long-standing illness (Yes)			4.01[3.61-4.46]	<0.05
Cognitive status (Poor)			1.70[1.51-1.91]	<0.01
Social Status (Medium)			1.55[1.38-1.74]	<0.01
(Low)			1.60[1.41-1.82]	<0.01
Education (Skilled)			1.31[1.15-1.48]	<0.01
(Low-skilled)			1.90[1.67-2.16]	<0.01

Source: Analysis of the ELSA Waves 5 to 9

*Reference group: Age discrimination (No), Age (65-69), Gender (Male), Long-standing illness (No), Cognitive status (Good), Social status (High), Education (Highly skilled).

5.4.5 Discussion of findings from Section 5.4

The relationship between reported age discrimination and poor health status have been analysed in this section (5.4). A total number of 2,385 cases were examined in the GEE analyses. The main findings in this section suggest that reported age discrimination significantly influenced the health status of the respondents in this study. The adjusted odd ratio of poor health status was 1.19[1.08-1.31] among individuals that reported age discrimination compared to those that did not report age discrimination.

Few studies have examined the relationship between age discrimination and the health of older individuals (Jackson et al. 2019; Stokes and Moorman 2020; Vogt Yuan 2007). Only one study was found to have prospectively examined the relationship between age discrimination and the health of older adults in the UK (Jackson et al. 2019). Unlike Jackson et al. (2019), this study focused on frailty as the main outcome and included self-reported health. Besides, this study extends the scope of the study conducted by Jackson et al. (2019) by including the cohort of individuals aged 65 years and over who

participated all through Waves 5 to 9. Some of the results from this study are consistent with findings reported by Jackson et al. (2019) concerning the association between reported age discrimination and poor health status. Findings from this study show that older individuals who reported age discrimination were more likely to have poor health status in the eight years analysed.

A previous meta-analysis examined the potential mechanism by which reported discrimination influences the mental and physical health of individuals (Pascoe and Smart Richman 2009). These authors conducted a meta-analysis of 132 papers to develop a conceptual framework linking perceived discrimination and health. Pascoe and Smart Richman (2009) found that changes in health behaviours were one of the ways to explain the relationship between reported age discrimination and health outcome. They hypothesised that individuals who experience age discrimination might become demotivated to perform physical activities such as gyms and games that could expose them to explicit discrimination or stereotypes from third parties. Jackson et al. (2019) held a similar opinion as Pascoe and Smart Richman (2009) on the possibility of changing health behaviours among older adults in the ELSA study following age discrimination. Further analyses conducted in this study show no significant cross-sectional association between health behaviour (baseline physical activity) and reported age discrimination among the participants in the present study (**Section 7.6.1**). More analysis would be needed to examine the changes in lifestyle following the experience of age discrimination and this could be an area of interest for future research.

Another potential mechanism suggested by Pascoe and Smart Richman (2009) is the physiological stress caused by perceived discrimination on health and well-being. Individuals who reported discrimination were found to have increased levels of biological stressors that reduce the effectiveness of the body systems to respond to illnesses (Smart Richman et al. 2010). Smart Richman et al. (2010) found that individuals who reported discrimination were more likely to be vulnerable to pathogenic stress compared to those that did not report discrimination. Although Smart Richman et al. (2010) considered racial discrimination in their study, it is possible that reported age discrimination also influences biological stressors that can influence the health of older individuals. Thus, this could also be an area for further research in future studies.

While the findings from this study suggest an association between reported age discrimination and poor health status, different factors could have contributed to the poor health status of the respondents in the eight years analysed. For instance, findings from this study show that poor cognitive status and poor SES had a significant influence on how participants rate their health status. This is consistent with findings from a previous prospective study that examined the determinants of self-reported health using

the European SHARE data, which reported that low SES was a significant predictor of self-reported health status among the participants (Verropoulou 2012). Furthermore, long-standing illness was significantly associated with self-reported health status in the present study. This finding suggests that if participants have a chronic illness or multimorbidity, they are more likely to perceive themselves to have poor/fair health status. Although health disparities have been shown to generally exist by age and gender (Tang et al. 2007), the results from this study suggest that age and gender were not significantly associated with self-reported health status in the longitudinal analysis of the ELSA data. This is consistent with findings from (Xu et al. 2019) that compared health outcomes between older adults in China and the US, who reported that age and gender were not significant predictors of self-reported health.

Overall, the findings from the longitudinal analyses of the relationship between reported age discrimination and self-reported health status in this study suggest that older individuals who reported age discrimination were significantly more likely to report poor health status. Additionally, the findings showed that poor cognitive status and poor SES were significantly associated with poor health status. However, there was no significant longitudinal association between (age and gender) and poor health status among the respondents in this study.

5.5 **Chapter summary**

Chapter five contains the analyses conducted to examine the longitudinal association between reported age discrimination and the outcome variables (frailty and health status). There was a section on gender disparities in frailty trajectory among the respondents in the study population. A total of 2,385 cases were analysed (except for incident frailty that was examined among a subset [n=2,097], individuals who were not-frail at baseline). The overall findings from the analyses in this chapter show that reported age discrimination is significantly associated with frailty among individuals aged 65 years and over in ELSA. The result suggest that age discrimination is a risk factor of frailty and directly addresses the aim of this thesis to examine the association between age discrimination and frailty. However, there is still the need to determine if the association between age discrimination and frailty is influenced by other determinants of frailty such as social isolation and loneliness.

6.0 CHAPTER SIX

Analysis of the relationship between age discrimination, social isolation and loneliness

6.1 Chapter overview

Focus: As discussed in the previous chapter, individuals who reported age discrimination in ELSA are significantly at higher risk of frailty compared to those who did not. In chapter one, there was a discussion on the influence of social relationship on frailty outcome. Thus, this chapter analyses the a priori hypothesis that age discrimination would lead to increased risk of social isolation and loneliness. It is projected that individuals who are discriminated could be socially isolated or lonely, which can be detrimental to health. This is crucial in determining if the association between age discrimination and frailty is temporal and to know this association can be explained using social variables as discussed in the next chapter.

Outline: Chapter 6 addresses the relationships between reported age discrimination, social isolation and loneliness. The relationships between reported age discrimination, social isolation and loneliness were examined longitudinally using the English Longitudinal Study of Ageing Waves 5 to 9. After the brief overview, the first section (6.2) addresses the relationship between reported age discrimination and future risk of social isolation in eight years. The following section (6.3) addresses the relationship between reported age discrimination and future risk of loneliness in eight years. The longitudinal analysis was conducted using the generalised estimating equation model. The results of the analyses were discussed in each of the sections and the chapter ends with a chapter summary (6.4).

6.2 Age discrimination as a predictor of social isolation

6.2.1 Introduction

The objective here is to examine if reported age discrimination was associated with future social isolation in eight years (Waves 6 to 9) among individuals who participated in the ELSA study.

Research question:

-Is there an association between age discrimination and social isolation among individuals aged 65 years and over?

6.2.2 **Procedure**

As done in the previous chapter, the generalised linear models and the generalised estimating equation were utilised to examine the relationship between age discrimination and social isolation. The following covariates: age, gender, cognitive status, long-standing illness, social status and educational level were used to examine for confounding effects as used in the previous studies. The outcome variable was categorised into 0= Not isolated and 1= Isolated. The model was fitted for social isolation as a repeated outcome (Waves 6 to 9) in the GEE models. The results are reported for the unadjusted model and the adjusted model at 95% CI.

The GEE models were fitted using exchangeable correlation structure:

Logit (μ ij) = α + β1 Age Discrimination ---------- (Unadjusted model)

Logit (μ ij) = α + β1 Age Discrimination + β2 Gender + β3 Long standing illness + β4 Cognitive Status + β5 Social Status + β6 Educational level ----------(Adjusted Model)

μ ij = marginal mean social isolation outcome for each subject 'i' at jth time-points, j=4 (Waves 6 through 9).

6.2.3 **Results**

Table 6.1shows the results of the GEE analysis to examine the relationship between reported age discrimination and social isolation.

Future social isolation:

The results from the binomial GEE analyses show that reported age discrimination was not a significant predictor of future social isolation outcome at P=0.07.

Table 6.1: Multivariate analysis using the generalised estimating equation to examine the relationship between reported age discrimination and future social isolation

Variables	OR [95% CI] Unadjusted	P-value	Odds [95% CI] Adjusted	P-value
Age discrimination	0.96[0.88-1.05]	0.40	0.92[0.84-1.00]	0.07
Age categories (70-74)			1.15[1.03-1.27]	<0.01
(75-79)			1.38[1.23-1.55]	<0.01
(80+)			2.06[1.78-2.39]	<0.01
Gender (Female)			0.98[0.89-1.07]	0.68
Long-standing illness (Yes)			1.19[1.10-1.30]	<0.05
Cognitive status (Poor)			1.14[1.02-1.28]	<0.01
Social Status (Medium)			1.26[1.14-1.39]	<0.01
(Low)			1.60[1.41-1.82]	<0.01
Education (Skilled)			1.07[0.96-1.19]	0.19
(Low-skilled)			1.06[0.95-1.19]	0.24

Source: Analysis of the ELSA Waves 5 to 9

*Reference group: Age discrimination (No), Age (65-69), Gender (Male), Long-standing illness (No), Cognitive status (Good), Social status (High), Education (Highly skilled).

The findings show no difference in the future social isolation status for those who reported age discrimination in the unadjusted and adjusted models. Also, there was no difference in future social isolation outcomes by gender. Conversely, long-standing illness and poor cognitive status remained significantly associated with future social isolation in the follow-up analysis. Respondents with long-standing illness and those with poor cognitive status had an odds ratio of 1.19[1.10-1.30] for baseline social isolation and 1.14[1.02-1.28] for future social isolation at 95%[CI]. Although education was not a significant predictor of future social isolation, low/medium social status was significantly associated with the risk of future social isolation.

6.2.4 Discussion of findings from Section 6.2

The association between reported age discrimination and social isolation was examined in this section and a total of 2,385 cases were included in the analyses. The main findings from the GEE models show there was no significant association between reported age discrimination and future risk of social isolation in the longitudinal analysis.

The strength and limitations of this doctoral study as related to the analyses conducted in this section are available in the overall discussion (**Sections 8.5 and 8.6**).

The relationship between perceived discrimination, social isolation and health has been examined in previous studies (Han et al. 2020; Kobayashi et al. 2009; Negi 2013). Despite significant association between social isolation and health (Kobayashi et al. 2009) and social isolation and perceived (racial) discrimination (Negi 2013), there is a paucity of research on the influence of age discrimination on social isolation. No study was found to have longitudinally examined the influence of reported age discrimination on the future social isolation status of older adults in the UK. Thus, this study expands on the discussion of the relationship between social isolation and age discrimination and other known determinants of social isolation by using a longitudinal approach. This is important as previously reported determinants of social isolation have mostly been tested on cross-sectional data, and thus, it may be difficult to establish a temporal relationship (de Jong Gierveld 1998; Jang et al. 2016).

Findings from the present study can be compared with previous studies that examined the risk factors of social isolation among the older population (Cudjoe et al. 2020; Jang et al. 2016). The results of the present study are consistent with findings from the analysis of the US National Health and Aging Trends Study on socioeconomic determinants and social isolation (NHATS) by Cudjoe et al. (2020). For instance, the present study shows that individuals who reported low social status were more at risk of social isolation compared to those who report high social status consistently with Cudjoe et al. (2020). Previous studies (Evans et al. 2019; Shankar et al. 2013) involving participants in the UK also reported similar findings to those in this study. For instance, Shankar et al. (2013) reported a significant longitudinal association between cognitive health and social isolation among older adults in England. Furthermore, Evans et al. (2019) concluded from the systematic review and meta-analysis of 65 papers that the risk of social isolation ($r = 0.054$, 95% CI: 0.043, 0.065) is significantly less among those with good cognition compared to those with poor cognition, while r is the standardised correlation direction.

This study's findings suggest an inverse relationship between reported age discrimination and social isolation, although there was no significant association between reported age discrimination and future risk of social isolation among the ELSA participants in the longitudinal analysis. Broadly, the disengagement theory by Cumming and Henry (1961) provides an early explanation for the high prevalence of social isolation among the older population. Cumming and Henry (1961) hypothesised that naturally, people tend to be less socially active as they age. This theory has been discredited in social gerontology for failing to recognise that the older population is a heterogeneous group with different

levels of social capacities and has been succeeded with the theories of successful ageing and active ageing, which are discussed in detail by Zaidi and Howse (2017). More specifically, the relationship between perceived discrimination and social isolation among older adults could be explained using the concept of avoidance behaviour in emotional psychology (Corr 2013). Using avoidance as a coping mechanism, individuals tend to evade harmful or difficult situations that question their capability or independence (Temple et al. 2018). For example, a previous longitudinal study examining stress and behavioural changes among 1,211 individuals in the US aged 55 to 65 years reported a significant association between avoidance behaviour and life stressors (Holahan et al. 2005). In the ELSA study analysed, the respondents were asked to indicate if they have been discriminated against in their day-to-day activities. Thus, it is possible that individuals who have an increased level of social activities or contacts could experience discrimination differently from those who are not socially engaging. Future studies may be necessary to further understand the nature of the association between both variables and the contributory factors to such association.

In summary, this section addresses the relationship between reported age discrimination and social isolation among older adults aged 65 years and over. The findings there was no significant association between social isolation and reported age discrimination among the ELSA participants. The following section examines the longitudinal association between reported age discrimination and loneliness.

6.3 **Age discrimination as a predictor of loneliness**

6.3.1 **Introduction**

This section addresses the longitudinal relationship between reported age discrimination and loneliness. The objective is to examine the association between reported age discrimination and loneliness among individuals who participated in the ELSA data (Waves 5 to 9).

6.3.2 **Research question**

-Is there an association between reported age discrimination and loneliness among individuals aged 65 years and over?

6.3.3 **Procedure**

The generalised estimating equation models were utilised to examine the relationship between age discrimination and loneliness. The outcome variable was categorised into 0= Not lonely and 1= Lonely. The GEE model was fitted for future risk of loneliness using the Waves 6 to 9 ESLA data. The unadjusted and adjusted results were reported for the main predictor (age discrimination) and the covariates, namely age, gender, cognitive status, long-standing illness, social status and educational level, for possible confounding effects.

The GEE models were fitted using exchangeable correlation structure:

Logit (μ ij) = α + β1 Age Discrimination ---------- (Unadjusted model)

Logit (μ ij) = α + β1 Age Discrimination + β2 Gender + β3 Long standing illness + β4 Cognitive Status + β5 Social Status + β6 Educational level ----------(Adjusted Model)

μ ij = marginal mean loneliness outcome for each subject 'i' at jth time-points, j=4 (Waves 6 through 9).

6.3.4 **Results**

The results of the binomial GEE analyses to examine the association between reported age discrimination and future loneliness are presented in Table 6.2.

Future loneliness:

Table 6.2 shows that reported age discrimination significantly predicted loneliness in the study population in eight years. Respondents who reported age discrimination had an odds ratio of 1.74[1.60-1.90] and 1.69[1.53-1.84] at 95% CI for the unadjusted and adjusted model, respectively.

Table 6.2: Multivariate analysis using a generalised estimating equation to examine the relationship between reported age discrimination and future loneliness

Variables	Odds [95% CI] Unadjusted	P-value	Odds [95% CI] Adjusted	P-value
Age discrimination	1.74[1.60-1.90]	<0.01	1.69[1.53-1.84]	<0.01
Age categories (70-74)			0.91[0.82-1.02]	0.13
(75-79)			1.11[0.98-1.26]	0.08
(80+)			1.63[1.39-1.90]	<0.01
Gender (Female)			1.64[1.49-1.81]	<0.01
Long-standing illness (Yes)			1.48[1.34-1.62]	<0.05
Cognitive status (Poor)			1.36[1.21-1.53]	<0.01
Social Status (Medium)			1.67[1.50-1.86]	<0.01
(Low)			1.98[1.73-2.27]	<0.01
Education (Skilled)			0.98[0.87-1.10]	0.79
(Low-skilled)			1.11[0.98-1.25]	0.07

Source: Analysis of the ELSA Waves 5 to 9

*Reference group: Age discrimination (No), Age (65-69), Gender (Male), Long-standing illness (No), Cognitive status (Good), Social status (High), Education (Highly skilled).

The GEE results show that all the covariates were significantly associated with loneliness except for education and age (for groups 70-74 years and 75-79 years). In the adjusted model, women had 64% higher odds of being lonely compared to men and those with long-standing illness had increased the odds of loneliness (1.48[1.34-1.62]). Respondents with poor cognition were significantly more likely to report loneliness compared to those with good cognition. Also, low/medium social status was significantly associated with loneliness at p<0.01, compared to those who did not report loneliness.

6.3.5 Discussion of findings from Section 6.3

This section addresses the relationship between reported age discrimination and loneliness. The main findings longitudinal analyses in this section show that reported age discrimination was significantly associated with loneliness at p<0.01 for older individuals aged 65 years and over in the ELSA data. The odds ratio of loneliness was in 1.74[1.60-1.90] in the unadjusted model and 1.69[1.53-1.84] in the adjusted model. The findings suggest that individuals who reported age discrimination were more likely to become lonely in future compared to those that did not report age discrimination. The strengths

and limitations relating to the findings from this section are available in the main discussion chapter.

Previous studies have examined the relationship between perceived discrimination and loneliness in different communities and ethnicities (Lee and Bierman 2018; Liu et al. 2014; Świtaj et al. 2015). Lee and Bierman (2018) found that perceived discrimination was significantly associated with loneliness and depressive symptoms after longitudinally analysing the American Health and Retirement from 7,130 community-dwelling older adults. However, there was inadequate data on the longitudinal relationship between reported age discrimination and loneliness among older adults aged 65 years and over in the UK. This is particularly relevant as the findings from this study suggest that there is a high prevalence of loneliness (29.2%) in the study population. The longitudinal design of this doctoral study thus addressed one of the limitations of previous cross-sectional research (de Jong Gierveld 1998; Domenech-Abella et al. 2017) that examined the determinants of loneliness by providing a better understanding of the temporal association between loneliness and some of its selected determinants. Furthermore, the findings from this study show that individuals living with long-standing illness or poor cognitive status were at higher risk of loneliness. This is consistent with the findings from previous research (Barlow et al. 2015; O'luanaigh et al. 2012). Barlow et al. (2015) found a significant association between chronic illness and loneliness among 121 community-dwelling older adults aged 65 years and over in the US. It is possible that limiting chronic illnesses will reduce social participation among older individuals, thereby increasing their feeling of loss of social connection and loneliness.

There are varying reports on the association between gender and reported loneliness. Both Maes et al. (2019) and Beutel et al. (2017) reported no significant association between gender and reported loneliness. Maes et al. (2019) conducted a systematic review and meta-analysis of 638 studies to examine gender differences in loneliness, while Beutel et al. (2017) examined the predictors of loneliness among 15,000 adults aged 35 to 74years and over in the Gutenberg Health Study (Beutel et al. 2017). Whereas Domenech-Abella et al. (2017) reported that the risk of loneliness (OR 0.64, CI [1.18, 1.09]) was significantly lower in women compared to men, although this became insignificant after they adjusted for age and socioeconomic status. van den Broek (2017) also found that there was a significant gender difference in the prevalence of loneliness (X^2= 54.9, $p < 0.001$), which was higher in male (64%) compared to female (52%) among 4,057 Japanese aged 50 years and over. In contrast, findings from this study show that women were significantly more likely to report loneliness compared to men. This is consistent with a previous analysis of the ELSA study by Gale et al. (2018) that involved 2,817 respondents, which showed that the female gender was significantly

correlated with higher loneliness scores (r= 0.110). Longer life expectancy in women has been suggested as the reason women lose their social connection or become lonely as they grow old (Victor and Bowling 2012). Considering that women in the UK currently have a higher life expectancy compared to men (ONS 2019a), women may experience loneliness differently from men. However, demographic data in many countries, including the UK, are beginning to show a gradual levelling of the difference in the life expectancies for both genders (Fedotenkov and Derkachev 2019). This means that gender disparity in loneliness prevalence may continue to change and thus, future studies might be relevant to further explain the determinants of loneliness in both genders. Nevertheless, both the findings from this study and Beutel's study showed that respondents with low social status from were significantly more likely to report loneliness or become lonely compared to those with high social status.

The interpretation of the findings in this study can also highlight the inter-relationship between social contacts (social isolation) and subjective feelings of social connectedness (loneliness). It can be observed that while social isolation and loneliness have usually shared similar determinants, the direction of association may differ (Fakoya et al. 2020). For example, findings from this study suggest that although social isolation was not significantly associated with age discrimination, individuals who reported age discrimination were more likely to report loneliness. This is important because, unlike social isolation, loneliness does not quantify the number of social contacts but measures the effectiveness (quality) of social connections. Thus, loneliness may explain the detrimental psychosocial impact of reported age discrimination on older individuals' physical and mental health (**Section 7.5**).

Overall, the findings from this study have shown that reported age discrimination is significantly associated with loneliness after adjusting for the selected confounders. It is crucial to consider the linking factor between reported age discrimination and loneliness. Previous authors have suggested that the mechanism linking ageism and loneliness includes self-embodied stereotypes and withdrawal behaviour arising from long-standing societal perceptions (Shiovitz-Ezra et al. 2018). For example, a person may report loneliness solely because they have erroneously held an ageist belief that old age is a lonely period in life. Although it is challenging to objectify the reported age discrimination in this study, outright age discrimination has been suggested to induce social exclusion and loneliness (Shiovitz-Ezra et al. 2018). Furthermore, mental health conditions such as depressive symptoms have been associated with both loneliness (Beutel et al. 2017) and reported age discrimination (Jackson et al. 2019). Thus, a future study examining the relationship between reported age discrimination and mental health would be relevant.

6.4 **Chapter summary**

The chapter addresses the relationship between reported age discrimination, social isolation and loneliness. The first section examined the association between reported age discrimination and social isolation, while the second section addressed reported age discrimination and loneliness. The generalised estimating equation was used to longitudinally examined the future risks of both social isolation and loneliness outcomes. The results were reported for the unadjusted models and the adjusted models that included the confounding variables. The main findings in this chapter shows that there is a significant longitudinal association between reported age discrimination and loneliness. The odds ratio of loneliness in eight years was 1.69[1.53-1.84] for the group that reported age discrimination. The implication of this result is that social variables such as social isolation and loneliness may play a role in explaining the relationship between age discrimination and frailty. This is crucial in understanding the detriment of age discrimination and risk of frailty among older individuals and the mechanisms to consider for planning interventions.

The next chapter examines the mediating role of social isolation and loneliness on the relationship between reported age discrimination and loneliness.

7.0 CHAPTER SEVEN: RESULTS OF THE MEDIATION ANALYSIS

The role of social isolation and loneliness on the relationship between reported age discrimination and frailty

7.1 Chapter overview

Focus: This chapter addresses a literature gap identified from the review chapter concerning the lack of adequate information on the mechanism linking ageism and frailty among older adults. While the findings from previous chapters suggest that individuals who reported age discrimination are more likely to become frail in future compared to those who did not report discrimination, it is important to consider how this association is manifested. Thus, the potential factors that mediate the association between reported age discrimination and frailty are examined in this chapter.

Outline: This chapter addresses the mediating role of social isolation and loneliness on the relationship between reported age discrimination and frailty. The analysis in this chapter highlights the discursive nature of this doctoral study, as it examines the interconnection between the topics addressed in the earlier chapters. The mediation analysis was conducted using regression analysis and bootstrapping function in the R software. The critical ratio for determining the significance of the indirect effect of reported age discrimination on frailty via the proposed mediators was calculated using the Sobel test, which is presented under the result section 7.4.

7.2 Introduction

The objective here is to examine the conceptual pathway that can explain the relationship between reported age discrimination and frailty among the study participants. From the findings in the previous chapters, some levels of the association have been established between reported age discrimination, social isolation and loneliness among older adults aged 65 years and over that participated in the ELSA study. Thus, it is proposed in this chapter that individuals who have reported age discrimination may become socially isolated or lonely, which could increase their frailty risk.

7.3 Research question

-What is the role of social isolation and loneliness in the relationship between age discrimination and loneliness?

7.4 Mediation analysis procedure

The mediation analysis was conducted to examine this research question, as explained in the methods chapter. The mediation analysis was achieved using regression analysis and bootstrapping (**Section 3.5**). The regression analysis was conducted using the GEE

model, and the bootstrapping was conducted using the MBESS package in the R software. Reported age discrimination was used as the independent variable (Wave 5), the proposed mediators were social isolation and loneliness (Waves 6 to 9), and the outcome variable was frailty (Waves 6 to 9). Among the proposed mediators, the physical activity (PA) variables had the highest numbers of missing values (>90%) from Waves 6 to 9. Thus, these physical activity variables were excluded from the main mediation analysis, except the baseline PA that was included in the supplementary analysis (**Section 7.6**). The independent variable was entered as a categorical variable, but the mediators and the outcome variables were included in the mediation analysis as continuous variables following previous research (Preacher and Hayes 2008). The Sobel test was used to examine if the indirect effect of reported age discrimination on frailty through the mediator is significant (**Section 3.5.7**). The bootstrapping approach was conducted to quantify the ratio of the indirect effect of reported age discrimination to its direct effect and total effect on frailty.

The GEE model was specified as:

The GEE gaussian models are specified as:

μij (social isolation) = α + β1Age discrimination ----------(Table 7.1)

μij (loneliness) = α + β1Age discrimination----------(Table 7.1)

μij (frailty) = α + β1Age discrimination + β1Lonelines----------(Table 7.2)

μij is the marginal mean outcome entered in continuous format for the respective response variables.

While the bootstrapping was specified using the following formular:

Bootfit<-mediation(Age Discrimination, Mediator, FrailtyLong, bootstrap = TRUE, which.boot = "both", B=1000, conf.level = 0.95)

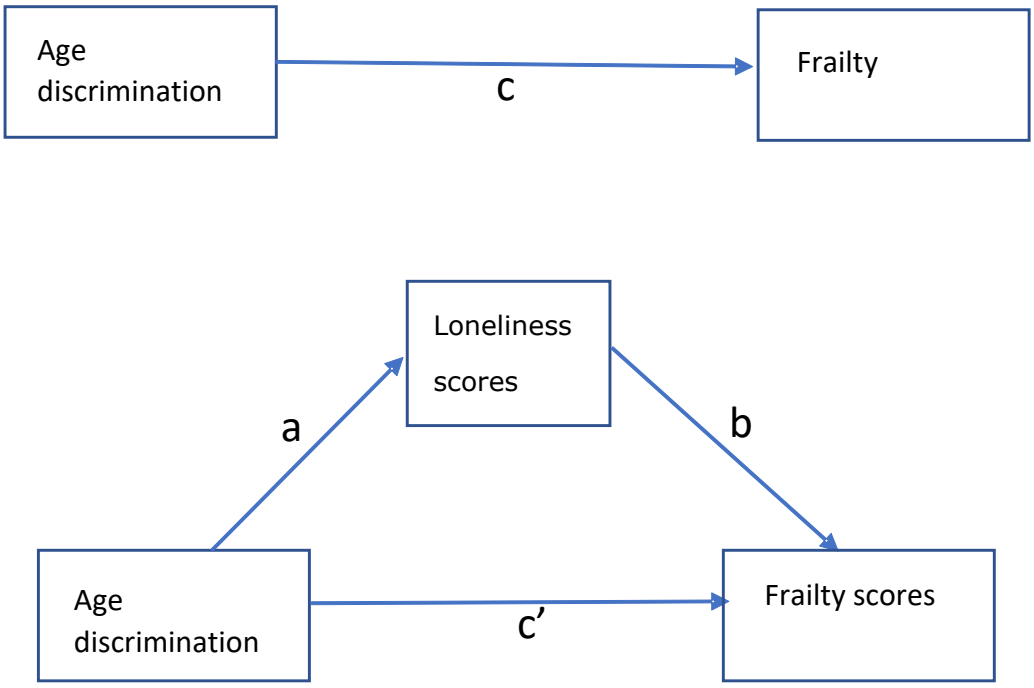

Figure 7.1: Directed Acyclic Graph for the relationship between reported age discrimination and frailty

The indirect effect is the product of paths a and b, where path a is the prediction of the mediators (social isolation or loneliness) using reported age discrimination and path b and c' is the prediction of the outcome (frailty) using both reported age discrimination and the mediators. Path c' is the direct effect of the predictor (age discrimination) on the outcome. The total effect (c) of the predictor on the outcome is the summation of both paths, that is, c' + a*b.

7.5 **Result**

The path 'a' result can be seen in Table 7.1, which includes the prediction of social isolation and loneliness using reported age discrimination alone.

Table 7.1: Multivariate analyses (1 & 2) using the generalised estimating equation to examine the fixed effect of age discrimination on future social and loneliness scores of the respondents

Variables	Estimates (Coefficients)	Standard Error	P-value
1. Social Isolation			
(Age discrimination)	-0.03970	1.12	>0.05
2. Loneliness			
(Age discrimination)	0.37713	0.02915	<0.01

Source: Analysis of the ELSA Waves 5 to 9

Table 7.1 includes results of two separate multivariate analyses to examine the association between reported age discrimination and social isolation and reported age discrimination and loneliness. Findings from the GEE analysis showed that reported age discrimination significantly predicted the future loneliness scores but did not predict the future social isolation scores of the respondents. Since there was no significant relationship between the reported age discrimination variable and the future social isolation outcome, it can be inferred that the effect of reported age discrimination on future frailty scores cannot be explained using social isolation. The next level of inquest involved the regression of frailty with both reported age discrimination and loneliness (path b and c).

Table 7.2: Multivariate analyses using the generalised estimating equation to examine the fixed effect of age discrimination and future loneliness scores on future frailty scores of the respondents

Variables	Estimates (Coefficients)	Standard Error	P-value
1. Frailty scores			
Age discrimination	0.0131201	0.0017612	<0.01
Loneliness	0.0196360	0.0006132	<0.01

Source: Analysis of the ELSA Waves 5 to 9

The result shown in Table 7.2 shows that loneliness and reported age discrimination were both significant predictors of future frailty scores. The coefficients from the GLM regression analysis can be used to explain the direct acyclic graph (a=0.37713,

b=0.0196360 and c=0.0131201). Using the Sobel calculator, it can be determined if the indirect effect of reported age discrimination on future frailty scores of the respondents via loneliness is significantly different from zero.

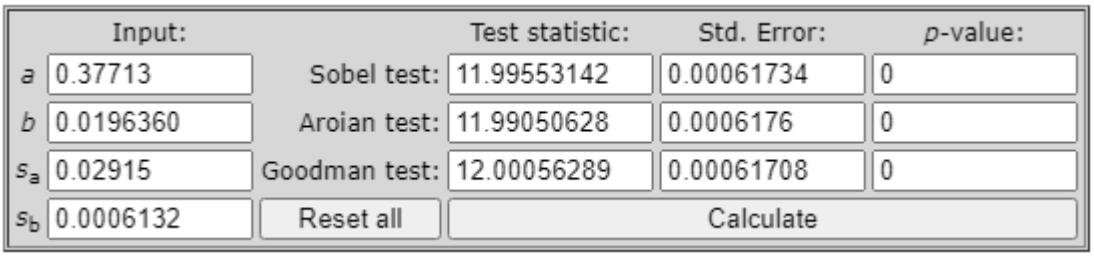

Figure 7.2: Sobel test to calculate significance for the indirect effect (Preacher and Leonardelli 2001)

The null hypothesis of the Sobel test is that the effect of the mediator equals zero in the study population. Since the P-value for the Sobel test for loneliness (Fig. 7.2) is less than 0.05, the null hypothesis is rejected. This means that the indirect effect of reported age discrimination on frailty via loneliness is significantly different from zero.

Table 7.3: Mediational analysis involving the bootstrapping approach to examine the mediating role of loneliness on the association between reported age discrimination and frailty

Effects	**Estimates (Coefficients)**	**Lower [95% CI]**	**Upper [95% CI]**
Indirect effect	0.0074	0.0062	0.0087
Indirect Effect Partially Standardized	0.084	0.070	0.099
Ratio of Indirect Effect to Total Effect	0.36	0.29	0.45
Ratio of Indirect Effect to Direct Effect	0.56	0.42	0.81

Source: Analysis of the ELSA Waves 5 to 9

The results shown in Table 7.3 include the relevant findings extracted from the bootstrapping outputs. The coefficients generated from the bootstrapping approach are consistent with the findings for the mediation analysis via regression modelling. The

results from Table 7.3 show that the indirect effect of reported age discrimination on the future frailty scores of the study population via loneliness accounts for approximately 36% of the total effect of reported age discrimination on frailty in the follow-up period (8 years).

7.6 Supplementary analyses

This section contains the details of the supplementary analysis to examine the association between reported age discrimination and baseline physical activity (PA) levels of the respondents in the ELSA study. It also includes an analysis of the association between frailty outcome (Wave 6 to 9) and baseline PA levels.

7.6.1 Association of frailty with physical activity, social isolation and loneliness

Supplementary analysis was conducted to examine the association between baseline physical levels and frailty. Additionally, the independent association of social isolation and loneliness with frailty was examined. The GEE analysis was utilised to examine the association between the variables. All the variables were entered into the GEE model in their original format: physical activity as a categorical variable and the rest in a continuous form. Table 7.4 presents the result of the association between the variables.

Table 7.4: The generalised estimating equation to examine associations between social isolation, loneliness, baseline physical activity and frailty scores of respondents in the ELSA data

Variables	Estimates (Coefficients)	Standard Error	P-value
1. Social Isolation	0.01	0.0009	<0.01
2. Loneliness	0.02	0.0006	<0.01
3. Physical activity			
Sedentary (Ref)			
Low PA	-0.03	0.004	<0.01
Moderate	-0.09	0.004	<0.01
Vigorous	-0.11	0.004	<0.01

Source: Analysis of the ELSA Waves 5 to 9

The GEE results show that social isolation and loneliness were significantly associated with frailty. The higher the social isolation and loneliness scores, the higher the frailty scores too. This means the individuals who are socially isolated or reported loneliness were significantly at risk of frailty. On the other hand, there was an inverse association between frailty scores and physical activity levels. This implies that the higher the physical activity, the lower the frailty scores of the respondents. The result shows that individuals with low PA, moderate PA and vigorous PA had significantly reduced frailty scores by 3%, 9% and 11% respectively when compared with those who were sedentary. The effect sizes remain the same whether the baseline and longitudinal variables are entered into the model separately or together. This means that the association between the variables does not change drastically with time. Furthermore, social isolation and physical activity were not mediators of the association between reported age discrimination and frailty, as discussed in **Sections 7.5 and 7.6.2**.

7.6.2 The association between baseline physical activity and reported age discrimination

Bivariate analysis was conducted using the Chi-squared test to examine the association between reported age discrimination and physical activity among the respondents in the ELSA data (Table 7.4).

Table 7.5:Baseline association between the independent variables and frailty outcome (n=2,385)

	Age discrimination		
Physical activity levels	No Count (%)	Yes Count (%)	Total
Sedentary	216 (3.67)	152 (4.15)	368
Low PA	1380 (23.49)	836 (22.82)	2216
Moderate PA	3120 (53.10)	2008 (54.80)	5128
Vigorous PA	1160 (19.74)	668 (18.23)	1828
Total	5876	3664	9540

Source: Analysis of the ELSA Waves 5 to 9

The result of the Chi-squared test shows that there was no significant difference in the physical activity levels between those who reported age discrimination and those who did not report age discrimination (X^2= 5.64, df=3, p=0.13).

7.7 Discussion

This chapter addresses the role of social isolation and loneliness on the relationship between reported age discrimination and frailty. A total of 2,385 cases were analysed using the ELSA data Waves 5 to 9. The main findings from this section show that baseline reported age discrimination had a significant indirect effect on future frailty scores of the respondents via loneliness; Sobel test (T-statistics=11.99, $p<0.01$). The findings from this study suggest that individuals who reported age discrimination were more likely to become lonely in the future, putting them at higher risk of frailty than those who did not report age discrimination. The strengths and limitations relating to the study design in this chapter are available in the overall discussion chapter (**Section 8.6**).

Supplementary analyses were conducted a priori to examine the relationship between the reported age discrimination, frailty and the baseline physical activity (PA) levels of the respondents in the ELSA data (**Section 7.6**). The findings show that there was a significant inverse association between baseline PA levels and future frailty scores of the respondents in ELSA. Compared to the group that was sedentary at baseline, the beta coefficients and standard errors of frailty were (β -0.03, SE 0.004), (β -0.09, SE 0.004) and (β -0.11, SE 0.004) for those with low, moderate and vigorous physical activity levels respectively. Previous studies have shown that a sedentary lifestyle is positively associated with frailty (Kehler et al. 2018) and that physical activity is a preventative factor of frailty (Peterson et al. 2009). This is consistent with the supplementary findings that suggest that baseline physical activity was significantly associated with a reduced risk of frailty in eight years. However, there was no significant relationship between reported age discrimination and physical activity at baseline, which means the PA levels could not have explained the association between reported age discrimination and frailty among the respondents in the cross-sectional analysis (Wave 5 of ELSA). Moreover, more than 90% of the cases had missing data for physical activity in the follow-up period and as such PA levels was excluded in the mediation analysis.

There is a paucity of data to compare the mediating role of social isolation and loneliness on the association between reported age discrimination and frailty. Thus, the findings from the present study expand on the research of social isolation and loneliness among older adults. However, there are published evidence on the association between social isolation and frailty (Gale et al. 2018; Jarach et al. 2021; Maltby et al. 2020; Merchant et al. 2020). For example, Merchant et al. (2020) found that social isolation was significantly associated with mean gait speed among 202 participants in a cross-sectional analysis of community-dwelling individuals aged 60 years and over. In contrast to

Merchant et al. (2020), findings from this study agree with a previous study by Gale et al. (2018), who found no significant association between social isolation and frailty cross-sectionally and prospectively. The inconsistency with Merchant et al. (2020) is not unexpected as they have only measured a subset of the broader domain of frailty considered in this study. Another study by Maltby et al. (2020) suggested a significant association exists between social isolation and frailty using a modified definition of social isolation. However, the modification of social isolation proposed by Maltby et al. (2020) has not been widely cited and may have affected the reliability of their results. Furthermore, other recent studies have reported that loneliness is a significant predictor of frailty, as shown in this doctoral study (Herrera-Badilla et al. 2015; Jarach et al. 2021; Mehrabi and Béland 2020).

The findings from this study have shown that the relationship between reported age discrimination and frailty can be possibly explained through loneliness. Although few studies have examined the relationship between perceived discrimination and loneliness, as discussed in the previous chapter of this thesis, only one study was found to have examined the mediating role of loneliness on the relationship between perceived discrimination and health (Lee and Bierman 2018). Lee and Bierman (2018) analysed estimated 7,130 cases and found out that older individuals who perceived discrimination in their daily activities were more likely to report loneliness and become depressed. It is not entirely clear how loneliness increases the risk of frailty among older adults. The pathway from loneliness to frailty is likely to be multisystemic, considering the inter-relationship between loneliness and other health determinants (Berg-Weger and Morley 2020). Previous research has suggested that loneliness interferes with the endocrine, immune and inflammatory systems that are central to the concept of frailty (Herrera-Badilla et al. 2015). This is beyond the scope of this doctoral study and can be examined further in future studies.

7.8 **Chapter summary**

This chapter addresses the role of social isolation and loneliness on the relationship between reported age discrimination and frailty using mediation analysis. The mediation analysis was achieved using the regression analysis and bootstrapping approach. The critical ratio of the indirect to direct/total effect of the reported age discrimination on frailty via the mediator was calculated using the Sobel test. Preliminary analyses were conducted to examine the mediator, exposure and outcome variables. The findings from preliminary analyses suggest that although physical activity and social isolation were associated with frailty, they cannot be considered as a mediator because of their lack of

association with reported age discrimination. Thus, only loneliness was included in the mediation analysis.

The result of the mediation analysis showed that reported age discrimination has an indirect effect on future frailty scores of the respondents through loneliness. The indirect effect accounted for 36% of the total effect of reported age discrimination on future frailty scores of the respondents.

In conclusion, this chapter links with both chapter 5 and 6 to explain the potential reason why discrimination might lead to frailty. It outlines the role of loneliness on the relationship between age discrimination and frailty. Additionally, the findings show that age discrimination could have a huge detrimental effect for the older population considering that loneliness and frailty can jointly increase the risk of mortality significantly among older adults (Hoogendijk et al. 2020a). The next chapter is the overall discussion chapter of this doctoral study. This chapter includes the analytic presentation of the strengths and limitations of the study findings and the summation of the findings in this doctoral study.

8.0 CHAPTER EIGHT: OVERALL DISCUSSION CHAPTER

This chapter contains the summary of the previous chapters and the discussion of the results compared to other studies.

8.1 Chapter introduction and overview

The overarching aim of this thesis is to determine if age discrimination is a potential risk factor of frailty, and to determine if there is gender difference in frailty trajectory. The research questions (**Section 1.8**) were examined using a longitudinal research design to analyse the ELSA data (Waves 5 through 9).

This chapter includes a discussion of the core findings from the analysis of the ELSA data. It examines the strengths of the methodological approach utilised in this thesis and discusses the corresponding limitations. After that, the potential implications of the findings on the advancement of knowledge, social policy and practice are discussed. The chapter ends with a recommendation on the directions for future studies and a conclusion.

8.2 Overall summary of previous chapters including core findings

Chapter 1 demonstrates the changes in the ageing population and the implication of the growth in the population of older people for frailty research. The introduction chapter further explores the definitions of frailty and the different instruments for assessing frailty in clinical and non-clinical settings. This chapter also buttresses the relevance of frailty research by explaining the associated adverse health outcomes and economic burden. The focus of the present thesis was introduced by discussing the existing knowledge gaps in the risk factors of frailty and the reason to explore the social components of frailty in the context of ageism. The chapter ends by drawing on the need for a systematic review to establish the current evidence on the relationship between ageism and the relevant questions to examine the relationship between reported age discrimination and frailty in the ELSA data.

Chapter 2 contains the details of the systematic review on ageism and frailty. The review's objective was to examine the measures of ageism and frailty used in the literature and ascertain if there was evidence of an association between ageism and frailty. The findings from the systematic review have been documented in detail in **Sections 2.2 and 2.3**. A total of 14 full texts were included in the systematic review out of 6,729 records identified via pre-determined inclusion criteria. The papers were appraised using the NIH quality assessment for observational and cross-sectional studies. There were 11 different instruments measuring ageism identified from the papers included in the systemic review. Eight of these instruments assessed ageing stereotypes and the remaining focused on reported age discrimination. Two major assessments of frailty were identified from the paper included in the systematic review (i) the Phenotype Frailty and (ii) the multidimensional Frailty Index (iii) FRAIL instrument

(**Section 2.2.6**). Additionally, the review shows that there was a paucity of data on the association between the age discrimination aspect of ageism and frailty development among older adults. Thus, the review finding's buttresses the need for further analysis of age discrimination and frailty in this thesis.

Chapter 3 is the materials and methods section of the thesis, and it details the study design and the rationale for the use of the generalised estimating equation statistical model for the longitudinal analysis. Data from the ELSA study Waves 5 to 9 were analysed because it included relevant information on participants' reported age discrimination and health variables (**Section 3.4** and **Section 3.5**). The physical activity variable was not included in the longitudinal analysis because the variable was not consistently measured in the five Waves of ELSA study analysed in this thesis. The choice of dropping this variable was further justified by the fact that in 90% of cases, the physical activity information was missing for the respondents in Waves 6, 7, 8 and 9. The frailty scores of the respondents were calculated using the multidimensional Frailty Index with the cut-off point ≥0.25 representing frailty. The frailty status of the respondents was examined at Wave 5 (baseline frailty) and combined data of Waves 6 to 9 (future frailty). Additionally, incident frailty was longitudinally examined among a subset of the study population that was not frail in Wave 5 (n=2,097). Gender disparity in the frailty outcomes was examined along with the respondents' frailty trajectory, which was plotted on a line graph. Social isolation was derived from responses to questions on contact with family and friends, marital status and social engagement level of the participants, whereas loneliness was measured using self-reported responses on the UCLA 3-item scale (**Section 3.5**). Mediation analysis was to explain the association between age discrimination and frailty via the mediators (social isolation and loneliness).

Chapter 4 establishes the sample characteristics, the baseline prevalence of reported age discrimination, frailty, health status, social isolation and loneliness and the bivariate association between the independent and dependent variables examined in the ELSA data. A total of 2,385 responses were included in the analysis after missing values were imputed using the multiple imputations technique. This study showed that the baseline prevalence of social isolation was 32.3% and the prevalence of loneliness was 29.2% among individuals aged 65 years and over in the Wave 5 of the ELSA dataset. The results also showed that the baseline prevalence of frailty using the multidimensional frailty index instrument was 12% among older adults aged 65 years and over in the ELSA study. Most respondents (79.2%) rated their health as good/very good/excellent, while 55.4% reported having a long-standing illness.

Chapter 5 further examines the association between the independent variables and frailty outcomes from the previous chapter. It includes separate analyses to examine

gender disparity in frailty trajectory and the association between age discrimination and frailty. The age discrimination variable from the ELSA study captured reported discriminatory events attributed to age. The relationship between age discrimination and frailty was examined cross-sectionally using the generalised linear model and longitudinally using the generalised estimating equation. There was a significant association between reported age discrimination and frailty outcomes in the adjusted and unadjusted analyses (**Section 5.3**). After adjusting for covariates, the odds ratio of becoming frail increased by 49% and 38% for future frailty and incident frailty respectively, among those who reported age discrimination compared to those who did not report age discrimination.

Chapter 6 examines the association between reported age discrimination, social isolation and loneliness. The respondents' social isolation and loneliness status were examined in Wave 5 (baseline status) and Waves 6 to 9 (future status). The association between reported age discrimination and social isolation was analysed longitudinally (**Section 6.2**). The result of the unadjusted model showed that individuals who reported age discrimination at baseline had a significant 74% increase in odds of becoming lonely in future, compared to those who did not report age discrimination. After adjusting for covariates, the future risk of loneliness was 69% significantly higher among those who reported age discrimination. On the contrary, the findings showed that there was no association between reported age discrimination and social isolation in the GEE analysis.

Chapter 7 examines the role of social isolation and loneliness on the association between age discrimination and frailty using mediation analysis. The findings showed a significant indirect effect of age discrimination on frailty via loneliness, which accounted for 36% of the association between age discrimination and frailty. This finding suggests that those who reported age discrimination in the ELSA study and developed frailty in the eight years of data collection were significantly more likely to become lonely in between this period.

8.3 **Discussion of the main findings**

This section includes a discussion of the result of this study as related to other findings in the literature. There is a critical comparison with previous studies, and plausible conclusions are drawn from the results.

8.3.1 **Frailty prevalence and gender disparity in frailty trajectories**

The cross-sectional (baseline) frailty prevalence from this study (12%) is closer to the 14% prevalence reported by Gale et al. (2014) and lower than the 17% prevalence

reported by Pradhananga et al. (2019), all of which involved participants in the UK. The disparity in the prevalence of frailty reported between this study and the previous studies may be partly explained by the methodological difference in measuring frailty (**Section 1.3**). Previous studies have suggested the need for a unified instrument for measuring frailty prevalence that would be comparable across all clinical and epidemiological research (Cesari et al. 2017; Morley et al. 2013). This will allow for the harmonisation of data and make it easier to suggest recommendations for policy changes to prevent frailty globally. Nevertheless, frailty research is crucial to advancing the strategy for health ageing (Cesari et al. 2014), and this present study has expanded the knowledge of the risk factors of frailty.

The results show that gender was significantly associated with frailty and the mean frailty scores increased significantly from Waves 5 through to 9 for both genders. The unadjusted analysis showed that the odds of being frail was 73% higher in women compared to men. After adjusting with other socio-demographic variables and covariates in the analyses (**Tables 5.1 to 5.4**), women remain significantly at risk of being frail compared to men. This result is consistent with findings from previous research that found a high prevalence among 113,299 European women compared to men in the SHARE data (Ahrenfeldt et al. 2019). The health-survival paradox provides a possible explanation for the disparity in frailty status or health status between both genders (Kingston et al. 2014). This paradox postulates that women have a higher life expectancy than men because they can cope longer with chronic illnesses in later life compared to men (Hubbard and Rockwood 2011).

Considering that the multidimensional frailty index definition includes chronic conditions, Hubbard and Rockwood (2011) suggested that women would be able to live longer with frailty and chronic conditions compared to men, based on the health-gender paradox. Firstly, there are varying reports on the prevalence of multimorbidity/chronic conditions for both genders (Gordon and Hubbard 2019). Women are more likely to self-report their health compared to men (Crimmins et al. 2011), which could potentially lead to the overestimation of chronic illness prevalence in women. Gordon and Hubbard (2019) thus argued that underlying chronic illness might not adequately explain the gender difference in frailty prevalence. Secondly, the narrowing gap in the life expectancies between both genders further challenges the health-gender paradox (Rosella et al. 2016; Sundberg et al. 2018). For instance, in the UK, the gender gap in life expectancy has narrowed from 6.3 years in 1971 to 3.7 years in 2019 (Leon et al. 2019), although it has slightly increased to 4 years in 2020 due to more COVID-19 mortality among men (Euromomo 2021). Aside from the biological causes, mortality related to lifestyle changes (higher smoking habits in women) has been suggested to account largely for

the narrowing gap in the life expectancy between both genders (Oksuzyan et al. 2018). Maiolo and Reid (2020) argued that an increased mortality rate linked to frailty among older women may instead explain the narrowing gender-longevity gap. This view is supported by findings from another study that showed that there is higher mortality in women compared to men in Sweden among frail individuals aged 60 years and over (Sundberg et al. 2018). Thus, the findings from this study showing a higher prevalence of frailty in women compared to men could mean a greater risk of adverse health outcomes for women in the ELSA data. Future research should thoroughly examine the determinants of disparity in frailty prevalence for both genders.

8.3.2 Increased risk of frailty and poor health: association with reported age discrimination

The present study results show that there is an increased risk of frailty and poor health status among those who reported age discrimination. The findings on age discrimination and health status (Chapter 5) are comparable to the research by Jackson et al. (2019), who examined the association between age discrimination and chronic diseases among individuals aged 50+years in the ELSA study. Conducting cross-sectional and longitudinal analysis, Jackson et al. (2019) reported ORs of poor self-reported health status was 32% significantly higher among those who reported age discrimination than those who did not. Furthermore, age discrimination was significantly associated with heart disease, cerebrovascular disease, diabetes, lung disease, terminal illness, and depressive symptoms at $p < 0.01$ in the longitudinal analyses. The present study results are consistent with Jackson's findings, as the adjusted ORs for poor self-reported health status increased by 19% among those who reported age discrimination.

In contrast to Jackson's study, the present study has used a different methodological approach in the longitudinal analysis and expands on the knowledge of ageism and frailty among older adults. Firstly, this study focused more on frailty outcomes rather than the chronic illnesses examined in Jackson's study. Frailty and chronic illness are different concepts (**Section 1.4**), a chronic illness only define the presence or absence of a long-standing disease and does not fully represent the true extent of the body's susceptibility to stressors as in the case of frailty (Espinoza et al. 2018; Fried et al. 2004). Secondly, the present study has used a different longitudinal approach compared to Jackson's study by including the same individuals/cohorts across five Waves of ELSA data in the longitudinal analysis covering eight years. Jackson et al. (2019) only analysed two Waves of ELSA data (Wave 5 and 8) involving different participants, so their study can be regarded as a repeated cross-sectional analysis. This repeated cross-sectional approach can make it difficult to track changes in participants' frailty scores

owing to the fact that different participants would have been included in the study at various points. Thus, the findings from the present study have contributed to the knowledge of the association between reported age discrimination and health outcomes of older adults in the ELSA data.

When compared with other studies in the field of frailty research, only one study was found to have directly examined the association between age discrimination and frailty like the present study. Ye's study is a cross-sectional study that involved 630 Chinese participants aged 60 years and over, while the present study involved 2,385 respondents aged 65 years and over in the UK. Nevertheless, the findings from this study and Ye et al. (2020) both showed a significant association between age discrimination and frailty. Furthermore, the present study provides further knowledge on the association between age discrimination and frailty development by analysing a subset of the study population who were not frail at baseline. Although the present study focused on the path leading from age discrimination to frailty, it is not entirely clear if the association between age discrimination and frailty is unidirectional. Moreover, Ye et al. (2020) proposed that the association between reported age discrimination and frailty can be facilitated by other factors such as ageing stereotypes or prejudice. The present study also addressed the pathway between reported age discrimination and frailty (**Section 8.3.5**).

8.3.3 Effect of reported age discrimination on social relationships

There is a lack of adequate research on the association between age discrimination, social isolation and loneliness among older adults in the UK to compare with the findings from the present study (Chapter 6). Han et al. (2020) examined the role of social isolation and loneliness on the relationship between perceived discrimination and mental health among HIV patients. They reported that perceived discrimination had a significant association with the participants' social isolation and loneliness scores. Han's result contrasts with the findings in this study that found social isolation was not associated with age discrimination. This could be because participants in Han's study who reported discrimination could have been affected by the stigma of the disease itself rather than the perceived or reported discrimination. An interesting discussion that emerges from the current study is the impact of age discrimination on the social activities of older individuals. The expectation was that individuals who have reported age discrimination may become socially isolated in the context of social disengagement among older adults (Toepoel 2013), this was not the case in the present study (**Section 6.2.4**). Findings from a systematic review of 199 articles by Marques et al. (2020) indicated that social contact was a significant determinant of age discrimination towards older individuals. It is possible that social isolation who vary depending on the composition of individual's

social contacts/networks (i.e, children, friends or family members). Thus, future study focusing on the sub-analysis of social isolation and age discrimination on specific groups of social contacts may be relevant.

The results in this study suggest that individuals who reported age discrimination had a significantly increased risk of loneliness in the longitudinal analysis. Previous studies have considered loneliness a subjective measure of social isolation (Holt-Lunstad et al. 2015; Nguyen et al. 2020). This is because loneliness characterises the feeling of loss of social connection and may explain why people who seem to maintain positive social or physical contact with others could still be at risk of feeling isolated adults (Han et al. 2020; Pascoe and Smart Richman 2009). Loneliness can affect the mental health of older adults, as indicated from previous research that reported a significant association between loneliness and depression among adults aged 65 years and over in Italy (Gerino et al. 2017). Thus, future research should thoroughly examine the relationship between perceived age discrimination and mental health in older. This was also crucial to the overall design of the current study to examine the frailty outcome by using a multidimensional measure of frailty that captures physical, mental and socio-environmental domains of health (**Section 3.5**).

8.3.4 Will a positive perception of ageing be protective of frailty?

The individual papers included in the systematic review reported that positive perceptions of ageing were significantly associated with reduced frailty levels. A previous systematic review reported that ageism-reduction interventions such as educational training and social contacts significantly improved the health of older adults (Burnes et al. 2019). This means that educational interventions that could positively influence people's perception of ageing may be relevant towards preventing frailty progression or to improving older adults' self-efficacy/self-belief in coping with impairments. The pooled effect of ageism on the risk of frailty was not feasible in the systematic review owing to the high heterogeneity between the papers reviewed. Future studies can examine further if positive perception ageing will be a useful interventional pathway to prevent frailty.

Additional findings from the systematic review (chapter 2) suggest that there are more instruments measuring attitude to ageing (ageing stereotypes) compared to age discrimination among frail older adults. A similar finding was reported in a previous review that examined the existing ageism scales after reviewing 106 papers (Ayalon et al. 2019). Ayalon et al. (2019) found 11 measures of ageism from their review but reported that some of these measures lacked psychometric validation and mostly focused on ageing stereotypes. This is the case for one of the papers reviewed in this thesis (Gale and Cooper 2018), which reported that the psychometric property of the

"attitude ageing scale" used in the ELSA study had not been validated. These findings imply that there is still a need to develop validated scales for measuring ageism that will capture the different components of ageism (i.e., age discrimination, prejudice and stereotype).

8.3.5 The pathway from age discrimination to frailty

Previous research has attempted to explain the pathway from perceived discrimination (sexism and racism) and poor health among older adults (Pascoe and Smart Richman (2009). Pascoe and Smart Richman (2009) conducted a meta-analysis of 132 papers to develop a conceptual framework linking perceived discrimination and health. The authors proposed that perceived discrimination is a social stressor that can heighten body inflammation leading to poor physical health or promoting unhealthy behaviours that can jeopardise health and well-being. Although the papers reviewed by Pascoe and Smart Richman (2009) focused on racism or sexism, they provide some plausible reasons to understand the link between reported age discrimination and health. The current study focused on the association between reported age discrimination and frailty, and the result adds to the knowledge of the detriment of reported discrimination on the health of older adults.

The result of the mediation analysis in this study shows that loneliness provides a potential pathway between age discrimination and frailty. Loneliness has been shown to mediate the effect of perceived discrimination on depression in a Chinese study (Han et al. 2020). Loneliness is significantly associated with frailty, as shown in a previous cross-sectional study involving 945 community-dwelling older adults aged 70 years in Mexico (Herrera-Badilla et al. 2015). A previous longitudinal study that analysed the ELSA data also found that the risk of frailty increased by 85% among individuals who reported loneliness (Gale and Cooper 2018). The combined effect of loneliness and frailty was reported by Hoogendijk et al. (2020a), who found that a joint association of frailty and loneliness increased the risk of mortality among 1400 community-dwelling individuals aged 65 years and over in the Netherlands by 83%. The present study shows that loneliness explains 36% of the total effect of reported age discrimination on frailty outcome among the respondents in the ELSA data. There is a lack of adequate information to explain the path between perceived (age) discrimination and health/frailty, which means that the present study potentially contributes to addressing a relevant gap in the literature. These findings imply that interventions to reduce ageism could impact both reported loneliness and frailty outcomes among older adults.

8.4 **The study findings and COVID-19**

The SARS-CoV-2 is a coronavirus that emerged in Southeast Asia in December 2019 and has spread to over 200 countries with a fatality of 4.9 million deaths (as of October 19, 2021), resulting in a substantial socioeconomic burden (WHO 2021b). The disease(s) attributable to this virus is known as the COVID-19. Although the immense vaccination programmes in many countries may mean optimism regarding the prevention of COVID-19 disease (Dye and Mills 2021), there are issues concerning the long-term effect of this pandemic on the health and well-being of people (Palmer et al. 2020). There are interesting findings from this study that will contribute meaningfully to the discussion on the impact of the COVID-19 pandemic on the health and well-being of older individuals. Although the data used in the current study were collected before the pandemic, the variables analysed in this study presented prominently in the discussion on the impact of COVID-19 on the general population. One of the most widely practised strategies to slow down the progression of a pandemic and that was used to break the chain of transmission of the SARS-CoV-2 infection was social distancing and physical isolation (Venkatesh and Edirappuli 2020). At the early phase of the pandemic, chronological age was the factor used by many countries, including the UK (70 years+), to determine individuals who must shield from the disease by staying alone or with people they lived with, in their own homes. While there are counter-opinions on the legitimacy of age-based segregation on healthcare resource allocation (Harris and Regmi 2012) or in the management of a ravaging pandemic (Oliver 2020), simply using chronological age as a basis of determining vulnerability could be argued to have had an ageist undertone in itself by portraying older individuals as a homogenous group (Swift and Chasteen 2021). The COVID-19 pandemic has heightened the problem of loneliness and social isolation generally in the population (Venkatesh and Edirappuli 2020). This is triggered by the barrier to intergenerational contact enforced during the lockdown protocol that was adopted for managing the COVID-19 (Arpino et al. 2020). For instance, a recent longitudinal study that compared pre-COVID and COVID data among 4,887 older adults in the UK reported that the risk of loneliness (OR 1·52, CI [1·26–1·84]) increased significantly during the pandemic (Steptoe and Di Gessa 2021). The findings from the present study suggest that reported age discrimination can increase the risk of loneliness, leading to greater frailty. Thus, it would be interesting to examine in future how the COVID-19 related ageism influences social isolation and frailty outcomes among older adults in both communities and care home settings.

8.5 Strengths

The main strengths of the current study relate to the quality of data analysed, the originality of the overall research work. Firstly, the ELSA study analysed in this study is the largest panel survey of individuals aged 50 years and over in the UK. The validity of methods used for data collection and the age cohort distribution strengthened the use of ELSA for longitudinal analysis (Steptoe et al. 2013a). Secondly, this study represents the first identified attempt to examine the relationship between reported age discrimination and frailty development and progression among adults aged 65 years and over in the UK. The eight-year longitudinal analysis over five Waves of ELSA allows establishing a plausible causal association between age discrimination and frailty. The findings from this study give some indications for interventions that might be useful for frailty prevention. This longitudinal approach also expands the knowledge of the association between age discrimination and loneliness and how this can increase the risk of frailty.

Lastly, this research work is part of the EuroAgeism research network that provides scientific data to support interventions and policies to reduce age discrimination (ageism) globally. This study benefitted from the knowledge acquired via the network's training and development programmes, including the use of the Multidimensional Frailty Index and the generalised estimating equation (international collaboration with colleagues at Fonty's University in Eindhoven, Netherlands) and designing the implication for policy and practice.

8.6 Limitations

Although the findings from this study are promising and offer to introduce important perspectives to the knowledge of frailty among older adults, some limitations should be acknowledged.

8.6.1 Limitation of systematic review

This study's systematic review, including the meta-analysis, was conducted to determine the link between frailty and ageism. The PRISMA guideline for systematic reviews was utilised in the design and reporting of the findings. One of the limitations of the review was in the area of the methodological design. Firstly, the literature search was limited only to articles published in Europe to manage the output generated from the search string. This means that it potentially excludes articles published in other parts of the world. Another limitation relating to the review is the high heterogeneity between the papers included in the review (**Section 2.3.1**). Nevertheless, the use of the PRISMA guideline reduced the risk of bias in the overall review protocol. The main reviewer

(doctoral student) was supported by additional assessors (the supervisors) for the abstract screening of the initial selection and the Kappa's statistics of 0.83 showed strong inter-rater reliability.

8.6.2 **Data limitations**

The ELSA data analysed in this study has been designed to be representative of individuals aged 50 years and over in England (Steptoe et al. 2013a). However, there is a possibility of bias in the sample selection that could affect the generalisability of the findings of this study on the general population. The ELSA study started in 2002 with initial recruitment of the participants from 1998, 1999 and 2001 Health Survey for England (HSE), and then the ELSA study continued data collection at two-year intervals. Refreshment data are also pooled from the HSE households every two years to ensure that the ELSA retains its sample size, gender and age composition (**Section 3.4.3**). This recruitment strategy means that individuals not included in the HSE survey are repeatedly left out of the ELSA study.

Another limitation is the low representation of minority groups in the ELSA study, which has been linked to the recruitment strategy and lack of funding (Clemens et al. 2019a). The ongoing COVID-19 pandemic has shown the disproportionate health inequalities among the Black, Asian and Minority Ethnic (BAME) communities compared to the general population (Proto and Quintana-Domeque 2020) and how crucial it is for health studies in the UK to be more inclusive (Patel et al. 2020). The baseline characteristics in Table 4.3 (**Section 4.6**) showed that 99% of the participants were Caucasians (White), and thus, the ethnicity variable could not be included in the analysis as a covariate. This further raises a question on the representativeness of the ELSA data and the need for caution concerning generalisability to the general population. Thus, future health studies in the UK must look at ways to include the under-represented groups.

The results could also be biased by the attrition of data between the baseline and the follow-up Waves of ELSA analysed in this study. Only 44.4% (2385/5377) of the total population of older adults aged 65 years and over at the baseline data (Wave 5 of ELSA) was analysed in this study. Data attrition is typical of longitudinal studies, and findings from this study consistently showed that the sample loss to follow-up included individuals who were older, more sedentary and less healthy as reported in previous studies (Cuer et al. 2020; Jackson et al. 2019). Thus, it is possible that the data attrition could have cofounded the association between reported age discrimination and frailty outcome among the ELSA participants.

8.6.3 **Measurement limitations**

There are limitations to the findings of this study based on the subjectivity of the measures used to assess the predictor and outcome variables. For instance, the age discrimination data utilised in this study was self-reported and related to previous experiences of discriminatory events that happened within one year before the data collection. Previous epidemiologic studies have indicated that the reliability of self-reported information can be influenced by the participants' cognitive health and thus lead to a potential risk of recall bias (Althubaiti 2016; Carroll 2014). However, the findings from this study showed a significant association between age discrimination and frailty after fully adjusting for specified covariates, including participants' cognitive health. Another intricate area was determining whether this discriminatory event was age-related or because of other reasons. This is because multiple factors could have precipitated the discriminatory event reported by the participants. For instance, the reported age discrimination may have reflected the participant's perception of ageing or embodied self-ageist stereotypes (Levy 2009). However, the ELSA questionnaire on discrimination was designed to include other possible reasons for discrimination such as disability, weight, gender, and race to avoid leading questions. Another potential limitation was that the reported age discrimination data in the ELSA study was only collected once (in 2010), more than a decade ago and predates the UK 2010 Equality Act against age discrimination (Fredman 2014; Gov-UK 2015). Thus, the result may not reflect the micro-level (individual), meso-level (organisational) and macro-level (societal) adjustment to the government policy in combating ageism. The authors of the ELSA study have announced that Wave 10 of the data collection will include questions on discrimination. It would be interesting to examine the effect of the UK 2010 Equality Act on the prevalence of age discrimination in the UK.

Frailty was measured in this study with the multidimensional Frailty Index (Rockwood and Mitnitski 2007) instead of the Phenotype Frailty tool (Fried et al. 2001), although both measures were identified from the systematic review and are widely used in research. Unlike the Phenotype Frailty that is based on objectively assessed anthropometric measurements, the frailty scores produced using the multidimensional Frailty Index are derived from self-reported health indicators. Thus, it means that the frailty scores generated using the multidimensional Frailty Index would be dependent on the quality or correctness of information supplied by the study participants. On the positive side, the multidimensional Frailty Index (FI) has been validated with the ELSA data in previous peer-reviewed studies (Gale and Cooper 2018; Niederstrasser et al. 2019). Furthermore, the FI covers a larger spectrum of health domains (social,

psychological, cognitive and physical) compared to Phenotype Frailty and the FRAIL instrument, which focuses on physical health.

8.6.4 Statistical model limitations

There are limitations to the interpretation of the findings in this study based on the statistical analysis conducted. The generalised estimating equation (GEE) was utilised in this study to examine the longitudinal association between age discrimination and frailty. Aside from the GEE, the other common statistical approach that is used to estimate the association between the exposure and the outcome variables in a longitudinal analysis with repeated/multilevel data is the mixed modelling approach (Gumedze and Dunne 2011). Unlike the mixed model that examines both random and fixed effects (**Section 3.5.5**), the GEE is only a fixed-effect model. The implication is that the GEE model assumes that all the participants, for instance, have experienced age discrimination the same way and thus do not account for individual variability. Although the mixed model can generate information that will be crucial for a deeper understanding of the participants' data, the current study was not focused on individual-level variability. Besides, the GEE has been arguably shown to accurately estimate a population-level result with verifiable assumptions compared to the mixed model (Hubbard et al. 2010).

8.7 Implications

This thesis demonstrates the need for evaluating the influence of social risk factors on frailty development and provides scientific findings that might be useful when planning frailty prevention strategies. The findings highlight that increased risk of frailty is significantly associated with reported age discrimination and that addressing this can potentially reduce frailty onset or progression. The result of this study implies that social interventions may be relevant to reducing the burden of frailty on the ageing population, and this could be tested in future research.

The following sections include the potential implications of the current study to knowledge and social policy and makes recommendations for future research.

8.7.1 Knowledge

The awareness of ageism is vital in facilitating strategies to combat it. The World Health Organisation has published its first report on global ageism, and one of the areas spotlighted is the issue of ageism in health and social care (WHO 2021a). Ageist

communication style has been reported in hospital and social care settings (Wyman et al. 2018), where health professionals attribute frailty syndromes to "old age". Age-based bias leading to a significant delay in the diagnosis and treatment of cancer among older adults have been reported in the literature (Turner et al. 1999). In the ELSA study, 10% of the participants reported the experiences of age discrimination from health professionals or in a hospital (Rippon et al. 2015). This demonstrates the need for more awareness of ageism and its detrimental effect on the health and well-being of older adults. The present study provides the knowledge to highlight the detrimental impact of age discrimination on older adults' overall health and well-being. Although many studies have been published on some of the modifiable risk factors of frailty (**Section 1.6**), most of these studies have focused on older adults' lifestyle changes. This thesis focused on an extrinsic modifiable factor (age discrimination) that could potentially increase the risk of frailty development among older adults and the results of this study underscores the need for social perspectives in the assessment and management of frailty. Additionally, the results demonstrate the differences in the frailty manifestation for both genders and why interventions to prevent frailty must address the specific needs of each gender.

8.7.2 **Practice**

The decision to examine frailty as the main outcome in this study comes when the ADVANTAGE Joint Action on Frailty (Mañas et al. 2018) reports the need to identify the risk factors of frailty and develop screening criteria to determine the prevalence of frailty across countries in Europe. The ADVANTAGE is a Joint Action group funded under the EU Health programmes (2014-2020), and it involved several academic and health organisations across different countries in Europe with the mandate of developing strategies to prevent frailty among the population. The group's report indicated that increasing prevalence of frailty is imminent owing to increasing life expectancy in the European population and recommends the need to train health workers on how to identify and manage the risk factors of frailty.

Despite the growing body of evidence on the effectiveness of early interventions in preventing frailty (Morley et al. 2013), there is currently a paucity of research detailing the use of social interventions in the management of frailty (Liu et al. 2019). For example, in the UK, although the electronic frailty assessment (eFI) used by general practitioners includes a patient's social vulnerability status, its use is only for pre-assessment and not included in the eventual management of frailty (Lansbury et al. 2017). A recent study that examined the ways to reduce COVID-related frailty proposed that social activities should be included in the strategies to prevent frailty progression during and after the pandemic (Boreskie et al. 2020). This study showed that loneliness

is associated with frailty and mediates the pathway between age discrimination and frailty. Thus, the result of this study highlights the relevance of training health and social care staff to recognise the cases where social intervention would be critical to improving the health and well-being of frail older adults.

8.7.3 **Policy impact**

One of the interesting findings from this study is the significant association between reported age discrimination and loneliness among the ELSA participants. Loneliness has been linked to poor physical and mental health among older adults (Beutel et al. 2017), with a 26% increase risk of mortality among lonely (Holt-Lunstad et al. 2015). The result of this study suggests that individuals who have experienced age discrimination are at risk of feeling a loss of social connections to others. Despite the significant link between loneliness and age discrimination as shown in this study, there is a lack of adequate data documenting how social interventions to reduce loneliness among older adults address possible ageism root-cause. This thesis has contributed to the awareness campaign to ageism against older adults (please see **U3A webinar** in the dissemination lists).

Furthermore, the result from this thesis feeds into the overall policy report (**Appendix VII**) of the EuroAgeism Network on ways in which ageism can be generally minimised. The policy report is expected to help guide the discussion with policymakers on ageism-related strategies to foster health promotion and illness prevention behaviour among older people. One of the key recommendations of the policy report is the need to train/educate health and social care providers on ways to reduce ageism in these settings. Previous studies have reported a higher risk of age discrimination in the hospital towards older adults during medical procedures or diagnosis compared to younger patients (Lawler et al. 2014; Wyman et al. 2018). Thus, it would be relevant for health and social care providers to continuously review routinely offered protocols or procedures to ensure that they are appropriate for all age groups. This study showed that individuals aged 65 years and over in the ELSA data reported a high prevalence of age discrimination (38.5%). Although age is already a protected entity in the UK 2010 Equality Act (Gov-UK 2015), ageism needs to be at the centre of the legislative, social and civic agenda. A key policy priority for the different governments in the UK should therefore be to promote strategies to combat ageism and ensure that there are appropriate systems, services, and support for frail older individuals at risk of discrimination.

8.8 Recommendations

Based on the systematic review of the literature, the meta-analysis and the longitudinal analysis of ELSA data in this thesis, there are areas of study identified that need further investigation.

8.8.1 Ageism in social care

A desirable but unattainable goal for this study is to analyse the association between ageism and frailty among older adults in institutionalised settings (care homes or nursing homes). The WHO global report on ageism raised a concern on the lack of adequate data on the prevalence of age discrimination in the social care setting (WHO 2021a). In the case of the present study, it was due to data limitation as there were less than 50 participants who moved to a care home in the ELSA study. Previous research has indicated that frailty is crucial for admission to care homes (Kojima 2018). With the result of this study showing a significant association between reported age discrimination and frailty among community dwellers, it would be interesting to observe the impact of ageism on the health and well-being of care home residents. A further study could assess how ageism/ageing stereotypes influence the quality of social care for frail older adults. More broadly, there is a need for ageism research focusing on care home residents.

8.8.2 Impact of social intervention on frailty

This study demonstrates the need to consider social interventions in the prevention of frailty among the growing UK ageing population. Although it was evident from the literature review that some assessment tools already include social determinants of frailty (**Section 1.3**), there is a lack of adequate data on the use of social interventions to prevent frailty among older adults. Thus, future research can further evaluate this gap to determine the deployment and/or effectiveness of social interventions to reduce the development or progression of frailty in both the community and care home settings.

8.8.3 Mapping ageism in the UK

Despite the scale of impact that ageism could potentially have on both the older and younger members of society, the attention given to age discrimination is still comparatively lower than other forms of discrimination such as sexism or racism. For instance, it would have been interesting to examine age discrimination in Scotland being

the primary constituent of this EuroAgeism project. However, it was not possible due to a lack of data to examine the influence of age discrimination on the health and well-being of older adults who are residents in Scotland. Besides, the ELSA study was the only large health study in the UK to have included data on age discrimination at the time of conducting the analyses in December 2020. Thus, collecting relevant data on ageism in the UK will be necessary to foster further research in this field.

8.8.4 Social disparity and frailty

Aside from demonstrating the detrimental impact of ageism, the result of this study highlights the underlying social disparity that influences the health and well-being of older adults. For instance, the results showed that women were significantly more likely to be frail or become frail compared to men from the analysis of the ELSA data. The findings also show that people in the lower socioeconomic level were significantly more likely to be frail or have poor health. Previous research that examined frailty among older European migrants has shown that older adults from a minority background were at a significantly higher risk of frailty compared to the predominant groups in the SHARE data (Walkden et al. 2018). The combination of these factors could mean that there is a greater risk of frailty among women from minority backgrounds. Thus, further work is needed to fully understand the implications of the findings of this study for the minority community.

8.8.5 Future direction

The natural progression of this study will be to explore the relationship between ageism and frailty further. One way to achieve this could be to initiate a multi-centre meta-analysis using individual participant data. Meta-analysis can be conducted in two ways (i) to use raw data from papers to be included in a meta-analysis – individual participant approach (ii) to use findings from already published papers as done in this thesis-aggregated data approach. The use of individual participant data provides access to the original data used in the individual studies, improves the analysed data's consistency, allows for standardised statistical analysis across studies, and enhances collaborations across research groups (Debray et al. 2013). The individual participant data meta-analysis is more effective and less prone to unverifiable assumptions and bias compared to the aggregated data approach (Riley et al. 2010). Another practical way to further examine the association between ageism and frailty among older adults will be to seek and/or advocate for the collection of more primary data on ageism in both the community and care home settings across the countries in the UK. This will facilitate the

comparison of data and provide more scientific evidence on how to achieve healthy ageing among the entire population.

8.9 **Conclusion**

With the increasing life expectancy globally, the total number of individuals reaching and living beyond 65 years is also increasing. As a continent currently accounting for 17% of the global population of adults aged 65 years and over, Europe (including the UK) is faced with rising health and social care demand. Although frailty may be preventable or reversible, there is a paucity of research exploring the social risk factors of frailty. This thesis examines the influence of age discrimination on frailty among older adults in the UK context by analysing the English Longitudinal Study of Ageing. Findings from this study are planned for scientific contributions in peer-reviewed journals (**Appendix VIII**). The conclusions of this study is as follows: (i) Self-reported age discrimination is significantly associated with the development and progression of frailty among older individuals aged 65 years and over in the ELSA study; (ii) Older women are significantly more at risk of frailty compared to older men in the analysed data; (iii) The association between reported age discrimination and frailty can be partly explained through loneliness, that is, those who reported age discrimination could become lonely and eventually become at risk of frailty. This result implies that reported age discrimination and loneliness are possible social risk factors of frailty. Therefore, social factors should be considered in assessing frail older adults and in the planning of interventions to reduce frailty and promote healthy ageing.

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APPENDICES

Appendix I: Peer-reviewed article on frailty by the author

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Cerebrovascular Diseases Extra

Translational Research in Stroke

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Self-Efficacy Is a Modifiable Factor Associated with Frailty in Those with Minor Stroke: Secondary Analysis of 200 Cohort Respondents

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Keywords
Self-efficacy · Frailty · Stroke management · Healthcare

Abstract

Background: Owing to the improvement in acute care, there has been an increase in the number of people surviving stroke and living with its impairments. Frailty is common in people with stroke and has a significant impact on the prognosis after stroke. To reduce frailty progression, potentially modifiable factors should be identified. Increasing levels of self-efficacy influence both behaviour and physical functioning, and therefore it could be a potential target to prevent frailty. ***Methods:*** This is a prospective cohort study that involved the secondary analysis of the RISE data to examine the relationship between self-efficacy and frailty. The RISE study is a longitudinal study that consists of 200 adults aged 18+ years after their first stroke event. Data were collected from the respondents at 3 weeks, 6 months, 12 months, and 24 months after their discharge from the hospital. Frailty was assessed using the multidimensional frailty index with scores ranging from 0 to 1, and self-efficacy was assessed using the SESx scale, which was dichotomized as low/moderate or high. Frailty trajectories were examined using the repeated linear model. The generalized estimating equation was used to examine the relationship between self-efficacy and frailty at baseline and in the future (6–24 months). The B coefficients were reported at 95% CI before and after adjusting for potential confounders (age, gender, stroke severity, education, and social support). ***Results:*** A total of 200 responses were analysed, and the mean age of the respondents was 67.78 ± 11.53. Females made up 64% of the sample, and the mean frailty score at baseline was 0.17 ± 0.09. After adjusting for confounders, respondents with low self-efficacy had an approximately 5% increase in their frailty scores at baseline and in the 24-month follow-up period compared to those with high self-efficacy. ***Conclusion:*** The result from this study showed that self-efficacy was significantly associated with frailty after stroke. Our findings suggest that self-efficacy may play a role in frailty progression among stroke survivors.

Introduction

According to the global burden of disease report in 2016, stroke is one of the leading causes of mortality worldwide with an estimated 5.5 million deaths and 116 million disability-adjusted life years [1]. Conversely, 50% of stroke-related deaths have been linked to poor man-

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Appendix II: PROSPERO protocol published on June 7, 2019

Systematic review protocol published with record number **CRD42019135851**

NIHR | National Institute for Health Research

PROSPERO
International prospective register of systematic reviews

Citation

Abodunrin Aminu, Nicola Torrance, Aileen Grant. Analysing the link between ageism and frailty among older people: a quantitative systematic review. PROSPERO 2019 CRD42019135851 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019135851

Review question

1) To conduct a systematic literature search of ageism in frail, older people, focusing on quantitative studies.

2) To examine the measures of frailty, ageism and health outcomes as used in previous studies.

3) To identify the relationship between these measures.

Searches

Electronic Database:

We will search the EBSCO content including all the search fields such as Title TI, Abstract AB, Author AU, All Text TX, Subject Term SU, Source SO, ISSN IS, ISBN IB.

The search will be conducted using four main electronic databases on EBSCO Host (AgeLIne, CINAHL, MEDLINE and PsycARTICLES).

A broad search was conducted on other databases (SocIndex, CAB Abstract, MED - The Allied and Complementary Medicine Database, Business Source Complete, International Pharmaceutical Abstracts and ERIC).

Further search will be conducted on the Web of Science to improve the rigor of the review.

Search dates:

Search will include all outputs on or before 31st April 2019

Studies written in English Language only

MEDLINE:
FRail* AND ("age discrimination" or agi* or age* or "age prejudice" or "self-perception* of ag*" or "age stereotype*" or "age identity") AND ("health*" or "well-being" or "wellbeing" or "well being")

Types of study to be included

Inclusion criteria for the review

• Studies with a quantitative measure of ageism (including cross sectional and longitudinal designs, cohort studies, randomised controlled trials of non - clinical trials of interventional medicinal products (non-CTIMPs).

• Human studies

Appendix III: PRISMA Checklist for the systematic review

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	**Pg. 47**
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	**Pg 47**
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	**Pg 48 & 49**
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	**Pg 49**
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	**Pg 51**
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	**Pg 50**
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	**Pg 50**
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	**Pg 51-53**
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	**Pg 51-53**
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	**Pg 54-56**
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	**Pg 54-56**
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	**Pg 54-56**
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	**Pg 56**
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	**Pg 57-59**
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	**Pg 60**
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	**Pg 61-63**

Section and Topic	Item #	Checklist item	Location where item is reported
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	**Pg 194**
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	**Pg 61-63**
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	**Pg 64-67** **Pg 203**
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	**Pg 194**
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	**Pg 59**
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	**Pg 67**
	23b	Discuss any limitations of the evidence included in the review.	**Pg 68**
	23c	Discuss any limitations of the review processes used.	**Pg 68**
	23d	Discuss implications of the results for practice, policy, and future research.	**Pg 67**
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	**Pg 50**
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	**Pg 50**
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	**Pg 191**
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	**Pg 56**

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

Appendix III(a): A full record of quality assessment measures for all the studies included in this review

Please note that some of the questions in the quality assessment questionnaire are not included in the Table to manage the formatting. Excluded questions are those not directly relevant to all of the papers reviewed.

Paper author and date	1. Was the research question or objective in this paper clearly stated?	2. Was the study population specified and defined?	3. Was the participation rate of eligible persons at least 50%?	4. Were all the subjects selected or recruited from the same or similar populations (including the same period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	6. For the analyses in this paper, were the exposure(s) of interest measured before the outcome(s) being measured?	9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	10. Was the exposure(s) assessed more than once over time?	11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	13. Was the loss to follow-up after baseline 20% or less?	14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?s	Rating (Poor, Fair or Good)
Beyer et al. (2015)	Yes, the aim was clearly stated. To examine the the notion that health behaviour acts as a mediator in the relationship between positive self-perception of ageing and health	Yes, community-dwelling older adults aged 65–85 year	Yes, 309 out of 443 consented to participate	Yes, participants were all recruited from the German Ageing Survey	CD – Longitudinal. However, the authors carried out longitudinal analysis but never stated if exposure comes before the outcome	Yes, exposure was measured as the perception of ageing.	Yes, it was assessed in 2009 and 2011	Yes, the outcome was measured as self-reported health	Yes, 210 participated in follow up out of 309	Yes: confounders included were Age, Sex, Chronic condition and Education	Good
Bowling (2008)	Yes, the aim was clearly stated as "to identify older people's perceptions and self-ratings of active ageing, to compare them with the literature, and to compare their perceptions with	Yes, older people aged 65 years and over who participate in Omnibus Survey in Britain	Yes, 1460 of 2786 responses were analysed (53%)	Yes, secondary data was collected from the same source (Omnibus survey)	Not Applicable - cross-sectional	Yes, exposure was self-reported successful ageing.	No: Cross-sectional study	Yes, the outcomes were health status, long-standing illness and quality of life.	Not Applicable	CD: Not mentioned	Good

	comparable literature on perceptions of successful ageing and QoL"										
Buckinx et al. (2018)	Yes, the authors hypothesized that negative attitudes to ageing among nursing home residents are associated with a higher level of frailty	Yes, older adults who participate in the Sample of Elderly Nursing home Individuals: Observational Research (SENIOR) in Liège, Belgium.	No, 272 out of 660 who participated in the SENIOR study were analysed	Yes, secondary data was collected from the same source (SENIOR)	Not Applicable - cross-sectional	Yes, exposure was measured as attitude towards ageing.	No: Cross-sectional study	Yes, the outcome was measured as frailty status.	Not Applicable	Yes: Age and Sex	Good
Gale and Cooper (2018)	Yes, the authors hypothesised that older people with more negative attitudes to ageing would be at higher risk of the onset or progression of frailty	Yes, older adults in England who participate in the ELSA wave 2,3,4 and 5	Yes, 3505 out of 6183 core participants aged 60 years and over in the ELSA wave 2 were analysed	Yes, secondary data was collected from the same source (ELSA)	CD – Longitudinal. However, the authors carried out longitudinal analysis but never stated if exposure comes before the outcome	Yes, exposure was measured consistently as a Self-perception of ageing.	Yes, Data on self-perception of ageing was collected in two different ELSA (2 & 4) waves used in the study	Yes, the outcome was measured using physical frailty status and frailty index	CD: This cannot be determined in the study	Yes: Age, Socioeconomic position, Education, Smoking, Depressive symptoms	Good
Jackson et al. (2019)	Yes, the paper examined the association between age discrimination and health and wellbeing among older adults in England	Yes, the paper analysed secondary data from ELSA waves 5 and 8	Yes, data of 7731 out of 9090 core participants eligible for the study were analysed	Yes, secondary data was collected from the same source (ELSA)	CD – Include longitudinal. However, the authors carried out longitudinal analysis but never stated if exposure comes before the outcome	Yes, exposure was measured as perceived age discrimination.	No – perceived age discrimination was only assessed once (ELSA wave 5).	Yes, the outcome was measured using self-reported health and long stand illnesses	Yes, 5595 out of 7731 baseline data	Yes: Age, Sex and Household wealth	Good
Kalfoss (2017)	Yes, the aim was to describe subjective attitudes towards ageing among Norwegian older adults	Yes, data for older people were drawn from the statistical bureau of Norway	Yes, but this was borderline, exactly at a 50% response rate (401 of 802 eligible participants)	No, Author noted that there was no clear reason for inclusion or exclusion criteria	Not Applicable – descriptive study	Not applicable: It was a descriptive study.	No: Cross-sectional study	Not Applicable	Not Applicable	Not Applicable	Fair
Kornadt et al. (2021)	Yes, the aim was to examine the association between perception of ageism during the COVID-19 pandemic	Yes, data from the TNS ILRES (Luxembourg)	Yes, all eligible individuals participated.	Yes, all participants were recruited from same study (TNS ILRES)	Not Applicable - cross-sectional	Yes, exposure was measured as perceived ageism and self-perception of ageing.	No: Cross-sectional study	Yes, the outcome was measured as subjective health and life satisfaction.	Not Applicable	Yes: Age and life satisfaction before pandemic.	Good

Moser et al. (2011)	Yes, the primary purpose of this study was to evaluate longitudinally the hypothesis of a relationship between self-perception of ageing and vulnerability to adverse outcomes (falls, hospitalizations, and need of assistance for ADL) in adults aged 65–70 years, controlling for sex and age	Yes, the sample consisted of older adults aged 65–70 years from Lausanne cohort data in Switzerland	Yes, 1152 of 1564 participants were analysed. Although paper failed to justify while 1,564 participated out of the initial 3054 who were selected to be part of the study	Yes, secondary data was collected from the same source (Lausanne cohort)	Not applicable - cross-sectional	Yes, exposure was self-perception ageing.	No: Cross-sectional study	Yes, the outcome was measured using the incidence of Fall, Basic activities of daily living (BADL) and instrumental activities of daily living (IADL)	Not Applicable	Yes: Age, Sex, Depressive feelings, Chronic conditions, Living arrangements, Income, Education.	Good
Rippon et al. (2015)	Yes, to examine cross-national differences in perceptions of age discrimination in England and the United States	Yes, contains data of older adults aged 50+ years who participated in wave 5 of ELSA	Yes, 7,478 of 9, 090 participants in ELSA and 4,818 of 4,822 participants in HRS	Yes, secondary data was collected from the same source.	Not applicable - cross-sectional	Yes, perceived age discrimination	No: Cross-sectional study	Not Applicable	Not Applicable	Yes: Age, Sex, Wealth, Education, Marital status and Work status	Good
Robertson and Kenny (2016)	Yes, authors hypothesized that hypothesis that the association between frailty and cognitive function will only exist in adults with negative perceptions of ageing.	Yes, contains data of older adults aged 50+ years who participated in wave 1 of the Irish Longitudinal Study on Aging (TILDA)	Yes, 4901 of 8175 of the participants of TILDA wave 1 were analysed	Yes, secondary data was collected from the same source (TILDA)	Not Applicable - cross-sectional	Yes, exposure was self-perception of ageing.	No: Cross-sectional study	Yes, the outcome was measured using the participant's frailty status	Not Applicable	Yes: Age, Sex, Education, Chronic conditions, Medication, Self-reported health and Depressive mood	Good
Salguero et al. (2019)	Yes, to examine the association between ageist attitudes and frailty.	Yes, participants from the US Department of Veteran Affairs, aged 50+ years	CD: 381 participants in total included in the study.	Yes, data collected from same source (US Department of Veteran Affairs)	Not Applicable - cross-sectional	Yes, exposure was measured as implicit and explicit ageist attitudes.	No: Cross-sectional study	Yes, the outcome was measured using the frailty status	Not Applicable	Yes: Age, race, ethnicity, median household income, and comorbidities	Good
Vauclair et al. (2015)	Yes, to examine the association between income inequality and older people's health through reported age discrimination.	Yes, older adults aged 70 years and over	CD: 7,819 participants in total included in the study.	Yes, secondary data analysis of European Social Survey	Not Applicable - cross-sectional	Yes, exposure was measured as income inequality and perceived age discrimination as a mediator.	No: Cross-sectional study	Yes, the outcome was measured as self-rated ill-health	Not Applicable	Yes: Age, gender, education	Good

Warmoth et al. (2018)	Yes, the aim clearly stated "to explore the relationship between older adults' perception of ageing" and frailty cross-sectionally and longitudinally	Yes, the paper analysed ELSA data waves 2 and 5.	Yes, this is a longitudinal analysis of 2418 of 4163 participants who participated in the wave 2 and 5 of ELSA	Yes, secondary data was collected from the same source (ELSA)	Not Applicable – largely cross-sectional. However, the authors carried out longitudinal analysis but never stated if exposure comes before the outcome	Yes, exposure was measured as the perception of ageing.	No: Self-perception of ageing was only assessed once using wave 2 of ELSA.	Yes, the outcome was the frailty status of participants	Yes, 2418 out of 4,190	Yes: Age, Sex, Socioeconomic status and Depressive symptoms.	Good
Ye et al. (2020)	Yes, to examine the mechanism of ageism on frailty based on the Stereotype Embodiment Theory	Yes, community-dwelling participants aged 60 to 94 years	CD: 630 participants recruited for the study.	Community-dwelling individuals recruited in same random locations in Shanghai, China.	Not Applicable - cross-sectional	Yes, exposure was measured as ageing stereotypes, ageing attitudes, and experiences of ageism.	No: Cross-sectional study	Yes, the outcome was the frailty status of participants	Not Applicable	Yes: Age, gender, education, marital status, economic condition and residence status	Good

Appendix III(b): Measures of Ageism and Frailty identified from the literature review

This is the report of the scoping review relating to the objective to examine measures of ageism and frailty identified from the literature in chapter two of the thesis (original).

Measures of Ageism:

The measures of ageism identified from the papers in this study are documented in this appendix section. Only two of the reviewed papers specifically referred to ageism assessment (Kornadt et al. 2021; Ye et al. 2020), while the remaining papers focused on perceived age discrimination or attitudes towards ageing. The majority of the reviewed papers (n=9/14) examined only ageing stereotypes or prejudice using different scales (listed below), while five papers (Kornadt et al. 2021; Jackson et al. 2019; Rippon et al. 2015; Vauclair et al. 2015) assessed perceived (ageism) age discrimination reported by the participants in their study. Only Ye et al. (2020) examined the different dimensions of ageism (ageing stereotype and age discrimination).

The other measures of ageism identified from the reviewed papers include the following:

- 12-item scale for assessing Attitude Towards Ageing developed for the ELSA study (n = 2); Clemens et al.(2019a).
- Ageing stereotype scale (n=1); (Kornadt and Rothermund 2012).
- Attitude to Ageing Questionnaire (n = 2); Laidlaw et al. (2007).
- B-APQ Brief Ageing Perception Questionnaire (n = 1); Sexton et al. (2014).
- Implicit ageing stereotypes (n=1) using the Implicit Association Test; (Greenwald et al. 1998).
- Kogan's Attitudes towards Older People Scale (n=1); (Kogan 1961)
- Open-ended questions on active ageing were collected in the Omnibus Survey (n = 1); ONS (2009).
- Perception of Ageing – Attitude Towards own Ageing, a subscale of the Philadelphia Geriatric Centre Morale Scale (n = 2); Lawton (1975).
- Self-perceptions of ageing (n=1)- Using the personal ageing experience scale by Steverink et al. (2001).

Both the AAQ and the Philadephia Geriatric Centre Morale Scale that has been widely validated, Gale and Cooper et al. (2018) noted that the 12-item scale on attitude to ageing collected in the ELSA study had not been widely validated, and no peer-reviewed paper on the psychometric properties of the scale has been published. Likewise, Bowling (2008) noted that there was no multi-item scale to measure active ageing at the time of publication of this study.

Measures of Frailty:

Three frailty instruments were identified in the systematic review namely FRAIL, Phenotype Frailty and Frailty Index. The Phenotype Frailty instrument is used to measure frailty through five poor physical health performance indicators in an individual; unintentional weight loss, slow walking speed (slowness), weak hand grip (weakness), low physical activities and exhaustion (Fried et al. 2001). Using the Phenotype Frailty instrument, participants who had three or more of the indicators are regarded as 'frail', one or two of the indicators as 'pre-frail and none of the indicators as 'robust'. Among the three papers that utilised the Phenotype Frailty Index, two studies (Gale and Cooper 2018; Robertson and Kenny 2016) utilised objectively measured Phenotype Frailty indicators of the participants, while Buckinx et al. (2018) relied on a self-reported account given by the participants in their study. The FRAIL instrument utilised by Ye et al. (2020) assesses physical frailty in a similar to the Phenotype Frailty instrument.

Another measure of frailty identified in the review is the multidimensional Frailty Index (Salguero et al. 2019; Gale and Cooper 2018; Warmoth et al. 2018). The three papers utilised this measure of frailty and calculated the frailty index score based on 44 items (Salguero et al. 2019), 52 items (Gale and Cooper 2018) and 54 items (Warmoth et al. 2018). Two of the papers provided longitudinal data that analysed data from similar populations (English Longitudinal Study of Ageing – ELSA), and both relied on self-reported sensory and functional impairments to develop the cumulative Frailty Index. However, Salguero et al. (2019) was a cross-sectional study that utilised the US Department of Veteran Affairs data.

List of frailty and ageism assessment tools/scales identified from the review

Name of Tool/Scale/Questionnaire	Primary citation	Description
Frailty instruments from the reviewed papers		
FRAIL	(Morley et al. 2012)	FRAIL is based on five criteria. It includes the presence of illness and walking resistance together with self-reported fatigue, slow walking speed (ambulation) and weight loss of ≥5 kg and produces a score of 0 to 5 and the outcome is categorised as **robust (0), pre-frail (1 to 2) and frail (≥3)**.
Frailty Index	(Rockwood and Mitnitski 2007)	This tool defines frailty based on the theory that frailty occurs as a result of multiple deficits in the body. It includes cognitive and physical health deficits: abnormal laboratory results, diagnosed conditions, and disabilities. Each of these deficits is assigned 1 if present and 0 if absent, and the mean (0 to 1) of the total score is used to define the frailty status of an individual.
Phenotype Frailty instrument	(Fried et al. 2001)	This tool defines frailty based on five physical criteria: weight loss, exhaustion, slowness, grip strength and low physical activity. Individuals with three or more features are termed **frail**, one to three features as **prefrail** and none of the features as **robust**.
Measures of ageism from the reviewed papers		

Ageing stereotype scale	(Kornadt and Rothermund 2012)	This is a 4-item scale for measuring internalised ageing stereotypes. (What extent do you disagree or agree with the following statements: 'as an older people, it should be…rather than…'; 'older people are too old for something, it's for young'; 'comparing to young, older people are more likely to make mistakes'; 'the older a person is, the more likely to be forgetful or muddled').
Attitude towards Ageing Questionnaire (AAQ)	(Laidlaw et al. 2007)	The AAQ contains a 24-item questionnaire with eight questions on sections covering psychosocial loss, physical change and psychological growth.
B-APQ Brief Ageing Perception Questionnaire	(Sexton et al. 2014)	The B-APQ is an abridged version of the 32-item Ageing Perception Questionnaire. The B-APQ contains 17-items for measuring ageing perceptions and has been psychometrically tested among the Irish population of 50+ years.
ELSA Attitude Towards Ageing scale	(Clemens et al. 2019a)	This is a 12-item questionnaire on attitudes to ageing. The questionnaire contains items developed from responses to 2 open-ended questions: "positive and negative things about ageing".
Implicit Association Test;	(Greenwald et al. 1998)	Participants are asked to pair the terms "Old People" and "Young People" with "affective" attributes that were either positive (a total of 10 words) or negative (a total of 10 words)
Kogan's Attitudes towards Older People Scale	(Kogan 1961)	The instrument consists of 17 matched pairs of positive and negative statements about older individuals.

ONS Active ageing questionnaire	(ONS 2009)	This questionnaire was collected in the British Omnibus survey and it contains two open-ended questions on respondents' perception of active ageing and their ageing.
Perceived age discrimination questions	(Clemens et al. 2019a; Smith J 2017)	This is a 5-item question on perceived discrimination from Wave 5 of the ELSA questionnaire. These questions were adapted from the American Health and Retirement Study.
Perceived ageism	(Kornadt et al. 2021)	"Have you felt that you were treated unfairly due to your age in the following circumstances": 1) media coverage, 2) health care, 3) activities of daily life (e.g. shopping), and 4) within my social network (friends, family) and 5) work place."
Philadelphia Geriatric Centre Morale Scale	(Lawton 1975)	The PGCM scale is a 17-item questionnaire that addresses the dimension of attitudes or perceptions. This questionnaire covers questions on Agitation, Attitude towards own ageing, Lonely dissatisfaction.
Single-item perceived age discrimination	(Vauclair et al. 2015)	"How often in the past year has someone treated you badly because of your age, for example, by insulting you, abusing you or refusing you a service?" (0 = "never", 4 = "very often").

Appendix III(c): Preliminary meta-analysis to examine the effect of ageism on the risk of frailty.

The preliminary analysis was conducted as a demo meta-analysis of the review papers to illustrate the possible effect of ageism on frailty risk and cannot be used to draw a conclusion on the association between ageism and frailty due to data limitation. To conduct the meta-analysis, the effect size from two of the papers were converted to risk ratios using a meta-analysis effect size conversion calculator (Polanin and Snilstveit 2016). The exposure group is the **ageism** group (negative perception/attitude to ageing) and the comparison group is **no ageism** (positive perception/attitude to ageing). The meta-analysis used the random-effect model due to the observed difference in the measure of frailty used in the reviewed papers. Additionally, a separate fixed-effect meta-analysis was conducted, including the papers (Salguero et al. 2019; Warmoth et al. 2018) that both used the multidimensional frailty index (FI) instrument to assess frailty. Although Gale and Copper also utilised the FI instrument in their study, Gale's paper was not included in the second meta-analysis because the authors did not report adequate information on the cross-sectional association between ageing attitudes and frailty. The meta-analysis was conducted using the review manager software version 5.3 created by the Cochrane group (RevMan 2014).

Findings:

The meta-analysis result can be seen in Image 1 and 2, which shows the comparison of the ageism and no ageism groups for the frailty outcome using risk ratio to measure the effect sizes. The findings from the meta-analysis of the five papers show that the risk of frailty was significantly reduced by 52% among the group with a positive perception/attitude to ageing (no ageism group). Summary of the findings in Image 1 show that the overall test effect was $Z= 3.18$ ($P < 0.0001$) and the heterogeneity $Tau^2= 0.05$; $Chi^2 = 163.81$, $df = 4$ ($P < 0.00001$); $I^2 = 98\%$.

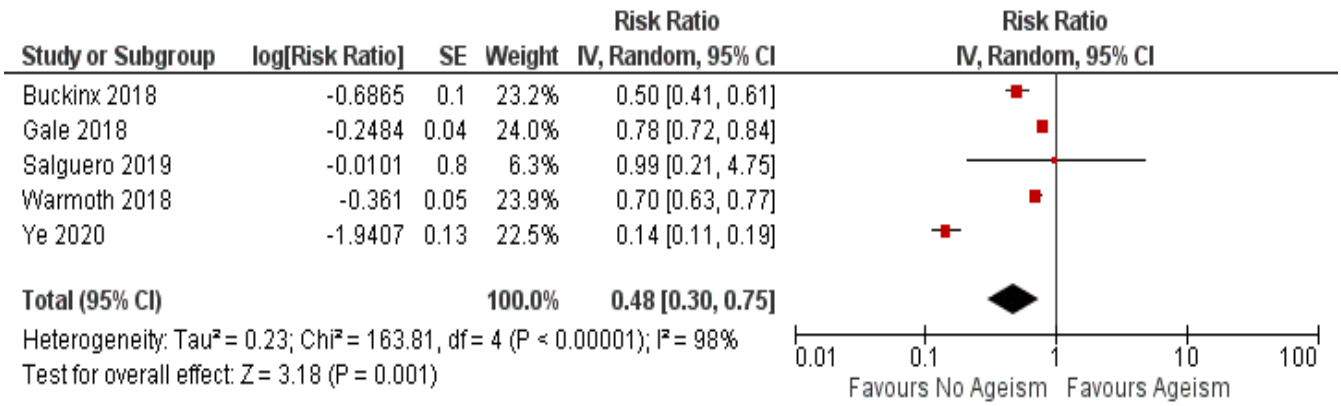


Image 1: Forest plot showing the random effect of ageism on frailty outcome reported by the reviewed papers (n=5)

The result of the meta-analysis of the two papers that measured frailty scores using the multidimensional frailty index (FI) is shown in Image 2. Summary of the findings in Image 2 show that the overall test effect was Z= 7.21 (P < 0.0001) and the heterogeneity test was insignificant; Chi^2 = 0.19, df = 1 (P = 0.66); I^2 = 0%. The findings show that the risk of frailty was significantly reduced by 30% in the no ageism group compared to the ageism group in the meta-analysis of the two papers.

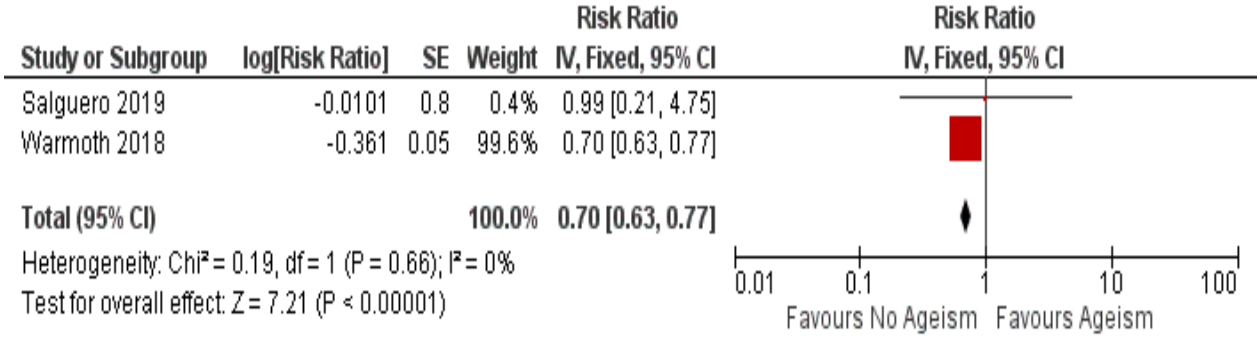


Image 2: Forest plot showing the fixed effect of ageism on frailty outcome reported by the reviewed papers (n=2)

Appendix IV: Ethical Review Panel (SERP) Approval confirmation from SNMPP, RGU for the original ethics application

ROBERT GORDON UNIVERSITY ABERDEEN

Abodunrin Aminu
PhD student
School of Nursing and Midwifery
Robert Gordon University

18/10/19

SERP reference number: 19-15

Dear Abodunrin

Research proposal name: Putting ageism in context: Examining the relationship between age discrimination, frailty and health status among individuals aged 65 years and over.

Thank you for submitting your application for ethical approval. The School of Nursing and Midwifery Ethics Review panel has now reviewed the above research proposal. Your proposal has been approved. You may go ahead with your research unless the project requires further approval. Where the project involves NHS patients, approval through IRAS system must be obtained. Where the project involves NHS staff, approval through the NHS R&D office must be obtained and this is usually done through IRAS. https://www.myresearchproject.org.uk/ Please email a copy of this approval letter along with your study protocol to Jill Johnston j.johnston4@rgu.ac.uk who tracks NHS IRAS applications on behalf of Sponsor Professor Paul Hagan.

SERP approval is valid for 1 year from the date of this letter. If your data collection period progresses beyond 1 year please notify the SERP convenor.

Please include your SERP reference number in a footer on all documents related to your study.

If you require further information please contact the committee by email on NM-Serp@rgu.ac.uk

Yours sincerely

Dr Aileen Grant
NM SERP Convenor on behalf of the committee.

Appendix V: Ethical Review Panel (SERP) Approval confirmation from SNMPP, RGU for the revised ethics application

Abodunrin Aminu
PhD student
School of Nursing and Midwifery
Robert Gordon University

18 December 2020

SERP reference number: 19-15

Dear Abodunrin

Research proposal name: Putting ageism in context: Examining the relationship between age discrimination, frailty and health status among individuals aged 65 years and over.

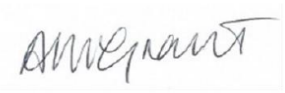
Thank you for submitting your amended proposal for ethical approval. The School of Nursing and Midwifery Ethics Review panel has now reviewed the above research proposal. Your proposal has been approved. You may go ahead with your research unless the project requires further approval. Where the project involves NHS patients, approval through IRAS system must be obtained. Where the project involves NHS staff, approval through the NHS R&D office must be obtained and this is usually done through IRAS. https://www.myresearchproject.org.uk/ Please email a copy of this approval letter along with your study protocol to Jill Johnston j.johnston4@rgu.ac.uk who tracks NHS IRAS applications on behalf of Sponsor Professor Paul Hagan.

SERP approval is valid for 1 year from the date of this letter. If your data collection period progresses beyond 1 year please notify the SERP convenor.

Please include your SERP reference number in a footer on all documents related to your study.

If you require further information please contact the committee by email at SNMP-SERP@rgu.ac.uk

Yours sincerely



Dr Aileen Grant
SNMP SERP Convenor on behalf of the committee.

Appendix VI: List of items in the ELSA data used in calculating the multidimensional Frailty Index scores

	Details of the listed items
1.	**Basic ADL and Instrumental ADL variables:** ADL: difficulty dressing, including putting on shoes and socks ADL: difficulty walking across a room ADL: difficulty bathing or showering ADL: difficulty eating, such as cutting up food ADL: difficulty getting in and out of bed ADL: difficulty using the toilet, including getting up or down IADL: difficulty using a map to figure out how to get around a strange place IADL: recognising when in physical danger IADL: difficulty preparing a hot meal IADL: difficulty shopping for groceries IADL: difficulty in making telephone calls IADL: communication (speech, hearing or eyesight) IADL: difficulty taking medications IADL: difficulty doing work around house and garden IADL: difficulty managing money, e.g paying bills, keeping track of expenses
2.	**Physical health and diagnosed conditions:** Whether often troubled with pain Self-reported general health Whether the long-standing illness is limiting Self-reported eyesight (while using lenses, if appropriate) Self-reported hearing (while using hearing aid if appropriate)

	Hearing: whether finds it difficult to follow a conversation when background noise Diagnosed high blood pressure Diagnosed angina Diagnosed heart attack Diagnosed congestive heart failure Diagnosed heart murmur Diagnosed abnormal heart rhythm Diagnosed diabetes or high blood sugar Diagnosed stroke Diagnosed high cholesterol Diagnosed with other heart diseases Diagnosed lung disease Diagnosed asthma Diagnosed arthritis Diagnosed osteoporosis Diagnosed cancer Diagnosed Parkinson's Disease Diagnosed Alzheimer's Disease Diagnosed dementia Diagnosed glaucoma Diagnosed diabetic eye disease Diagnosed macular degeneration Diagnosed cataract
3.	**Musculoskeletal health:** Mobility status

4.	**CES-D depressive symptoms** Whether felt depressed much of the time during the past week Whether felt everything they did during the past week was an effort Whether felt their sleep was restless during the past week Whether was happy much of the time during the past week Whether felt lonely much of the time during the past week Whether enjoyed life much of the time during the past week Whether felt sad much of the time during the past week Whether could not get going much of the time during the past week

Appendix VI(a): Baseline characteristics of the dropped-out cases in the ELSA datasets

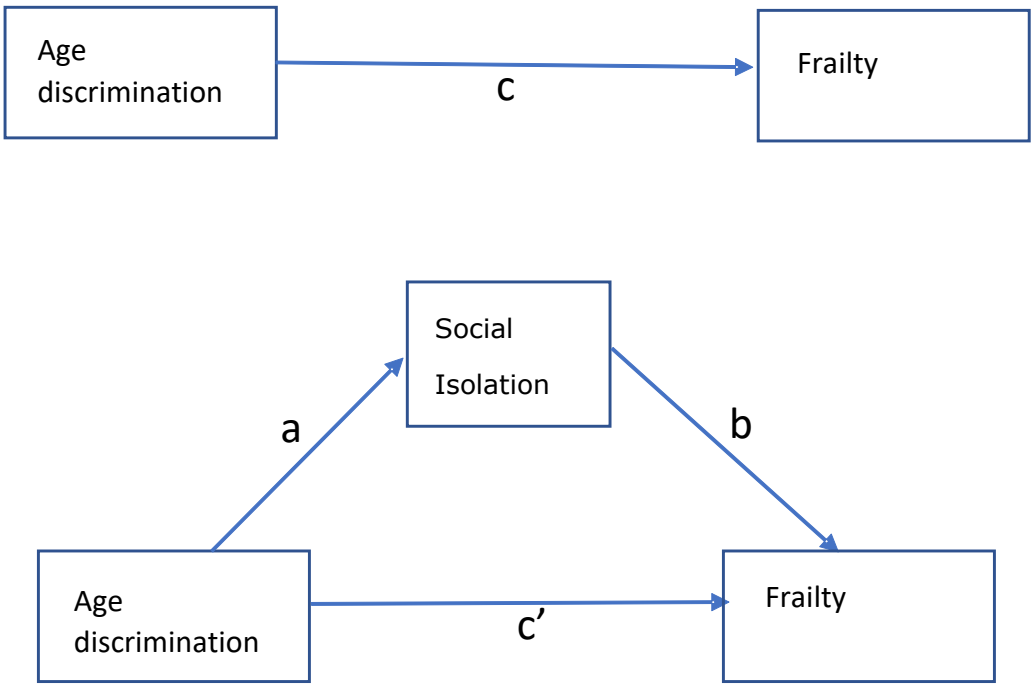
Variables	*N = 2,992	*Valid percent (%)
Age		
65 to 69	668	(23.8)
70 to 74	711	(25.2)
75 to 79	620	(22.0)
80+	817	(29.0)
Gender		
Female	1395	(53.4)
Male	1597	(46.6)
Age discrimination		
No	1472	(64.1)
Yes	826	(35.9)
Self-reported health		
Poor/Fair	1085	(41.3)
Good/V.Good/Excellent	1604	(59.7)
Long-standing illness		
Yes	1988	(66.6)
No	998	(33.4)
Physical activity level		
Sedentary	539	(18.1)
Low	983	(33)
Moderate	1177	(39.5)
Vigorous	278	(9.3)

***Valid percent and counts do not account for missing values in each of the variables.**

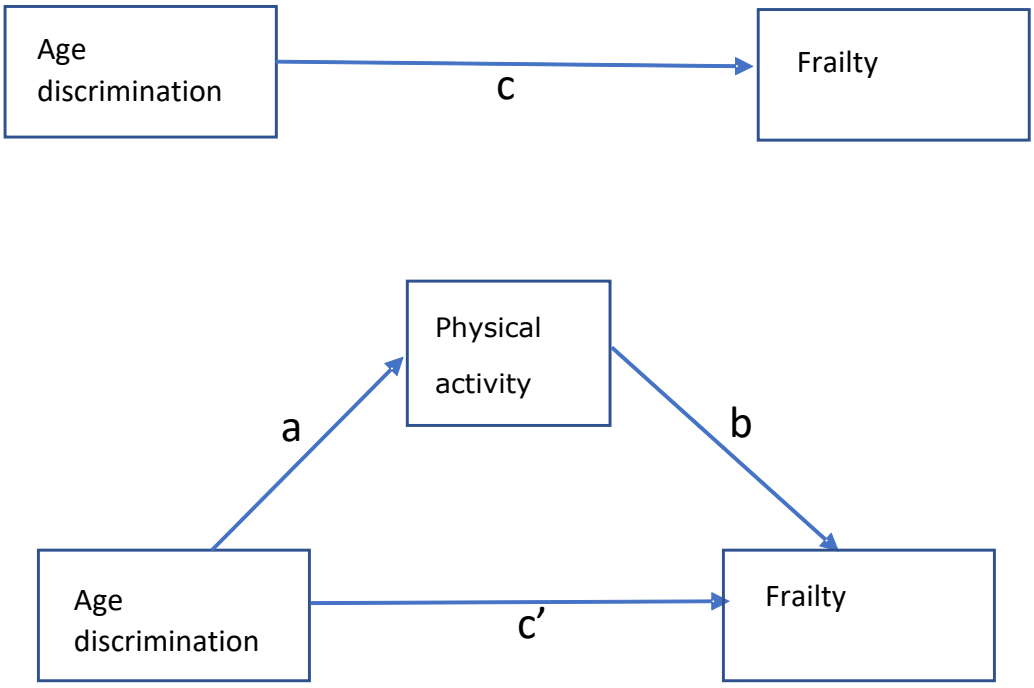
Appendix VI(b): Direct Acyclic Graph for other mediation postulated

Both factors do not qualify as a potential mediator for the mediation analysis between reported age discrimination and future frailty scores among ELSA participants (**Section 7.5**).

1. Social isolation as a mediator:



2. Physical activity as a mediator:



Appendix VII: Policy report on enhancing healthy life among older adults (EuroAgeism Work Package 2)

Please follow the link to read the full policy report (**Issue 3**)

Implications for policy and planning to foster solidarity between the generations and enhance healthy life among older adults

Work Package 2

WP2 Early-Stage Researchers: Wenqian Xu, Laura Allen, Jovanna Brkic, Abodunrin Aminu and Atiqur sm-Rahman

WP2 Leader: Professor Angela Kydd

WP2 Deputy Lead: Professor Daniella Fialova

Appendix VIII: Planned publications from thesis results

The plans for publication			
S/N	Topic	Journal	Timeline
1.	There is an association between age discrimination and frailty: A Longitudinal analysis of the ELSA data	The Lancet Public Health BMC Geriatrics	Manuscript started. Planned for submission in November 2021
2.	Ageism and frailty among older adults: a systematic review and meta-analysis.	PloS one journal Maturitas journal	The writing of the manuscript is planned for November – December 2021. Submission planned for January 2021.
3.	Social isolation and loneliness among older adults: Association with reported age discrimination in the ELSA study	Journal of Gerontology European Journal of Ageing	The writing of the manuscript is planned for January – February 2021. Submission planned for March 2021.
4.	The mediating role of loneliness on the association between age discrimination and frailty among older individuals.	Age and Ageing journal Public Library of Science (PloS one) journal	The writing of the manuscript is planned for April 2021 – May 2022. Submission planned for June 2022.