COGNITIVE IMPAIRMENT AND DEMENTIA IN OLDER AUSTRALIANS: RISK FACTORS AND ADVERSE HEALTH OUTCOMES

A Thesis submitted by

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ABSTRACT

Dementia is a progressive neurodegenerative disorder characterised by a sustained decline in memory, thinking, and functional abilities, severely impacting daily life. It is often preceded by a prolonged preclinical phase, potentially spanning up to two decades, during which cognitive impairment may emerge. Cognitive impairment refers to a measurable decline in cognitive function that does not yet meet the diagnostic criteria for dementia. These conditions not only reduce the quality of life for affected individuals but also impose considerable emotional and financial burdens on families and society. Despite rising awareness, the existing literature lacks comprehensive exploration of the multifaceted risk factors and adverse health outcomes associated with dementia and cognitive impairment. This thesis addresses these gaps by investigating three critical aspects: (i) the prevalence and risk factors of dementia; (ii) the adverse health outcomes, including self-care limitations, various health outcomes, and socio-economic inequalities in health-related quality of life (HRQoL); and (iii) potential pathways for improving the HRQoL of people living with cognitive impairment. The thesis is divided into three themes comprising six chapters. Utilising data from two sources—the Survey of Disability, Ageing, and Carers (SDAC) and the Household, Income and Labour Dynamics in Australia (HILDA) survey—this research applies various econometric methods, including multivariable logistic regression, pooled ordinary least squares (OLS), pooled ordered logit, random effects models, generalised estimating equations, and the Wagstaff-Doorslaer-Watanabe standard concentration index to assess the relationships rigorously. Key findings reveal that older adults in major cities had higher odds of dementia than those in regional and remote areas, and that chronic pain significantly increased the odds of developing dementia. Furthermore, the co-occurrence of dementia and chronic pain demonstrated a synergistic negative impact on self-care abilities. The analysis of health-related quality of life (HRQoL) indicated significant pro-rich inequalities, and cognitive impairment was associated with lower self-assessed health and health satisfaction. Importantly, engaging in physical activity 1-3 times weekly was linked to significant improvements in physical and mental health components, as well as overall health utility, among individuals with cognitive impairment. This research offers vital evidence to inform Australian policymakers and guide the development of more effective health interventions to reduce the impact of dementia and enhance health outcomes for those living with cognitive impairment.

CERTIFICATION OF THESIS

I, Rezwanul Haque declare that the PhD Thesis entitled *Cognitive Impairment and Dementia in Older Australians: Risk Factors and Adverse Health Outcomes* is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This thesis is the work of Rezwanul Haque except where otherwise acknowledged, with the majority of the contribution to the papers presented as a Thesis by Publication undertaken by the student. The work is original and has not previously been submitted for any other award, except where acknowledged.

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STATEMENT OF CONTRIBUTION

This PhD thesis is drawn from the following published papers in peer-reviewed journals. As the lead author, I have taken primary responsibility for each publication and manuscript, contributing extensively to conceptual development, data extraction, analysis, interpretation, initial drafting, final revisions, and overall ownership of the submission. My quantitative expertise has played a significant role, comprising approximately 60% to 75% of the overall research effort in each study. While I am grateful for the invaluable support of my supervisors and co-authors, it is essential to clearly define each researcher's scientific contributions. The following information is the agreed share of contribution for the candidate and co-authors in the presented publications in this thesis:

Paper 1:

Haque R, Alam K, Gow J and Neville C (2023) 'Changes in the prevalence of dementia in Australia and its association with geographic remoteness', *PLoS ONE*, 18(8):e0289505, https://doi.org/10.1371/journal.pone.0289505 **(Q1-ranked journal)**

Rezwanul Haque contributed 70% to the concept development, data management, analysis, interpretation, and drafting of the final manuscript. Khorshed Alam, Jeff Gow, and Christine Neville collectively provided the remaining 30%, offering critical intellectual input, assisting with concept refinement, and contributing to editing.

Paper 2:

Haque R, Alam K, Gow J, Neville C and Keramat SA (2024) 'Age and gender differences in the relationship between chronic pain and dementia among older Australians', *Value in Health,* https://doi.org/10.1016/j.jval.2024.07.022 **(Q1-ranked journal)**

Rezwanul Haque contributed 75% to the concept development, data management, analysis, interpretation, and drafting of the final manuscript. Khorshed Alam, Jeff Gow, Christine Neville, and Syed Afroz Keramat collectively provided the remaining 25%, offering critical intellectual input, assisting with concept refinement, and contributing to editing.

Paper 3:

Haque R, Alam K, Gow J, Neville C and Keramat SA (2025) 'Beyond the sum of their parts: the combined association of dementia and chronic pain with self-care limitations in older Australians', *Journal of Affective Disorders*, 369:633-642, https://doi.org/10.1016/j.jad.2024.10.046 **(Decile 1-ranked journal)**

Rezwanul Haque contributed 70% to the concept development, data management, analysis, interpretation, and drafting of the final manuscript. Khorshed Alam, Jeff Gow, Christine Neville, and Syed Afroz Keramat collectively provided the remaining 30%, offering critical intellectual input, assisting with concept refinement, and contributing to editing.

Paper 4:

Haque R, Alam K, Gow J, Neville C and Keramat SA (2024) 'Socio-economic inequalities in health-related quality of life and the contribution of cognitive impairment in Australia: A decomposition analysis', *Social Science & Medicine*, 361:117399, https://doi.org/10.1016/j.socscimed.2024.117399 **(Decile 1-ranked journal)**

Rezwanul Haque contributed 70% to the concept development, data management, analysis, interpretation, and drafting of the final manuscript. Khorshed Alam, Jeff Gow, Christine Neville, and Syed Afroz Keramat collectively provided the remaining 30%, offering critical intellectual input, assisting with concept refinement, and contributing to editing.

Paper 5:

Haque R, Alam K, Gow J, Neville C and Keramat SA (2025) 'Cognitive impairment and self-reported health outcomes amongst older adults: longitudinal evidence from Australia', *Acta Psychologica*, 253:104770, https://doi.org/10.1016/j.actpsy.2025.104770 **(ABDC ranking: A; Q1-ranked journal)**

Rezwanul Haque contributed 75% to the concept development, data management, analysis, interpretation, and drafting of the final manuscript. Khorshed Alam, Jeff Gow, Christine Neville, and Syed Afroz Keramat collectively provided the remaining 25%, offering critical intellectual input, assisting with concept refinement, and contributing to editing.

Paper 6:

Haque R, Alam K, Gow J, Neville C and Keramat SA (2025) 'Staying active, staying sharp: the relationship between physical activity and health-related quality of life for people living with cognitive impairment', *Quality of Life Research*, https://doi.org/10.1007/s11136-025-03910-5 **(ABDC ranking: A; Q1-ranked journal)**

Rezwanul Haque contributed 70% to the concept development, data management, analysis, interpretation, and drafting of the final manuscript. Khorshed Alam, Jeff Gow, Christine Neville, and Syed Afroz Keramat collectively provided the remaining 30%, offering critical intellectual input, assisting with concept refinement, and contributing to editing.

This thesis has also contributed towards several engagements:

1. The 2023 Annual Australian Dementia Research Forum (ADRF) 2023 on 29-31 May 2023 at JW Marriott Gold Coast Resort & Spa, Gold Coast, Queensland, Australia.
2. The 30th Postgraduate and Early Career Researcher Group Research Symposium on 8 September 2023 via online Zoom.
3. A workgroup on cost effectiveness and decision modelling using R, The Decision Analysis in R for Technologies in Health (DARTH), Ontario, 27-29 August 2024.
4. A 3-day hands-on introductory Household, Income and Labour Dynamics in Australia (HILDA) Survey training course, Australian National University, 15–17 February 2023.

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Finally, to my 8-year-old son, Saifan Haque, thank you for your understanding and maturity beyond your years. I deeply miss you, and I hope this accomplishment makes you proud.

DEDICATION

This thesis is lovingly dedicated to my beloved parents, S. M. Abul Bashar and Begum Farida Bashar.

To my mother, for her boundless love, unwavering support, and endless prayers (dua) that have been my source of strength and inspiration.

To my late father, whose guidance, encouragement, and dreams for my success have always been with me. Though he is no longer with us, I know he would have been the happiest to witness this achievement. This is for you, ‘Abba'.

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ACRONYMS AND ABBREVIATIONS

ABS	Australian Bureau of Statistics
AD	Alzheimer's Disease
ADA	Australian Data Archive
ADL	Activities of Daily Living
ADRD	Alzheimer's Disease and Related Dementias
AHPF	Australian Health Performance Framework
AIHW	Australian Institute of Health and Welfare
AOR	Adjusted Odds Ratio
ARIA	Accessibility Remoteness Index of Australia
ATSI	Aboriginal or Torres Strait Islander
BDS	Backward Digit Span
BMI	Body Mass Index
BP	Bodily Pain
CDC	Centre for Disease Control
CI	Confidence Interval
DSM-V	Diagnostic and Statistical Manual of Mental Disorders -V
DYNOPTA	Dynamic Analyses to Optimise Ageing
GEE	Generalised Estimating Equation
GLS	Generalised Least Squares Estimates
HILDA	Household, Income and Labour Dynamics in Australia
HRQoL	Health-Related Quality of Life
IADL	Instrumental Activities of Daily Living
MCI	Mild Cognitive Impairment
MCS	Mental Component Summary
MH	Mental Health
NSMHW	National Surveys of Mental Health and Wellbeing
OECD	Organisation for Economic Co-operation and Development

RE	Role Emotional
RP	Role Physical
RRR	Relative Risk Ratio
SD	Standard Deviation
SDAC	Survey of Disability, Ageing, and Carers
SDMT	Symbol Digit Modalities Test
SF-36	36-Item Short-Form Health Survey
SF-6D	Short-Form Six-Dimension
VT	Vitality
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background

A significant hallmark of modern societies is the steady progress in extending human longevity (Brito et al. 2023). Within a single century, life expectancy has dramatically increased globally, with over 57 countries now surpassing an average lifespan of 80 years, compared to virtually none a century ago (World Population Review 2025). This unprecedented longevity has contributed significantly to population ageing, characterised by a growing elderly population relative to younger cohorts (United Nations 2015). The global population aged 65 and over is projected to increase significantly, rising from 10% in 2022 to 16% in 2050 (United Nations 2022). In Australia, the share of the population aged 65 and older is projected to increase to 21%–23% by 2066, up from 16% in 2020 (Australian Institute of Health and Welfare 2023). This demographic shift will result in a dramatic reversal of age ratios, with the elderly population surpassing the number of children under 5 by more than double and approaching the number of children under 12 by 2050 (United Nations 2022). While an extended lifespan can facilitate personal and societal enrichment, enabling individuals to explore new endeavours and maintain their active participation within the community (Grande et al. 2020), it is also accompanied by a gradual deterioration in the physical and mental health of older adults, leading to a growing need for medical and social care (Santoni et al. 2016).

The ageing population faces an elevated risk and prevalence of various age-related disorders, including cancer, arthritis, cardiovascular diseases, and neurodegenerative conditions (Finch 2010). Older people are at greater risk of cognitive decline, which can affect their mental processes such as memory, concentration, and problem-solving abilities (Pais et al. 2020a). According to prior studies, approximately 40% of individuals aged 65 and older experience some form of memory loss (Brayne et al. 1995; Aigbogun et al. 2017; Brito et al. 2020). Furthermore, the likelihood of developing dementia increases significantly with age, particularly between 65 and 90 years, doubling approximately every five years within this range (Jorm and Jolley 1998).

Cognitive impairment constitutes a preclinical stage of the pathology, characterised by a discernible decline in cognitive abilities that does not yet satisfy the diagnostic criteria for dementia (Jessen et al. 2020). Dementia, a progressive neurodegenerative disorder, can exhibit

a preclinical phase that may extend for up to two decades prior to clinical manifestation (Gil-Peinado et al. 2023). Dementia and cognitive impairment are among the leading causes of disability and dependency among older adults, contributing significantly to the need for long-term care. The financial burden of dementia, encompassing health and social care costs, surpasses that of other chronic diseases such as cancer, cardiovascular disease, and stroke (Amieva et al. 2005). Despite its profound societal and economic impacts, dementia research has historically received less attention and funding compared to cancer and cardiovascular disease. In Australia, dementia is recognised as a critical public health concern (Australian Institute of Health and Welfare 2024). In 2022, dementia emerged as the second leading cause of mortality in Australia, contributing to nearly 17,800 deaths, which was 9.3% of all deaths (Australian Institute of Health and Welfare 2024). Notably, it was the primary cause of death for women and the second for men, following coronary heart disease (Australian Institute of Health and Welfare 2024). Given these alarming trends, exploring cognitive impairment and dementia from an Australian perspective is both timely and essential for informing public health strategies and guiding policy development.

The primary objective of this thesis is to examine key risk factors comprehensively, explore adverse health outcomes, and improve the health-related quality of life (HRQoL) of people living with dementia and cognitive impairment in Australia. Two studies within this thesis focus on specific risk factors: geographic remoteness and chronic pain. The subsequent three studies delve into the adverse health outcomes of people living with cognitive impairment and dementia, specifically examining self-care limitations, socio-economic inequalities in HRQoL, and the impact of different health outcomes on overall well-being. The final study investigates the potential of physical activity in improving the HRQoL of people living with cognitive impairment. This “PhD by publication” thesis contributes significantly to the existing literature by generating methodological and empirical knowledge and offering valuable policy recommendations for improving the health and well-being of individuals living with cognitive impairment and dementia.

1.2 Definition of cognitive impairment and dementia, diagnosis and classification

1.2.1 Cognitive impairment

A potential challenge in addressing memory concerns and cognitive impairment in healthcare and research is how to define and measure them effectively (Molinuevo et al. 2017). Recent efforts have aimed to standardise terminologies, using "subjective memory complaints" (SMC) or "subjective cognitive decline" (SCD), both of which refer to self-reported experiences of memory or cognitive decline that are not detected through objective measurements or assessments (Steinberg et al. 2013). In contrast, people with MCI do show a clear decline in cognition based on objective assessments, but it is not intense enough to impair daily functioning or to be considered dementia (Gauthier et al. 2006). MCI serves as an intermediary state between normal cognitive changes owing to ageing and the decline characteristic of dementia (Reisberg et al. 2008; Wang et al. 2014). The risk of developing dementia is markedly higher for individuals with MCI than for the general population (Petersen et al. 2014), with an annual progression rate estimated between 10% and 15% (Farias et al. 2009; Xue et al. 2017). In this thesis, the term "cognitive impairment" is used to encompass various phrases describing objective cognitive decline that does not meet the criteria for dementia. Figure 2 provides a visual representation of the case definitions and how they fit within the dementia pathway.

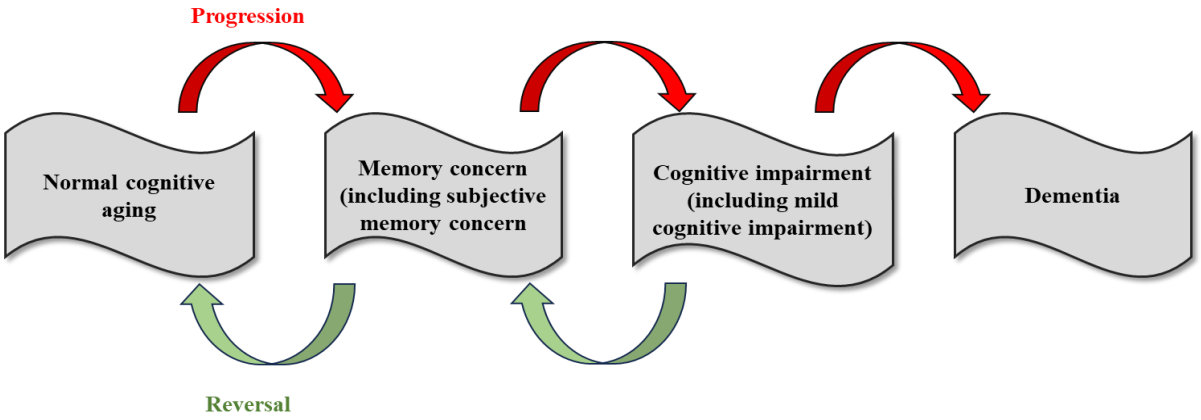

Figure 1: The potential pathways of progression and reversal in dementia development

Source: (Hallam 2023)

1.2.2 Dementia

The term "dementia" originated from the Latin word *demens*, meaning "without mind" (Assal, 2019). Dementia is not a natural part of the ageing process, nor is it one particular disease. Dementia is a broad term encompassing a range of symptoms caused by abnormal brain changes associated with various conditions, including AD, leading to cognitive decline, impaired daily functioning, and impacts on behaviour, emotions, and relationships (Alzheimer's Association

2024; National Institute of Neurological Disorders and Stroke 2024). AD is the most common cause of dementia, accounting for 60-80% of cases, followed by vascular dementia, which results from microscopic bleeding and blockages in the brain (Alzheimer's Association 2024). Other conditions, such as thyroid problems and vitamin deficiencies, can cause cognitive impairment but are not considered dementia, with some being reversible, while mixed dementia occurs when multiple types of dementia are present simultaneously. Different types of dementia are shown in Figure 3.

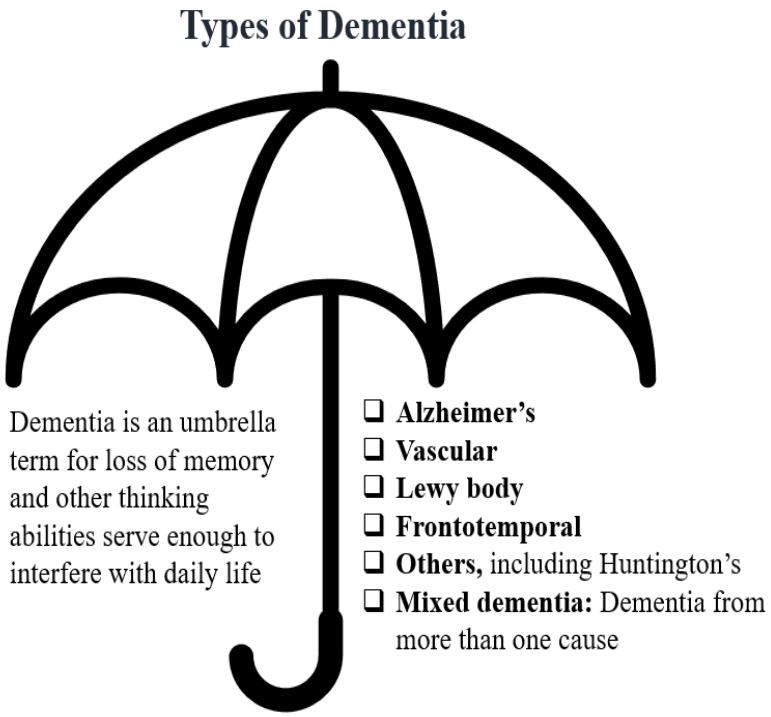

Figure 2: Different types of dementia

Source: (Alzheimer's Association 2024)

1.2.3 Diagnosis and classification

The conceptualisation of dementia and its subsequent classification have been refined through the progressive accumulation of evidence derived from clinicopathological investigations and the postulated etiological factors. Two major diagnostic classification systems used for dementia diagnosis are the World Health Organization (WHO)'s International Classification of Diseases, Tenth Revision (ICD-10) and the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). In 2011, the National Institute

on Aging and the Alzheimer's Association (NIA-AA) introduced new diagnostic criteria for dementia, Alzheimer's disease (AD), and mild cognitive impairment (MCI) (McKhann et al. 2011; Albert et al. 2013), while a separate working group proposed criteria for preclinical AD, which refers to the early disease stage detectable through brain biomarker analysis (Sperling et al. 2011). In addition to the NIA-AA, an international working group also proposed research diagnostic criteria for AD. Similarly to the NIA-AA criteria, this framework defines three stages of AD: preclinical AD; prodromal AD (which corresponds to MCI owing to AD in the NIA-AA criteria); and AD dementia (Dubois et al. 2014). While acknowledging the nuanced variations on the conceptualisation of these stages, this thesis does not examine these distinctions further. The diagnostic guidelines, as illustrated in Figure 1, delineate a spectrum of cognitive stages, encompassing normal cognition to dementia.

This framework is based on diagnostic criteria proposed by Sperling et al. (Henriksen et al. 2014) for preclinical dementia, Petersen et al. (Benichou and Gail 1990) for MCI) and Albert et al. (Neergaard et al. 2016) for revised MCI classification. The figure is adapted from (Andersen et al. 1993), with the concept of SNAP (Subjective Normal Aging Plus) introduced by Jack et al. (Gray 1988). In this context, SNAP encompasses common amyloid-negative neurodegenerative conditions such as cerebrovascular disease, hippocampal sclerosis, and preclinical brain lesions associated with frontotemporal dementia (FTD) and Lewy body dementia (LBD).

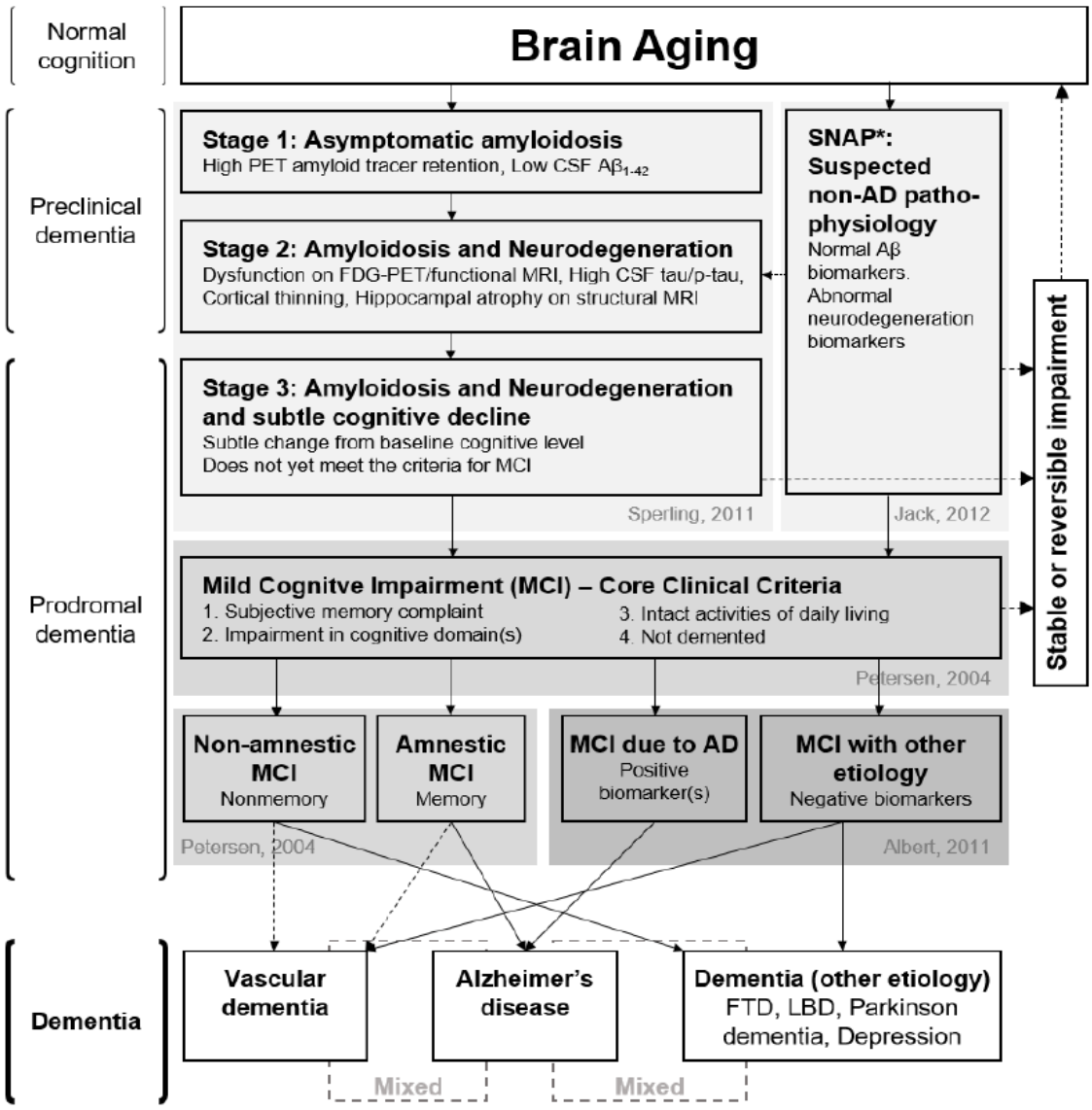

Figure 3: An overview of cognitive stages progressing from normal cognition to dementia.

Source: (Neergaard 2017)

Abbreviations: CSF: Cerebrospinal fluid; FDG: Fluorodeoxyglucose; MCI: Mild Cognitive Impairment; MRI: magnetic resonance imaging; PET: positron emission tomography.

1.3 The state of cognitive impairment and dementia

1.3.1 Prevalence of cognitive impairment

A central vision of the National Dementia Action Plan 2024–2034 is to recognise MCIs, even those not classified as dementia, as an opportunity for primary care intervention, providing guidance on dementia awareness and promoting healthier lifestyle choices (Department of Health and Aged Care 2024). It is crucial to gain a deeper understanding not only of the number

of individuals living with dementia but also of those experiencing cognitive impairments that do not meet the criteria for a dementia diagnosis. Examining the prevalence and incidence of memory concerns and cognitive impairment can provide valuable insights into the scope of this issue and its potential impact on affected populations. While research on the prevalence of memory concerns and cognitive impairment in primary care and community settings remains limited, a few studies have addressed this area.

The COSMIC (Cohort Studies of Memory in an International Consortium) research, published in 2015, utilised data from cohort studies conducted across various countries, standardised the data using uniform criteria, and reported the prevalence of cognitive impairment (Sachdev et al. 2015). The COSMIC study comprised a cohort of 39,387 cognitively unimpaired individuals aged 60 years and older, recruited from a diverse range of 16 studies conducted across 15 countries. Memory concerns were reported by 6% to 52% of participants across the studies, with an average prevalence of approximately 24-25% (Röhr et al. 2020). A previous systematic review encompassing 80 studies estimated that the global prevalence of cognitive impairment varies widely, ranging from 5.1% to 41% in community-dwelling older adults, with a median prevalence of 19% (Pais et al. 2020b). In Australia, a recent study in Australia found that around 10.16% of adults aged 50 and older had moderate cognitive impairment (Keramat et al. 2023).

1.3.2 Prevalence of dementia

Globally, dementia affected more than 55 million people in 2020, with projections indicating that this number would nearly double every 20 years, reaching 78 million by 2030 and 139 million by 2050 (Alzheimer's Disease International 2017). The OECD estimated that the prevalence of dementia in Australia was 13.2 cases per 1,000 population in 2021, slightly less than the OECD average of 15 per 1,000 population and ranking 12th lowest out of 38 countries (Australian Institute of Health and Welfare 2024). Given the projected growth and ageing of the Australian population, the number of people living with dementia is anticipated to increase significantly. Applying the prevalence rates derived by the Australian Institute of Health and Welfare (AIHW) to Australian Bureau of Statistics (ABS) population projections for the period 2023 to 2054, it is estimated that the number of people with dementia in Australia will be more than double, rising from just over 411,100 in 2023 to 849,300 in 2054 (Australian Institute of

Health and Welfare 2023). This projected increase is further broken down by gender, with an estimated 315,500 men and 533,800 women living with dementia by 2058. Figure 4 depicts the estimated prevalence of dementia in the Australian population from 2024 to 2054, with data disaggregated by gender.

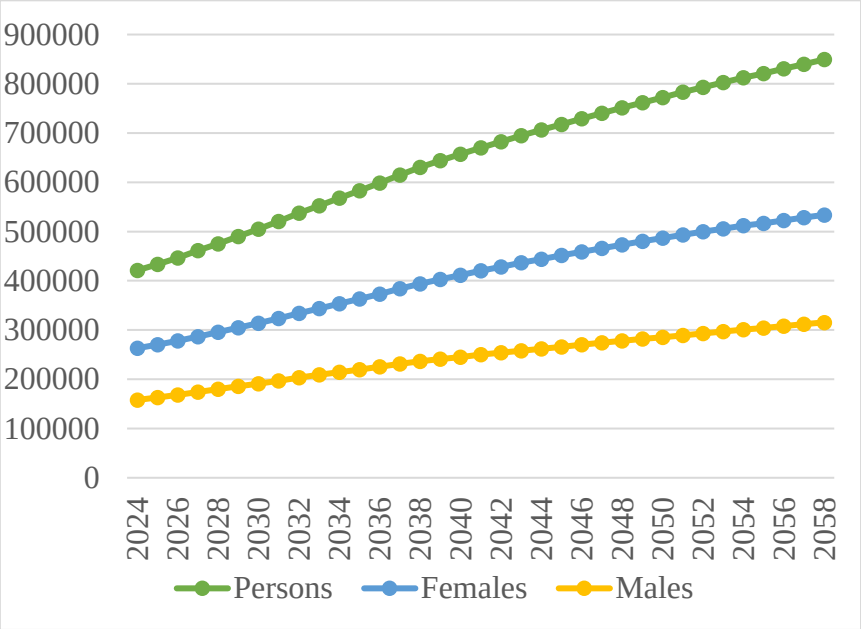

Figure 4: Projected number of Australians living with dementia from 2024 to 2054, disaggregated by gender

Source: (Australian Institute of Health and Welfare 2024)

1.3.3 Factors influencing cognitive impairment and dementia

Cognitive impairment represents a preclinical stage of dementia, often emerging up to two decades before clinical diagnosis. The preclinical phase of the disease presents the most opportune window for the potential application of disease-modifying or neuroprotective therapies, thus emphasising the paramount importance of early detection of cognitive impairment (Ramos et al. 2021). Despite the lack of a definitive treatment for dementia, which remains an unstoppable progression, certain risk and protective factors associated with the disease can be modifiable (Livingston et al. 2020; Ramos et al. 2021).

Risk factors influencing the onset and progression of cognitive impairment and dementia are broadly classified into two categories: non-modifiable and modifiable. Non-modifiable factors are those that cannot be changed, such as age, genetics, and biological sex. Modifiable factors,

on the other hand, are subject to individual or societal intervention, and include not only lifestyle-related risks but also socio-economic determinants such as education and occupation. Although factors like education and occupation are often described as "difficult-to-modify," especially in older populations, economic theory—particularly Grossman's model of health demand—suggests these are indeed modifiable over the life course (Grossman, 2017). According to this model, health is a function of both exogenous depreciation (e.g., age, genetics) and endogenous factors like past health investments, including educational attainment and occupational choices, which significantly shape an individual's health trajectory in later life. Individual risk of developing dementia can differ significantly. Age emerges as the most prominent risk factor, with the risk of developing Alzheimer's or vascular dementia doubling approximately every five years (Nichols et al. 2022). Genetic factors can influence an individual's vulnerability to developing dementia (Fan et al. 2019). Although age and genetic predisposition are non-modifiable, research highlights several modifiable lifestyle choices that significantly impact the risk of developing dementia. The Lancet Commission 2020 initially identified 12 modifiable risk factors for dementia, including a lack of education, head injury, physical inactivity, smoking, excessive alcohol consumption, hypertension, obesity, diabetes, hearing loss, depression, infrequent social contact, and air pollution (Livingston et al. 2020). Livingston and colleagues posited that up to 40% of dementia cases could be potentially averted through the successful mitigation of these 12 identified modifiable risk factors. The recent Lancet Commission report supports adding vision loss and high cholesterol as potentially modifiable risk factors for dementia (Livingston et al. 2024). Building upon the 12 factors identified by the Lancet Commission, Alzheimer's Disease International, and the WHO, the A-to-Z Dementia Knowledge list incorporates additional factors to enhance the memorability of factors influencing cognitive impairment and dementia (Morley et al. 2015; Prince et al. 2016; World Health Organization 2017; Livingston et al 2020).

These factors are categorised as follows:

Non-modifiable factors: Age, gender, and genetics.

Modifiable factors:

Health and lifestyle: Physical inactivity, poor diet, smoking, excessive alcohol consumption, poor sleep hygiene.

Socioeconomic and cognitive engagement: Education, occupation, cognitive stimulation (e.g., reading, social interaction), and dementia awareness.

Clinical and environmental: Chronic diseases (e.g., hypertension, diabetes), hearing loss, obesity, certain medications (e.g., anticholinergics, benzodiazepines), brain injuries, air pollution, infections, and vision loss.

1.3.4 Burden of dementia in Australia

Dementia constitutes a major chronic disease of the 21st century, imposing substantial health, social, and economic burdens on individuals, families, and society. Dementia ranks as the second leading cause of disease burden in men aged 85 and older, and the leading cause in women of the same age group. The total burden of disease from dementia is now equally attributed to disability associated with living with the condition (years lived with disability) and premature mortality caused by the disease (years of life lost). As the prevalence of dementia is projected to rise significantly in the coming decades, these costs are expected to escalate. In 2016, the total economic burden of dementia in Australia was substantial, reaching $14.25 billion, which translated to an average cost of $35,550 per person with dementia (Brown et al. 2017). Direct costs, including healthcare and caregiving expenses, comprised 62% of the total economic burden (Brown et al. 2017). Conversely, indirect costs, primarily attributable to lost productivity among individuals with dementia and their caregivers, accounted for the remaining 38% (Brown et al. 2017). The implementation of initiatives that prioritise dementia prevention, early intervention, timely diagnosis, and community-based support is of paramount importance. These initiatives offer the potential for substantial long-term benefits, including significant reductions in direct healthcare costs and productivity losses, while simultaneously enhancing the quality of life for individuals with dementia and their families.

1.4 Theoretical framework

In this subsection, I discuss some theoretical frameworks that underpin the key research questions of the thesis

1.4.1 Human development model of disability

The human development model of disability, health, and well-being, rooted in Amartya Sen's (1982, 1992) capability approach, emphasises empowering individuals to achieve their full potential and lead fulfilling lives. This model adopts a holistic perspective on disability and well-being, incorporating social, economic, and environmental factors to enhance health and quality of life. It builds on emerging evidence from social epidemiology (Marmot, 2005) and disability research (Burchardt 2004; Terzi 2005; Mitra 2006).

The following explanation outlines key concepts from the theory through a probabilistic lens. These concepts can be statistically represented as equation (i):

$$D = f(P, E, S) + e \qquad \text{(i)}$$

where D, P, E, and S represent disability, personal, environmental/resources, and societal/structural factors respectively, and e is the random error.

The human development model outlines critical factors influencing well-being, categorised into personal factors, resources, and structural/environmental factors outlined in Figure 5. Personal factors include demographic attributes such as age, gender, race, and personality traits, with some being fixed and others modifiable. Resources encompass goods, services, and information that individuals either possess or access through networks. Structural/Environmental factors refer to physical, social, economic, and environmental contexts, ranging from immediate surroundings to broader societal conditions. These components interact dynamically, shaping an individual's capabilities and functioning. The model serves as a practical framework for designing policies to improve disability and health outcomes in real-world contexts.

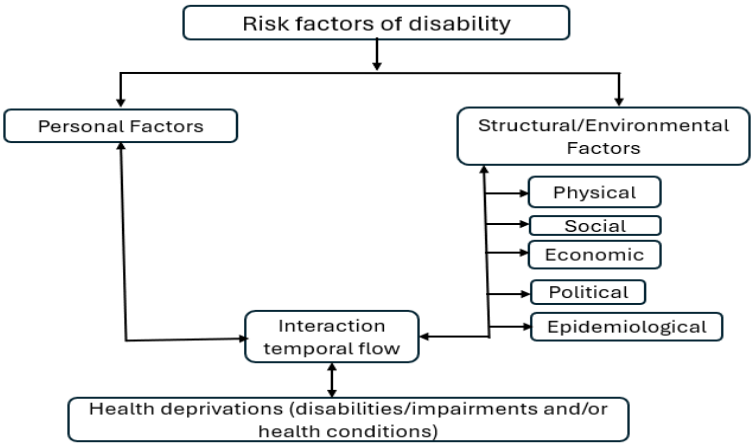

Figure 5: Human development model of disability

1.4.2 International Classification of Functioning, Disability, and Health (ICF) model

The WHO's International Classification of Functioning, Disability, and Health (ICF) framework evaluates disability at the individual and population levels by examining the interaction between environmental and personal factors, influenced by health conditions (Surendiran et al. 2022). Environmental factors include physical, social, and attitudinal elements such as homes, workplaces, and societal structures, while personal factors involve traits like age, gender, and lifestyle (World Health Organization 2007). These factors collectively describe an individual's functioning. The ICF model applies universally, not just to those with disabilities, and helps provide insights into health and functioning across different contexts. The specifics of the ICF model are illustrated in Figure 6.

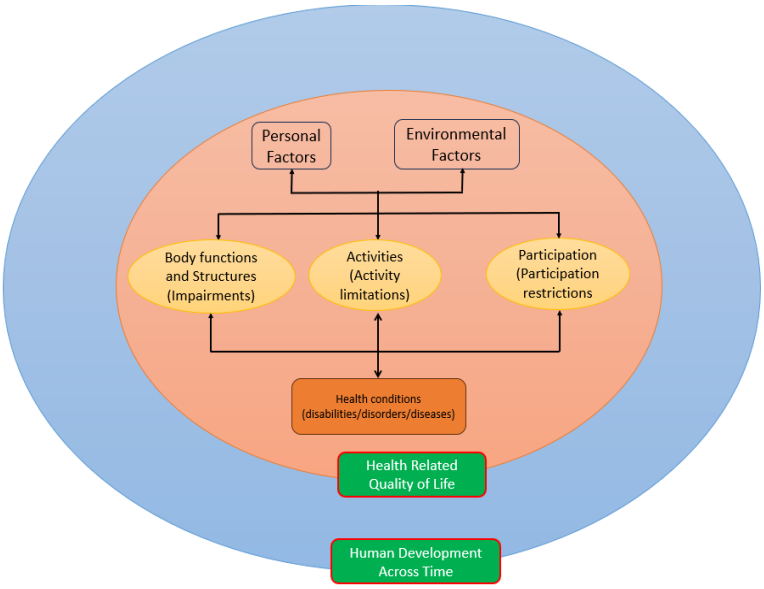

Figure 6: Modified IFC model

1.4.3 Rawls' social contract theory

A quintessential example of contractarian theory is John Rawls' theory of justice, which posits that individuals implicitly enter into a contract with society, thereby establishing a framework of rights and obligations (Rawls 1971, 2001). Rawls defines justice as "fairness", emphasising that societal structures must be designed to ensure equitable distribution of the burdens and benefits of social cooperation among all members. To achieve this, Rawls proposes two fundamental principles of justice:

(1) Everyone has an equal right to the most extensive basic liberties compatible with similar liberties for all; and

(2) Social and economic inequalities are permissible only if they benefit the least advantaged members of society while ensuring equal opportunities for all.

Critics contend that applying Rawls' principles may lead to resource depletion within a community by allocating significant healthcare resources to cases with limited potential for improvement. Furthermore, they argue that it may be unjust to allocate resources to individuals whose poor health stems from their own risky behaviours or choices (Le Grand 1987; Mooney 1987).

1.4.4 Egalitarianism

Egalitarianism, an ideology that views equality as essential for justice, is founded on the principle of inherent human equality. While strict egalitarianism, with its emphasis on equal distribution for all, presents limitations, "luck egalitarianism" offers a refined perspective, focusing on rectifying inequalities stemming from factors beyond individual choice and effort (Dworkin 1981a, 1981b; Anderson 1999). Luck egalitarianism contends that inequalities in well-being should be attributed solely to individual choices and not to circumstances beyond one's control. This philosophy distinguishes between outcomes resulting from "brute luck" (unforeseen events like accidents) and those arising from deliberate choices (such as engaging in risky behaviour). Two distinct approaches to implementing luck egalitarianism emerge. The first emphasises the principle of equality of opportunity, aiming to create a "level playing field" by ensuring equal access to resources and opportunities for all (Arneson 1989; Roemer 1998). The second approach, inspired by Sen's (1982, 1992) capability approach, emphasises individual freedom as the primary moral concern. This perspective defines well-being in terms of an individual's capabilities and actual achievements, rather than simply their material possessions or resources.

The *Human Development Model of Disability* and the *International Classification of Functioning, Disability, and Health (ICF)* model provide the conceptual foundation for understanding the multifactorial nature of dementia and cognitive impairment, as well as their impact on individual functioning and self-care (addressing RQs 1–3 and RQ 5). These models support the investigation into how chronic conditions and contextual factors contribute to functional limitations and health outcomes over the life course. Furthermore, *Rawls' Social Contract Theory* and *principles of Egalitarianism* underpin RQs 4 and 6 by guiding the analysis of socio-economic inequalities in health-related quality of life (HRQoL). These theories emphasize fairness and justice in the distribution of health and resources, which align with the

thesis's focus on identifying and addressing disparities in HRQoL among older Australians, particularly those living with cognitive impairment.

1.5 Objectives and research questions

This thesis aims to conduct a comprehensive analysis of risk factors, adverse health outcomes, and potential improvements for older Australians living with dementia and cognitive impairment. To achieve this aim, the following specific research objectives (ROs) have been established:

RO 1: Examine changes in dementia prevalence and its association with geographic remoteness.
RO 2: Explore age or gender differences in the relationship between chronic pain and dementia.
RO 3: Investigate the association between dementia and chronic pain with self-care limitations.
RO 4: Examine socio-economic inequalities in HRQoL and the contribution of cognitive impairment.
RO 5: Explore the association between cognitive impairment and health outcomes among older Australians.
RO 6: Investigate the relationship between physical activity and HRQoL among older Australians with cognitive impairment.

To achieve its objectives, this thesis aims to address key research gaps identified in the existing literature, which are outlined in detail within the literature review section of each study. To bridge these gaps, several research questions (RQs) have been formulated, each serving as a foundation for a distinct empirical investigation. These studies not only provide robust justifications for the research undertaken but also yield findings that offer valuable insights for policy development. The formulated research questions are as follows:

RQ 1: What are the changes in dementia prevalence in Australia? How is geographic remoteness associated with the risk of dementia?
RQ 2: What is the association between chronic pain and dementia? How does that association vary by age and gender?
RQ 3: How can co-occurring dementia and chronic pain affect self-care limitations?
RQ 4: Are there any inequalities in HRQoL among older Australians? If such inequality exists, what is the contribution of cognitive impairment?

RQ 5: What is the association between cognitive impairment and various health outcomes, such as general health, mental health, self-assessed health, and health satisfaction, among older Australians?
RQ 6: How does physical activity influence (HRQoL) among older Australians living with cognitive impairment?

1.6 Overview of methods

This section outlines the research design and data collection process.

1.6.1 Data sources

This thesis utilised two datasets: the Survey of Disability, Ageing and Carers (SDAC), a cross-sectional dataset, and the Household, Income and Labour Dynamics in Australia (HILDA) survey, a longitudinal dataset.

The SDAC dataset was employed to address the research questions related to dementia. It is the only publicly accessible dataset in Australia containing dementia-related data and is a nationally representative household survey conducted by the ABS. Households for the SDAC were selected using a stratified, multi-stage area sampling approach designed by the ABS. Data collection was carried out by trained interviewers using computer-assisted personal interviews. Details of the development of survey instruments and data collection methodologies can be found in other sources (Australian Bureau of Statistics 2015, 2018). The survey covered all Australian states and territories, encompassing both urban and rural areas, and included individuals residing in private households as well as institutional settings such as nursing homes, hospitals, and retirement communities. The SDAC provides comprehensive data on the prevalence of disability and the support needs of individuals with disabilities. It offers a detailed socio-economic and demographic profile of individuals with disabilities, older adults, and caregivers, enabling comparisons with the general population. The SDAC survey has been conducted periodically in Australia since 1981. Although earlier iterations were conducted in 1988, 1993, 1998, 2003, 2009, and 2012, this thesis focuses specifically on the 2015 and 2018 surveys, as these were the only years that included data on dementia, a key exposure variable in the analysis.

The HILDA survey was utilised to address the research questions related to cognitive impairment. This dataset was chosen primarily because it includes information on cognitive

impairment and related health outcomes. Additionally, it provides comprehensive data on socio-demographic and lifestyle characteristics, such as age, gender, education, marital status, employment status, ethnicity, and health behaviours like smoking and alcohol consumption at various time points. Another key advantage of using the HILDA dataset is its status as a nationally representative, household-based longitudinal survey, making it well-suited for addressing the research questions. The HILDA survey is comparable to other prominent household panel surveys, including the Panel Study of Income Dynamics (PSID) in the United States, the British Household Panel Survey (BHPS), and the German Socio-Economic Panel (SOEP). Conducted annually, the survey gathers data from adult members of the same households, focusing on three primary domains: economic and subjective well-being; labour market dynamics; and family life. The survey collects extensive information on topics such as wealth, retirement, fertility, health, education, skills, job-related discrimination, non-co-residential family relationships, health insurance, diet, and material deprivation. Data are collected through self-completion questionnaires and face-to-face interviews conducted by trained interviewers with household members aged 15 years or older. Initiated in 2001, the HILDA survey collected data from 19,914 individuals across 7,682 households under the ethical guidelines of the University of Melbourne. Since then, it has gathered annual information from over 17,000 Australians. The sample households are selected using multi-stage sampling techniques to ensure representation of the Australian population. Detailed descriptions of the HILDA sampling methods and survey procedures are available elsewhere (Wooden et al. 2002). To explore the research questions related to cognitive impairment, the thesis restricted its analysis to waves 12 (2012) and 16 (2016) of the HILDA survey, the only waves containing pertinent questions. Wave 12 was treated as the baseline, and wave 16 was used as the follow-up survey.

1.6.2 Study design

This thesis comprises a combination of cross-sectional and longitudinal studies, employing a diverse array of health economics and epidemiological methods to address various research questions. Table 1 provides a concise overview of the research focus, research questions, study designs, data sources, analytic samples, and methodologies utilised across the six studies. Subsequently, Figure 7 outlines the studies associated with each research theme, including details on their publication status and journal submissions.

Table 1: Research questions, study designs, data sources, analytic samples, and methods of the six studies at a glance

Research focus	Study	Research questions (RQ)	Study design	Data source	Analytical sample	Methods
Prevalence and risk factors of dementia	Study 1	How does geographic remoteness associate with the risk of dementia?	Cross-sectional	SDAC; 2 waves (2015 and 2018)	20,671 and 20,081 individuals in 2015 and 2018, respectively	Multivariable logistic regression
	Study 2	What is the association between chronic pain and dementia?	Cross-sectional	SDAC; 2 waves (2015 and 2018)	20,671 participants in 2015 and 20,081 in 2018, with a final pooled sample of 40,752 participants	Multivariable logistic regression, Multiplicative interaction

Research focus	Study	Research questions (RQ)	Study design	Data source	Analytical sample	Methods
Adverse health outcomes of dementia and cognitive impairment	Study 3	How can co-occurring dementia and chronic pain affect self-care limitations?	Cross-sectional	SDAC; 2 waves (2015 and 2018)	20,671 participants in 2015 and 20,081 in 2018, with a final pooled sample of 40,752 participants	Ordered logistic regression, Average marginal effect
	Study 4	Are there any inequalities in HRQoL among older Australians? If inequality exists, what is the contribution of cognitive impairment?	Cross-sectional	HILDA; 2 waves wave 12 (2012) and wave 16 (2016)	5,247 and 5,614 unique individuals from 2012 and 2016, respectively	Ordinary Least Squares, Wagstaff-Doorslaer-Watanabe standard concentration index
	Study 5	What is the association between cognitive impairment and various health outcomes, such as general health, mental health, self-assessed health, and health satisfaction, among older Australians?	Longitudinal, retrospective study	HILDA; 2 waves wave 12 (2012) and wave 16 (2016)	11,146 person-year observations from 7,035 unique individuals	Longitudinal random-effects GLS regression model, Random effect ordered logistic regression, Average marginal effect, Generalised estimating equation (GEE)

Research focus	Study	Research questions (RQ)	Study design	Data source	Analytical sample	Methods
Improvement in HRQoL	Study 6	How does physical activity influence HRQoL) among older Australians living with cognitive impairment?	Longitudinal, retrospective study	HILDA; 2 waves wave 12 (2012) and wave 16 (2016)	1,168 person-year observations from 985 unique persons	Random-effects GLS regression, random effect generalised estimating equation (GEE)

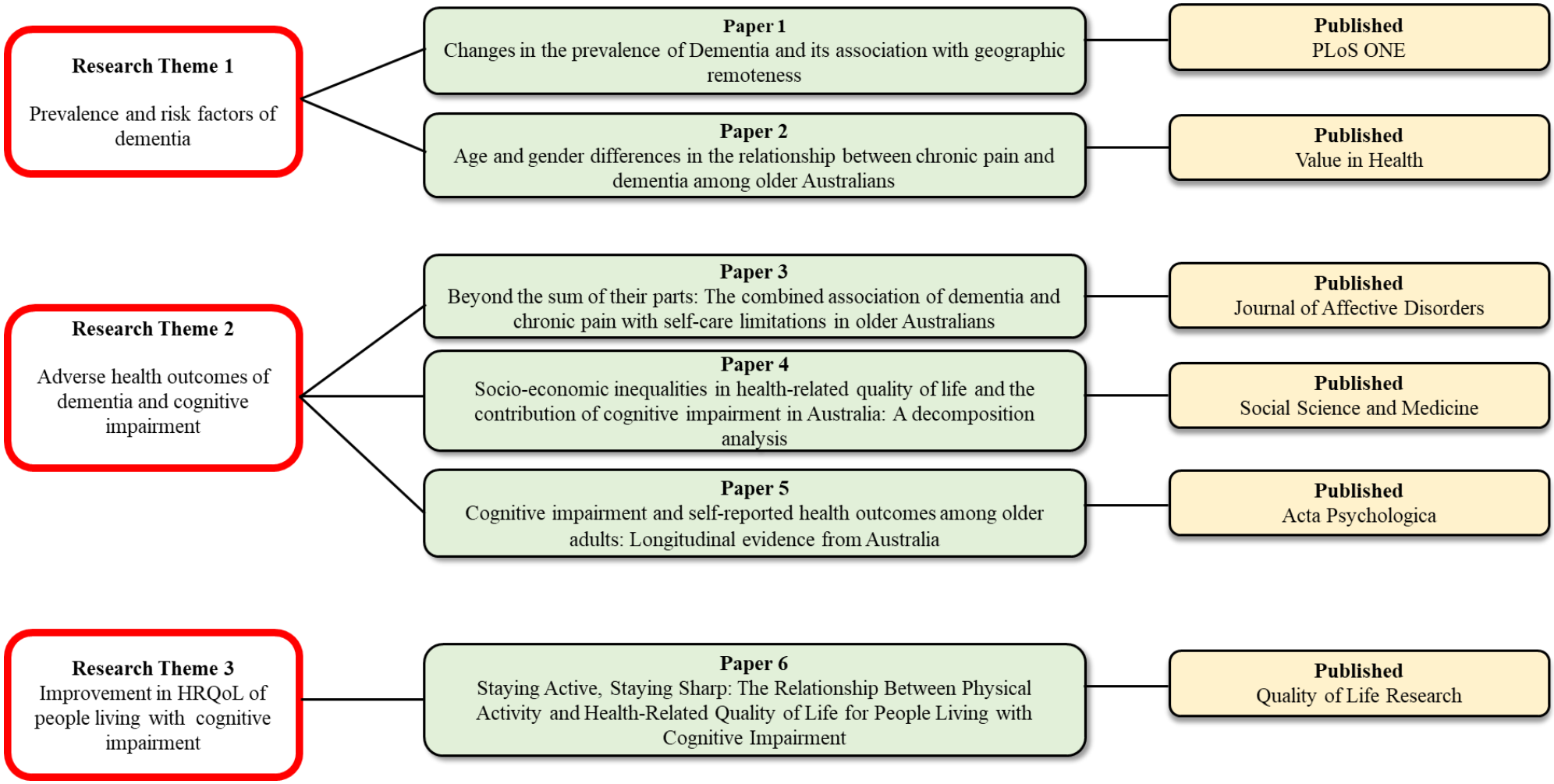

Figure 7: Research theme and study papers included in the thesis

1.7 Conceptual framework of the thesis

Dementia and cognitive impairment are influenced by various factors and impose significant health and economic burdens on individuals and society. The conceptual framework of this thesis, depicted in Figure 8, was adapted from the Australian Health Performance Framework (AHPF) to explore the risk factors and adverse health outcomes associated with dementia and cognitive impairment. While it does not aim to encompass all possible determinants, the framework visualises key factors contributing to these conditions and their impacts on different health outcomes. The determinants of the health domain in the conceptual framework encompass socio-economic factors, health behaviours, personal biomedical characteristics, and environmental influences that affect individuals' health status. Under this domain, this thesis investigates specific risk factors, including (i) geographic remoteness and (ii) chronic pain, and their impact on dementia among older Australians. The health system domain addresses aspects such as effectiveness, safety, appropriateness, continuity of care, accessibility, efficiency, and sustainability, capturing the healthcare system's activity, quality, and performance. The health status domain reflects population health conditions, functionality, well-being, and mortality. In alignment with this context, the thesis conducts four studies examining: (i) the relationship between dementia and self-care limitations; (ii) cognitive impairment and socio-economic inequalities in HRQoL; (iii) cognitive impairment and self-reported health outcomes; and (iv) the impact of physical activity on HRQoL among individuals with cognitive impairment. The health system context domain highlights demographic factors, community and social capital, governance and structure, financing, workforce, infrastructure, and research and evidence required to support the planning of a sustainable healthcare system.

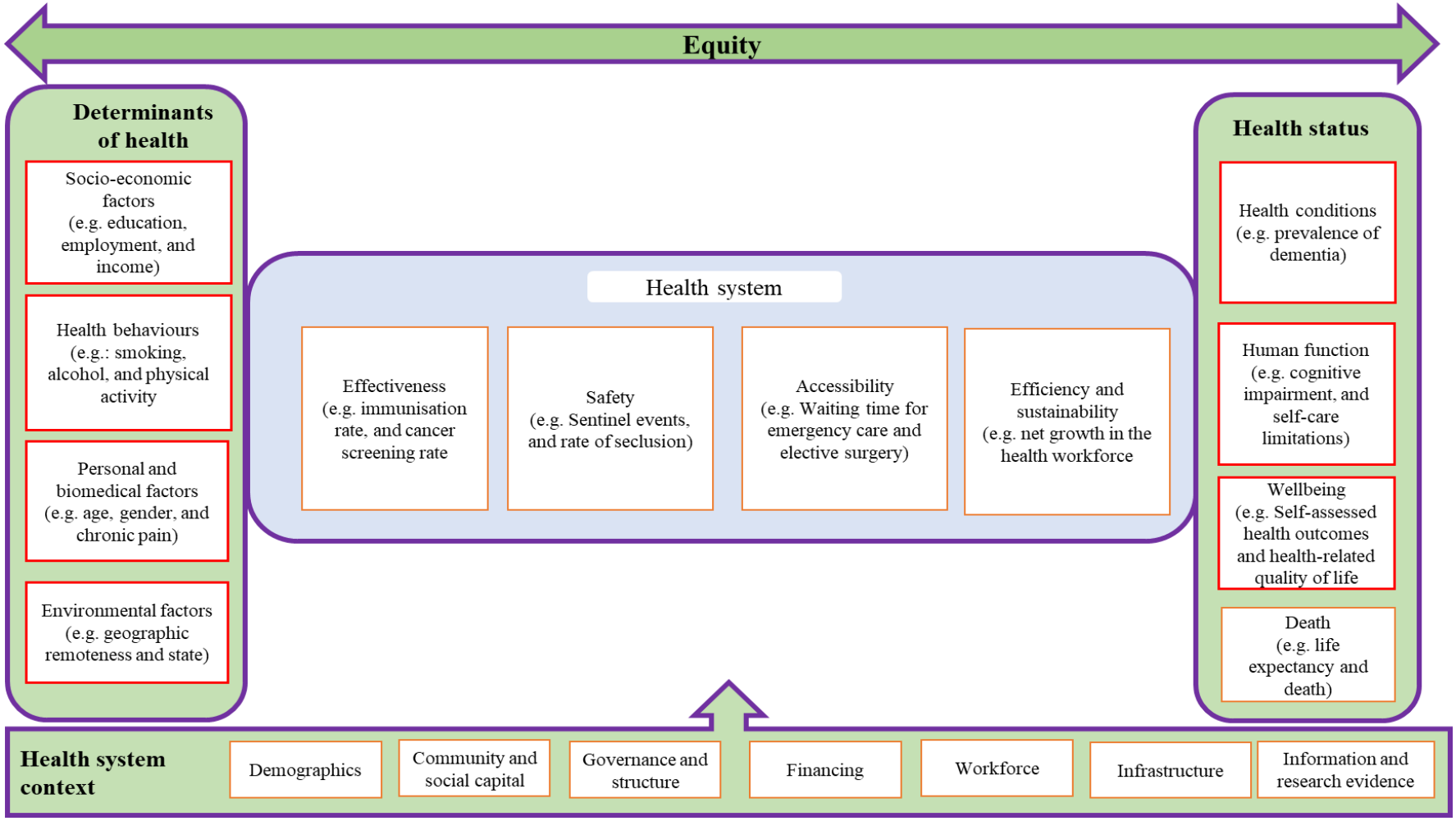

Figure 8: Conceptual framework for the risk factors of dementia and cognitive impairment and their adverse health outcomes (Based on Australian Health Promotion Framework and Performance Logic Model)

1.8 Contribution of the research

This research makes several significant contributions to the existing body of knowledge on dementia and cognitive impairment in Australia.

- Prevalence and Risk Factors

This research contributes to a more accurate understanding of dementia prevalence and identifies key risk factors within the Australian context. Previous studies on dementia prevalence in Australia have been limited by methodological variations and reliance on data primarily from aged care institutions. This research addresses these limitations by utilising a nationally representative dataset encompassing both household and institutional care settings. This provides a more comprehensive and accurate picture of dementia prevalence in Australia. Investigating the influence of geographic remoteness and chronic pain on dementia expands upon existing literature on dementia risk factors in Australia. Previous research has primarily focused on established risk factors such as age, family history, and lifestyle factors. This research contributes new insights into the unique risk factors that may be particularly relevant within the Australian context, such as the impact of geographic remoteness on access to healthcare and the prevalence of chronic pain conditions. These findings have important implications for the development of targeted prevention strategies, such as improving access to healthcare services in rural and remote areas and addressing the prevalence of chronic pain conditions through community-based programs and pain management initiatives.

- Adverse Health Outcomes

This research significantly advances our understanding of the adverse health outcomes associated with dementia and cognitive impairment. By exploring the impact of these conditions on self-care limitations, socio-economic inequalities in HRQoL, and the broader health outcomes of cognitive impairment, this research contributes to a more comprehensive understanding of the burden of these conditions. These findings build upon existing literature by providing a more nuanced understanding of the complex interplay among dementia, cognitive impairment, and health outcomes in the Australian context. This knowledge informs the development of more effective and person-centred care models that address the multifaceted needs of individuals living with dementia and their caregivers.

- Potential for Improvement in HRQoL

The findings of this research have important implications for policy and practice. The research on the potential benefits of physical activity in enhancing the HRQoL of individuals with cognitive impairment informs the development of evidence-based policies and interventions aimed at improving the well-being of this population.

By addressing these critical research questions and contributing new knowledge to the field, this research has a significant impact on our understanding of dementia and cognitive impairment in Australia and informs the development of more effective prevention, diagnosis, and management strategies for these conditions.

1.9 Thesis structure

This PhD thesis follows a thesis by publication format, comprising nine chapters. The working titles and a brief overview of each chapter are outlined below.

Chapter 1—*Introduction*—provides an overview of the study, presenting the problem statement, research objectives, research design, theoretical framework, conceptual framework, and scope of the research.

Chapter 2—*Literature Review*—narrates a brief review of the literature and the identifying research gaps in the existing evidence and conveys the research aims and motivations of the thesis.

Chapter 3, Paper 1—*Changes in the Prevalence of Dementia and its Association with Geographic Remoteness*—explores recent changes in the prevalence of dementia in Australia. This study also investigates geographic remoteness as a potential risk factor for developing dementia.

Chapter 4, Paper 2—*Age and Gender Differences in the Relationship Between Chronic Pain and Dementia Among Older Australians*—explores the link between chronic pain and dementia, with an additional focus on whether this relationship differs across age groups and genders.

Chapter 5, Paper 3—*Beyond the Sum of Their Parts: The Combined Association of Dementia and Chronic Pain with Self-Care Limitations in Older Australians*—examines the relationship

among dementia, chronic pain, and self-care limitations, with a particular emphasis on the combined effects of dementia and chronic pain on these limitations.

Chapter 6, Paper 4—*Socio-Economic Inequalities in Health-Related Quality of Life and the Contribution of Cognitive Impairment in Australia: A Decomposition Analysis*—investigates the influence of socio-economic inequalities on HRQoL by applying concentration indices. The unique contribution of this research is its integration of cognitive impairment into the analysis, supported by a longitudinal examination of factors influencing HRQoL disparities, with critical implications for healthcare policy development.

Chapter 7, Paper 5—*Cognitive Impairment and Self-Reported Health Outcomes Among Older Adults: Longitudinal Evidence from Australia*—explores the hypothesis that cognitive impairment is linked to a decline in several health outcomes, including general health, mental health, self-rated health, and health satisfaction among older Australians. Additionally, the study examines whether the association between cognitive impairment and health outcomes varies across subgroups based on age and gender.

Chapter 8, Paper 6—*Staying Active, Staying Sharp: The Relationship Between Physical Activity and Health-Related Quality of Life for People Living with Cognitive Impairment*—investigates the association between physical activity and HRQoL among older Australians with cognitive impairment. Findings from this research can inform evidence-based policies aimed at enhancing the HRQoL of individuals with cognitive impairment, ultimately contributing to more effective and equitable resource allocation within future health interventions.

Chapter 9—*Conclusion and Policy Implications*—encompasses chapter summaries, a presentation of key findings, policy recommendations, a discussion of contributions to the field of research, study limitations, and concluding remarks.

References

The references for Chapters 1, 2, and 9 are consolidated and placed at the end of the thesis.

CHAPTER 2: LITERATURE REVIEW

There is a growing literature that focuses on the risk factors and adverse health outcomes of people with cognitive impairment and dementia. Several interventional studies have been completed, and the WHO released its first guidelines for reducing the risk of cognitive decline and dementia. The focus has been given to the early identification, risk reduction, and well-being of people living with cognitive impairment and dementia (World Health Organization 2019). This chapter aims to provide a comprehensive literature review of the risk factors, adverse health outcomes, and potential solutions for people living with cognitive impairment and dementia. This in-depth review of existing knowledge serves as a crucial foundation, providing a clear rationale for the research questions and methodologies employed in the subsequent studies conducted within this thesis.

2.1 Geographic remoteness and dementia

Despite the projected increase in dementia patients worldwide from almost 50 million in 2017 to 131.5 million in 2050 (Alzheimer's Disease International 2017), the future prevalence and incidence of dementia are both unknown. In countries such as the United Kingdom, Sweden, Spain, the Netherlands, France, Nigeria, and the United States, most research has found a probable drop or stability in dementia prevalence and incidence estimates over time (Wu et al. 2017). Japan, on the other hand, showed an increased prevalence of dementia (Dodge et al. 2012; Ohara et al. 2017). In a systematic review, Stephan et. al. (2021) concluded that the evidence of secular changes in dementia prevalence and incidence is equivocal, with contradictory findings in specific countries using various (and in some cases the same) datasets (e.g., the United States, the United Kingdom, and Sweden) (Stephan et al., 2018). Prior research investigating trends in dementia prevalence within the Australian context has been relatively limited. In 2010, a seminal study conducted by Anstey et al. employed data from two National Surveys of Mental Health and Wellbeing (NSMHW) conducted by the ABS and the Dynamic Analyses to Optimising Ageing (DYNOPTA) longitudinal study to estimate the prevalence of dementia among the population aged 65 and older (Anstey et al. 2010). Australian dementia prevalence estimates, derived from DYNOPTA, NSMHW 1997, and NSMHW 2007, were compared to those from European meta-analyses. However, the reliability of these estimates for future projections was questionable, as they assumed a static

age-specific prevalence rate despite an ageing population. Limited research, primarily a retrospective analysis of long-term care residents, has examined temporal trends in dementia prevalence in Australia (Harrison et al. 2020).

Geographic disparities in the incidence of non-communicable disease are critical for public health interventions because they reveal illnesses with higher-than-average prevalence or "hot spots". A prior study reported a within-country disparity in the prevalence of AD in western European countries (Russ et al. 2015). Another systematic review and meta-analysis found that dementia prevalence is greater in rural areas (Russ et al. 2012). This research was conducted in the United States, Canada, the United Kingdom, Italy, Turkey, Nigeria, China, Peru, Mexico, and India. Previous research identified several environmental factors as potential risk factors for dementia. Notably, studies have demonstrated an association between exposure to elevated levels of air pollution in urban environments and cognitive decline, as well as an increased risk of AD (Chin-Chan et al. 2015; Costa et al. 2017). Recent research has demonstrated a potential positive association between access to green spaces and cognitive performance (Zijlema et al. 2017; Cherrie et al. 2018). This association may be more pronounced in areas with greater access to green spaces, typically found outside urban centres. Furthermore, research findings indicate that individuals residing in close proximity to major roads exhibit an elevated risk of dementia, even after controlling for the potentially confounding effects of air pollution (Chen et al. 2017). This evidence suggests that dementia may exhibit a higher prevalence in urban environments, contrary to the findings of most prior research. Notably, the Sax Institute's 45 and Up Study, conducted among residents of New South Wales, represents the only Australian study specifically investigating the influence of geographic location on AD risk (Astell-Burt et al. 2020). Utilising multilevel longitudinal analysis, the study demonstrated a significantly lower risk of AD among individuals residing in rural and outlying locations compared to those residing in metropolitan areas.

2.2 Chronic pain and dementia

Emerging evidence from observational and experimental studies suggests a link between chronic pain and an increased risk of neurocognitive impairment, including AD and related dementias (Berryman et al. 2013; Cao et al. 2019; Cravello et al. 2019; Khalid et al. 2020, 2022; Kao et al. 2021). Cross-sectional studies have consistently demonstrated a significant correlation between chronic pain and a decline in overall cognitive function. For instance, a

previous study reported a notably higher incidence of cognitive impairment (Adjusted Odds Ratio: 1.88) among individuals experiencing neuropathic pain compared to the general Spanish population (Povedano et al. 2007). Consistent with other cross-sectional studies, a recent study conducted in China demonstrated a significant association between frequent pain and an increased risk of dementia development. Individuals reporting frequent pain exhibited a 1.34-fold higher likelihood of developing dementia compared to those without pain (Duan et al. 2024). A study conducted in the United States demonstrated that adults experiencing pain interference, regardless of osteoarthritis presence, exhibited an increased risk of developing Alzheimer's disease and related dementias (ADRD) (Ikram et al. 2019). Furthermore, a study conducted in the United States demonstrated a statistically significant association between pain interference and a decline in overall cognitive performance (van der Leeuw et al. 2016).

The relationship between chronic pain and cognitive decline is currently being investigated more extensively through a growing body of longitudinal cohort studies (Whitlock et al. 2017; Kao et al. 2021; Rouch et al. 2022; Tian et al. 2023). A longitudinal cohort study encompassing 10,065 older adults in the United States revealed that individuals experiencing persistent pain exhibited a more pronounced decline in memory function over time, with a 9.2% steeper decline in memory scores compared to those without pain. Furthermore, this cohort demonstrated a significantly higher prevalence of dementia (7.7%) among individuals with persistent pain (Whitlock et al. 2017). Consistent with previous findings, a Taiwanese study demonstrated a significantly elevated risk of dementia development among individuals aged over 50 years experiencing pain. The adjusted hazard ratio for dementia development in this population was 1.21 (95% CI: 1.15-1.26), indicating a 21% increased risk compared to individuals without pain (Kao et al. 2021). A recent study demonstrated a significant association between the number of chronic pain conditions experienced by individuals and an elevated risk of developing dementia and AD (Tian et al. 2023). It is essential to acknowledge that the existing literature on the association between chronic pain and cognitive impairment exhibits some inconsistencies, with certain studies failing to demonstrate a significant relationship (Veronese et al. 2018; Rouch et al. 2022). These studies posit that pain may represent a related factor or an early symptom of dementia, rather than a primary etiological factor (Kumaradev et al. 2021). Two recent meta-analyses have yielded divergent findings regarding the relationship between chronic pain and cognitive decline. While one meta-analysis, encompassing 37 studies, demonstrated a significant association (Xueying Zhang et al. 2021), another meta-analysis of 10 longitudinal cohort studies failed to establish a robust

association (de Aguiar et al. 2020). These discrepancies may be attributed to variations on research design, methodologies employed for assessing pain and cognitive function, the characteristics of the study populations, and the diagnostic criteria for dementia employed across the included studies.

2.3 Dementia, chronic pain, and self-care limitations

Previous research has consistently identified cognitive impairment as a significant predictor of subsequent declines in Activities of Daily Living (ADL) (Barberger-Gateau and Fabrigoule 1997; Pedone et al. 2005; McGuire et al. 2006). Utilising the World Health Organization Disability Assessment Schedule 2.0, a Taiwanese study demonstrated that individuals with dementia experienced significant functional limitations across all six key domains of activity (Huang et al. 2016). Furthermore, research conducted within the United States has demonstrated a significant association between cognitive impairment and an increased risk of functional decline, encompassing both ADLs and Instrumental Activities of Daily Living (IADLs) (McGrath et al. 2020). A study conducted in Taiwan, employing the IADL scale, demonstrated that medication management and shopping emerged as the most discriminating activities in differentiating between individuals with MCI and those with normal cognitive function (Lee et al. 2019).

Prior research has consistently demonstrated a significant association between pain and functional limitations (Eggermont et al. 2014; Makris et al. 2014; Stamm et al. 2016; Valderrama-Hinds et al. 2017). Individuals with musculoskeletal conditions, such as osteoarthritis and chronic back pain, frequently experience limitations in their ability to perform specific ADLs. These limitations often include difficulties with tasks such as heavy chores, bending, kneeling, and ascending stairs (Stamm et al. 2016). Another study revealed a significant association between mobility impairment, characterised by difficulties such as walking a quarter mile or climbing stairs, and the presence of limiting back pain (Makris et al. 2014). Functional limitations, particularly those affecting the upper and lower extremities, are frequently reported among older adults experiencing arthritic pain. These limitations can manifest as difficulties performing activities such as raising arms above shoulder level, lifting heavy objects, and manipulating small objects (Valderrama-Hinds et al. 2017).

Multimorbidity, defined as the presence of multiple diseases within a single individual, represents a prevalent and debilitating health condition among older adults, frequently resulting

in a progressive decline in functional capacity over time (Marengoni et al. 2009). Individuals with dementia frequently exhibit multimorbidity, characterised by the coexistence of multiple health conditions, including diabetes, osteoporosis, a history of falls and fractures, and heart failure (Welsh 2019). AD, recognised as the most prevalent form of dementia, frequently presents in conjunction with chronic pain (Cao et al. 2019). Recent research findings indicate that the presence of chronic pain in multiple body regions constitutes a significant risk factor for the development of dementia (Harris 2023; Haque et al. 2024). Previous research has consistently demonstrated that both dementia and chronic pain independently constitute significant risk factors for declines in ADLs. However, the literature examining the combined impact of co-occurring dementia and chronic pain on self-care limitations remains relatively limited. While some studies conducted in the United States have investigated the impact of other co-occurring conditions, such as visual or auditory impairments, in conjunction with dementia, the specific influence of co-occurring dementia and chronic pain on self-care limitations remains understudied (Patel et al. 2020; Assi et al. 2021). A United States study found that adults with dementia and self-reported visual impairment exhibited poorer functional activity than expected when considering the individual impacts of each condition alone (Patel et al. 2020). Another cross-sectional study demonstrated that adults with dementia and concomitant dual sensory impairments, encompassing both visual and auditory impairments, exhibited a significant increase in both mobility limitations and restrictions in self-care activities (Assi et al. 2021).

2.4 Socio-economic inequalities in health-related quality of life and the contribution of cognitive impairment

Among the key indicators for assessing health inequalities across socio-economic groups, health-related quality of life (HRQoL) has gained significant prominence (Djärv et al. 2013; Arcaya et al. 2015; Rezaei et al., 2018) . Prior research has consistently established a positive correlation between socio-economic status (SES) and HRQoL (Kind et al. 1998; Burström et al. 2001; Djärv et al. 2013). Previous research has highlighted the significant impact of various factors on HRQoL, including age, healthcare access, financial status, education, chronic illness, and lifestyle factors such as physical activity and smoking. While existing literature extensively explores the primary determinants of HRQoL across different social groups, research specifically examining socio-economic inequalities in HRQoL is limited. Notably, an Iranian study investigating socio-economic inequality in HRQoL identified a pattern of “pro-rich

inequality", where individuals with low HRQoL experienced greater disparities in health outcomes across socio-economic groups (Rezaei et al. 2018). The study identified income, a sedentary lifestyle, the presence of chronic health conditions, and lack of health insurance coverage as the four primary determinants of health inequalities among individuals experiencing low HRQoL. These findings are consistent with the observation of a widening disparity in health outcomes across the socio-economic gradient in Australia, indicating a deterioration in health equity (Flavel et al. 2022).

While prior research has established an association between cognitive impairment and reduced HRQoL in older adults, as evidenced by studies conducted in China, Sweden, and Turkey, the literature lacks a comprehensive understanding of the mechanisms through which cognitive impairment contributes to health inequalities across different socio-economic strata (Johansson et al. 2012; Akdag et al. 2013; Pan et al. 2015). The CDC HRQOL-4 served as the primary instrument for assessing HRQoL in the Turkish study, whereas the EQ-5D was utilised in the Chinese and Swedish studies. However, it is important to note that other studies have yielded findings that diverge from this pattern. For instance, research has demonstrated that cognitive impairment may not exert a significant impact on HRQoL in specific populations, such as residents of long-term care facilities (Elliott et al. 2009), individuals with dementia (Banerjee et al. 2009), and older Canadians residing in institutionalised settings (Davis et al. 2015).

A recent longitudinal study conducted within the Australian context utilised the SF-36 and SF-6D instruments to investigate the association between cognitive decline and HRQoL in a cohort of older Australian adults (Keramat et al. 2023). The findings of this study indicated a significant association between cognitive impairment and a decline in HRQoL. However, the study did not delve into the specific mechanisms through which cognitive impairment may contribute to socio-economic inequalities in HRQoL.

2.5 Cognitive impairment and health outcomes

Understanding the intricate relationship between cognitive impairment and health outcomes is of critical significance, as it has profound implications for patient care. This knowledge will empower healthcare providers to predict accurately and manage effectively the needs of individuals with cognitive impairment, thereby potentially mitigating disease progression and enhancing overall well-being. It is noteworthy that nearly 40% of individuals with cognitive impairment reported that their medical practitioners were unaware of their condition,

highlighting a critical gap in current clinical practice (Chodosh et al. 2004). Self-assessed health, representing an individual's subjective evaluation of their overall health status, constitutes a widely utilised metric for assessing health outcomes in various research contexts. Empirical evidence supports the validity of self-assessed health as an independent indicator of health status, even among individuals experiencing the early stages of dementia or MCI (Walker et al. 2004). Prior research has employed a diverse range of measures to assess self-reported health outcomes, including measures of general health (Lee 2000; Dwyer-Lindgren et al. 2017), mental health (Lee 2000), self-assessed health (Hu et al. 2016) and health satisfaction (Paul et al. 2016).

Cognitive impairment has been demonstrated to be associated with a spectrum of adverse health outcomes, including an elevated risk of mortality, an increased likelihood of developing dementia, heightened rates of disability and hospitalisation, and a subsequent decline in overall quality of life (Chen et al. 2022; Pike et al. 2022; Keramat et al. 2023). Prior longitudinal research has consistently demonstrated a significant association between cognitive function and physical performance in older adult populations. Notably, cognitive measures have been shown to possess predictive value regarding declines in both ADLs and IADLs (Tabbarah et al. 2002; Wang et al. 2002; Atkinson et al. 2007). Cognitive impairment has been identified as a significant risk factor for a range of mental health conditions, including depression and anxiety, as demonstrated by previous research (Yates et al. 2013). Furthermore, a recent study conducted by Stone et al. (2023) revealed that individuals with cognitive disorders, including autism spectrum disorder, attention-deficit/hyperactivity disorder, and memory impairments, exhibit lower levels of subjective well-being and health satisfaction when compared to the general population.

2.6 Physical activity and health-related quality of life in people living with cognitive impairment

Individuals with cognitive impairment are more likely to be physically inactive (Vancampfort, Stubbs et al. 2017), which can increase their risk of further cognitive decline (Aichberger et al. 2010) and the development of dementia (Grande et al. 2014). Physical inactivity, compounded by chronic illnesses, has profound adverse effects on health and well-being, leading to reduced physical performance, poorer overall health, and diminished HRQoL (Megari 2013; Vancampfort, Koyanagi et al. 2017). HRQoL is a crucial measure for understanding the health

and well-being of older adults, offering insights into their overall quality of life as they age, and guiding the prevention and management of various illnesses (Chai et al. 2010).

Regular physical activity has well-documented physical and mental health benefits (Marquez et al. 2020). Both cross-sectional (Anokye et al. 2012; Brown et al. 2014; Halaweh et al. 2015) and longitudinal studies (Balboa-Castillo et al. 2011; Xuxi Zhang et al. 2021) consistently show that engaging in the recommended levels of physical activity enhances HRQoL, particularly in the general older population. Additionally, a recent systematic review highlighted that frequent physical activity improves functional mobility, independence, balance, and social interactions, and reduces anxiety, in older adults (Baldelli et al. 2021). While some studies in Australia have shown a positive relationship between physical activity and HRQoL, their focus has largely been on the general population (Perales et al. 2014) or on older people with disabilities (Keramat et al. 2022).

For individuals with cognitive impairment and dementia, physical activity emerges as a protective factor, positively influencing both cognitive and non-cognitive functions (Laurin et al. 2001; Wang et al. 2014; Demurtas et al. 2020). A meta-analysis of 18 randomised controlled trials revealed that physical activity significantly improves cognitive function and quality of life in people living with dementia (Groot et al. 2016). Moreover, physical activity is a cost-effective and low-risk intervention to enhance brain health and cognitive function in older adults (Angevaren et al. 2008). Compared to the general population, individuals with disabilities, including those with cognitive impairment, can experience even greater benefits from physical activity, improving their overall well-being and quality of life (Rosenbaum et al. 2014; Groot et al. 2016). The WHO recommends that older adults engage in at least 150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity activity weekly, combined with strength training, to help mitigate cognitive decline (World Health Organization 2010). However, despite national efforts to promote physical activity, only 18% of Australian adults met the recommended guidelines in 2022 (Australian Institute of Health and Welfare 2022). This underscores the urgent need for targeted interventions to promote physical activity, particularly among those with cognitive impairment, to improve their HRQoL and overall health outcomes.

2.7 Research gap

Dementia prevalence is steadily increasing in Australia, posing a significant public health challenge. Understanding the risk factors associated with dementia is crucial for developing effective preventive strategies. However, existing studies in the Australian context have significant limitations. Specifically, there is limited evidence on dementia risk factors within the older population using nationally representative datasets. For instance, the role of geographic remoteness and chronic pain as potential contributors to dementia risk remains underexplored.

While the global literature provides some insights into the association between dementia and its adverse health outcomes, these relationships have received limited attention in the Australian context. Notably, the links between dementia and cognitive impairment with self-care limitations and health outcomes—such as general health, mental health, health satisfaction, and self-assessed health—remain unexplored. Additionally, the role of cognitive impairment in contributing to socio-economic inequalities in HRQoL has been insufficiently investigated, particularly through longitudinal research designs. Moreover, the potential of physical activity as an intervention to enhance the well-being of individuals living with cognitive impairment has yet to be comprehensively examined in Australia.

This study aims to address these critical gaps in the literature by leveraging data from two nationally representative surveys: the SDAC and the HILDA survey. It provides the first systematic investigation into the risk factors, adverse health outcomes, and improvement in HRQoL of people living with cognitive impairment and dementia in Australia. By employing both cross-sectional and longitudinal research designs, this research generates robust evidence to inform policies and interventions aimed at mitigating the burden of dementia and improving quality of life for affected populations.

CHAPTER 3: PAPER 1 - CHANGES IN THE PREVALENCE OF DEMENTIA AND ITS ASSOCIATION WITH GEOGRAPHIC REMOTENESS

3.1 Introduction

This chapter presents the first study of the thesis, focusing on recent changes in the prevalence of dementia and the role of geographic remoteness as a potential risk factor. Despite its growing public health significance, the precise prevalence of dementia in Australia remains uncertain owing to varying methodologies and the absence of a single reliable data source. While the AIHW provides national-level data, limited insights exist regarding differences within the country, particularly between urban and remote areas. Most previous studies have relied on aged care institutional data, which often exclude household populations, leading to potential underestimations. This study is the first to analyse dementia prevalence trends in Australia using a nationally representative dataset encompassing both household and institutional care accommodations. Additionally, it explores the relationship between geographic remoteness and dementia, addressing the unique challenges posed by Australia's vast geographic distances.

PLOS ONE

RESEARCH ARTICLE

Changes in the prevalence of dementia in Australia and its association with geographic remoteness

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Abstract

Background

The exact prevalence of dementia in Australia is ambiguous. Australia is a vast continent with a small population, and 80% of the population live in five cities. This study explores recent changes in the prevalence of dementia. It also investigates geographic remoteness as a potential risk factor for developing dementia.

Methods

Survey of Disability, Ageing and Carers (SDAC), a nationally representative database, was used to conduct this study. A total of 74,862 and 65,487 individuals from 2015 and 2018, respectively, were considered for this study. A multivariable logistic regression model was used to evaluate the association between dementia and geographic remoteness for older adults aged 65 years and over.

Results

The results reveal that from 2015 to 2018, the prevalence of dementia among adults aged 65 years and older was higher in 2018 (5,229 per 100,000) than in 2015 (5,099 per 100,000). Significant geographical differences in the prevalence of dementia are observed among Australian adults, and this trend appears to be increasing. Furthermore, the unadjusted model revealed that, in 2015, older adults living in major cities had 1.29 (AOR: 1.29, 95% CI: 1.17–1.41) times higher odds of having dementia compared with their counterparts from outer regional and remote areas. In 2018, the adjusted model found that older adults living in major cities had 1.12 (AOR: 1.12, 95% CI: 1.01–1.25) times elevated odds of having dementia than their peers living in outer regional and remote areas.

Abbreviations: ABS, Australian Bureau of Statistics; AOR, Adjusted Odd Ratio; CI, Confidence Interval; DYNOPTA, Dynamic Analyses to Optimise Ageing; NSMHW, National Surveys of Mental Health and Wellbeing; SDAC, Survey of Disability, Ageing, and Carers; WHO, World Health Organization.

Conclusion

There is a rising prevalence of dementia in Australia. Further investigation is required to identify the causes of this increase. Increased public health initiatives should concentrate on behavioural characteristics and contextual environmental factors to ameliorate this trend.

Introduction

Despite the projected increase of people living with dementia worldwide from approximately 55 million in 2020 to 139 million in 2050 [1], it is unknown how the prevalence of dementia will be in the future. According to the literature, there is no indication that the age-specific prevalence of dementia will change globally [2]. Nevertheless, the World Health Organization warned that estimates might not be reliable, particularly for older age groups [3]. For example, most research has found that estimates of the prevalence and incidence of dementia have likely decreased or remained stable over time in countries such as Nigeria, the Netherlands, the United Kingdom, Spain, Sweden, and the United States [4]. Japan, on the other hand, showed an increased prevalence of dementia [5, 6]. An earlier systematic review also concluded that the evidence on secular changes in dementia prevalence and incidence is equivocal, with contradictory findings in specific countries using various (and in some cases the same) datasets (e.g., the USA, the UK, and Sweden) [7]. Increasing education levels and implementing public health initiatives targeted at improving cardiovascular health are some changes to the primary causes of dementia risks that may help to lower prevalence rates. Conversely, a Western diet and an increase in sedentary behaviour may be responsible for a rise in dementia prevalence in several countries, including Japan [8].

Only a few previous studies have tried to determine trends in dementia prevalence in Australia. In 2010, Anstey and colleagues used information from two National Surveys of Mental Health and Wellbeing (NSMHW) conducted by the Australian Bureau of Statistics (ABS) and Dynamic Analyses to Optimising Ageing (DYNOPTA), a longitudinal study, to estimate the expected prevalence of dementia among individuals aged 65 years and older [9]. Later, these results were compared with estimates of the prevalence of dementia derived from meta-analyses of European studies. The Australian estimates found that the prevalence rates of probable dementia for those aged 65 to 69 years were, respectively, 3.78%, 6.22%, and 4% in three distinct surveys: DYNOPTA, NSMHW 1997, and NSMHW 2007. In these surveys, the prevalence of probable dementia among those aged 70 to 74 years was 5.16%, 9.09%, and 5.02%, respectively. DYNOPTA estimations were 10.63%, 16.32%, and 22.36% for the age groups of 75 to 79, 80 to 84, and 85 to 89, respectively. However, the NSMHW survey revealed less conformity with the meta-analyses, even though the DYNOPTA dataset was comparable to estimates obtained from meta-analyses, indicating that these are untrustworthy sources of information for forecasts. Since the population is expected to continue to age and it is assumed that the age-specific prevalence of dementia will not change, projection estimates for the future scale of dementia are mostly based on these assumptions. Only one recent study has looked at changes in dementia prevalence over time in Australia. However, it was a retrospective analysis of older adults who exclusively used long-term care [8]. According to the authors, age- and sex-standardized prevalence (95% confidence interval) of dementia decreased for those utilising long-term care from 50.0% (49.6, 50.5) in 2008 to 46.6% (46.0, 47.2) in 2014 and for those utilising home care from 25.9% (25.0, 26.5) in 2005 to 20.9% (20.2, 21.7) in 2014.

Geographic disparities in the incidence of non-communicable diseases are critical for public health interventions because they reveal illnesses with higher-than-average prevalence or

'hot spots' [10]. Most Western European nations have within-country disparities in Alzheimer's disease, according to a previous study [11]. However, a systematic review found that only a few studies have investigated the environmental causes of Alzheimer's disease [12]. According to a previous systematic review and meta-analysis, those who have lived or currently reside in rural settings are more likely to have dementia [13]. This research was conducted in the United States, Canada, the United Kingdom, China, India, Italy, Nigeria, Turkey, Peru, and Mexico.

Prior studies have identified several environmental contributors as risk factors for dementia. For example, the concentration of air pollution in metropolitan areas may degrade cognitive function and raise the risk of Alzheimer's disease [14, 15]. According to recent studies, being around green space may improve cognitive performance [16, 17], which is more prevalent outside of cities. Furthermore, even after controlling for air pollution, those who live close to major roads have been found to have an increased risk of dementia [18]. This evidence implies that dementia is more prevalent in urban than rural areas, notwithstanding the findings of most preceding studies. The Sax Institute's 45 and Up study data for residents of New South Wales was the only Australian study to examine differences in Alzheimer's disease risk based on geography [19]. The study found that the risk of Alzheimer's disease was lower in rural and outlying locations compared to metropolitan cities using multilevel longitudinal analysis.

The precise prevalence of dementia is currently unknown in Australia because of multiple methodologies and the absence of a single reliable data source [20]. The Australian Institute of Health and Welfare provides data on dementia prevalence at the national level. Still, little is known regarding geographic remoteness and within-country differences, such as remote area living versus cities. Earlier studies on dementia prevalence in Australia were conducted using routinely collected aged care institutional data. However, this is the first study to look at trends in dementia prevalence in Australia using a nationally representative dataset that includes household and institutional care accommodation components. Investigating the relationship between geographic remoteness and dementia in Australia might also be prudent because of the significant geographic distances encountered. Therefore, this study intends to examine trends in dementia prevalence in Australia from 2015 to 2018 and to establish a link between dementia risk and geographic remoteness.

The present study is novel since it includes the distribution and comparison of dementia prevalence across Australian cities and rural-urban areas and the association between geographic remoteness and dementia using a nationally representative dataset for the first time.

Methods

Data source and settings

The current study uses microdata from the Survey of Disability, Ageing, and Carers (SDAC), a nationally representative household survey conducted by the ABS. A stratified, multi-stage area sample created by the ABS was used to choose the households. Computer-assisted personal interviews were used to gather data by trained interviewers. Instrument development and data collection methods adopted by the ABS are specified elsewhere [21, 22]. The survey was conducted in all states and territories, in both urban and rural locations. It included people who resided in private residences/households and institutions, including nursing homes, hospitals, and retirement communities. The SDAC includes data to assess the prevalence of disability and the need to aid persons with disabilities. It also provides a socioeconomic and demographic profile of individuals with disabilities, older adults, and caregivers compared to

the general population. In addition, the dataset contains information about individuals with disabilities, long-term health conditions, and older adults.

Study participants

Following comparable surveys conducted in 1981, 1988, 1993, 1998, 2003, 2009, 2012, and 2015, the 2018 SDAC is the seventh national survey. However, information concerning dementia, the primary variable of interest, is available only in 2015 and 2018. Therefore, this study considered data from these two rounds. The total sample comprised 74,862 and 65,487 individuals from private (e.g. houses and flats) and non-private dwellings (e.g. hotels and motels), and institutional cared accommodation establishments (e.g. hospitals and residential aged care) in 2015 and 2018, respectively. The study participants aged 65 years and older numbered 20,671 and 20,081 in 2015 and 2018, respectively. Distribution of the participants are displayed in Fig 1.

Outcome variable

The primary focus of the current study is dementia, which was ascertained by self-reported and carer responses to the question "do you/persons have dementia?". The answer came from a binary choice of "yes" or "no". A follow-up question was to ask who else in the household had dementia. Dementia data was collected from both households and cared accommodation. The data obtained from the household component, which includes both private and non-private dwellings, is primarily derived from self-reported responses. Alternatively, a proxy, such as a carer, may provide the information in cases where the individual of interest is unable to respond on their own behalf. However, in the context of cared accommodation, the survey is not reliant on self-reporting, but rather is administered by carer who is obligated to document any chronic medical conditions. The scope of the gathered data was confined to the knowledge that can reasonably be anticipated from medical, nursing, and administrative records accessible to staff.

Exposure variable

Geographic remoteness was the exposure of interest measured by the Accessibility Remoteness Index of Australia (ARIA). The ABS reclassified it into the following categories: i) "major city," (ii) "inner regional area," (iii) "outer regional," (iv) "remote", and (v) "extremely distant" [23].

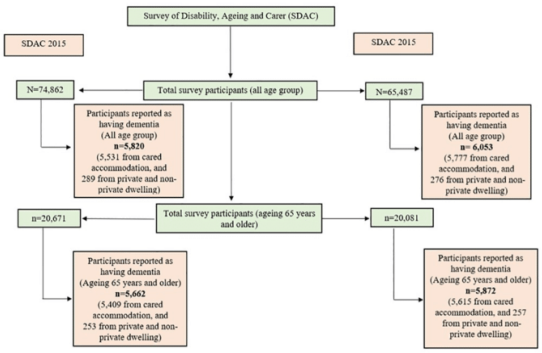

Fig 1. Distribution of study participants and year of survey.

https://doi.org/10.1371/journal.pone.0289505.g001

Due to the small numbers in each group, individuals from "outer regional," "remote," and "very remote" areas in the SDAC dataset were combined into one category as "outer regional or remote area."

Confounders

The SDAC's cared-accommodation component collected limited data than the household component since some topics were either unsuitable for proxy data collection or irrelevant to people living in cared-accommodation [24]. Thus, this study could not sustain all potential confounders to conduct a complete case analysis because most data on people with dementia came from care accommodation. Covariates included in this study were age (65–69, 70–74, 75–79, 80–84, and 85 years or older), sex (male and female), and country of birth (Australia, English-speaking countries, and non-English-speaking countries).

Estimation strategies

The current study uses Basic Confidentialised Unit Records Files from the 2015 and 2018 datasets for cross-sectional analysis. A weighted percentage was used to ensure that the individual estimate conforms to an independently determined distribution of the Australian population. The STATA command "svy set" was utilised in the analysis to handle the intricate survey design.

The characteristics of the study subjects have been compiled as frequency (n) and weighted percentage (%) with 95% confidence intervals (CIs). The chi-square test was used to examine the bivariate correlation between the primary variable of interest and covariates associated with the outcome variable. Only those predictors with a statistically significant level of 5% or less in the bivariate analysis were included in the adjusted model.

Multivariable logistic regression models examined the association between dementia and geographic remoteness. The logistic regression results were expressed as adjusted and unadjusted odds ratios (ORs) with 95% CIs, and a P-value at <0.05 level was found to be statistically significant. STATA 16 (Stata Corp LLC) was used to conduct the analysis, including cross-tabulation, regression, and summary statistics.

Results

Fig 2 displays the changes in the prevalence of dementia for older Australians from 2015 to 2018. Fig 2 also shows that the prevalence rate of dementia among people aged 65 years and older increased from 5,099 per 100,000 in 2015 to 5,229 per 100,000 in 2018.

Fig 3 illustrates the state-wise change in the prevalence (overall) of dementia in Australia. New South Wales, Victoria, and Western Australia observed an increased prevalence of dementia from 2015 to 2018. Victoria experienced a noticeable increase in the prevalence of dementia from 4,881 per 100,000 in 2015 to 5,637 per 100,000 in 2018. However, during the study period, South Australia, Tasmania, Northern Territory, Queensland and the Australian Capital Territory showed a decreasing trend in dementia prevalence.

Fig 4 demonstrates the changes in the prevalence (overall) of dementia from 2015 to 2018 by geographic remoteness. A substantial increase in the prevalence of dementia in major cities has been observed (from 5,010 in 2015 to 5,590 in 2018 per 100,000). Fig 4 also reveals that dementia among people living outer regional and remote areas dropped from 4,810 to 3,760 per 100,000 between 2015 and 2018.

Table 1 shows the changes in the prevalence of dementia in Australia by age and gender from 2015 to 2018. The overall prevalence of dementia rose from 0.84% to 0.89%. In addition, the prevalence of dementia among Australians aged 65 years and older increased from 5.10%

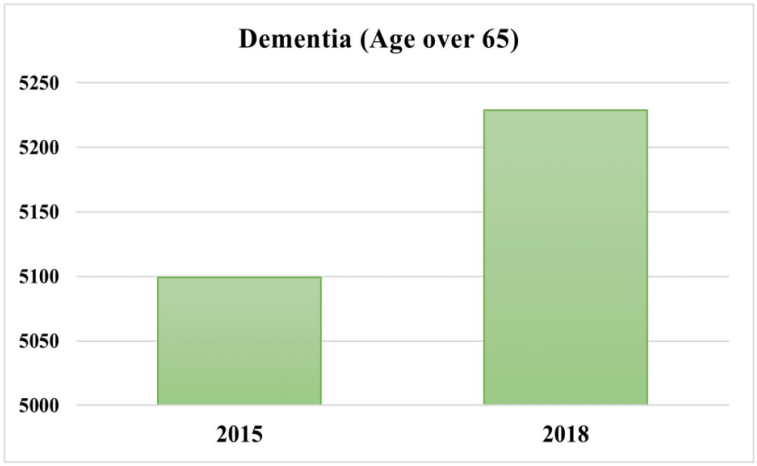

Fig 2. Changes in prevalence of dementia (per 100,000) in Australia, 2015–2018.

https://doi.org/10.1371/journal.pone.0289505.g002

to 5.23%. In both years, the largest prevalence was observed among individuals aged 85 years and older. Male prevalence of dementia increased while female prevalence decreased among older Australians.

Table 2 describes the socio-demographic characteristics of older adults with dementia that changed between 2015 and 2018. In both years, around 47–48% of older adults with dementia was found in the age group of 85 years and older. Among older adults with dementia, the proportion of women was found higher compared to men (62.33% vs 37.67% in 2015 and 57.54% vs 42.46% in 2018). The percentage of older adults with dementia climbed Australia's major

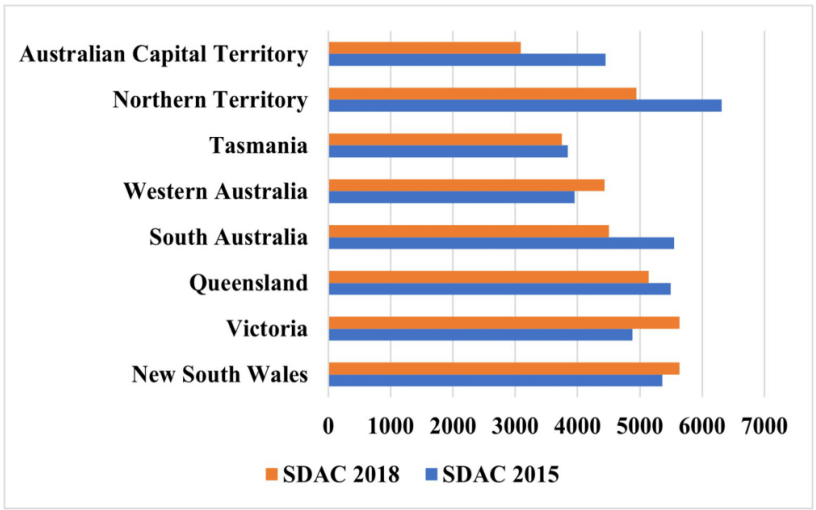

Fig 3. Changes in the prevalence of dementia (per 100,000) by state, 2015–2018.

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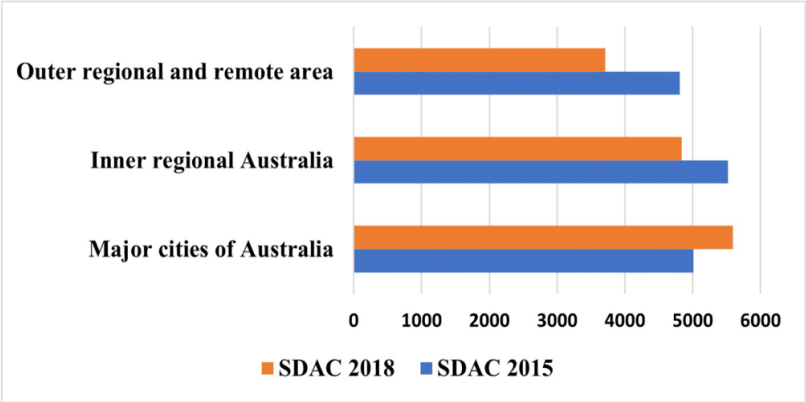

Fig 4. Changes in the prevalence of dementia (per 100,000) by geographic remoteness in Australia, 2015–2018.

https://doi.org/10.1371/journal.pone.0289505.g004

cities from 65.97% in 2015 to 71.78% in 2018, whereas it decreased in inner regional, outer regional, and remote areas during the study period. In comparison with 2015, persons with dementia who were born in Australia decreased in 2018; however, at the same time, the prevalence of dementia among those who were born in either English-speaking (except Australia) or other non-English speaking countries showed substantial increases.

Table 3 displays the unadjusted and adjusted multivariate logistic regression analyses for the association between dementia and geographic remoteness in 2015 and 2018. In 2015, although the adjusted model showed no significant association between dementia and geographic remoteness, the unadjusted model showed a significant association that older adults living in major cities had 1.29 (AOR: 1.29, 95% CI: 1.17–1.41) times higher odds of having

Table 1. Weighted dementia prevalence by age and sex in Australia.

	SDAC 2015		SDAC 2018	
	n	% (95% CI)	n	% (95% CI)
Dementia prevalence (overall)	74,862	0.84 (0.78–0.89)	65,487	0.89 (0.82–0.96)
Dementia prevalence (age 65 years and older)	20,671	5.10 (4.76–5.46)	20,081	5.23 (4.85–5.64)
Dementia prevalence by Age				
Below 65 years	54,191	0.07 (0.05–0.09)	45,406	0.07 (0.04–0.10)
65–69 years	3,823	0.85 (0.60–1.22)	3,406	0.87 (0.59–1.28)
70–74 years	3,135	2.20 (1.67–2.89)	3,357	1.99 (1.49–2.66)
75–79 years	2,972	3.90 (3.21–4.72)	2,854	5.29 (4.36–6.39)
80–84 years	3,183	8.81 (7.58–10.21)	3,056	8.02 (6.81–9.42)
85 years and older	7,558	19.07 (17.52–20.73)	7,408	19.83 (17.95–21.86)
Dementia prevalence by Sex (overall)				
Male	34,987	0.65 (0.57–0.73)	30,302	0.77 (0.68–0.88)
Female	39,875	1.02 (0.94–1.11)	35,185	1.00 (0.91–1.10)
Dementia prevalence by Sex (age 65 years and older)				
Male	8,033	4.12 (3.65–4.65)	7,831	4.74 (4.17–5.38)
Female	12,638	5.96 (5.50–6.45)	12,250	5.66 (5.18–6.18)

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Table 2. Weighted sample characteristics of participants reported as having dementia (aged 65 years and older).

	SADC 2015			SADC 2018		
	Dementia (n = 5,662)			Dementia (n = 5,872)		
	n	% (95% CI)	P Value	n	% (95% CI)	P Value
Age						
65–69 years	161	5.41 (3.82–7.61)	<0.001	186	5.11 (3.51–7.39)	<0.001
70–74 years	302	10.48 (8.09–13.46)		398	9.98 (7.56–13.07)	
75–79 years	603	13.59 (11.33–16.22)		644	18.25 (15.30–21.62)	
80–84 years	1,076	21.61 (18.85–24.65)		1,119	19.05 (16.37–22.05)	
85 years and older	3,520	48.92 (45.52–52.32)		3,525	47.60 (43.78–51.46)	
Sex						
Male	1,710	37.67 (34.30–41.17)	<0.001	1,875	42.46 (38.81–46.19)	<0.001
Female	3,952	62.33 (58.83–65.70)		3,997	57.54 (53.81–61.19)	
Accessibility and remoteness index						
Major cities in Australia	3,787	65.97 (62.62–69.17)	<0.001	4,111	71.78 (68.12–75.16)	<0.001
Inner regional Australia	1,265	23.21 (20.38–26.30)		1,182	20.92 (17.95–24.23)	
Outer regional and remote area	610	10.82 (8.89–13.10)		579	7.31 (5.41–9.79)	
Country of birth						
Australia	3,797	65.76 (62.48–68.90)	<0.002	3,728	58.65 (54.71–62.78)	<0.001
Other English Speaking Countries	718	10.94 (9.20–12.96)		733	13.29 (10.83–16.22)	
Non-English-speaking countries	1,147	23.30 (20.45–26.41)		1,411	28.06 (24.65–31.85)	

Abbreviations: CI: Confidence Interval

https://doi.org/10.1371/journal.pone.0289505.t002

dementia compared with their counterparts from outer regional and remote areas. In 2018, both unadjusted and adjusted models showed a significant association between dementia and geographic remoteness. The adjusted model revealed that, in 2018, older adults living in major cities had 1.12 (AOR: 1.12, 95% CI: 1.01–1.25) times elevated odds of having dementia compared with their peers living in outer regional and remote areas.

Discussion

Over the three-year study period, the results demonstrate variations in the prevalence of dementia in Australia. They showed a significant regional disparity in frequency and an overall upward trend in dementia. Secondly, using cross-sectional nationally representative data, it was revealed that dementia was associated with geographic remoteness and that individuals residing in major cities had a higher risk of developing the disease than those in outer regional and rural locations.

The results demonstrate that the prevalence of dementia increased in Australia from 2015 to 2018. This result is consistent with eight extensive population studies conducted in Japan between 1985 and 2012, where all causes of dementia prevalence among those aged 65 years and over were increasing which ranged from 5.6% to 11.3% [6]. However, a study in the United States of America found that cumulative hazard rates of dementia were 3.6, 2.8, 2.2, and 2.0 per 100 persons during the first (the late 1970s to early 1980s), second (late 1980s to early 1990s), third (late 1990s to early 2000s) and fourth (late 2000s to early 2010s) epochs, respectively [25]. Other studies in the United Kingdom [26], Sweden [27], and Spain [28] for men alone, have also found a decrease in the prevalence or incidence of dementia. In addition, another study in the Netherlands reported a reduction in the prevalence of dementia, albeit without statistically significance [29].

Table 3. Multivariate analysis for the adjusted association between dementia and geographic remoteness.

	SDAC 2015		SDAC 2018	
	n = 20,671		n = 20,081	
	UOR (95%CI)	AOR (95%CI)	UOR (95%CI)	AOR (95%CI)
Age				
65–69 years	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
70–74 years	2.42*** (1.99–2.95)	2.42*** (1.99–2.95)	2.33*** (1.94–2.79)	2.33*** (1.94–2.79)
75–79 years	5.79*** (4.83–6.94)	5.71*** (4.76–6.85)	5.04*** (4.25–5.99)	5.01*** (4.22–5.96)
80–84 years	11.62*** (9.76–13.82)	11.37*** (9.55–13.53)	10.00*** (8.48–11.8)	9.81*** (8.32–11.57)
85 years and older	19.83*** (16.83–23.37)	18.99*** (16.11–22.4)	15.72*** (13.46–18.34)	15.19*** (13–17.73)
Sex				
Male	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Female	1.68*** (1.58–1.8)	1.23*** (1.14–1.32)	1.54*** (1.44–1.64)	1.18*** (1.1–1.26)
Accessibility and remoteness index				
Major cities in Australia	1.29*** (1.17–1.42)	1.06 (0.96–1.19)	1.20***(1.08–1.33)	1.12*(1.01–1.25)
Inner regional Australia	1.28*** (1.15–1.43)	1.11 (0.98–1.25)	0.99 (0.88–1.11)	0.99 (0.87–1.12)
Outer regional and remote area	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Country of birth				
Australia	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Other English Speaking Countries	0.89* (0.81–0.98)	0.97 (0.87–1.07)	0.95 (0.86–1.04)	0.97 (0.88–1.07)
Non-English-speaking countries	1.09* (1.01–1.18)	1.16*** (1.06–1.27)	1.32***(1.22–1.42)	1.27***(1.17–1.37)

Abbreviation: UOR: Unadjusted Odds ratio; AOR: Adjusted Odds Ratio; CI: Confidence Interval

P values:

***P< 0.001,

**P<0.01;

*P<0.05

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In contrast to our findings, earlier Australian research, along with those of the majority of high-income nations, showed a downward trend in dementia prevalence. For example, in one retrospective study, dementia prevalence among older adults aged 65 years and older who used long-term aged care services between 2005 and 2014 was investigated [8]. According to that study, aged care service users in Australia experienced a decline in age- and sex-standardised dementia prevalence, which fell from 50% in 2008 to 46.6% in 2014. However, earlier in 2010, Anstey and colleagues compared the prevalence rates of dementia based on meta-analyses from European research to the probable dementia prevalence rates from the two most important sources of population-based data in Australia [9]. The study concluded that the incidence of dementia doubles approximately every five years within the age range of 70 to 84 years. However, the rate of escalation decelerates beyond this age range.

The observed rising trends in dementia could be due to a variety of factors. Earlier studies considered only those individuals who accessed long-term care while this study employed a nationally representative SDAC dataset. The aged care assessments employed in earlier studies may have only captured around 80% of people with dementia, according to a prior study using Australian-linked health data [30]. Hence, it is possible that previous studies underreported dementia from an Australian perspective. The time frame of the analysis could be another factor. Earlier research used datasets from 2008 to 2016, but this analysis included data from 2015 to 2018.

Age is considered the most significant risk of dementia [31], and the percentage of people aged 65 years and older in Australia with dementia rose from 12.2% to 15.7% over the 20 years

between 1998 and 2018 [32], this may be a contributing factor to the growing prevalence of dementia. Additionally, the prevalence of diabetes, high blood pressure, obesity, undernutrition, depression, and brain injuries have increased over time in Australia; this may be a factor in the rise in dementia rates [8]. Additionally, rising public knowledge of dementia may have made functional and cognitive deficits that could have previously been written off as 'normal ageing' now be included as dementia [6]. Recent research indicates that overall, 88% of Australians can recognise the symptoms of dementia from the written clinical vignettes [33], an increase from 82% in a study conducted a decade ago [34]. Dementia might become more prevalent if persons with a stroke or Transient Ischemic Attack (TIA) survive longer due to advancements in medical care [6].

This study results also revealed that older Australians living in major cities had a higher risk of dementia than those living in rural and outlying regions. In contrast to our findings, a prior study using cross-sectional data claimed that the rate and frequency of Alzheimer's disease were greater in the countryside than in urban settings [13]. However, our results are consistent with a prior Australian study where the authors used multi-level longitudinal analysis and concluded that after adjusting for socio-demographic and geographic disadvantages as confounders, compared to rural and remote places, major cities had a higher risk of Alzheimer's disease [35]. In addition, the findings of this study are consistent with research from Spain and the UK, which found that the prevalence of Alzheimer's disease was lower in rural areas than in urban ones [36, 37]. In Australia, it was estimated that as of June 2020, two-thirds of older people (aged 65 years and older) lived in major cities (66%, 2.7 million) [38]; this is the most likely cause of the elevated incidence of dementia in metropolitan areas. Another potential explanation for the higher risk of having dementia in urban areas might be environmental factors. For example, earlier research identified chronic noise exposure, air pollution, and a paucity of green space as probable risk factors for cognition reduction, which are more prevalent in metropolitan areas [16–18, 39, 40].

It is possible that people residing in urban areas have a greater understanding of dementia due to their higher levels of education and income, which could explain the higher rates of people reported as having dementia in major cities compared to inner regional and outer regional areas. Prior research found that a higher level of education is a predictor of increased dementia knowledge [41–43]. In Australia, there are educational disparities, as 72% of students in metropolitan areas, 65% of students in regional areas, and 36% of students in remote areas complete secondary school [44]. Moreover, people residing in major cities were more likely to hold a bachelor's degree or higher (36%) than those residing in inner regional areas (21%), outer regional areas (19%), and remote and very remote areas (18%) [45]. Furthermore, people with higher incomes have greater access to dementia-related information and, thus, increased dementia knowledge [41]. In 2017–18, the average weekly income and average household net worth of Australians living outside of capital cities were 19% and 30% lower, respectively, than those residing in capital cities [46].

The study findings have critical public health ramifications because they showed a statistically significant link between dementia and living in cities. Governments in Australia, particularly those at the federal, state, territorial, and local levels, can play an essential role in developing and delivering dementia-specific policies and services. Additionally, state and territory governments could provide additional funding for vital services such as memory clinics, geriatric assessments and home visits for older adults, services for older adults' mental health, hospital-to-residential aged care transition services, and assistance for those who are exhibiting behavioural and psychological signs of dementia. These policies align with findings of the 2019 Aged Care Quality and Safety Royal Commission [47].

Prior research indicates that green spaces and increasing the number of urban trees could lower dementia risk [19, 48] by encouraging physical activity, social interaction, and network building while simultaneously reducing exposure to air pollution. Councils could develop standalone urban forest strategies or integrate the conservation of urban forests into municipal strategic planning statements to ensure that residents and communities have healthier environments. For Greater Sydney councils, the NSW Government has provided updated tree canopy data (2019) which can be treated as a foundation for developing urban forest initiatives [49].

The main strength of this study is the use of the SDAC dataset, a nationally representative sample of the population [50], in examining Australia's dementia prevalence. Much of the prior information regarding dementia prevalence in Australia was derived from studies conducted using routinely collected aged care assessment data. However, individuals with dementia residing at-home were ignored in earlier research. This is the first study in Australia that used a nationally representative dataset that covers households and cared accommodation components to examine changes in the prevalence of dementia. Further, this study considers a new geographic characteristic, geographic remoteness, to check its association with dementia using a nationally representative dataset.

It is essential to consider the study's limitations. First, the utilisation of self-report or proxy-reporting poses a significant challenge, especially in cases where an individual's cognitive abilities are compromised, leading to a prolonged and uncertain diagnosis process. In addition, the presence of stigma may cause individuals to be hesitant to identify themselves. The SDAC may lead to underestimating mild and moderate dementia within the household population. Identifying individuals with dementia, especially at advanced ages, presents additional challenges due to co-occurring health conditions that obscure the symptoms of dementia. The aforementioned challenges are likely to have an impact on the information obtained through self-administered or proxy-based questionnaires. Although the cared accommodation component of the SDAC is considered as a strength of Australian data, it lacks comprehensive information regarding the socio-demographic characteristics of its residents. Furthermore, within the realm of cared accommodation, there may exist obstacles to the acquisition of a dementia diagnosis. However, the implementation of the Aged Care Funding Instrument (ACFI) within residential aged care has the potential to enhance identification practices in this sector, thereby leading to enhancements in the cared accommodation component of the SDAC [51]. Second, due to the cross-sectional research design, this study was unable to identify the causal pathways between dementia and geography. Third, the adjusted model of dementia and geographic remoteness had to be restricted to accessible confounders to provide a complete case analysis because most of the dementia data were collected from aged care accommodations and information on several socio-economic characteristics were not available. After considering these constraints, the results imply that future research should focus on prospective longitudinal studies to explore further the prevalence and the role of geography over time.

Conclusion

Using a nationally representative data set, this study has revealed changes in the prevalence of dementia among Australian older adults by examining individual and geographical characteristics. This study has shown substantial differences in dementia prevalence among Australians during the study period. It was shown that there is a significant geographic disparity in the prevalence of dementia in Australia. Estimates from multivariable logit models support the finding that people who live in large cities have a greater risk of dementia than those living in outer regional and remote areas. Public health initiatives that are geographically focused and health education that encourages awareness and a healthy lifestyle could aid in halting

Australia's rising dementia rate. This study adds to the scant body of knowledge about regional variations in dementia prevalence in Australia.

Author Contributions

Conceptualization: Rezwanul Haque.

Data curation: Rezwanul Haque.

Formal analysis: Rezwanul Haque.

Investigation: Rezwanul Haque.

Methodology: Rezwanul Haque.

Software: Rezwanul Haque.

Supervision: Khorshed Alam, Jeff Gow, Christine Neville.

Validation: Khorshed Alam, Jeff Gow, Christine Neville.

Writing – original draft: Rezwanul Haque.

Writing – review & editing: Rezwanul Haque, Khorshed Alam, Jeff Gow, Christine Neville.

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3.2 Links and implications

The significance of this study lies in its potential to fill critical knowledge gaps in dementia research, offering a more comprehensive understanding of prevalence trends and risk factors. By identifying the association between geographic remoteness and dementia, this study provides valuable evidence for policymakers and healthcare professionals to design targeted interventions and allocate resources more effectively, particularly for underserved and remote populations. Furthermore, understanding these trends is vital for planning future healthcare services and improving outcomes for individuals living with dementia across diverse settings in Australia. The subsequent chapter identifies another risk factor of dementia.

Note: Appendix A presents a selection of newspaper clippings and images from television interviews, illustrating the significant media attention and broad public engagement generated by the research presented in this chapter.

CHAPTER 4: PAPER 2 - AGE AND GENDER DIFFERENCES IN THE RELATIONSHIP BETWEEN CHRONIC PAIN AND DEMENTIA AMONG OLDER AUSTRALIANS

4.1 Introduction

This chapter presents the second study of the thesis, which examines the association between chronic pain and dementia. The study also explores whether this relationship varies by age and gender. Chronic pain is a debilitating condition that disproportionately affects older adults and is hypothesised to increase the likelihood of cognitive impairment. However, limited quantitative research has been conducted in Australia to explore the relationship between chronic pain and dementia.

The primary objective of this study was to investigate whether chronic pain is associated with heightened odds of dementia among older Australians, while also identifying potential age and gender differences in this association. By addressing these gaps, this study provides crucial insights into the interplay between chronic pain and dementia, which may have been overlooked in previous research.

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Health Policy Analysis

Age and Gender Differences in the Relationship Between Chronic Pain and Dementia Among Older Australians

Rezwanul Haque, MS, Khorshed Alam, PhD, Jeff Gow, PhD, Christine Neville, PhD, Syed Afroz Keramat, PhD

ABSTRACT

Objectives: Chronic pain is a highly debilitating condition that affects older adults and has the potential to increase their odds of experiencing cognitive impairment. The primary objective of this study was to examine the correlation between chronic pain and dementia. Additionally, this research endeavors to ascertain whether the association between chronic pain and dementia differs by age and gender.

Methods: Cross-sectional data were derived from the Survey of Disability, Ageing, and Carers. A total of 20 671 and 20 081 participants aged 65 years and older in 2015 and 2018, respectively, were included in this study. The pooled association between chronic pain and dementia was assessed using a multivariable logistic regression model. Furthermore, the study also examined the multiplicative interaction effects between chronic pain and age, as well as chronic pain and gender, with dementia.

Results: The pooled analysis demonstrated that chronic pain was associated with a heightened odds of dementia (adjusted odds ratio 1.95; 95% CI 1.85-2.05) among older Australians compared with their counterparts without chronic pain. The interaction effect indicated that individuals with chronic pain across all age groups exhibited increased odds of living with dementia. Additionally, women with chronic pain had higher odds of dementia compared with their counterparts without chronic pain and being male.

Conclusions: A continuous, coordinated, and tailored healthcare strategy is necessary to determine the pain management goals and explore early treatment options for chronic pain in older adults, particularly in groups with the greatest need.

Keywords: Australia, chronic pain, dementia, older adults, SADC.

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Highlights

- Research on chronic pain and cognitive decline shows mixed results. Some studies suggest a positive relationship, with chronic pain potentially increasing the risk of cognitive impairment and dementia. However, other studies have not found a clear connection. No prior study in Australia examined the age and gender differences in the relationship between chronic pain and dementia.
- Our findings demonstrate that chronic pain was associated with an increased odds of dementia among older Australians. We found that this relationship exists across all age groups with varying magnitudes. Additionally, women with chronic pain had higher odds of dementia compared with their male counterparts without chronic pain.
- This article emphasizes the need for a comprehensive healthcare approach for chronic pain management in older adults. It suggests a continuous, tailored strategy to assess pain and explore early treatment options. This proactive approach aims to minimize potential cognitive decline associated with chronic pain, ultimately informing healthcare decisions by prioritizing early intervention and potentially reducing future cognitive complications.

Introduction

Dementia, a pressing and growing public health concern, refers to a range of conditions that impair memory, cognition, and the capacity to perform everyday activities. Dementia is one of the prominent contributors to disability and dependency among older adults, affecting an estimated 55 million individuals globally.[1] Nearly 1 in every 12 people aged 65 years or older in Australia are diagnosed with dementia,[2] and the prevalence of dementia is projected to increase almost 2-fold by 2058, mostly because of the phenomenon of population aging.[3] In 2022, dementia accounted for 4.4% of Australia's disease burden and ranked as the second most prevalent cause of death in the country, contributing to 9.6% of all recorded fatalities.[4]

Despite extensive clinical research spanning many decades, a definitive cure for dementia remains elusive, and the availability of effective disease-modifying medications is still lacking.[5] Currently, there is a growing emphasis on preventive and early intervention strategies, which include rigorous methods to identify and address the modifiable risk factors linked to dementia.[6] According to the Lancet Commission's estimation, approximately 40% of dementia cases globally might be averted or postponed by addressing 12 critical risk factors.[7] The risk factors are lower educational levels, impairment of hearing, midlife hypertension, midlife obesity, excessive intake of alcohol, diabetes, brain injury resulting from a severe and distressing event, tobacco consumption, depression, social exclusion, lack of physical exercise, and exposure to air pollution. However, there is an urgent need to identify and target additional modifiable dementia risk factors for the implementation of preventive strategies.

Chronic pain, defined as prolonged and recurring pain lasting for at least 3 months, is one of the most prevalent and significant worldwide health conditions, particularly among older adults.[8,9] The prevalence of chronic pain among older adults residing in the community is estimated to range from 25% to 50% on a global scale[10] and up to 83% in residential aged-care facilities.[11] Earlier research has indicated that a substantial percentage of older Australians, ranging from 29.9% to 36.2%, experience chronic pain.[12] Prior research also indicated that pain in older adults may impair cognitive performance because of its capacity to demand attention and potentially compete for attentional resources.[13] According to this research, the presence of pain affects other dimensions of cognitive performance as well. There is a potential for pain to coincide with or worsen cognitive decline that is associated with age-related changes in brain function.[14] Because of the potential harm that pain may do to cognition, as well as the increasing awareness of the influence of age-related alterations in brain function on the deterioration of balance and movement,[15,16] it is critical to comprehend the link between chronic pain and cognition in older adults.

There is a growing body of data from observational and experimental studies indicating that chronic pain can be associated with an increased susceptibility to neurocognitive impairment and the development of Alzheimer's disease and related dementia.[9,17–21] Several cross-sectional studies have established a correlation between chronic pain and a decline in overall cognitive abilities. For instance, a prior study reported that the incidence of cognitive impairment was significantly higher (adjusted odds ratio [AOR] 1.88) in people with neuropathic pain compared with the reported prevalence in the general Spanish population.[22] Among other cross-sectional studies, a recent Chinese study found that individuals who frequently report pain exhibit a 1.34 times higher likelihood of developing dementia when compared with those who do not report any pain.[23] Similarly, another study in the United States revealed that adults who experience pain interference, even without osteoarthritis, are more likely to develop Alzheimer's disease and related dementia (ADRD).[24] Furthermore, another United States study identified a statistically significant association between pain interference and overall cognitive impairment.[14] The link between chronic pain and cognitive decline is further studied by a growing number of recent longitudinal cohort studies.[18,25–27] For example, a longitudinal cohort study using a sample of 10 065 older persons in the United States found that those with persistent pain experienced a steeper decline in memory scores (9.2%) over time and had a significantly higher prevalence of dementia (7.7%) compared with those without persistent pain.[25] Likewise, a Taiwanese study showed that people aged over 50 years experiencing pain had a greater risk (adjusted hazard ratio 1.21; 95% CI 1.15-1.26) of developing dementia compared with those without pain.[18] A recent study also found that having more chronic pain sites was linked to an elevated risk of dementia and Alzheimer's disease.[27] It is crucial to highlight that the current evidence on the link between chronic pain and cognitive impairment is not always consistent. Some studies have found no link between pain and cognitive decline or dementia.[26,28] These studies propose that pain might be a related factor or an early symptom rather than a direct catalyst of dementia.[29] Furthermore, 2 recent meta-analyses yielded conflicting results. One of the meta-analyses, which examined 37 study results, discovered a connection between chronic pain and cognitive decline.[30] However, another meta-analysis of 10 longitudinal cohort studies, revealed no association between chronic pain and an increased risk of cognitive decline.[31] Differences in the research design, methods of assessing pain and cognition, composition of the study population, and criteria for diagnosing dementia between studies may contribute to these divergent findings.

The age and gender disparities in the association between chronic pain and the risk of dementia are most likely due to biological factors, such as sex hormones, and pain perception, as well as the cumulative effects of aging. Female sex hormones, particularly estrogen, play a well-established role in both pain perception[32,33] and cognitive function.[34] Estrogens offer various advantages for brain health by acting as antioxidants, promoting DNA repair, stimulating the production of growth factors, and regulating blood flow in the brain.[35] Therefore, the natural decline in estrogen levels following menopause could contribute to a stronger association between chronic pain and dementia in women. Prior research established a connection between the decline in sex hormones after menopause and the higher rates and severity of Alzheimer's disease observed in women compared with men.[36–38] In addition, women typically exhibit a greater pain sensitivity,[39] which may lead to an increase in anxiety and tension.[40] A previous study discovered that women are more likely to experience both depression and anxiety when suffering from chronic pain,[41,42] potentially worsening the pain's impact on the brain and heightening the risk of cognitive decline. Age is another crucial factor influencing the association between chronic pain and dementia risk. Both chronic pain[43] and dementia prevalence[44] rise dramatically with aging. The cumulative burden of chronic pain over a lifetime, particularly in older adults, could exacerbate cognitive decline. A study from Ireland investigated the interaction between age and chronic pain, discovering that older adults with chronic pain experienced more significant cognitive decline than their healthy peers of the same age and younger adults with chronic pain.[45] A separate study determined that the risk of ADRD is elevated by chronic pain (hazard ratio 1.23) and that the incidence of ADRD was substantially higher in women and increased with age.[46]

To the best of our knowledge, there has been limited quantitative study on the relationship between chronic pain and dementia in Australia. The purpose of this research was to investigate the hypothesis that chronic pain is associated with heightened odds of dementia among older Australians. This study also aims to determine whether there are any age or gender differences in the association between chronic pain and the odds of dementia. The research findings will have significant implications in the development of well-informed interventions aimed at promoting independence and healthy aging among older adults in Australia and comparable jurisdictions.

Methods

Data Source and Settings

This article used data obtained from the Survey of Disability, Ageing, and Carers (SDAC) in 2015 and 2018. The SDAC provides data for evaluating the prevalence of disability and the requirement for supporting individuals with disabilities in Australia. Additionally, it provides a comprehensive analysis of the socioeconomic and demographic characteristics of those with disabilities, older adults, and caregivers in comparison with the overall population. SDAC collected data from both household and care accommodations.[47] The information collected from the household settings encompasses many forms of residential accommodation, such as self-care facilities for retired or elderly individuals, as well as other private homes, including houses, apartments, condominiums, garages, tents, and other buildings utilized as personal residences. In contrast, cared accommodation encompasses

several facilities, including hospitals, residential aged-care establishments, components of retirement villages that provide care services, aged-care hostels, psychiatric institutions, and other residential settings, such as group homes catering to those with disabilities. The survey sample was selected using multistage sampling procedures.

Study participants

The SDAC 2018 is the ninth nationwide comprehensive survey conducted since its inception in 1981. The surveys carried out in 1988, 1993, 1998, 2003, 2009, 2012, and 2015 were meticulously crafted to systematically collect comparable data pertaining to disability, aging, and carers in Australia. The current research was limited to 2 specific survey rounds conducted in 2015 and 2018 because those were the only rounds for which data on dementia, the outcome variable being studied, were available. The total sample size in 2015 encompassed 74 862 individuals, whereas it comprised 65 487 individuals in 2018. The research specifically targeted persons aged 65 years and older Australian. Therefore, the final sample size for the study was 20 671 individuals in 2015 and 20 081 individuals in 2018. Figure 1 depicts the distribution of the study participants.

Outcome Variable

Data on dementia, the primary outcome variable, were obtained from both households and care accommodations. In the household survey questionnaire, SDAC used a self-reported question "Count persons identified as having dementia/Alzheimer's in the household." The responses to the survey questions were coded in binary form, in which 0 denoted "no," and 1 denoted "yes." Data from the household component, covering both private and nonprivate dwellings, primarily relied on self-reported responses.[48] In cases which the individual in question could not provide the information, a proxy, often a caregiver, may have supplied it. Notably, in the context of cared accommodation, the survey methodology differs because it is not reliant on self-reporting but is instead administered by the carers, who recorded the details related to self-care and chronic medical conditions. In this study, data on dementia were mostly derived from the cared accommodation component. For instance, in 2015, 95.53% of participants with dementia data were from cared accommodation settings, whereas only 4.47% were community dwelling. This distribution remained steady in 2018 (95.57% vs 4.43%). Although the dementia assessment approach in different settings varies somewhat, we expect little variation in dementia measurement throughout the sample owing to the bulk of data coming from cared accommodations that adhere to standardized procedures.

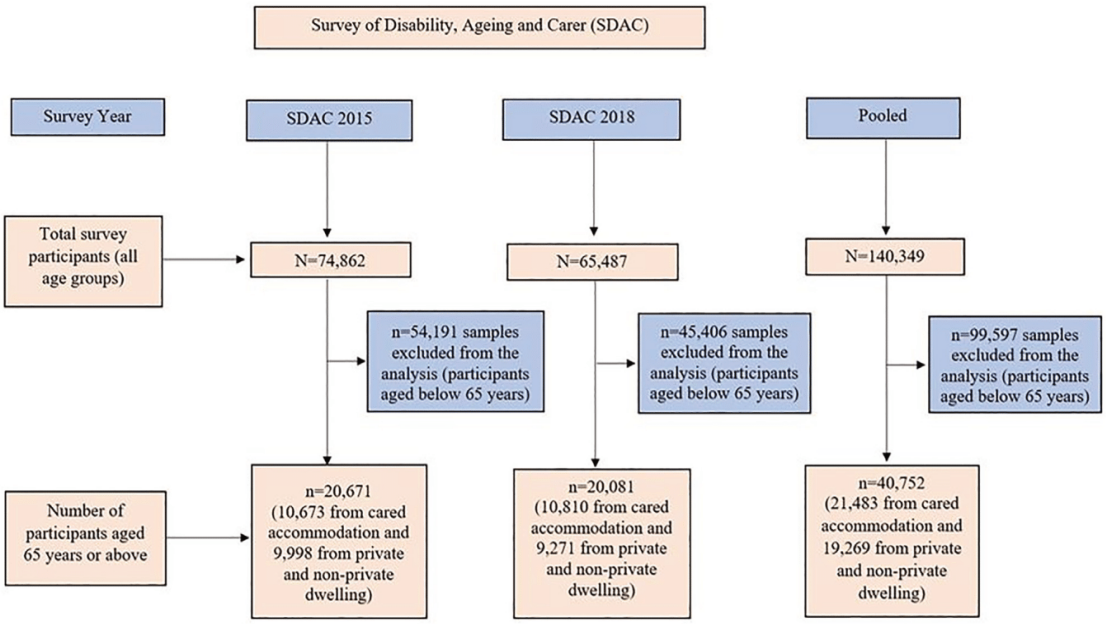
Explanatory Variable

Chronic pain was the exposure of interest and SDAC used the question "Do you/anyone in the household have chronic or recurrent pain or discomfort?" in the household questionnaire to collect the information. The patient must have had recurrent pain during the preceding 12 months to meet the criteria for chronic pain. The answers to the questions were documented in binary form, with 0 indicating "no" and 1 indicating "yes." The responses were collected from both household and care accommodation and were based on self-reported responses or a proxy such as a caregiver or a carer who is required to record any self-care and chronic medical conditions in care accommodation.

Covariates

The study was unable to include all potential confounders because of data availability constraints because data on dementia were mostly gathered from cared accommodation, and data about certain variables were either proved not appropriate for proxy data or were irrelevant to individuals residing in such care settings.[49] The study incorporated the following covariates: age,

Figure 1. Study participant distribution and survey year.



gender, accessibility remoteness index of Australia, country of birth, and state. Building on prior research, this study classified age into 3 distinct groups: individuals aged 65 to 74 were categorized as the "youngest old," those aged 75 to 84 as the "middle old," and those aged 85 and above as the "oldest old."[50,51] The accessibility remoteness index of Australia was classified by the Australian Bureau of Statistics into 5 categories: (1) "major city," (2) "inner regional area," (3) "outer regional," (4) "remote," and (5) "extremely distant."[52] In this study, because of the small number of individuals in each group, individuals from "outer regional," "remote," and "extremely distant areas" in the SDAC data set were merged as "outer regional or remote area."

Estimation Strategies

This study used basic confidential unit records files extracted from the 2015 and 2018 SDAC data sets for conducting a cross-sectional analysis. Descriptive statistics, encompassing frequencies (n) and percentages (%), along with corresponding 95% confidence intervals (CIs), were utilized to present the pooled characteristics of the study sample. Because of the complexity of the survey design, survey weights were used in this study to generate accurate variance estimates. The study made use of the population weight calculated by the Australian Bureau of Statistics for the data set because it offers a more comprehensive view of any given result by including the entire population. Further details on the SDAC study, including sampling and population weighting, can be found elsewhere.[47] The "svyset" STATA command was used to coordinate the intricate survey design during the analysis.

The study used multivariable logistic regression models to explore the association between chronic pain and dementia. The test outcomes are displayed in the form of odds ratio (OR), accompanied by 95% CIs and the respective *P* values for each variable. A predictor was considered statistically significant if the *P* value associated with a specific exposure was equal to or less than .05 in the multivariate regression analyses. The analysis was conducted using STATA 16 (Stata Corp LLC), which involved performing cross-tabulation, regression, and summary statistics.

Results

Table 1 illustrates the weighted background characteristics of the study participants in 2015, 2018, and pooled data. The pooled prevalence of dementia among older adults in Australia was 5.17%. Between 2015 and 2018, there was an observed increase in the prevalence of dementia, with rates rising from 5.10% to 5.23%. However, the prevalence of chronic pain decreased during this time, from 32.50% in 2015 to 30.38% in 2018. Table 1 (pooled) indicates that 56.81% of the participants were aged 65 to 74 years, 53.26% were female, and 67.08% were living in the major cities in Australia. Most older Australians were born in Australia (64.64%) and residing in New South Wales (33.22%).

Figure 2 represents the weighted changes in the prevalence of dementia by age and gender from 2015 to 2018. There was a consistent rise in dementia prevalence in males across all age groups (youngest old: 13%, middle old: 15%, oldest old: 15%). However, females experienced fluctuating dementia prevalence: a 20% decrease in the youngest-old group, a 2% increase in the middle-old group, and no change in the oldest-old group. Age and gender-stratified prevalence of dementia from 2015 to 2018 is presented in Appendix Figure 1 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2024.07.022.

Figure 3 depicts changes in the prevalence of chronic pain by age and gender from 2015 to 2018. Overall, there was a decrease in chronic pain prevalence for both males and females during this period. The most significant decline occurred in females aged oldest old (9.27%), whereas the least change was observed in middle-aged females (1.57%). In the youngest-old group, there was a significant decline of 8.75% among males.

The weighted prevalence of dementia among individuals with and without chronic pain over time is presented in Appendix Figure 2 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2024.07.022. The results showed an increase in the prevalence of dementia among older Australians living with chronic pain from 9.10% in 2015 to 9.28% in 2018. This study also explored the number of people without dementia and chronic pain for a more comprehensive picture. Appendix Tables 1 and 2 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2024.07.022 detail these findings using bivariate statistics.

Table 2 exhibits both unadjusted and adjusted multivariate logistic regression analyses, investigating the pooled association between dementia and chronic pain. Both the unadjusted and adjusted models demonstrate that older adults suffering from chronic pain exhibited a greater odds of living with dementia. The unadjusted analysis indicated that individuals experiencing chronic pain had 1.07 times elevated odds (OR 1.07; 95% CI 1.02-1.12) of living with dementia in comparison with those without chronic pain. These likelihoods were even higher in the adjusted model in which individuals with chronic pain had 1.95 times (AOR 1.95; 95% CI 1.85-2.05) greater odds of living with dementia compared with those without chronic pain.

Table 3 displays the results from the adjusted logistic regression models, which aim to elucidate the group comparison in the interaction effect between chronic pain and age, and chronic pain and gender, with dementia. The findings from model 1 indicate that individuals with chronic pain across all age groups exhibited significantly increased odds of living with dementia compared with those without chronic pain and the youngest old counterparts, and the magnitude of this association was higher with advancing age. For example, the youngest-old, middle-old, and oldest-old individuals with chronic pain, had a 3.40 (AOR 3.40; 95% CI 2.98-3.87), 12.60 (AOR 12.60; 95% CI 11.25-14.10), and staggering 19.99 times (AOR 19.99; 95% CI 17.94-22.28) higher odds of living with dementia, respectively, compared with their counterparts with youngest old and no chronic pain. Model 2 additionally showed that women with chronic pain had 2.41 times higher odds (AOR 2.41; CI 2.24-2.60) of living with dementia compared with those without chronic pain and being male.

Discussion

Key Findings

This study offered novel insights into the association between chronic pain and dementia in at-risk Australian communities, specifically among older Australians. Using a multivariable logistic regression model, this article investigates the pooled association between chronic pain and dementia from a nationally representative data set. According to SDAC, the cross-sectional study found that around 31% of older Australians had chronic pain in 2018. During both study periods of 2015 and 2018, the prevalence of chronic pain was higher among women than men. The pooled association revealed that older Australians who experienced chronic pain had a greater odds of living with dementia compared with those without chronic pain. The study also found that individuals with chronic pain across all age groups had higher odds of living with dementia compared with those without chronic pain and the youngest old counterparts, and this magnitude of

Table 1. Background characteristics of the study participants in 2015, 2018, and pooled data.

Parameters	2015			2018			Pooled		
	Unweighted n = 20 671	Weighted n = 3 546 360	Weighted % (95% CI)	Unweighted n = 20 081	Weighted n = 3 909 217	Weighted % (95% CI)	Unweighted n = 40 752	Weighted n = 7 455 577	Weighted % (95% CI)
Outcome variable									
Dementia									
No	15 009	3 365 573	94.90 (94.54-95.24)	14 209	3 704 791	94.77 (94.36-95.15)	29 218	7 070 364	94.83 (94.56-95.09)
Yes	5662	180 787	5.10 (4.76-5.46)	5872	204 426	5.23 (4.85-5.64)	11 534	385 213	5.17 (4.91-5.44)
Exposures and covariates									
Chronic pain									
No	9928	2 393 742	67.50 (66.50-68.48)	9363	2 721 548	69.62 (68.59-70.63)	19 291	5 115 291	68.61 (67.89-69.32)
Yes	10 743	1 152 618	32.50 (31.52-33.50)	10 718	1 187 669	30.38 (29.37-31.41)	21 461	2 340 286	31.39 (30.68-32.11)
Age									
Youngest old (65-74)	6958	2 008 677	56.64 (55.47-57.80)	6763	2 226 825	56.96 (55.75-58.17)	13 721	4 235 502	56.81 (55.97-57.65)
Middle-old (75-84)	6155	1 073 990	30.28 (29.24-31.35)	5910	1 191 633	30.48 (29.39-31.60)	12 065	2 265 622	30.39 (29.63-31.16)
Oldest old (85 and above)	7558	463 693	13.08 (12.40-13.78)	7408	490 759	12.55 (11.84-13.30)	14 966	954 453	12.80 (12.30-13.32)
Gender									
Male	8033	1 654 433	46.65 (45.95-47.36)	7831	1 830 346	46.82 (46.07-47.58)	15 864	3 484 779	46.74 (46.22-47.26)
Female	12 638	1 891 927	53.35 (52.64-54.05)	12 250	2 078 871	53.18 (52.42-53.93)	24 888	3 970 798	53.26 (52.74-53.78)
Accessibility and remoteness index									
Major cities in Australia	13 505	2 378 783	67.08 (65.86-68.27)	13 472	2 622 707	67.09 (65.80-68.35)	26 977	5 001 490	67.08 (66.20-67.96)
Inner regional Australia	4535	760 614	21.45 (20.39-22.54)	4448	883 523	22.60 (21.48-23.76)	8983	1 644 138	22.05 (21.28-22.85)
Outer regional and remote area	2631	406 963	11.48 (10.72-12.27)	2161	402 987	10.31 (9.54-11.13)	4792	809 949	10.86 (10.32-11.43)
Country of Birth									
Australia	13 872	2 285 906	64.46 (63.29-65.61)	13 228	2 533 537	64.81 (63.58-66.02)	27 100	4 819 442	64.64 (63.79-65.48)
English Speaking Countries	2853	523 733	14.77 (13.97-15.60)	2709	557 465	14.26 (13.44-15.13)	5562	1 081 198	14.50 (13.92-15.10)
Non-English-speaking countries	3946	736 721	20.77 (19.78-21.80)	4144	818 215	20.93 (19.88-22.03)	8090	1 554 937	20.86 (20.13-21.61)
State or territory									
New South Wales	5470	1 189 051	33.53 (32.26-34.82)	5901	1 287 503	32.94 (31.65-34.25)	11 371	2 476 554	33.22 (32.31-34.14)
Victoria	4543	892 056	25.15 (24.03-26.31)	4761	991 202	25.36 (24.19-26.55)	9304	1 883 258	25.26 (24.45-26.09)
Queensland	2994	680 240	19.18 (18.16-20.25)	3144	765 485	19.58 (18.56-20.64)	6138	1 445 725	19.39 (18.66-20.14)
South Australia	2979	293 550	8.28 (7.75-8.84)	2030	318 212	8.14 (7.18-9.21)	5009	611 762	8.21 (7.63-8.82)
Western Australia	2403	336 270	9.48 (8.86-10.15)	2800	373 252	9.55 (8.97-10.16)	5203	709 522	9.52 (9.09-9.96)
Tasmania	1260	93 610	2.64 (2.39-2.91)	895	103 695	2.65 (2.34-3.00)	2155	197 304	2.65 (2.44-2.87)
Northern Territory	225	14 076	0.40 (0.33-0.47)	133	16 137	0.41 (0.29-0.58)	358	30 212	0.41 (0.33-0.49)
Australian Capital Territory	797	47 508	1.34 (1.20-1.49)	417	53 732	1.37 (1.17-1.61)	1214	101 240	1.36 (1.23-1.50)

association increased with age. Additionally, women with chronic pain had a higher odds of living with dementia compared with those without chronic pain and being male.

The study's findings, which indicate an association between chronic pain and dementia, are consistent with earlier research demonstrating an increased odds of dementia among persons experiencing chronic pain or pain-related disorders.[18,22-24,45,53] Using comparable analytic methods to this study, a cross-sectional study conducted in the United States revealed that adults who experience pain interference, even without osteoarthritis, are more likely to develop ADRD.[24] Specifically, individuals with pain interference alone have 1.44 times higher odds of developing ADRD, whereas those with both pain interference and osteoarthritis have 1.37 times higher odds, compared with individuals without pain or osteoarthritis. A recent Chinese cross-sectional study also found that individuals who frequently report pain exhibit a 1.34 times higher likelihood of developing dementia when compared with those who do not report any pain.[23] Furthermore, another cross-sectional study discovered that the incidence of cognitive impairment was significantly greater (AOR: 1.88) in patients with neuropathic pain compared with the reported prevalence in the general Spanish population.[22] The negative association between chronic pain and dementia has also been established in longitudinal settings. For instance, in 2 retrospective United States cohort studies, it was shown that people with non-cancer chronic pain conditions had an increased

Figure 2. Changes in the prevalence of dementia by age and gender from 2015 to 2018.

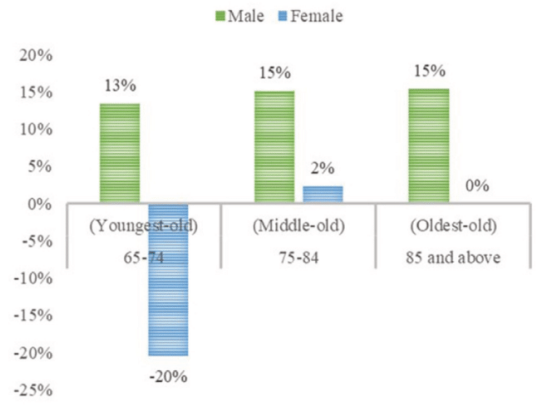
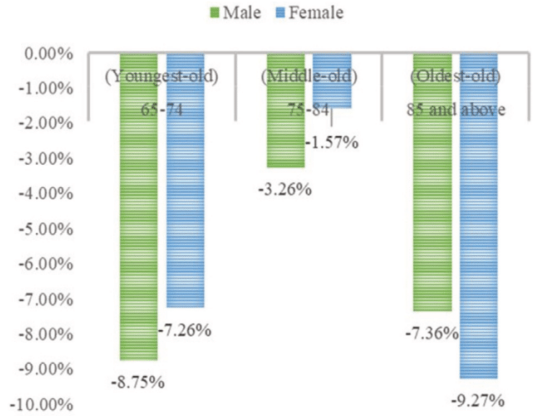


Figure 3. Changes in the prevalence of chronic pain by age and gender from 2015 to 2018.



risk of Alzheimer's disease and associated dementias over the course of 2 years of follow-up than people without pain conditions.[19,20] Another study, spanning a median period of 8.6 years, revealed an association between chronic pain and accelerated deterioration of memory function, as well as an elevated risk of developing dementia.[25] A recent study showed that having more chronic pain locations was linked to an elevated risk of dementia and Alzheimer's disease.[27] On the contrary, a study with a small sample conducted over a period of 24 years revealed that the existence of chronic pain did not exhibit any significant association with the occurrence of all-cause dementia.[26] Likewise, another research found no statistically significant association between pain and cognitive deterioration throughout a 4-year period of observation.[28] Differences in the research design, methods of assessing pain and cognition, composition of the study population, and criteria for diagnosing dementia between this study and previous research may contribute to these divergent findings.

There are several potential mechanisms that could explain the link between chronic pain and dementia. These include disruptions in attention and memory,[13,54,55] impaired decision-making abilities, decreased processing speed and psychomotor speed,[56,57] increased stress levels that may trigger the release of cortisol, which is associated with degeneration of the hippocampus and memory problems,[58-60] and the presence of other underlying health conditions.[61-63] During instances of chronic pain, nerve endings provide quick pain signals to the brain to prompt necessary remedial responses, and this process depletes the neuronal resources that are also engaged in cognitive activities.[64,65] Furthermore, the existence of chronic pain disorders has been connected to the dysregulation of noradrenergic-modulated endogenous pain autoinhibition,[65] which has been linked to unfavorable cognitive consequences, such as loss of working and long-term memory.[64]

Our findings also indicate that individuals with chronic pain across all age groups exhibited significantly increased odds of living with dementia compared with those without chronic pain and the youngest old counterparts, and the magnitude of this association increased with advancing age. The results of this study are consistent with a previous study conducted in Ireland, in which the authors examined the relationship between age and chronic pain.[45] They found that older adults with chronic pain experienced a greater pronounced cognitive decline compared with their healthy peers of the same age, as well as younger adults with chronic pain. Likewise, another study revealed that chronic pain elevated the risk of ADRD (hazard ratio = 1.23) and that the incidence of ADRD was substantially greater in women and escalated with age.[46] The cumulative burden of chronic pain over a lifetime, particularly in older adults, may aggravate cognitive deterioration.

Researchers believe that estrogen levels, a key female sex hormone, may be a critical factor influencing the disparities observed between men and women in terms of brain aging and neurodegeneration.[34] A link has been suggested between the decrease in sex steroid hormones after menopause and the increased prevalence and severity of Alzheimer's diseases in women compared with men.[36-38] Thus, a decrease in estrogen levels during menopause might make elderly women more susceptible to the damaging effects of chronic pain on cognitive function. Moreover, there are gender differences in pain response, with women generally showing greater sensitivity to pain.[39] This heightened pain sensitivity may result in increased stress and anxiety.[40] For example, earlier research found that women are more prone to co-occurring depression and anxiety with chronic pain.[41,42] This complex interplay can exacerbate the effects of pain on the brain and increase the risk of cognitive decline.

Strengths, Limitations, and Avenues for Further Research

One of the key strengths of this study lies in its utilization of the SDAC data set, which is a nationally representative large sample of the population.[66] To the best of our knowledge, this study represents one of the first Australian investigations into the association between chronic pain and dementia.

This study is not without limitations. First, the cross-sectional research design hinders the determination of causal relationships between chronic pain and dementia. Moreover, it did not allow this study to explore the temporality and reverse causality. In older adults, the link between chronic pain and cognitive decline might be bidirectional. Chronic pain could heighten the risk of cognitive issues, whereas brain degeneration linked to cognitive decline may, in turn, worsen pain perception. Second, since most of the data on long-term conditions were collected from aged-care facilities, it was not possible to incorporate all

Table 2. Multivariate logistic regression examining the association between dementia and chronic pain, pooled data.

Parameters	Model 1	Model 2
	Dementia (yes vs no)	Dementia (yes vs no)
	OR (95% CI)	AOR (95% CI)
Chronic pain		
No (ref)		
Yes	1.07* (1.02-1.12)	1.95* (1.85-2.05)
Age		
Youngest old (65-74) (ref)		
Middle-old (75-84)		4.32* (4.00-4.66)
Oldest old (85 and above)		8.50* (7.90-9.14)
Gender		
Male		
Female		1.14* (1.08-1.20)
Accessibility and remoteness index		
Major cities in Australia		1.13* (1.04-1.23)
Inner regional Australia		1.08 (0.99-1.18)
Outer regional and remote area (ref)		
Country of birth		
Australia (ref)		
English speaking countries		0.98 (0.91-1.05)
Non-English-speaking countries		1.21 (1.14-1.29)
State or territory		
New South Wales (ref)		
Victoria		0.94 (0.88-1.01)
Queensland		0.88* (0.82-0.95)
South Australia		1.14* (1.05-1.23)
Western Australia		0.86* (0.79-0.93)
Tasmania		0.88† (0.78-1.01)
Northern Territory		1.48‡ (1.12-1.97)
Australian Capital Territory		0.81† (0.70-0.94)

Note. Model 1 shows the unadjusted association between chronic pain and odds of dementia.
AOR indicates adjusted odds ratio; CI, confidence interval; OR, odds ratio; ref, reference.
*$P < .001$.
†$P < .01$.
‡$P < .05$.

Table 3. Group comparison in the interaction effect between chronic pain and age, chronic pain and gender, with dementia, pooled data.

Multiplicative interaction	Model 1	Model 2
	Chronic pain and age	Chronic pain and gender
	AOR (95% CI)	AOR (95% CI)
Group comparison in the interaction between chronic pain status and age		
No chronic pain and youngest old (65-74 years) (ref)		
No chronic pain and middle old (75-84 years)	4.93* (4.37-5.56)	
No chronic pain and oldest old (85 years and over)	14.98* (13.32-16.83)	
Has chronic pain and youngest old (65-74 years)	3.40* (2.98-3.87)	
Has chronic pain and middle old (75-84 years)	12.60* (11.25-14.10)	
Has chronic pain and oldest old (85 years and over)	19.99* (17.94-22.28)	
Group comparison in the interaction between chronic pain status and gender		
No chronic pain and male (ref)		
No chronic pain and female		1.41* (1.30-1.52)
Has chronic pain and male		2.43* (2.24-2.64)
Has chronic pain and female		2.41* (2.24-2.60)

Note. Models 1 and 2 were adjusted for accessibility and geographic remoteness, country of birth, and state.
AOR indicates adjusted odd ratio; CI, confidence interval; ref, reference.
*$P < .001$.

the confounding socioeconomic factors into the adjusted model and conduct a comprehensive case analysis. Therefore, systematic bias, such as unmeasured confounders, is possible. Third, the assessment of chronic pain presents difficulties because of its subjective characteristics and inconsistencies in the design of survey items utilized for evaluating chronic pain. Moreover, various types of pain can be experienced by individuals, including cancer-related pain, neuropathic pain, and musculoskeletal pain. The survey data analyzed in this study do not evaluate these particular categories separately but instead combine them, which presents difficulties in examining the many forms of chronic pain that are widespread in Australia. Fourth, because the SDAC data lack information on pain treatment, pain's interference with daily activities, and pain severity, the study was unable to determine whether pain treatment increases the risk of dementia or mitigates it by lessening pain's impact on attention and other mechanisms. Finally, the process of self-reporting or proxy-reporting presents a considerable challenge, especially when individuals exhibit reduced cognitive capacities, leading to a prolonged and indeterminate diagnostic procedure. Furthermore, the existence of social stigma may serve as a deterrent for individuals to openly disclose their conditions and/or identities. The prevalence of mild and moderate dementia among the household population may be underestimated by the SDAC. The identification of patients with dementia, particularly of advanced age, is a complex task because of the presence of concurrent health disorders that might mask the signs of dementia. The difficulties listed above are expected to have an impact on the data obtained through self-reported or proxy-reporting surveys. Nevertheless, previous studies conducted on population-based research often relied on self-reported data.[67-69]

Implications for Policy and Practice

The study's findings have major implications for public health policy because they demonstrate a statistically significant association between chronic pain and dementia. In 2010, Australia was the first country to adopt a national framework for pain, outlining the management of acute, chronic, and cancer pain. However, despite having a huge influence on people's lives, pain has not yet been prioritized in national health policies. Many people who experience pain are unable to access best practices in pain management, either because of financial constraints or a lack of knowledge about available alternatives, and the disparity is even more pronounced in rural and remote regions.[70] In the context of rural and regional Australia, it is imperative to undertake measures such as evaluating current models of "mini pain programs" that may facilitate the delivery of coordinated care packages and enhance the capabilities of healthcare professionals operating in these areas.[70] Moreover, a continuous, aligned, and personalized healthcare strategy is needed to establish pain management priorities, especially in groups with the greatest need.

Conclusion

Using a nationally representative data set, this cross-sectional study revealed that older adults with chronic pain were associated with a higher odds of living with dementia compared with those without chronic pain. The study also found that individuals with chronic pain across all age groups had higher odds of dementia compared with those without chronic pain and the youngest old counterparts, and this magnitude of association increased with age. Additionally, women with chronic pain had higher odds of dementia compared with their counterparts without chronic pain and being male. Further investigation is necessary to enhance estimations about chronic pain in the elderly population, to understand the underlying processes of pain in the context of aging and dementia, and to foster the development and progression of safer and more effective treatment options. Additionally, the research also proposes the use of an early assessment and management strategy for chronic pain to minimize the potential cognitive consequences.

Author Disclosures

Author disclosure forms can be accessed below in the Supplemental Material section.

Supplemental Material

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Data Availability: Data for this study are available to registered users of Australian Bureau of Statistics microdata (https://www.abs.gov.au/statistics/microdata-tablebuilder). For information about eligible organizations, see https://www.abs.gov.au/statistics/microdata-tablebuilder/absuniversities-australia-agreement

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4.2 Links and implications

The significance of this study lies in its potential to inform targeted interventions and healthcare policies aimed at promoting healthy ageing and maintaining independence among older adults. The findings may guide the development of age- and gender-specific strategies to mitigate the dual burden of chronic pain and dementia in Australia and similar settings. This research contributes to the growing body of evidence needed to improve the quality of life and well-being of older adults facing these interrelated challenges. The next chapter explores the adverse health outcomes of dementia.

Note: Appendix B presents a selection of newspaper clippings and images from television interviews, illustrating the significant media attention and broad public engagement generated by the research presented in this chapter.

CHAPTER 5: PAPER 3 - BEYOND THE SUM OF THEIR PARTS: THE COMBINED ASSOCIATION OF DEMENTIA AND CHRONIC PAIN WITH SELF-CARE LIMITATIONS IN OLDER AUSTRALIANS

5.1 Introduction

This chapter presents the third study of this thesis investigating the association among dementia, chronic pain, and self-care limitations among older Australians. Additionally, it explores how the co-occurrence of dementia and chronic pain influences self-care limitations. Previous research highlights that both dementia and chronic pain independently increase the likelihood of declining ADLs in various countries. However, limited attention has been paid to the combined impact of these conditions, particularly in an Australian context.

International studies suggest that co-occurring conditions, such as vision or hearing impairments alongside dementia, exacerbate functional activity limitations and self-care restrictions. Despite these findings, little is known about how the coexistence of dementia and chronic pain impacts self-care limitations, leaving a critical gap in the literature.

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Research paper

Beyond the sum of their parts: The combined association of dementia and chronic pain with self-care limitations in older Australians

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A B S T R A C T

Background: The purpose of this study was to investigate the association between dementia, chronic pain and self-care limitations. Additionally, the study sought to explore the relationship of co-occurring dementia and chronic pain with self-care limitations.
Methods: Cross-sectional data derived from the Survey of Disability, Ageing and Carers (SDAC) was used to conduct this study. The pooled association between dementia, and chronic pain, with self-care limitations was assessed using ordered logistic regression model. Furthermore, the study also examined the group comparison of interaction effects between co-occurring dementia and chronic pain with self-care limitations.
Results: The ordered logistic regression analysis indicated that people with dementia had significantly higher odds of experiencing greater self-care limitations (adjusted odds ratio [aOR]: 15.12, 95 % confidence interval [CI]: 12.50–18.29) compared to people without dementia. Similarly, chronic pain was independently associated with increased self-care limitations (aOR: 5.98, 95 % CI: 5.49–6.52) compared to people without chronic pain. Additionally, interaction effect analysis revealed that the co-occurrence of dementia and chronic pain substantially heightened the likelihood of self-care limitations (aOR: 66.54, 95 % CI: 52.27–84.69) relative to people without either condition.
Conclusions: Disability was higher among older Australians with dementia and chronic pain, and this risk can be increased if the two conditions co-exist. A continuous, aligned, and personalised healthcare approach is needed to establish self-care priorities, especially in groups of people with the greatest need.

1. Introduction

Approximately half of older Australians, aged 65 years and older, have disabilities, and 1.3 million living at home have mobility or self-care limitations and require support (Australian Bureau of Statistics, 2019). The Centre for International Economics predicts that 5.75 million Australians will have mobility issues by 2060 (Centre for International Economics, 2020). Most older adults with disabilities receive help from family or friends, and the need for formal care rises with the severity of the disability (Van Houtven et al., 2020). People who do not actively manage their health have significantly poorer health outcomes despite equality of health service access (Hibbard et al., 2009). Furthermore, activity limitations are linked to a wide range of detrimental effects, including decreased social interaction (Cudjoe et al., 2020), nursing home admission (Wolff et al., 2018), and an increased risk of mortality (Pongiglione et al., 2016).

Dementia is one of the leading causes of disability and dependency among older adults, affecting an estimated 55 million people globally (World Health Organization, 2023). In Australia, the prevalence of dementia among people aged 65 years and older rose from 5099 per 100,000 in 2015 to 5229 in 2018 (Haque et al., 2023), and the number of people with dementia is predicted to more than double by 2058, owing to the ageing population (Australian Institute of Health and Welfare, 2023). Previous research identified cognitive impairment as a predictor of declining activities of daily living (ADL) (Barberger-Gateau and Fabrigoule, 1997; McGuire et al., 2006; Pedone et al., 2005). For instance, using the World Health Organisation Disability Assessment Schedule 2.0 ratings, a Taiwanese study found that people with dementia had global activity limitations and were restricted from participating in all six key functional domains (Huang et al., 2016). Furthermore, cognitive impairment was associated with higher odds of functional decline in ADL and Instrumental Activities of Daily Living (IADL) in the USA (McGrath et al., 2020). A study conducted in Taiwan determined that on the IADL scale, medication management and shopping were the most discriminating activities between people with normal cognitive function and those with mild cognitive impairment

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(Lee et al., 2019).

An estimated 31 % of people worldwide have chronic pain (Steingrímsdóttir et al., 2017). Prior research found that chronic pain affected between 29.9 % and 36.2 % of older Australians (Henderson et al., 2013), 55.5 % of older Swiss (Jakobsson, 2010), and 69.8 % of older Germans (Bauer et al., 2016). As shown by earlier research, there is an association between pain and functional limitations (Eggermont et al., 2014; Makris et al., 2014; Stamm et al., 2016; Valderrama-Hinds et al., 2017). For instance, older people with musculoskeletal issues (such as osteoarthritis and chronic back pain) have reported difficulty performing specific ADL tasks, like completing heavy chores, bending over or kneeling, and ascending stairs without a walking stick (Stamm et al., 2016). Another study found mobility impairment, i.e., walking a quarter mile or climbing stairs, was strongly associated with limiting back pain (Makris et al., 2014). Functional constraints involving the upper and lower extremities were reported more frequently, and ADL handicaps in older adults with arthritic pain, result in being unable to raise arms above shoulder level, push or pull heavy objects, or pick up a coin (Valderrama-Hinds et al., 2017).

The co-existence of multiple diseases in one person, i.e., multimorbidity, is the most prevalent and debilitating ailment in older adults, resulting in functional decline over time (Marengoni et al., 2009). People with dementia generally suffer from multimorbidity such as diabetes, osteoporosis, falls and fractures, stroke, and heart failure (Welsh, 2019). Alzheimer's disease (AD), the most prevalent form of dementia, frequently co-occurs with chronic pain (Cao et al., 2019). Recent research revealed that dementia risk was found to be increased by chronic pain, primarily when it occurred in several different body parts (Haque et al., 2024; Harris, 2023).

It is evident from previous research that both dementia and chronic pain increased the likelihood of declining ADLs in different country settings. Nevertheless, little is known about the association between co-occurring dementia and chronic pain with self-care limitations. A few studies in the USA considered the co-existence of conditions such as vision or hearing impairment with dementia to assess the association with self-care limitations (Assi et al., 2021; Patel et al., 2020). According to their study of adults aged 65 years and older in the USA, those with dementia and self-reported visual impairment scored worse than predicted on measures of functional activity, given the individual contributions of both disorders (Patel et al., 2020). Another cross-sectional study found that adults with dementia and dual sensory (vision and hearing) impairment had additional mobility limitations and self-care restrictions (Assi et al., 2021).

To the best of our knowledge, this study represents the first Australian investigation into the association of dementia, chronic pain, and their co-occurrence, with self-care limitations in older adults. The study's findings are crucial for planning well-informed interventions to support older individuals' independence and healthy ageing.

2. Methodology

2.1. Data source and settings

This study used data collected from the Survey of Disability, Ageing and Carers (SDAC) in 2015 and 2018. The SDAC includes data to assess the prevalence of disability and the need to assist people with disabilities. It also provides a socio-economic and demographic profile of people with disabilities, older adults, and caregivers compared to the general population. In addition, the dataset contains information about people with disabilities, long-term health conditions, and elderly people. SDAC collected data from both household and care accommodations (Australian Bureau of Statistics, 2018b). The data obtained from the household component includes self-care accommodation for the retired or aged, and other private dwellings, including houses, flats, home units, garages, tents, and other structures used as private residences. On the other hand, cared accommodation includes hospitals, residential aged care, cared components of retirement villages, aged care hostels, psychiatric institutions, and other homes (such as group homes for people with disability). Multi-stage sampling techniques were used to select the sample for the survey. In 2015, the refusal rates from two household components, namely private dwellings and self-care retirement villages, were 3.7 % and 3.8 %, respectively (Australian Bureau of Statistics, 2015). From cared-accommodation components, non-responding establishments were 10.6 %. In 2018, the refusal rate for household components was 4.9 %, while cared-accommodation non-responding rate was 9.1 % (Australian Bureau of Statistics, 2018b). The data on self-care limitations, dementia, chronic pain, and other socio-demographic variables were derived predominantly from self-reported responses from the household components (Australian Institute of Health and Welfare, 2006). Alternatively, a proxy, such as a carer, may provide the information in cases where the individual of interest cannot respond. However, in the context of cared accommodation, the survey is not reliant on self-reporting but is administered by the carer obligated to document any self-care and chronic medical conditions.

2.2. Study participants

The data for this study were drawn from the 2015 and 2018 iterations of the Survey of Disability, Ageing and Carers (SDAC), a nationwide survey conducted regularly in Australia since 1981. While earlier surveys were conducted in 1988, 1993, 1998, 2003, 2009, and 2012, this analysis focuses on 2015 and 2018, as data on dementia, one of the key exposure variables, were only available for these two years.

The total number of participants in the SDAC was 74,862 in 2015 and 65,487 in 2018, resulting in a pooled dataset of 140,349 participants. Given that dementia, a primary exposure variable, predominantly affects older individuals, the study was restricted to participants aged 65 years and older. Consequently, 54,191 participants from 2015 and 45,406 from 2018 were excluded, leaving 20,671 participants in 2015 and 20,081 in 2018, with a final pooled sample of 40,752 participants.

All relevant variables for this analysis—self-care limitations, dementia, chronic pain, age, gender, geographic remoteness, country of origin, and state—had complete data. Therefore, there were no missing observations, and the final sample sizes remained at 20,671 in 2015, 20,081 in 2018, and 40,752 in the pooled dataset. The distribution of study participants across the datasets is depicted in Fig. 1.

2.3. Outcome variable

The Survey of Disability, Ageing and Carer (SDAC) collects information about a person's self-care, communication, and mobility limitations. These three factors are regarded as "core activity limitations" (Australian Bureau of Statistics, 2018a). This paper only examined self-care limitations resulting from impairments closely aligned with Activities of Daily Living (ADL), such as requiring assistance with dressing, eating, showering or bathing, toileting, and bladder or bowel control (Australian Institute of Health and Welfare, 2006). The self-care limitations variable in SDAC is self-reported and categorised as profound, severe, moderate, mild, or no limitation. The categories are defined as follows.

Profound: A person always needs help with at least one of the self-care activities.

Severe: A person sometimes needs help with at least one of the self-care activities.

Moderate: A person who struggles with at least one of self-care activities but does not need assistance.

Mild: A person who uses aids but does not have difficulties with any self-care activities.

No limitation: Not restricted in their ability to perform self-care activities.

This study reclassified the original five categories into three. Profound and severe limitations were merged as "profound or severe",

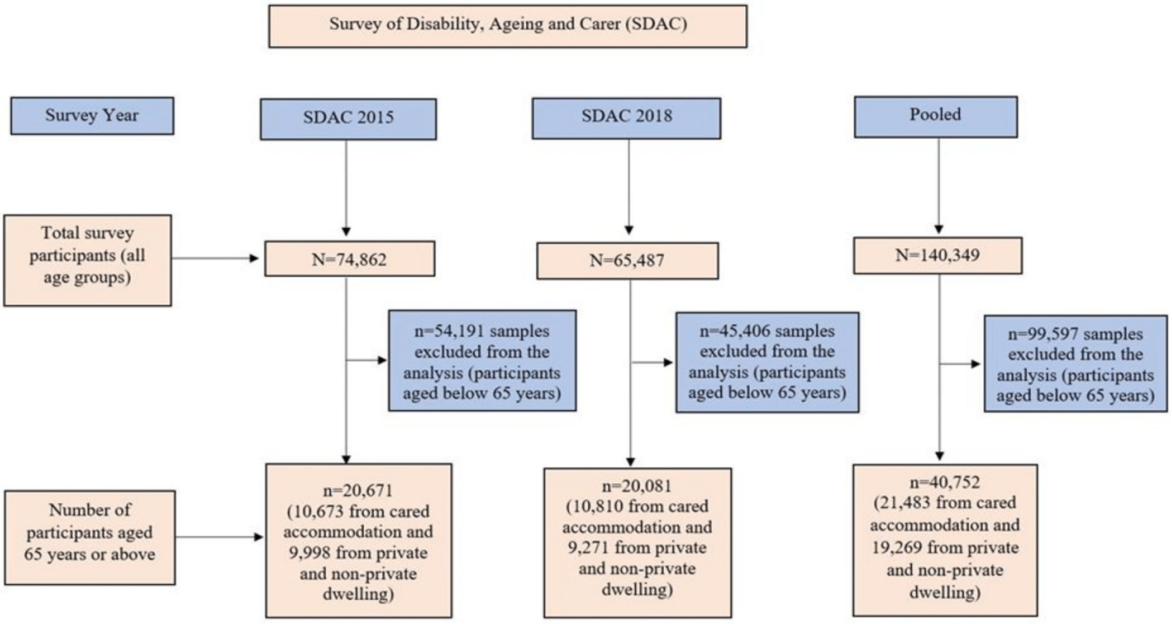

Fig. 1. Distribution of study participants and year of survey.

moderate and mild limitations became "moderate or mild," and "no self-care limitation" remained unchanged. The reclassification of self-care limitations from five categories into three was undertaken to simplify the analysis while retaining meaningful distinctions between levels of impairment. This grouping enhances interpretability by combining similar levels of functional limitations, ensuring robust comparisons across categories.

2.4. Exposure variable: dementia and chronic pain status

Data on dementia was obtained by self-reported and carer responses to the question, "Do you/persons have dementia?". However, to obtain information regarding chronic pain, the respondent was asked, "Do you experience recurring pain or discomfort?" To meet the criteria for chronic pain, the patient must have experienced recurrent pain within the past 12 months. The responses on dementia and chronic pain were coded as "yes" or "no".

2.5. Covariates

Data collection for the SDAC's cared-accommodation component was more constrained than for the household component because certain subjects were either inappropriate for proxy data collection or unrelated to those residing in cared-accommodation (Australian Bureau of Statistics, 2015). The study tried to keep the potential confounders; however, since care facilities provided much of the data on people with dementia, this study could not sustain all potential confounders to undertake a complete case analysis. Age (65–69, 70–74, 75–79, 80–84, and 85 years or more), gender (male and female), Accessibility Remoteness Index of Australia (ARIA), country of birth (Australia, English-speaking countries, non-English-speaking countries), and state were covariates included in this study. The ABS classified the Accessibility Remoteness Index of Australia (ARIA) as follows: i) "major city," ii) "inner regional area," iii) "outer regional," iv) "remote," and v) "extremely distant" (Australian Bureau of Statistics, 2016). In this study, due to the small number of individuals in each group, individuals from "outer regional," "remote," and "very remote" areas in the SDAC dataset were grouped together as "outer regional or remote area."

2.6. Estimation strategy

The characteristics of the cohorts were first summarised using descriptive statistics in the form of frequency (n) and weighted percentage (%) with 95 % confidence intervals (CI). Due to the complex survey design, additional adjustments, such as weighting, were necessary to generate correct variance estimates. The ABS has calculated a population weight for the data set; this weight was applied to the data for this analysis as it provides a broader population perspective of any result obtained. In this study, the variables 'person weight' and 'household identifier' were used for weighting. Full details on the SDAC study, including sampling and population weighting, can be found elsewhere (Australian Bureau of Statistics, 2018b). The STATA command "svy set" was utilised in the analysis to manage the intricate survey design. To evaluate the bivariate relationship between the outcome variable with dementia, chronic pain, and other variables, chi-square tests or *t*-tests have been performed.

The outcome variable, self-care limitations, was measured on an ordinal scale and categorised into three levels: "0 = No self-care limitation," "1 = Mild or moderate self-care limitation," and "2 = Profound or severe self-care limitation," with higher values indicating greater self-care limitations. Consequently, we employed an ordered logistic regression model to examine the association between dementia, and chronic pain with self-care limitations. Additionally, we conducted a group comparison to analyse the interaction effect of co-occurring dementia and chronic pain on self-care limitations. The results of the adjusted ordered logistic regression model were presented as adjusted odds ratio (aOR) and were considered statistically significant at a *p*-value of 0.05. Stata 16 (StataCorp LLC., College station, Texas) was utilised for all statistical analyses, including cross-tabulation, regression, and summary statistics.

2.7. Robustness check and heterogenous effects

To validate the reliability of our results, we undertook a sensitivity analysis using the original five categories of self-care limitations rather than the reclassified three categories. In addition, we explored possible variations in the association between co-occurring dementia and chronic pain with self-care limitations through subgroup analyses based on age and gender.

3. Results

Table 1 provides a summary of the study participants' weighted sample characteristics. The result showed that in 2015, 12.27 % (95 % CI: 11.71–12.86) of older Australians had profound or severe self-care limitations, while 5.10 % (95 % CI: 4.76–5.46) and 32.50 % (95 % CI: 31.52–33.50) had dementia and chronic pain, respectively. The data from 2018 indicates a decrease in the weighted percentage of people experiencing profound or severe self-care limitations (11.24 %, 95%CI: 10.67–11.84) and chronic pain (30.38 %, 95 % CI: 29.37–31.41) compared to the figures reported in 2015. Moreover, in 2018, the proportion of female respondents was 53.18 % (95 % CI: 52.42–53.93), and 12.55 % (95 % CI: 11.84–13.30) were 85 years of age or older.

Fig. 2 illustrates the proportion of self-care limitations among people living with dementia from 2015 to 2018. Among the people living with dementia, the proportion of profound or severe self-care limitations increased from 30.85 % in 2015 to 32.41 % in 2018. In the pooled data, a significant proportion of older adults living with dementia experienced self-care limitations, with 4.47 % reporting mild or moderate and 31.63 % reporting profound or severe self-care limitations.

Fig. 3 depicts the proportion of self-care limitations among people with chronic pain between 2015 and 2018. During this period, the proportion of profound or severe self-care limitations among those with chronic pain showed a slight decline, from 67.58 % in 2015 to 66.38 % in 2018. In the pooled data, a substantial proportion of older adults with chronic pain experienced self-care limitations, with 62.42 % reporting mild or moderate and 66.98 % reporting profound or severe self-care limitations.

The bivariate analyses examining the association of dementia, chronic pain, and other covariates with self-care limitations can be found in Appendix Table A1 of the supplementary documents. The bivariate analyses showed that self-care limitation was significantly associated with dementia, chronic pain status and other covariates at a 5 % level of significance. Additionally, Appendix Tables A2 and A3 provide the distribution of characteristics of study variables for the years 2015, 2018 and pooled data categorised by exposure group (chronic pain and dementia).

Table 2 presents the results from ordered logistic regression, highlighting the relationship between dementia, chronic pain, and self-care limitations. In Model 1, the findings reveal that people living with dementia had higher odds of self-care limitations [adjusted odds ratio (aOR): 15.12, 95 % confidence interval (CI): 12.50–18.29] compared to those without dementia. Additionally, chronic pain was independently associated with increased self-care limitations (aOR: 5.98, 95 % CI: 5.49–6.52) compared to people without chronic pain. Model 2 examines the interaction between chronic pain and dementia in relation to self-care limitations. The findings suggest that people with chronic pain, but without dementia, had significantly higher odds of experiencing self-care limitations (aOR: 6.25, 95 % CI: 5.73–6.83) compared to those without either condition. This association was even stronger for those with dementia but without chronic pain, who exhibited even greater odds of self-care limitations (aOR: 19.77, 95 % CI: 15.41–25.36). The combined presence of both dementia and chronic pain further amplified the risk, with a substantially increased likelihood of self-care limitations (aOR: 66.54, 95 % CI: 52.27–84.69) compared to people without either condition.

Table 3 presents the average marginal effects of self-care limitations (with dementia and chronic pain) based on the regression results from Model 1 in Table 2. The findings indicate that people with dementia were 47 % points less likely to have no self-care limitations compared to those without dementia. However, the probability of experiencing self-care limitations for people with dementia was 9 % points more likely to have mild or moderate limitations, and 38 % points more likely to experience profound or severe limitations compared to peers without dementia. Likewise, the probability of experiencing self-care limitations for people with chronic pain was 10 % points more likely to have mild or moderate limitations, and 15 % points more likely to experience profound or severe limitations than their counterparts not experiencing chronic pain.

3.1. Sensitivity analysis

We conducted sensitivity analyses to assess the robustness of our findings by using the original five categories of self-care limitations instead of the combined three categories. The results of ordered logistic regression and average marginal effects, presented in Appendix Tables A4 and A5, respectively, remained consistent with the main analyses.

3.2. Heterogenous effect

Tables 4 and 5 present the results of ordered logistic regression used to assess whether the relationship between co-occurring dementia and chronic pain with self-care limitations differs by age and gender, respectively. Table 4 shows that people with both dementia and chronic pain had higher odds of self-care limitations across all age groups compared to those without either condition, consistent with the main regression findings. However, the magnitude of the association between co-occurring dementia and chronic pain with self-care limitations appears to diminish with increasing age. For example, among people aged 65–69 years, those with both dementia and chronic pain had significantly higher odds of experiencing self-care limitations (aOR: 102.46, 95 % CI: 45.56–230.41) compared to their counterparts without either condition. In contrast, among people aged 85 years and older with both dementia and chronic pain, the odds were lower but still notably elevated (aOR: 44.42, 95 % CI: 29.39–67.12).

Table 5 indicates that, regardless of gender, people with both dementia and chronic pain exhibited significantly higher odds of self-care limitations compared to those without either condition, which is consistent with the main findings. For example, males with both dementia and chronic pain had markedly increased odds of experiencing self-care limitations (aOR: 64.25, 95 % CI: 44.15–93.53) than those without either condition.

4. Discussion

This study investigated older Australians aged 65 years and over from a nationally representative Survey of Disability, Ageing and Carers (SDAC) dataset to ascertain the association of dementia, and chronic pain with self-care limitations. The study further examined the association of co-occurring dementia and chronic pain with self-care limitations. The study found that dementia and chronic pain independently are associated with increased odds of self-care limitations. However, the most concerning finding is the interaction effect, which suggests that co-occurring dementia and chronic pain significantly amplify a person's self-care limitations.

The results showed that dementia is associated with self-care limitations, which is consistent with earlier research in which it was found that as dementia progresses, cognitive impairment makes it more difficult for people to engage in regular tasks (self-care domain) (Barberger-Gateau et al., 2002; Muò et al., 2005; Rocha et al., 2013). According to a previous study conducted in the USA, people with dementia were more likely to indicate functional limitations in 11 out of the 12 activity

Table 1
Background characteristics of the study participants.

Characteristics	2015			2018			Pooled		
	Unweighted n = 20,671	Weighted N = 3,546,360	Weighted % (95 % CI)	Unweighted n = 20,081	Weighted N = 3,909,217	Weighted % (95 % CI)	Unweighted n = 40,752	Weighted N = 7,455,577	Weighted % (95 % CI)
Level of self-care limitations									
No self-care limitations	8820	2800,086	78.96 (78.14–79.75)	8277	3,109,750	79.55 (78.67–80.41)	17,097	5,909,836	79.27 (78.66–79.86)
Moderate or Mild	1161	311,026	8.77 (8.19–9.39)	1080	359,931	9.21 (8.55–9.90)	2241	670,957	9.00 (8.55–9.46)
Profound or severe	10,690	435,248	12.27 (11.71–12.86)	10,724	439,536	11.24 (10.67–11.84)	21,414	874,784	11.73 (11.33–12.15)
Dementia									
No	15,009	3,365,573	94.90 (94.54–95.24)	14,209	3,704,791	94.77 (94.36–95.15)	29,218	7,070,364	94.83 (94.56–95.09)
Yes	5662	180,787	5.10 (4.76–5.46)	5872	204,426	5.23 (4.85–5.64)	11,534	385,213	5.17 (4.91–5.44)
Chronic Pain									
No	9928	2,393,742	67.50 (66.50–68.48)	9363	2,721,548	69.62 (68.59–70.63)	19,291	5,115,290	68.61 (67.89–69.32)
Yes	10,743	1,152,618	32.50 (31.52–33.50)	10,718	1,187,669	30.38 (29.37–31.41)	21,461	2,340,287	31.39 (30.68–32.11)
Age									
65–69	3823	1,148,837	32.39 (31.31–33.50)	3406	1,200,980	30.72 (29.6–31.86)	7229	2,349,817	31.52 (30.73–32.31)
70–74	3135	859,840	24.25 (23.30–25.22)	3357	1,025,845	26.24 (25.21–27.30)	6492	1,885,685	25.29 (24.58–26.01)
75–79	2972	630,363	17.77 (16.94–18.64)	2854	705,799	18.05 (17.18–18.96)	5826	1,336,161	17.92 (17.31–18.55)
80–84	3183	443,627	12.51 (11.81–13.25)	3056	485,834	12.43 (11.7–13.19)	6239	929,461	12.47 (11.96–12.99)
85 and above	7558	463,693	13.08 (12.40–13.78)	7408	490,759	12.55 (11.84–13.30)	14,966	954,453	12.80 (12.30–13.32)
Gender									
Male	8033	1,654,433	46.65 (45.95–47.36)	7831	1,830,346	46.82 (46.07–47.58)	15,864	3,484,779	46.74 (46.22–47.26)
Female	12,638	1,891,927	53.35 (52.64–54.05)	12,250	2,078,871	53.18 (52.42–53.93)	24,888	3,970,799	53.26 (52.74–53.78)
Accessibility and remoteness index									
Major cities in Australia	13,505	2,378,783	67.08 (65.86–68.27)	13,472	2,622,707	67.09 (65.80–68.35)	26,977	5,001,490	67.08 (66.20–67.96)
Inner regional Australia	4535	760,615	21.45 (20.39–22.54)	4448	883,523	22.60 (21.48–23.76)	8983	1,644,138	22.05 (21.28–22.85)
Outer regional and remote area	2631	406,962	11.48 (10.72–12.27)	2161	402,987	10.31 (9.54–11.13)	4792	809,950	10.86(10.32–11.43)
Country of birth									
Australia	13,872	2,285,906	64.46 (63.29–65.61)	13,228	2,533,537	64.81 (63.58–66.02)	27,100	4,819,442	64.64 (63.79–65.48)
English Speaking Countries	2853	523,733	14.77 (13.97–15.60)	2709	557,465	14.26 (13.44–15.13)	5562	1,081,198	14.50 (13.92–15.10)
Non-English-speaking countries	3946	736,721	20.77 (19.78–21.80)	4144	818,215	20.93 (19.88–22.03)	8090	1,554,937	20.86 (20.13–21.61)
State or territory									
New South Wales	5470	1,189,051	33.53 (32.26–34.82)	5901	1,287,503	32.94 (31.65–34.25)	11,371	2,476,554	33.21 (32.30–34.13)
Victoria	4543	892,056	25.15 (24.03–26.31)	4761	991,202	25.36 (24.19–26.55)	9304	1,883,258	25.26 (24.45–26.09)
Queensland	2994	680,240	19.18 (18.16–20.25)	3144	765,485	19.58 (18.56–20.64)	6138	1,445,725	19.39 (18.66–20.14)
South Australia	2979	293,550	8.28 (7.75–8.84)	2030	318,212	8.14 (7.18–9.21)	5009	611,762	8.21 (7.63–8.82)
Western Australia	2403	336,270	9.48 (8.86–10.15)	2800	373,252	9.55 (8.97–10.16)	5203	709,521	9.52 (9.09–9.96)
Tasmania	1260	93,609	2.64 (2.39–2.91)	895	103,695	2.65 (2.34–3.00)	2155	197,304	2.65 (2.44–2.87)
Northern Territory	225	14,076	0.40 (0.33–0.47)	133	16,137	0.41 (0.29–0.58)	358	30,212	0.41 (0.33–0.49)
Australian Capital Territory	797	47,508	1.34 (1.20–1.49)	417	53,732	1.37 (1.17–1.61)	1214	101,240	1.36 (1.23–1.50)

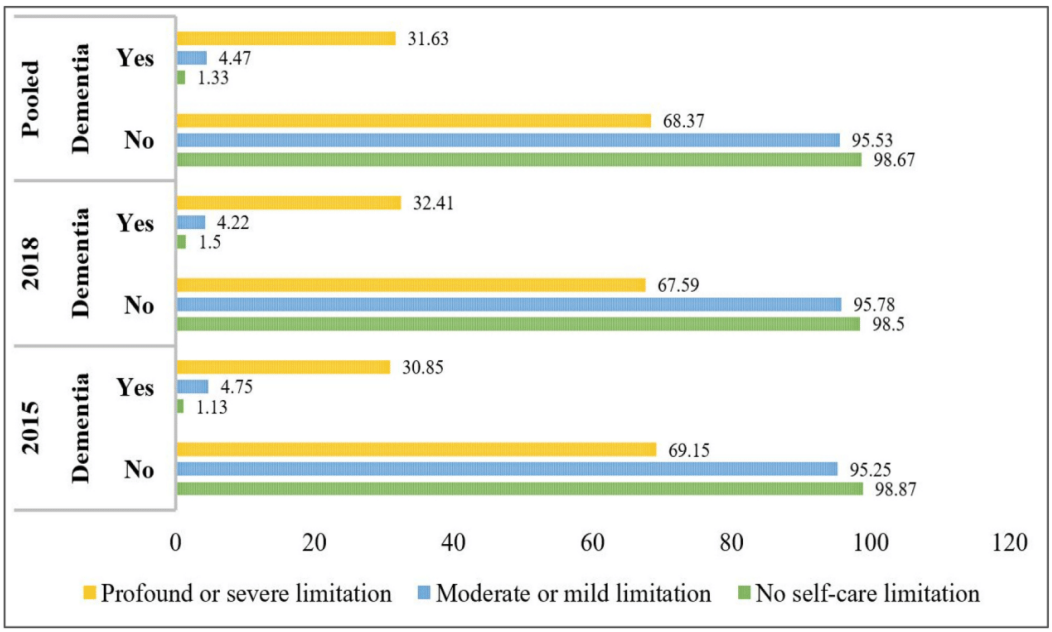

Fig. 2. Weighted prevalence of self-care limitations by the dementia status.

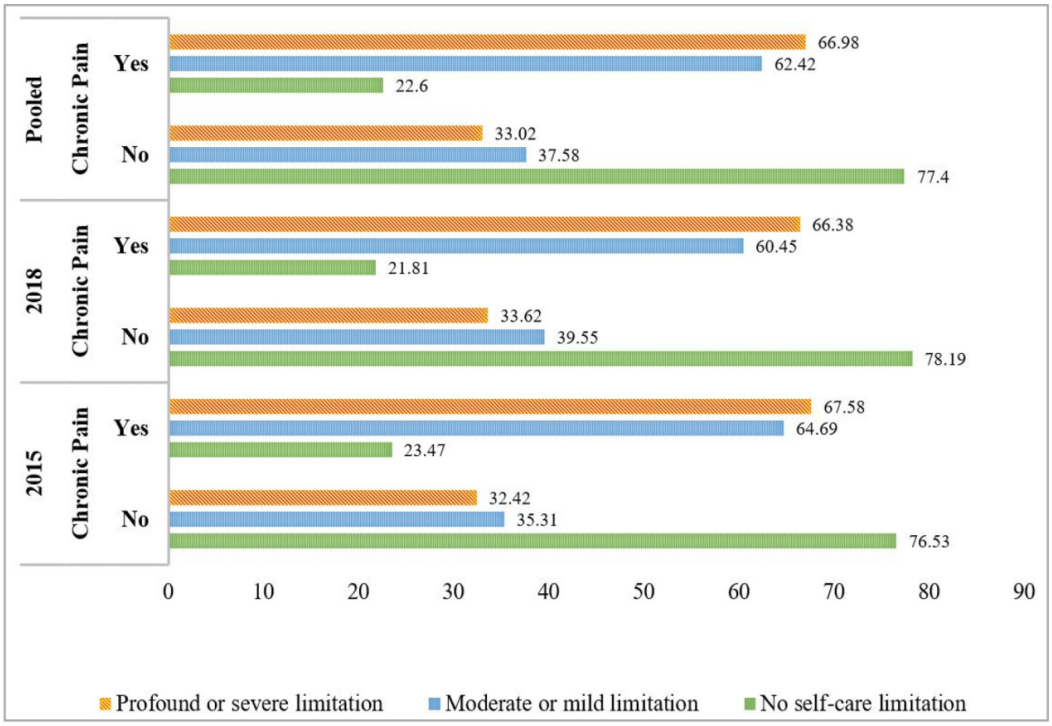

Fig. 3. Weighted prevalence of self-care limitations by the chronic pain status.

categories, and respondents with dementia-related functional limitations reported a greater mean number of limited activities (6.84 versus 4.87 in the cohort without dementia-related functional limitations) (Arrighi et al., 2010).

This study revealed that chronic pain was associated with greater self-care limitations. Earlier studies on older adults indicated that worse pain, that is,—more pervasive or intense pain, has a bigger impact on daily activities (Dueñas et al., 2020; Montgomery et al., 2016; Perneros

Table 2
Ordered logistic regression examining the association of dementia and chronic pain with self-care limitation, Pooled data.

	Model 1	Model 2
	Level of self-care limitation	Level of self-care limitation
	aOR (95%CI)	aOR (95%CI)
Dementia		
No (ref)		
Yes	15.12 *** (12.50–18.29)	
Chronic pain		
No (ref)		
Yes	5.98*** (5.49–6.52)	
Group comparison in the interaction between dementia and chronic pain status		
No dementia and no chronic pain (ref)		1.0 (Reference)
No dementia but has chronic pain		6.25***(5.73–6.83)
Has dementia but no chronic pain		19.77***(15.41–25.36)
Has dementia and chronic pain		66.54***(52.27–84.69)

Notes: 1. P-values: ***P < 0.001.
2. Abbreviations: ref. = Reference; aOR = Adjusted Odds Ratio; CI = Confidence Interval;
3. Only exposure variables are reported in the adjusted models 1 and 2.
4. The models are adjusted with age, accessibility and remoteness index, country of birth, and state.

Table 3
Relevant marginal effects results for ordered logistic regressions.

Self-care limitation score	Level of self-care limitation	Level of self-care limitation
	Variable of interest- dementia	Variable of interest- chronic pain
	Marginal effect, P value	Marginal effect, P value
0	−0.47; 0.001	−0.25; 0.001
1	0.09; 0.001	0.10; 0.001
2	0.38; 0.001	0.15, 0.001

Note: Self-care limitation score: 0 = No self-care limitation, 1 = mild or moderate self-care limitation, and 2 = severe or profound self-care limitation.

and Tropp, 2009). Another study also revealed that the severity of chronic back pain affected the quality of life regarding one's health, symptoms of depression and anxiety, the ability to work and carry out daily activities, and the quantity of healthcare used (Stamm et al., 2016). These researchers indicated that, even if pain cannot be removed entirely, therapies that lessen the intensity of the pain may still improve several health outcomes. This might be because people with chronic pain worry about physical activity since it could exacerbate their anguish (Friedrich et al., 2009; Nijs et al., 2008).

This study also demonstrated that co-occurring dementia and chronic pain were associated with greater self-care limitations. Notably, no prior studies have investigated this specific association. While related research in the USA has identified connections between co-existing dementia and visual impairment (Patel et al., 2020) or sensory limitations (Assi et al., 2021) with functional limitations, these studies did not explore chronic pain as a co-occurring factor. The findings of our study extend existing knowledge by highlighting the magnified impact of dementia alongside chronic pain on self-care limitations in older adults.

Policymakers and public health professionals seeking to measure and manage this growing burden at the population level may find these insights on the nature and extent of disability in dementia and chronic pain co-occurring in people to be valuable. At the policy level, there are a few current programmes in place related to self-care, but there is no evidence that they successfully target those people who require the most assistance with self-care and self-management. The current self-care related programmes include consumer-directed care arrangements in which eligible older adults receive a pre-determined fixed subsidy that can be used for various self-care services (such as physical fitness activities, social engagement and inclusion, and medical equipment) but not for medication (Duggan et al., 2017). However, in the absence of a deliberate national strategy that provides a formal definition of self-care and additional guidance on how these funds can be used to support self-care, it is unlikely that consumer-directed care will significantly impact self-care practices. Regarding chronic pain, a prior study found that more severe and extensive pain and the self-perception of pain's impact on work and social life were associated with greater levels of limitations in ADLs (Dueñas et al., 2020). Hence, determining what makes some people more limited than others could help guide future prevention and treatment efforts to ensure that chronic pain does not have negative consequences for other family members or individual's own work, and social lives. This will assist in the development of future prevention and treatment programmes. Recently, the Australian government allocated $20 million to a pilot programme called Pain MedsCheck that will assist people in using medications to treat chronic pain (Duggan et al., 2017). As part of Pain MedsCheck, pharmacists will monitor people using medicine to treat chronic pain that has lasted three months or more. In addition to pharmacological intervention, Pain Australia's national pain strategy includes self-management techniques such as 'pacing' to prevent pain episodes, which involves sustaining a consistent level of daily activity, as well as physical exercise and mental health strategies such as mindfulness (Painaustralia, 2019). As intriguing as these and other contemporary initiatives may be, it is evident that a continuous, aligned, and personalised healthcare approach is needed to establish self-care priorities, especially in groups with the greatest need, as evidenced by the inadequacy of isolated programmes and projects. Future research may contribute to further refining the clinical practice guidelines currently used to manage pain and dementia.

The primary strength of this study is the use of the SDAC dataset, a nationally representative sample of the population (Schofield et al., 2019). This study is one of the first to investigate the association between dementia and chronic pain with self-care limitations in an Australian context. Moreover, this study considered the co-occurrence of dementia and chronic pain, a prevalent co-morbidity with self-care limitations, which is barely explored in previous studies.

While interpreting the findings, it is crucial to consider the limitations of the study. First, the cross-sectional research design prevented this study from determining the causal links between self-care limitations and the co-occurrence of dementia and chronic pain. Second, since the data on disability were mostly collected from aged-care facilities, information about several socio-economic characteristics was unavailable, restricting this study from incorporating all confounders into the adjusted model to provide a complete case analysis. Hence, there is a possibility of systematic bias such as unmeasured confounders. Third, the measurement of chronic pain poses challenges due to its subjective nature and discrepancies in the formulation of questions used to assess chronic pain in survey instruments. People may encounter several forms of pain, such as cancer-related pain, neuropathic pain, and musculoskeletal pain. The surveys and data collections analysed in this research do not individually assess these specific categories, however rather aggregate them, posing challenges in exploring the various types of chronic pain prevalent in Australia. Finally, self-reporting or proxy-reporting poses a significant challenge, particularly in cases where a person's cognitive abilities are impaired, resulting in a protracted and ambiguous diagnosis process. Moreover, the presence of stigma may discourage people from identifying themselves. The SDAC may underestimate the prevalence of mild and moderate dementia among the household population. Identifying people with dementia, particularly at

Table 4
Heterogenous effect: group comparison in the interaction effect of cooccurring dementia and chronic pain with self-care limitations by age using ordered logistic regression, pooled data.

	Model 1	Model 2	Model 3	Model 4	Model 5
	Level of self-care limitations (Age 65–69)	Level of self-care limitations (Age 70–74)	Level of self-care limitations (Age 75–79)	Level of self-care limitations (Age 80–54)	Level of self-care limitations (Age 85 years and over)
	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Dementia and chronic pain interaction					
No dementia and no chronic pain (ref)					
No dementia but has chronic pain	8.99*** (7.37–10.95)	7.19*** (5.89–8.78)	6.24*** (5.09–7.63)	4.78*** (3.90–5.86)	4.43*** (3.69–5.31)
Has dementia but no chronic pain	73.70*** (24.44–222.23)	20.46*** (9.98–41.98)	16.15*** (9.41–27.71)	19.03*** (11.32–31.98)	13.92*** (9.42–20.55)
Has dementia and chronic pain	102.46*** (45.56–230.41)	78.86*** (44.34–140.23)	75.69*** (45.43–126.12)	61.80*** (36.02–106.04)	44.42*** (29.39–67.12)

Notes: 1. P-values: ***P < 0.001.
2. Abbreviations: ref. = Reference; aOR = Adjusted Odds Ratio; CI = Confidence Interval.
3. Only exposure variables are reported in the adjusted models 1–5.
4. The models are adjusted with age, accessibility and remoteness index, country of birth, and state.

Table 5
Heterogenous effect: group comparison in the interaction effect of cooccurring dementia and chronic pain with self-care limitations by gender using ordered logistic regression, pooled data.

	Model 1	Model 2
	Level of self-care limitations (Gender: Male)	Level of self-care limitations (Gender: Female)
	aOR (95%CI)	aOR (95%CI)
Dementia and chronic pain interaction		
No dementia and no chronic pain (ref)		
No dementia but has chronic pain	6.28*** (5.49–7.18)	6.23*** (5.55–6.99)
Has dementia but no chronic pain	18.22*** (12.54–26.48)	21.20*** (15.27–29.43)
Has dementia and chronic pain	64.25*** (44.15–93.53)	67.30*** (49.48–91.53)

Notes: 1. P-values: ***P < 0.001.
2. Abbreviations: ref. = Reference; aOR = Adjusted Odds Ratio; CI = Confidence Interval;
3. Only exposure variables are reported in the adjusted models 1 and 2.
4. The models are adjusted with age, accessibility and remoteness index, country of birth, and state.

advanced ages, is complicated by co-occurring health conditions that obscure dementia symptoms. The aforementioned obstacles will likely influence the data collected via self-administered or proxy-based questionnaires. However, earlier population-based research frequently utilised self-reported data (Assi et al., 2021; Frank et al., 2019; Patel et al., 2020).

5. Conclusions

In conclusion, this study sheds light on the significant challenges faced by Australian older adults living with both dementia and chronic pain. The results, based on a nationally representative sample, showed that dementia and chronic pain were independently associated with self-care limitations. Furthermore, the group comparison in the interaction effect reveals that co-occurring dementia and chronic pain were associated with significantly higher self-care limitations.

These findings have significant implications for improving the health of older people with dementia. Given the potential for chronic pain treatment to alleviate the constraints associated with dementia, it is critical to investigate low-cost and easily accessible pain management solutions customized to this demographic. This might include non-pharmacological therapies like physical therapy, relaxation methods, or cognitive-behavioural therapy approaches tailored to people with dementia.

Further study is urgently required to validate the reported interaction effect and understand possible mechanisms. Studies exploring the specific types of chronic pain experienced by older people with dementia, as well as their influence on self-care limitations, might be beneficial. Furthermore, studying the efficacy of various pain treatment techniques in older adults is critical for informing clinical practice and improving care. By managing chronic pain, we may be able to considerably enhance or preserve the functional abilities of older people, especially those with dementia, enabling them to live more satisfying lives.

Abbreviations

ABS	Australian Bureau of Statistics
ADL	Activities of Daily Living
ARIA	Accessibility Remoteness Index of Australia
CI	Confidence Interval
IADL	Instrumental Activities of Daily Living
OR	Odds Ratio
SDAC	Survey of Disability, Ageing, and Carers
WHO	World Health Organization

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CRediT authorship contribution statement

Rezwanul Haque: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Khorshed Alam:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Conceptualization. **Jeff Gow:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Conceptualization. **Christine Neville:** Writing – review & editing, Writing – original

draft, Visualization, Validation, Supervision, Conceptualization. **Syed Afroz Keramat:** Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Conceptualization.

Ethics approval and consent to participate

Data for SDAC were collected by the Australian Bureau of Statistics (ABS) under the provisions of the Census and Statistics Act (CSA) 1905. Prior to field operations, the survey was submitted to the Australian Privacy Commissioner and tabled in parliament. Confidentiality of these data is guaranteed under the Act, and information was provided freely by respondents. This study did not require ethical approval as the dataset is from publicly de-identified available data, and data were made available to the authors through the ABS and Universities Australia agreement.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Grammarly and OpenAI in order to improve the readability and language of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Declaration of competing interest

We declare no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2024.10.046.

Data availability

Data for this study are available to registered users of Australian Bureau of Statistics microdata (https://www.abs.gov.au/statistics/microdata-tablebuilder). For information about eligible organisations, see https://www.abs.gov.au/statistics/microdata-tablebuilder/absuniversities-australia-agreement

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5.2 Links and implications

This study represents the first Australian investigation into this important issue, utilising nationally representative data to provide new insights into the relationship among dementia, chronic pain, and self-care limitations. Its findings are significant for informing targeted, personalised healthcare strategies and planning interventions to promote independence and healthy ageing for older adults. By addressing a critical area of need, this research underscores the importance of integrated healthcare approaches for those with the greatest self-care challenges. In the subsequent study, presented in Chapter 6, the concentration index and decomposition analysis are applied to investigate how cognitive impairment affects the distribution of HRQoL across various socio-economic classes amongst older Australians. The following study identifies the extent of inequalities that greatly contribute to the HRQoL of older Australians.

Note: Appendix C provides online supplementary material and associated appendix tables, as referenced in this chapter.

CHAPTER 6: PAPER 4 - SOCIO-ECONOMIC INEQUALITIES IN HEALTH-RELATED QUALITY OF LIFE AND THE CONTRIBUTION OF COGNITIVE IMPAIRMENT IN AUSTRALIA: A DECOMPOSITION ANALYSIS

6.1 Introduction

This chapter presents the fourth study of this thesis, which examines the distributional effects of cognitive impairment on inequalities in HRQoL among older Australians, addressing a significant gap in the Australian health inequality literature. While it is well-established that individuals from lower SES groups tend to experience lower HRQoL compared to those from higher SES groups, the specific contribution of cognitive impairment to this disparity remains unexplored. This study seeks to determine whether inequality in HRQoL exists among older Australians and, if so, to what extent cognitive impairment contributes to this inequality.

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Socio-economic inequalities in health-related quality of life and the contribution of cognitive impairment in Australia: A decomposition analysis

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ABSTRACT

Background: The distributional effects of cognitive impairment on inequalities in health-related quality of life (HRQoL) are not well studied. This relationship has not been studied in any Australian health inequality literature. Therefore, this study aims to examine how cognitive impairment affects the distribution of HRQoL across various socio-economic classes amongst older Australians.

Methods: Data for this study was collected from the Household, Income and Labour Dynamics in Australia (HILDA) survey. The final analysis consisted of 5,247 and 5,614 unique individuals from wave 2012 and wave 2016, respectively. An ordinary least squares (OLS) regression model was used to investigate the relationship between cognitive impairment and HRQoL. Additionally, the Wagstaff-Doorslaer-Watanabe standard concentration index was used to examine socioeconomic inequality in HRQoL.

Results: The findings revealed pro-rich inequalities in HRQoL, as indicated by the concentration indices of 0.029 and 0.025 for wave 12 and wave 16, respectively. Additionally, the results showed that mild cognitive impairment accounted for 7.60% and 9.03%, respectively, of pro-rich socioeconomic inequality in HRQoL in 2012 and 2016.

Conclusion: People from lower socioeconomic status (SES) groups tend to have lower HRQoL compared to those from higher SES. This leads to a greater disparity in HRQoL based on SES. Cognitive impairment positively contributed to this inequality in HRQoL. Therefore, it is critical to incorporate cognitive impairment into the design of interventions to reduce socioeconomic inequality in HRQoL.

1. Introduction

Improving the health of populations and decreasing health disparities across different socioeconomic groups and geographical areas are two of the world's most pressing public health concerns (Marmot, 2005; Rezaei et al., 2018a,b). Assessing the population's overall health and distribution of health outcomes across different socioeconomic strata is an essential first step to evaluate the degree to which these objectives have been met. One important indicator of health status that has been increasingly used to assess health inequalities across various socioeconomic groups is the Health-Related Quality of Life (HRQoL) (Arcaya et al., 2015; Djärv et al., 2013; Rezaei et al., 2018a,b). Prior research has established a positive link between socioeconomic status (SES) and HRQoL (Burström et al., 2001; Djärv et al., 2013; Kind et al., 1998). These studies emphasized the noteworthy effects on HRQoL linked to factors such as age, healthcare coverage, financial status, educational level, having a diagnosed chronic illness, and behavioural variables including physical activity and tobacco smoking. The extant literature mostly addresses the primary determinants that contributed to HRQoL across different social groups. However, there is a dearth of research that specifically investigates socioeconomic inequality in HRQoL. The authors of a recent Iranian study on socioeconomic inequality in HRQoL identified pro-rich inequality in individuals with low HRQoL (Rezaei et al., 2018a,b). The study identified income, a sedentary lifestyle, the

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existence of chronic health conditions, and not having health insurance as the four primary contributors to inequality for people with low HRQoL. In Australia, there has been an increasing disparity in health outcomes along the socioeconomic gradient, indicating a deteriorating inequality (Flavel et al., 2022). Therefore, it is crucial to determine the variables that contribute to the socioeconomic disparities in the HRQoL of older individuals in Australia.

The existing literature has not adequately explored how cognitive impairment contributes to inequalities in HRQoL. Cognitive impairment refers to a reduced ability to comprehend and perceive the environment a person inhabits (Folstein et al., 1985). The spectrum of cognitive impairment spans from mild to severe. While severe cognitive impairment can result in a person being unable to live independently due to challenges in planning and carrying out daily tasks, and applying sound judgment, mild impairment is defined as a state in which there are discernible changes in cognitive functioning, but the person is still able to perform their daily activities (Dhakal and Bobrin, 2022). Previous research from China, Sweden, and Turkey showed a link between cognitive impairment and reduced HRQoL in older people (Akdag et al., 2013; Johansson et al., 2012; Pan et al., 2015). The CDC HRQOL-4 was used to measure HRQoL in the Turkish study, while the EQ-5D was used in the Chinese and Swedish studies. In contrast, other research indicated that cognitive impairment does not affect the HRQoL of people living in nursing homes (Elliott et al., 2009), people living with dementia (Banerjee et al., 2009), and older Canadians residing in institutions (Davis et al., 2015). A recent longitudinal study conducted in Australia used the SF-36 and SF-6D measures to examine the relationship between cognitive decline and HRQoL in older Australians (Keramat et al., 2023). The results indicated a link between cognitive impairment and a decrease in HRQoL. However, the study did not investigate the contribution of cognitive impairment on socio-economic inequality in HRQoL. Understanding this link is crucial for designing health equity strategies and implementation plans to achieve health equality for older Australians.

Although there has been significant progress in the overall health of people worldwide, disparities in health between wealthier and poorer countries, as well as across various socioeconomic strata within each country, have remained stagnant or, in some instances, even deteriorated (Robert et al., 2000; Sibanda and Doctor, 2013). Therefore, the goal of this research was two-fold. Firstly, to identify if there is any inequality in HRQoL among older Australians. Secondly, if inequality exists, what is the contribution of cognitive impairment? Comprehending this association is essential for formulating and implementing health equity strategies to mitigate health disparities among older Australians. This understanding, ideally, can contribute to the implementation of equitable health policies and practices that enhance their HRQoL.

2. Methods

2.1. Data source and settings

Data were derived from the Household, Income, and Labour Dynamics in Australia (HILDA) survey. The survey, in operation since 2001, gathers annual data from a sample of nationally representative Australians. The study tracks more than 17,000 people across their lifetimes and collects information on various subjects such as family and home dynamics, labour supply and income, levels of education, and health outcomes. A comprehensive grasp of HILDA records and information may be obtained elsewhere (Watson, 2021).

2.2. Study participants

This analysis relies on data collected from two waves of the survey—wave 12 (2012) and wave 16 (2016)— as these were the only waves that included questions on cognitive impairment. Wave 12 served as the starting point, while wave 16 served as the subsequent measurement. The analysis focused exclusively on older people in Australia, specifically individuals aged 50 years or above. Participants who lacked complete information on the outcome variables (HRQoL outcomes) or exposure factors (cognitive function test scores) were excluded from the study. The study participants aged 50 years and older numbered 5,247 and 5,614 individuals in 2012 and 2016, respectively. Figure A1 of the Appendix in online supplementary material provides a comprehensive overview of the sample selection process, including the criteria used to exclude certain observations and a detailed breakdown of any missing data.

2.3. Outcome variable

The HILDA study gathered information on HRQoL by administering the RAND Corporation-developed 36-Item Short Form (SF-36) survey (Brazier et al., 1992). This survey has 36 standard, easy-to-ask questions that cover four aspects of mental health and four aspects of physical health. The responses of the participants are evaluated using a numerical scale of 0–100, with 0 indicating the worst health status and 100 representing the best possible health status for each component of health. The obtained results are then transformed into two summary component scores: the mental component summary (MCS) score and the physical component summary (PCS) score.

While the SF-36 serves as a reasonably comprehensive assessment tool for evaluating health status, it fails to account for utility. Therefore, this study utilised the SF-6D utility index to measure HRQoL. A modified iteration of the SF-36, the SF-6D generates utility values, making it more economically relevant from an analytical perspective (Ferreira et al., 2013). The six multi-level aspects that comprise the SF-6D scale include physical functioning, role limitations, social functioning, body pain, mental health, and vitality. The SF-6D scale has a range of values from 0.29 to 1, with 1 representing optimal health and 0.29 indicating the most severe state of ill health.

2.4. Exposure variable

HILDA assesses participants' cognitive abilities using validated cognitive function tests, which are conveniently implemented and compatible with HILDA's in-person survey design. The relevant markers of cognitive function used are the Symbol Digit Modalities Test (SDMT) (Smith, 1982) and the Backward Digit Span (BDS) test (Lamar et al., 2007). This specific set of tests was previously used to identify cognitive impairment in people diagnosed with multiple sclerosis (Parmenter et al., 2007; Van Schependom et al., 2014) and people who were acutely hospitalised (Leung et al., 2011). In the BDS cognitive assessment test, participants are asked to repeat a series of digits in reverse order (Lamar et al., 2007). The BDS evaluates the capacity of working memory and is graded on a scale ranging from 0 to 8. For the SDMT, respondents are required to match particular numbers with arbitrary geometric figures (Smith, 1982). The SDMT scores between 0 and 110 and evaluates central brain processing.

The threshold for cognitive impairment in this study was established using earlier established criteria: people with mild cognitive impairment (MCI) are defined as having a score $\geq$ 1 standard deviation (SD) lower than the mean on the BDS, SDMT, or both, and people with severe cognitive impairment are defined as having a score of SD $\geq$ 1.5 below the mean on both tests (Aschwanden et al., 2020; Keramat et al., 2023). As a result, the BDS cut-off score was set at $\leq$ 3, and the SDMT cut-off score was set at $\leq$ 30. This means that any person who scores at or below the cut-off score on either test is classified as having MCI. However, a score of $\leq$2 on the BDS and $\leq$24 on the SDMT tests indicates severe cognitive impairment.

2.5. Income

The estimation of SES and the calculation of the concentration index

were based on equivalised household disposable income. The total disposable income comprises earnings from a job and self-employment, income generated from investments, and Australian income assistance payments. The research employed the OECD-modified scale to account for variations in income. The equation for equivalised household income is provided by ABS (ABS, 2006):

$$\text{Equivalised Income} = \frac{\text{Household Disposable Income}}{1 \times \text{First Adult} + 0.5 \times \text{Additional Adults} + 0.3 \times \text{Additional Children}} \quad (1)$$

2.6. Covariates

This study considered various demographic, SES variables, health-related traits, as well as health-related behaviours, as potential covariates that might be associated with HRQoL. The factors encompassed are age, gender, marital status, educational attainment, annual disposable income of the family, labour force participation, Indigenous origin, area of residence, Body Mass Index (BMI), smoking habits, and alcohol drinking. The variables are categorised and shown in Table A1 of the Appendix in the online supplementary material.

2.7. Conceptual framework

To explore the socio-economic inequality in HRQoL and the contribution of cognitive impairment, this study developed a conceptual framework of HRQoL for older people following an earlier established framework (McDool et al., 2024). Figure A2 of the Appendix highlights that factors associated with HRQoL are broadly categorised as health-related behavioural characteristics such as smoking habits, alcohol drinking, health-related characteristics such as cognition status, and Body Mass Index (BMI), socioeconomic status such as level of education, household yearly income, participation in the labour force, area of residence, and demography factors such as age, gender, indigenous status, marital status.

2.8. Estimation strategy

This study used the standard concentration index (SCI) to measure socioeconomic inequity in HRQoL where equivalised household income was used as a proxy of the SES. The study also presents socio-economic inequality in HRQoL using the concentration curve (CC). The concentration curve demonstrates the cumulative share of HRQoL (SF-6D) in comparison with the cumulative share of the population ranked by equivalised household income. The CC outlined three key points regarding its position on the 45-degree equality line: inequalities that favour the poor (above the line), inequalities that favour the rich (below the line), and no inequalities (on the line itself).

This study followed the approach used by Hashmi et al. (2020) to identify the inequality that exists in HRQoL and the contribution of cognitive impairment to this disparity (Hashmi et al., 2020).

The study used the Concentration Index (CI), which is a rank-dependent inequality metric that quantifies socio-economic inequality (Wagstaff et al., 1989). CI is mainly based on the CC of two variables; the number is twice the area between the CC and the line of perfect equality. As a result, the CI is constrained between −1 (perfectly pro-poor inequality) and 1 (perfectly pro-rich inequality) and defined as follows (Kakwani, 1980; Kakwani et al., 1997):

$$CI = \frac{2}{\bar{h}} cov(h_i, R_i) \quad (2)$$

$$\Rightarrow CI = \frac{2}{n\bar{h}} \sum_{i=1}^{n} h_i, R_i - 1 \quad (3)$$

Here, a population consisting of n people with varying health levels h_i is ranked by income and some other measure of SES, ordered from the poorest to the richest resulting in a fractional rank $R_i = \frac{2i-1}{2n}$, $\bar{h} = \frac{\sum_{i=1}^{n} h_i}{n}$ and $i = 1,2,\ldots,n$. A pro-rich distribution is shown by a positive value of the CI; whereas, a pro-poor distribution is shown by a negative value of CI.

In earlier research (Wagstaff et al., 2003), showed that if health is a linear function of K variables (such as demographic, health-related and behavioural factors, and SES), then CI is a weighted sum of socio-economic disparities in these variables.

Therefore, the CI may be broken down based on the following regression:

$$h_i = \alpha + \sum_{j=1}^{k} \beta_j, x_{ij} + u_i \quad (4)$$

where, α and β_j, $j = 1, \ldots, k$ are coefficients that are required to be estimated, and u_i represents the error term with $E[u_i] = 0$. Through the substitution of (4) into (3) as well as some algebra, Wagstaff et al. showed that (Wagstaff et al., 2003):

$$CI = \sum_k \eta_k CI_k + \frac{GC_u}{\bar{h}} \quad (5)$$

in this context, CI_k represents the concentration index of the factor x_k, while $\eta_k = \beta_k \frac{\bar{x}_k}{\bar{h}}$ stands for the average elasticities, or magnitude of the impact of k factors. The initial term, $\eta_k CI_k$, of each component, x_k, reveals its contribution to socioeconomic disparities caused by x_k. Therefore, $\sum_k \eta_k CI_k$ is the model's overall contribution to explaining socioeconomic disparity. The residual term, $\frac{GC_u}{\bar{h}}$, represents unexplained socioeconomic inequalities.

The following procedures were used to determine the factor decomposition of the concentration index:

Step 1 A regression analysis using Ordinary Least Squares (OLS) was performed to investigate the link between HRQoL and various characteristics including cognitive impairment, age, gender, marital status, highest level of schooling achieved, household yearly disposable income, labour force participation, indigenous origin, area of residence, BMI, smoking habits, and alcohol drinking. The findings of the regression are depicted in Table 3.

Step 2 To compute the average value of all variables, this study employed the mean command.

Step 3 Based on the mean values and coefficients obtained from the OLS regression, elasticities were calculated for all the independent variables.

Step 4 The coindex commands were used to compute concentration indices for all independent variables.

Step 5 The percentage contribution of each variable was derived by multiplying the elasticities and concentration indices of each independent variable.

Step 6 The processes were iterated for each wave.

Table 1
Distribution of test scores, cognitive impairment, and other covariates in wave 12 and wave 16.

Variables	Baseline wave (2012)		Final wave (2016)	
	n	mean (SD/ %)	n	mean (SD/ %)
Utility score				
SF-6D	5,247	0.74 (0.13)	5,614	0.74 (0.13)
BDS test score	5,247	4.79 (1.39)	5,614	4.86 (1.40)
SDMT score	5,247	41.91 (12.07)	5,614	43.09 (11.76)
Cognitive impairment, n (%)				
No	4,593	87.54	5,061	90.15
Mild	617	11.76	507	9.03
Severe	37	0.71	46	0.82
Age (in years)				
50–64	3,075	58.60	3,268	58.21
65 and above	2,172	41.40	2,346	41.79
Gender				
Male	2,459	46.86	2,653	47.26
Female	2,788	53.14	2,961	52.74
Indigenous Origin				
Non Aboriginal or Torres Strait Islander	5,162	98.38	5,503	98.04
Aboriginal or Torres Strait Islander	85	1.62	110	1.96
Marital Status				
Unpartnered	1,837	35.01	1,998	35.59
Partnered	3,410	64.99	3,616	64.41
Highest level of schooling achieved				
Year 12 and below	2,318	44.18	2,261	40.27
Professional qualifications	1,724	32.86	1,967	35.04
University qualifications	1,205	22.97	1,386	24.69
Household yearly disposable income (Quintile)				
Quintile 1 (lowest)	1,049	19.99	1,123	20.00
Quintile 2	1,050	20.01	1,123	20.00
Quintile 3	1,049	19.99	1,124	20.02
Quintile 4	1,050	20.01	1,122	19.99
Quintile 5 (highest)	1,049	19.99	1,122	19.99
Participation in the labour force				
Employed	2,467	47.02	2,671	47.58
Unemployed/Not in the labour force	2,780	52.98	2,943	52.42
Area of residence				
Major Cities	3,368	64.19	3,544	63.13
Regional/remote	1,879	35.81	2,070	36.87
BMI				
Healthy weight	1,712	32.63	1,750	31.17
Underweight	72	1.37	64	1.14
Overweight	2,026	38.61	2,107	37.53
Obese	1,437	27.39	1,693	30.16
Smoking habits				
Former smoker/never smoked	4,588	87.44	4,905	87.37
Currently smoking	659	12.56	709	12.63
Alcohol drinking				
Former drinker or never drunk	965	18.39	1,058	18.85
Active drinker	4,282	81.61	4,556	81.15

All analysis was conducted using STATA 16 (Stata Corp LLC).

3. Results

Table 1 provides a summary of the distribution of various factors including the outcome variable (SF-6D score), the exposure variable (BDS and SDMT scores, cognitive impairment), demographic characteristics, SES, health-related characteristics, and health-related behaviours in the baseline wave (2012), and the final wave (2016). The mean utility score (SF-6D) remained consistent at 0.74 (SD = 0.13) in both 2012 and 2016 waves. The distribution of exposure measures in the final wave (2016) of the participants was as follows: the mean BDS score was 4.86 (SD = 1.40), the mean SDMT score was 43.09 (11.76), 90.15% had no cognitive impairment, 9.03% had mild cognitive impairment, 0.82% had severely cognitively impaired. Additionally, the data revealed that in wave 16, approximately 41% of the participants were aged 65 years or older, just over half were female (52%), 2% identified as indigenous, 64% were in a relationship with a partner, 24% held a bachelor's degree or higher, around 52% were unemployed or not in the labour force, 36% resided in a regional or remote area, 30% were obese, 12% were current smokers, and 81% were current alcohol drinkers.

Fig. 1 illustrates the findings of SCI to calculate the CC of SF-6D scores by equivalised household income for waves 12 and 16. The CI values of 0.029 and 0.025 in waves 12 and 16, respectively, indicated that socioeconomic disparity in HRQoL is evident in Australia. Additionally, the CCs are below the 45^0 line, suggesting that the highest income quintiles have higher HRQoL utility scores. The differences in HRQoL across socioeconomic groups warrant an examination of the factors that contribute to these disparities.

Table 2 presents the findings from two distinct OLS regressions conducted for wave 12 and wave 16. All results, except for indigenous origin, highest level of schooling achieved, and area of residence, were statistically significant in both years. The findings indicated that people with mild and severe cognitive impairment had a poorer HRQoL compared to people without cognitive impairment, in both years. Compared to people with no cognitive impairment, people with mild and severe cognitive impairment patients had 0.038 and 0.051 points lower HRQoL, respectively, in wave 12. Likewise, in wave 16, the HRQoL in participants with mild cognitive impairment was 0.047 points lower, while in people with severe cognitive impairment, it was 0.043 points lower, compared to people with no cognitive impairment.

Table 3 depicts the Wagstaff-Doorslaer-Watanabe decomposition estimation of socio-economic inequalities in HRQoL. The mean elasticity, represented in the first column of each wave, indicates the extent to which the exposures contributed to inequality in HRQoL. The second column quantifies the level of inequality through the CI or income-related component. The third column measures the contribution of each factor on HRQoL by multiplying the values from the first two columns. When a health variable, such as the HRQoL utility score, has a higher value indicating better health, a positive (negative) impact of a factor means that higher HRQoL is more prevalent among the wealthy (poor) due to increasing inequality, resulting in a pro-rich (pro-poor) distribution with respect to that factor (O'Donnell et al., 2008).

The results show that the socio-economic disparity in HRQoL varied between 0.025 and 0.029 points during the study period (last row in Table 3). Consistent with the regression results, all cognitive impairment factors in both waves had a negative elasticity indicating the presence of mild and severe cognitive impairment was associated with lower HRQoL. The presence of mild and severe cognitive impairment showed a negative CI indicating a pro-poor distribution of these variables. Resultingly, these factors all had a positive contribution to the overall pro-rich distribution in HRQoL. The cognitive impairment that contributed the most to the overall pro-rich distribution was mild cognitive impairment which explained 7.60% and 9.09% of the inequality in HRQoL in 2012 and 2016, respectively.

Apart from cognitive impairment, household income and lack of employment were major drivers of overall inequality in HRQoL. Compared to the highest income quintile, all other income quintiles reported a negative elasticity. As the poorest (quintile 1) and poor income (quintile 2) quintiles had a negative CI value, these variables contributed to the observed inequality explaining 29.52% and 12.65% of the overall inequality in wave 16. Being unemployed or not in the labour force had a negative elasticity and CI value in both waves, and in wave 16, it explained about 38% of the overall inequality in HRQoL.

The impact of unemployment and not being in the labour force on the inequality in HRQoL may be attributed to the fact that younger people within the older population (aged 50–64 years) are more likely to be employed and earn higher salaries compared to older adults (aged 65 years and over) who may have cognitive impairments and are no longer in the workforce. Therefore, this study conducted a sensitivity analysis that included the concentration index, regression and decomposition analyses, using the average household wealth as a proxy for SES instead

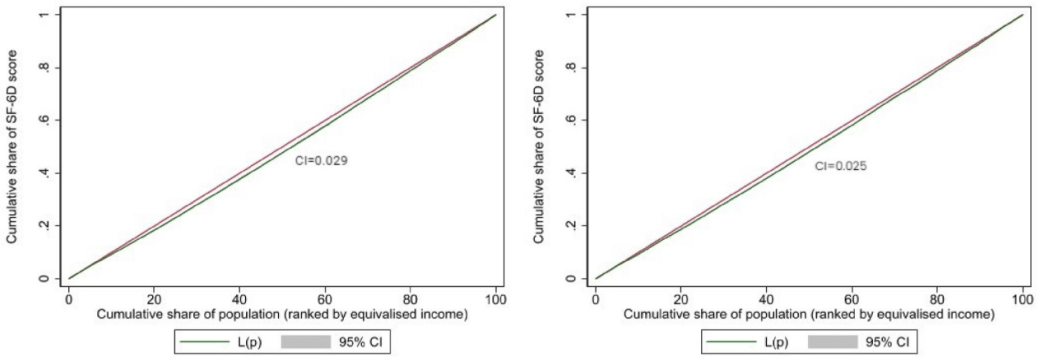

Fig. 1. Concentration curve of health-related quality of life using standard concentration index with equivalised household disposable income ranking.
Notes: Abbreviation: CI = Concentration Index; 95% CI = 95% Confidence Interval.

of equivalised household disposable income. Due to the unavailability of wealth data for wave 12 and wave 16, this study imputed wealth values that the HILDA survey collected every fourth wave, beginning with wave 2. Net household wealth within the HILDA dataset is determined by deducting total debts from total assets. A detailed description of the wealth variable calculation methodology can be found in the HILDA User Manual, Release 22 (Summerfield et al., 2023). For this study, the mean wealth values from waves 10 and 14 were allocated to wave 12, while the mean values from waves 14 and 18 were assigned to wave 16. The results of SCI are consistent with our previous findings with CI values of 0.019 and 0.023 for waves 12 and 16, respectively (see Figure A3 of Appendix in the online supplemental material). Moreover, consistent with our prior findings, the regression analysis revealed that people with mild and severe cognitive impairment exhibited lower HRQoL scores, by 0.046 and 0.043 points, respectively, in wave 16 compared to people with no cognitive impairment (see Table A2 of Appendix in the online supplemental material). Finally, decomposition analysis using average household wealth also revealed a pro-rich distribution of HRQoL, with mild cognitive impairment contributing 1.87% and 2.27% to inequality in HRQoL in 2012 and 2016, respectively (Table A3 of Appendix in the online supplemental material). However, the magnitude of the contribution of cognitive impairment in explaining inequality in HRQoL decreased compared to previous findings. In both waves, being unemployed or not in the labour force had a negative elasticity and CI value. In wave 16, it accounted for around 13% of the total disparity in HRQoL. However, there was a significant decrease in the magnitude of this contribution (38%) compared to the previous analysis.

Fig. 2 displays the contribution of board category variables by waves. In wave 12, cognitive impairment (both mild and severe) accounted for 8.45% of the inequality in HRQoL, whereas in wave 16 it accounted for 9.88%. On the other hand, SES explained 88.61% and 80.31% of the inequality in HRQoL in wave 12 and wave 16, respectively.

4. Discussion

4.1. Key findings

Using data from the HILDA survey, this research initially investigated if there is any inequality in HRQoL among older Australians. Additionally, the research examined the contribution of cognitive impairment on disparities in overall HRQoL across various socioeconomic strata. In both years, people with mild and severe cognitive impairment had a reduced HRQoL than people with no cognitive impairment. Additionally, mild and severe cognitive impairment was identified as a contributing factor to pro-rich socioeconomic inequality in HRQoL. Furthermore, unemployment and low household income were recognized as significant factors that contribute to overall disparities in HRQoL, alongside cognitive impairment. Several studies conducted in Australia have examined the association of different factors on HRQoL across population groups. These factors include social health and stressful life events (Phyo et al., 2022), body mass index (Renzaho et al., 2010), dietary quality (Milte et al., 2015), and cardiovascular disease (O'Neil et al., 2013). A recent study investigated the link between cognitive impairment and HRQoL in older Australians (Keramat et al., 2023), while another study in Iran decomposed socioeconomic inequality in HRQOL (Rezaei et al., 2018a,b). However, none of the prior research decomposed the contribution of cognitive impairment in the context of HRQoL inequality.

The study found that the prevalence of MCI among older Australians aged 50 years and over was 11.76% and 9.03% in 2012 and 2016, respectively. The results of this study are comparable to those of a previous Australian study, which reported a pooled prevalence of 10.16% for MCI (Keramat et al., 2023). Supporting our findings, research from other countries, including Spain (Lara et al., 2016; Lopez-Anton et al., 2015), China (Lu et al., 2021) and Italy (Ravaglia et al., 2008), also reported an MCI prevalence range of 7–12%. However, according to a prior review study, the reported prevalence of MCI varies significantly across international studies, ranging from around 3%–42% (Ward et al., 2012). The observed variations in MCI prevalence can be attributed to several factors, including heterogeneity in study samples, the application of diverse diagnostic criteria for MCI, variations in study settings, and discrepancies in methodological approaches. For example, a meta-analysis of 53 studies from 17 countries found that the pooled global prevalence of MCI among older adults living in nursing homes was 21.2% (Chen et al., 2023). This finding contrasts with the prevalence of MCI in the general older population, which is typically much lower. The higher prevalence of MCI in nursing homes can be explained by the fact that cognitive impairment is one of the major reasons for admission to nursing homes (Helvik et al., 2014; Kijowska and Szczerbińska, 2018), resulting in a higher concentration of people with MCI residing in these facilities compared to the general, community-dwelling population. The study further revealed low rates of severe cognitive impairment, with 0.71% and 0.82% prevalence in 2012 and 2016, respectively. The findings are consistent with another Australian study that reported a comparable pooled prevalence of 0.72% for severe cognitive impairment (Keramat et al., 2023). The possible explanation for the low prevalence of mild and severe cognitive impairment may be attributed to the study's design, which relied only on cognitive test results (i.e., BDS and SDMT) to define cognitive impairment. According to the Diagnostic and Statistical Manual of Mental Disorders Text Revision (DSM-5-TR), diagnosing cognitive impairment and dementia, also

Table 2
Regression results.

Cognitive impairment, n (%)	Wave 12		Wave 16	
	Coefficient (SE)	P-value	Coefficient (SE)	P-value
No (ref)				
Mild cognitive impairment	−0.0386 (0.0053)	0.001	−0.0475 (0.0057)	0.001
Severe cognitive impairment	−0.0517 (0.0191)	0.001	−0.0439 (0.0172)	0.011
Age (in years)				
50-64 (ref)				
65 and above	0.0227 (0.0041)	0.001	0.0195 (0.004)	0.001
Gender				
Male (ref)				
Female	−0.0094 (0.0034)	0.001	−0.0089 (0.0032)	0.006
Indigenous origin				
Non Aboriginal or Torres Strait Islander (ref)				
Aboriginal or Torres Strait Islander	0.0035 (0.0126)	0.783	0.0029 (0.0112)	0.795
Marital status				
Unpartnered (ref)				
Partnered	0.0161 (0.0035)	0.001	0.0202 (0.0033)	0.001
Highest level of schooling achieved				
Year 12 and below (ref)				
Professional qualifications	−0.001 (0.0038)	0.803	−0.0039 (0.0037)	0.293
University qualifications	−0.0002 (0.0044)	0.970	0.0003 (0.0043)	0.943
Household yearly disposable income (Quintile)				
Quintile 1	−0.0573 (0.0059)	0.001	−0.0338 (0.0057)	0.001
Quintile 2	−0.0332 (0.0055)	0.001	−0.029 (0.0053)	0.001
Quintile 3	−0.0173 (0.0052)	0.001	−0.0089 (0.005)	0.076
Quintile 4	−0.0004 (0.0051)	0.938	−0.0014 (0.0049)	0.774
Quintile 5 (ref)				
Labour force participation				
Employed (ref)				
Unemployed/Not in the labour force	−0.0515 (0.0042)	0.001	−0.0545 (0.004)	0.001
Area of residence				
Major Cities (ref)				
Regional/remote	−0.0042 (0.0034)	0.206	−0.0013 (0.0032)	0.685
BMI				
Healthy weight (ref)				
Underweight	−0.0245 (0.0139)	0.077	−0.0395 (0.0147)	0.007
Overweight	−0.0146 (0.0038)	0.001	−0.0112 (0.0038)	0.003
Obese	−0.0441 (0.0041)	0.001	−0.0493 (0.004)	0.001
Smoking habits				
Former smoker/never smoked (ref)				
Currently smoking	−0.0185 (0.0049)	0.001	−0.0288 (0.0048)	0.001
Alcohol drinking				
Former drinker or never drunk (ref)				
Active drinker	0.0223 (0.0042)	0.001	0.0284 (0.0041)	0.001

Notes: 1. Standard errors are in the parentheses. 2. Ref indicates reference group.

known as major neurocognitive disorder, usually requires a thorough clinical examination that includes evaluating functional limits and other relevant clinical criteria (American Psychiatric Association, 2022). This constraint may have resulted in an underestimation of the occurrence of mild and severe cognitive impairment in this sample, as some people with lower cognitive abilities on specific tests may not have met the predetermined scores utilised in this study. However, they might have the potential to meet the diagnostic criteria for these conditions with a more comprehensive assessment.

The results show that cognitive impairment is negatively linked with HRQoL in older Australians. This result is consistent with other studies conducted in older people in Australia (Keramat et al., 2023; Phyo et al., 2021), China (Pan et al., 2015), and Sweden (Johansson et al., 2012). On the other hand, another study discovered no correlation between cognitive decline and HRQoL among older people residing in the community (Davis et al., 2015). However, this discrepancy may be explained using the Euro QOL (EQ-5D) metric as the HRQoL measure, which does not include a cognition-specific category and therefore might not be congruent with the cognitive impairment screening instrument. The contribution of SES on HRQoL in Australia aligns with findings from research conducted in other countries, indicating that those with higher income levels tend to have better HRQoL (Matute et al., 2017; Rezaei et al., 2018a,b).

This research provides a substantial contribution by investigating the inequality in HRQoL, considering cognitive impairment and SES. The negative elasticity of cognitive impairment indicates that increasing exposure to cognitive impairment reduces HRQoL and contributes to inequality in HRQoL. Both mild cognitive impairment and severe cognitive impairment exhibit a negative CI, suggesting that they are distributed in a way that disproportionately affects those with lower SES. One plausible reason is that access to resources is linked to being able to deal with health problems, and being poor makes it harder to get those resources (Lima-Costa et al., 2005), which makes people more likely to experience a lower HRQoL.

The consequences of cognitive impairment are similarly comparable to some of the other socioeconomic factors identified, as both elasticities and CI exhibited negative values. This indicates that being female, belonging to the lowest income quartile group, being unemployed or not participating in the labour force, residing in regional and remote areas, being underweight or obese, and engaging in certain health-related behaviours such as smoking reduce HRQoL and creating pro-poor inequality in HRQoL. Among the socioeconomic determinants, this study found employment and household income had the most significant contribution to poor individuals' HRQoL inequality. This result is consistent with prior decomposition analysis where it was found lack of wealth is a main contributor to poor HRQoL (Rezaei et al., 2018a,b). The inverse association between poor wealth status and HRQoL may be attributed to different factors. For example, wealth disparity may lead to health disparities due to unequal distribution of resources and material opportunities, such as access to nutritious food, adequate housing, and healthcare services (Abbott, 2002; Hajizadeh et al., 2012).

In contrast, being partnered, having university qualifications, and alcohol drinking are distinct in nature in their contribution to inequality. In this scenario, both CI and elasticity are positive meaning wealthy individuals are partnered, have more education, consume more alcohol, and have higher earnings; having higher levels of these traits are indicative of a higher HRQoL. Due to the varying impacts of these factors on HRQoL for people in various socioeconomic categories, the inequality in HRQoL in Australia continues to widen over time.

4.2. Strengths, limitations, and avenues for further research

The use of a comprehensive population-based longitudinal design and a wide spectrum of older age cohorts constituted a significant strength of this research. This study is the first to decompose the contribution of cognitive impairment to pro-rich inequality in HRQoL from the Australian context. A wide range of socioeconomic characteristics related to health and health-related behaviour were controlled in this study which makes the findings robust. The cognitive impairment measures (SDMT and BDS) are also validated and demonstrate strong efficacy in representing fundamental aspects of cognitive aging and

Table 3
Wagstaff - Doorslaer – Watanabe - decomposition analysis.

Variables	wave 12				wave 16			
	η^2	CI[3]	Co[4]	%Co[5]	η	CI	Co	%Co
Mild cognitive impairment	−0.0061	−0.3573	**0.0021**	7.6098	−0.0058	−0.3862	**0.0022**	9.0369
Severe cognitive impairment	−0.0004	−0.4895	**0.0002**	0.8382	−0.0005	−0.4306	**0.0002**	0.8451
Age (in years)								
65 and above	0.0127	−0.2488	**−0.0031**	−10.9729	0.0110	−0.2300	**−0.0025**	−10.2240
Gender								
Female	−0.0067	−0.0381	**0.0002**	0.8922	−0.0064	−0.0381	**0.0002**	0.9791
Indigenous origin								
Aboriginal or Torres Strait Islander	0.0000	−0.0333	**0.0000**	−0.0087	0.0001	0.0264	**0.0000**	0.0081
Marital Status								
Partnered	0.0141	0.0814	**0.0011**	4.0015	0.0176	0.0755	**0.0013**	5.3566
Highest level of schooling achieved								
Professional qualifications	−0.0004	0.0262	**−0.0000**	−0.0384	−0.0019	0.0207	**−0.0000**	−0.1538
University qualifications	−0.0000	0.3244	**−0.0000**	−0.0590	0.0001	0.2860	**0.0000**	0.1170
Household yearly disposable income (Quintile)								
Quintile 1	−0.0155	−0.7998	**0.0124**	43.0629	−0.0092	−0.8000	**0.0073**	29.5268
Quintile 2	−0.0089	−0.3998	**0.0035**	12.4479	−0.0079	−0.3999	**0.0031**	12.6522
Quintile 3	−0.0047	0.0001	**−0.0000**	−0.0031	−0.0024	0.0004	**−0.0000**	−0.0034
Quintile 4	−0.0001	0.4002	**−0.0000**	−0.1480	−0.0004	0.4004	**−0.0002**	−0.6153
Labour force participation								
Unemployed/Not in the labour force	−0.0370	−0.2540	**0.0094**	32.5902	−0.0388	−0.2468	**0.0096**	38.5113
Area of residence								
Regional/remote	−0.0020	−0.1063	**0.0002**	0.7591	−0.0007	−0.1027	**0.0001**	0.2724
BMI								
Underweight	−0.0004	−0.2537	**0.0001**	0.4008	−0.0006	−0.1549	**0.0001**	0.3805
Overweight	−0.0076	0.0153	**−0.0001**	−0.4057	−0.0057	0.0364	**−0.0002**	−0.8366
Obese	−0.0163	−0.0244	**0.0004**	1.3883	−0.0202	−0.0575	**0.0012**	4.6691
Smoking habits								
Currently smoking	−0.0031	−0.0665	**0.0002**	0.7279	−0.0049	−0.1145	**0.0006**	2.2693
Alcohol drinking								
Active drinker	0.0246	0.0525	**0.0012**	4.4851	0.0313	0.0555	**0.0017**	6.9789
Total estimate contribution	**0.0278**				**0.0247**			
CI of HRQoL (SF-6D)	**0.029**				**0.025**			

Notes: 1. The 0 values do not represent actual zeros. The values are close to zero. 2. η symbolises elasticity. The equation is defined as $\eta_k = \beta_i \frac{\overline{X}_k}{\overline{h}}$, 3. The concentration index (CI) is calculated by ranking the row variable based on equivalised household income, 4. Co represents the contribution to the concentration index of HRQoL, 5. The contribution is calculated as a percentage by determining the proportion of the contribution to the actual concentration index. The sum of all Co represents the explained portion of the CI of HRQoL in a given wave.

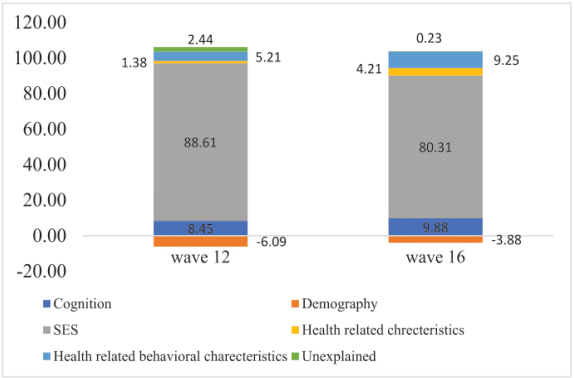

Fig. 2. Broad category factors' contribution in CI by wave.

impairment. Utilising validated methodologies enables the direct comparison of the results with earlier studies.

The study is not without limitations. First, one noteworthy limitation of this research was the methodologies employed to obtain data on HRQoL. Due to the self-reported nature of HRQoL, social desirability bias may have contributed to an elevation of HRQoL scores. Second, a distinct consensus regarding the thresholds for scoring for the SDMT and BDS scales to delineate cognitive impairment is lacking. Consequently, these metrics lack diagnostic value for cognitive impairment and might not comprehensively represent the entire range of clinically significant cognitive impairment. Third, due to unavailability of data, the study could not incorporate two important confounders - chronic conditions and pharmacological treatment, which may result in systematic bias, such as unmeasured confounders. Fourth, the observational design of this study precludes the establishment of definitive causal relationships between cognitive impairment and HRQoL. It is possible that lower HRQoL could contribute to the development of cognitive impairment, or that both factors might share a common underlying cause. Fifth, while the BDS and SDMT offer valuable insights into core cognitive processes, they may not fully capture the specific cognitive profile of MCI or dementia, which often entails memory deficits. This limitation may have resulted in an underestimation of the prevalence of mild and severe cognitive impairment in this sample, as some people with lower cognitive abilities on specific tests may not have met the predetermined scores utilised in this study. The use of memory-oriented tests, such as Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005), Mini-Mental Status Examination (MMSE) (Folstein et al., 1985), or Saint Louis University Mental Status (SLUMS) examination (Morley and Tumosa, 2002), could have provided a more targeted approach and thus facilitated comparisons with the existing literature. Additionally, this could also reinforce the possibility of reverse causation, whereby pre-existing memory decline could influence working memory and processing speed. Finally, it is crucial to acknowledge that the constraints of the dataset necessitated that the study concentrate on neurodegenerative cognitive impairment. This limits the generalisability of the study's findings to

other forms of cognitive impairment, including lifelong learning disabilities. Neurodegenerative cognitive impairment typically progresses over time, potentially explaining the observed associations with HRQoL. Lifelong learning disabilities are generally stable and may not have the same effect on the specific cognitive functions that this study measured. Although the study's focus on the progressive decline is enhanced by their exclusion, future research utilising datasets that enable the differentiation between neurodegenerative and other forms of cognitive impairment could offer a more nuanced understanding.

5. Implications for policy and practice

The National Disability Insurance Scheme (NDIS) in Australia is structured to provide funding directly to eligible people, allowing them to purchase the services they require (NSW Health, 2018). Cognitive impairment is recognized as a disability under this scheme. Prior research has demonstrated that challenges in accessing and navigating disability support services are prevalent in Australia and often arise because of socioeconomic and clinical issues (Warr et al., 2017). Recent policy analysis emphasized promoting equity for people living with disabilities in Australia (Olney and Dickinson, 2019). Our results highlight the importance of government policy to focus on supporting these vulnerable populations, especially people with cognitive impairment from low SES groups, given the large contribution to inequality these factors create. The findings also suggest older Australians from disadvantaged SES groups, people who have been unemployed or not included in the labour force, are at risk of much lower HRQoL as a result of cognitive impairment. Government social assistance, such as cash transfers, may be provided to these individuals. Understanding the effect size of a proposed policy or intervention is crucial for making informed decisions. By carefully measuring the magnitude of impact, policymakers can enhance the likelihood of successful and effective interventions (Matthay, 2020). Research findings with large effect sizes are likely to have practical implications, whereas those with minimal effect sizes may have limited real-world applications (Bhandari, 2023). This study used generic preference-based HRQoL measures which are generally less sensitive to detecting improvements in health-related quality of life compared to disease-specific measures (Halme et al., 2015). However, they are still valuable for estimating the overall impact of interventions on quality-adjusted life years, which is essential for cost-effectiveness analysis (Halme et al., 2015).

6. Conclusion

The present study adds cognitive impairment as a variable in the investigation of socioeconomic inequality in HRQoL. Our results showed that disparities in socioeconomic inequality exist for older people in Australia. To identify the contribution of cognitive impairment to this inequality, we fit OLS regression to check the association between cognitive impairment and HRQoL. The result showed that both mild and severe cognitive impairment were negatively associated with HRQoL. Furthermore, mild and severe cognitive impairment was identified as a contributing factor to pro-rich socioeconomic inequality in HRQoL. In this study, the cognitive impairment status that contributed the most to the overall pro-rich distribution was mild cognitive impairment. When compared with people in the higher socioeconomic strata, people with mild cognitive impairment who are in the lower SES are more susceptible to inequalities in HRQoL. The results also indicated that socioeconomic variables play a role in driving this inequality, with labour force participation being a significant contributor to the overall inequality. The results have important ramifications for the formulation of future policy, emphasising the need to include cognitive status to construct fair and inclusive policies.

Cognitive decline-induced socioeconomic disparities can be mitigated through the implementation of targeted welfare initiatives, including financial aid, psychological counselling, and the seniors connected program (Department of Social Services, 2023), which aim to alleviate social isolation and loneliness that older Australian's may experience. In welfare states such as Australia, short-term welfare targeting for groups of low-income people with cognitive impairment will enhance HRQoL and reduce the strain on the healthcare system. An assessment of the efficacy of these programs can be conducted by monitoring HRQoL inequality and conducting comparative analyses with other developed countries. Consequently, insights gained from this research can enhance understanding regarding the contribution of cognitive impairment on socio-economic inequality in HRQoL in other developed countries. To design strategies to address cognitive impairment-related disparities in HRQoL, further research is required.

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Ethical approval

This study used secondary data from de-identified existing unit records from the HILDA Survey, so ethical approval was not required. However, the authors completed and signed the Confidentiality Deed Poll and sent it to NCLD (https://ncldresearch@dss.gov.au) and ADA (https://ada@anu.edu.au) before receiving approval for their data application. The datasets analysed and/or generated during the current study are subject to the signed confidentiality deed.

CRediT authorship contribution statement

Rezwanul Haque: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Khorshed Alam:** Writing – review & editing, Visualization, Validation, Supervision, Formal analysis, Conceptualization. **Jeff Gow:** Writing – review & editing, Visualization, Validation, Supervision. **Christine Neville:** Writing – review & editing, Visualization, Validation, Supervision. **Syed Afroz Keramat:** Writing – review & editing, Validation, Supervision, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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Abbreviations

BDS	Backward Digit Span test
CC	Concentration Curve
CI	Concentration Index
HILDA	Household, Income and Labour Dynamics in Australia
HRQoL	Health-related quality of life
MCI	Mild Cognitive Impairment
OLS	Ordinary Least Squares

SE	Standard Error
SDMT	Symbol Digit Modalities test
SES	Socioeconomic Status

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2024.117399.

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6.2 Links and implications

Health disparities between socio-economic strata have persisted or even worsened globally despite advancements in healthcare, underscoring the critical need to address these inequities. Cognitive impairment, as this study highlights, exacerbates SES-based inequalities in HRQoL, making it imperative to integrate cognitive health into strategies aimed at reducing health disparities. The findings of this study are significant for public health planning and policy, offering valuable insights into the interplay among SES, cognitive impairment, and HRQoL. By understanding these dynamics, policymakers and practitioners can design equitable health interventions that specifically target vulnerable populations, ultimately improving HRQoL and promoting health equity among older Australians. The subsequent study identifies the association between cognitive impairment and health outcomes.

Note: Appendix D provides online supplementary material and associated appendix tables, as referenced in this chapter.

CHAPTER 7: PAPER 5 - COGNITIVE IMPAIRMENT AND SELF-REPORTED HEALTH OUTCOMES AMONG OLDER ADULTS: LONGITUDINAL EVIDENCE FROM AUSTRALIA

7.1 Introduction

This chapter presents the fifth study of this thesis, which examines the association between cognitive impairment and health outcomes among older Australians. Despite growing concerns over cognitive decline, there is a significant gap in comprehensive Australian research on how cognitive impairment relates to various health outcomes. This study is among the first in Australia to investigate these associations in detail. The findings hold important implications for the development of targeted interventions aimed at promoting independence and healthy ageing for older Australians. As Australia's ageing population continues to grow, the management of cognitive impairment presents both challenges and opportunities. Effective intervention strategies could not only improve individual quality of life but also significantly alleviate pressure on the healthcare system and contribute to the national economy. Moreover, early detection and management of cognitive impairment can lead to better outcomes, with the potential to reverse MCI in some cases. Thus, this research is a critical step towards addressing the needs of an ageing population and improving the health and well-being of older Australians.

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Cognitive impairment and self-reported health outcomes among older adults: Longitudinal evidence from Australia

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ABSTRACT

Background: Australia's population is ageing, with forecasts indicating that individuals aged 65 years and over will account for >20 % of the total population by 2066. Ageing is strongly linked with a significant decrease in cognitive capabilities. This study aimed to explore the association between cognitive impairment and four types of health outcomes among older Australians.

Methods: Data used for this study was collected from the Household, Income and Labour Dynamics in Australia (HILDA) Survey. The final analysis consisted of 11,146 person-year observations from 7035 unique individuals from Wave 2012 and Wave 2016, respectively. A longitudinal random-effects generalised least squares, and ordered logistic regression were used to analyse the association between cognitive impairment and health outcomes.

Results: The study results suggest that cognitive impairment was negatively associated with general health, mental health, self-assessed health and health satisfaction. Older Australians with cognitive impairment scored lower on general health ($\beta = -2.82$, SE = 0.56), mental health ($\beta = -2.93$, SE = 0.53), self-assessed health ($\beta = -0.75$, SE = 0.10), and health satisfaction ($\beta = -0.19$, SE = 0.09) compared to the counterparts without cognitive impairment. The heterogeneous results also showed cognitive impairment was associated with poor health outcomes across age groups.

Conclusion: This study found evidence that cognitive impairment is associated with poor health outcomes. To enhance the physical and mental health and well-being of older adults, the community, government and non-government organizations, and other stakeholders should prioritize routine healthcare prevention, targeted interventions, and treatment practices, particularly for individuals with or at risk of cognitive impairment.

1. Introduction

The global population's demographic composition is transitioning towards an older age profile due to advancements in life expectancy (Ataollahi Eshkoor et al., 2015). With increasing life expectancy, the quality of life of older individuals has become an important societal concern. Cognitive impairment, which significantly affects the quality of life due to diminishing capabilities and skills, is a key factor in this context (Comijs et al., 2005). As individuals age, they are more likely to experience cognitive decline in areas such as thinking, memory, and concentration, reflecting the physiological changes that occur in the brain and body (Pais, Ruano, Moreira, et al., 2020). Declines in cognitive skills such as memory, attention, orientation, language, and executive function may adversely affect many dimensions of a person's life (Pan et al., 2015). For example, diminished verbal abilities can result in communication challenges, limiting an individual's capacity to sustain social roles at preferred levels (Kiely, 2014). Moreover, attention impairments may lead to physical limitations, self-reported disabilities (Ble et al., 2005), and difficulties in performing daily activities such as eating, bathing, and maintaining personal hygiene (Bronnick, 2006). Additionally, deficits in attention, memory, and executive function may contribute to the mechanisms underlying chronic pain (Attal et al., 2014).

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A potential challenge in addressing memory concerns and cognitive impairment in healthcare and related research is accurate identification and measurement of these conditions (Molinuevo et al., 2017). Cognitive impairment differs from normal ageing in the extent of its impact on everyday functioning. While normal ageing involves mild, gradual changes like occasional forgetfulness and slower processing speed, cognitive impairment includes more noticeable and persistent issues, such as frequent memory lapses, poor judgment, and difficulties with language and daily tasks (Grundman, 2004). People with cognitive impairment do show a clear decline in cognition based on objective assessments. However, this cognitive decline is not severe enough to interfere with daily activities or meet the diagnostic criteria for dementia (Gauthier et al., 2006). Cognitive impairment represents an intermediary stage, falling between the typical cognitive decline associated with ageing and the more pronounced decline characteristic of dementia (Reisberg et al., 2008; Wang et al., 2014). The risk of developing dementia is markedly higher for individuals with mild cognitive impairment compared to the general population (Petersen et al., 2014), with an annual progression rate estimated between 10 % to 15 % (Farias et al., 2009; Xue et al., 2017). Cognitive impairment, encompassing mild impairment to dementia (severe cognitive impairment), is commonly associated with ageing (Keramat et al., 2023). The age at which the risk of cognitive decline associated with ageing begins to affect cognitive capacities is a topic of ongoing debate (Finch, 2009; Nilsson et al., 2009; Salthouse, 2009). Nevertheless, longitudinal data has demonstrated that cognitive decline is observable across all age groups ranging from 45 to 70 years, with a more rapid decrease observed in the oldest age cohort, those aged 70 years and above (Singh-Manoux et al., 2012). The global rate of incidence of cognitive impairment among adults aged over 50 years varies significantly, ranging from 5.1 % to a staggering 41 %, with a median prevalence of 19.0 % (Pais, Ruano, & P. Carvalho O, Barros H., 2020). Estimates show that among older Australians (65 years and over), the rate of cognitive impairment varies substantially, ranging from 7.7 % to 33.3 % in various settings (Anderson et al., 2007; Low et al., 2004). The global prevalence of severe cognitive impairment is projected to reach 82 million by 2030 and increase further to 152 million by 2050 (WHO, 2017; WHO, 2019). Given the significant public health burden of cognitive impairment, comprehensive health assessments are crucial for early identification and intervention. These assessments should ideally include a range of measures, such as cognitive function tests (e.g., memory tests, neuropsychological assessments) in addition to self-reported health outcomes (National Institute on Aging, 2020). Self-reported health outcomes are important because they provide insights into an individual's perceived well-being, quality of life, and functional status, which are not always captured by objective tests (Jylhä, 2011). They also reflect the subjective experience of health, including symptoms and the impact of cognitive impairment on daily life, enabling a more holistic understanding of an individual's condition (National Institute on Aging., 2020). Early detection allows for timely interventions, including lifestyle modifications, cognitive training, and pharmacological therapies, which may help to slow cognitive decline and improve quality of life (National Institute on Aging., 2021).

Self-assessed health outcome is a frequently employed metric for evaluating overall health that captures individuals' subjective assessment of their own health at a given point of time. Assessing the health status is essential for determining variations within and across groups, monitoring changes over time, and evaluating the effectiveness of health interventions (Sibthorpe et al., 2001). Evidence suggests that self-reported health is an independent and valid indicator of health, even for those in the early stages of dementia or mild cognitive impairment (Walker et al., 2004). Prior studies have measured self-reported health outcomes using measures such as general health (Dwyer-Lindgren et al., 2017; Lee, 1978), mental health (Lee, 1978), self-assessed health (Hu et al., 1978) and health satisfaction (Paul et al., 2016).

Cognitive impairment is associated with a multitude of adverse health outcomes, encompassing an elevated mortality risk, an increased likelihood of developing dementia, heightened rates of disability and hospitalization, as well as deterioration in overall health-related quality of life (Chen et al., 2022; Keramat et al., 2023; Pike et al., 2022). Prior studies found that cognitive impairment is associated with the deterioration in physical performance, such as activities of daily living and instrumental activities of daily living (Atkinson et al., 2007; Tabbarah et al., 2002; Wang et al., 2002). Moreover, cognitive impairment is a major risk factor for depression, anxiety, and other mental health conditions (Yates et al., 2013). Furthermore, a recent study found that individuals with cognitive disorders, such as autism, attention deficit, and memory loss, exhibit lower levels of satisfaction with their health status compared to the general population (Stone et al., 2023).

Understanding the link between cognitive impairment and health outcomes holds significance because of its far-reaching implications. This will help healthcare providers accurately predict and manage the needs of affected individuals, potentially delaying the progression of the condition and improving overall health and well-being. There is evidence that approximately 40 % of individuals with cognitive impairment had medical practitioners who were unaware of their condition (Chodosh et al., 2004). Failing to assess cognitive or memory problems can impede the treatment of underlying diseases and co-occurring disorders, and it can pose a risk to the patient and others (Bradford et al., 2009). Additionally, cognitive impairment is often associated with a greater likelihood of experiencing other health concerns, such as cardiovascular diseases (Leng et al., 2018) and mental health disorders (Mirza et al., 2017), making early detection and intervention essential for preventing further complications. Cognitive impairment may also have a substantial influence on an individual's capacity to manage their own health effectively. Challenges related to adhering to medicine, following treatment plans, and comprehending medical information can all be worsened by cognitive decline (Smith et al., 2017). Furthermore, patients with cognitive impairment are at increased risk for adverse hospital experiences, including but not limited to confusion, distress, and trouble following directions or interacting with healthcare workers (Australian Commission on Safety and Quality in Health Care, 2019). Therefore, investigating the relationship between cognitive decline and health outcomes will allow healthcare practitioners to develop improved communication and support systems. This, in turn, can improve health outcomes for individuals with cognitive impairment.

The findings of this study will play a crucial role in guiding the development of evidence-based interventions to promote independence and healthy ageing. The growing population of older Australians has significant benefits and opportunities for Australia as it steadily expands to provide a substantial and expanding consumer base for a broad spectrum of healthcare products and services. For instance, an increase of 5 % in the employment rate of Australians aged 55 and over would result in a significant increase of $48 billion in national income annually (Deloitte Access Economics., 2012). Though cognitive impairment is more likely to progress to dementia, it can sometimes revert to normal or not advance further. There is evidence that as many as 44 % of individuals who initially exhibit mild cognitive impairment are expected to be back to their normal cognitive functioning within one year (Wada-Isoe et al., 2012). Therefore, early detection of cognitive impairment can enable more effective management, improved quality of life, and planning for the future, even if complete reversal of normal ageing may not be possible in all cases.

There is a lack of comprehensive Australian research that investigating the relationship between cognitive impairment and various health outcomes. A prior study revealed that older adults with cognitive decline face a higher risk of encountering various negative outcomes during hospital stays (Fogg et al., 2018). Another study revealed that individuals with cognitive impairment experienced a lower health-related quality of life (Keramat et al., 2023). To the best of our knowledge, no previous Australian study has explored the association between cognitive impairment and a wide array of health outcomes using nationally representative longitudinal data. Therefore, the purpose of this

research is to investigate the following hypotheses: (1) Cognitive impairment is negatively associated with the general health of older Australians. (2) Cognitive impairment is associated with a decline in self-reported mental health among older Australians. (3) Older adults with cognitive impairment are more likely to report lower levels of self-assessed health. (4) Cognitive impairment is negatively associated with self-reported health satisfaction.

2. Methods

2.1. Data source

This research utilizes data collected from the Household, Income and Labour Dynamics in Australia (HILDA) Survey, initiated in 2001. The HILDA dataset encompasses a broad spectrum of variables, including wealth, labour market experiences, household dynamics, fertility, health status, and educational attainment. Choosing the initial sample involved a multistage sampling procedure. Initially, 488 Census Collection Districts (CDs) were selected by a probability proportional to size sampling technique. Every district has a range of 200 to 250 dwellings. Furthermore, a random selection of 22–34 houses was made from each CDs. Ultimately, a total of 12,252 households were selected, with a maximum of three homes picked from each residence. Commencing in 2001, the annual data collection for the HILDA Survey has included a representative sample of individuals aged 15 years and over residing in households. Data collection was carried out by trained interviewers through face-to-face and telephone interviews. In this case, a self-administered questionnaire was utilized, adhering to the ethical principles established by the University of Melbourne. As time progressed, the sample size increased. The household includes all children born or adopted by the participants, and anyone new who joins the household because the original families changed. Therefore, the survey encompasses an annual average of approximately 17,000 individuals residing in Australia. The sampling technique, research design, and data-collecting procedures for the waves have been thoroughly examined elsewhere (Wooden et al., 2002).

2.2. Study participants

To focus on cognitive impairment, we restricted our analysis to data from the HILDA Survey waves 12 (2012) and 16 (2016), as these were the only waves with relevant questions. Wave 16 was utilized as the follow-up survey, while wave 12 was considered as the baseline. The analytic samples were restricted to older adults residing in Australia, defined as individuals aged 50 years or older. The study omitted participants who did not provide comprehensive information regarding the exposure factors (cognitive impairment test scores) and the outcome variables (general health, mental health, self-assessed health, and health satisfaction). The final analytic sample comprises 11,146 person-year observations from 7035 unique individuals. Fig. 1 provides a detailed dissection of any missing data and outlines the criteria that were employed to exclude specific observations.

2.3. Outcome variables

We utilized four distinct variables to measure health outcomes. We measured health outcomes through general health, mental health, self-assessed health, and health satisfaction. This study used the SF-36 Health Survey to measure general and mental health. General health score is generated using 10 questions from the SF-36 health survey. The data encompass participants' self-perceptions of their overall health, emotional state, and level of independence in carrying out daily activities. The raw scores were transformed into a scale of 0 to 100, where a higher number signifies a better level of general health. Mental health score is derived using five specific questions from the SF-36 health survey. These questions assess the degree to which mental health issues impact everyday tasks on an emotional level. The mental health index is derived using the same methodology as the general health index and

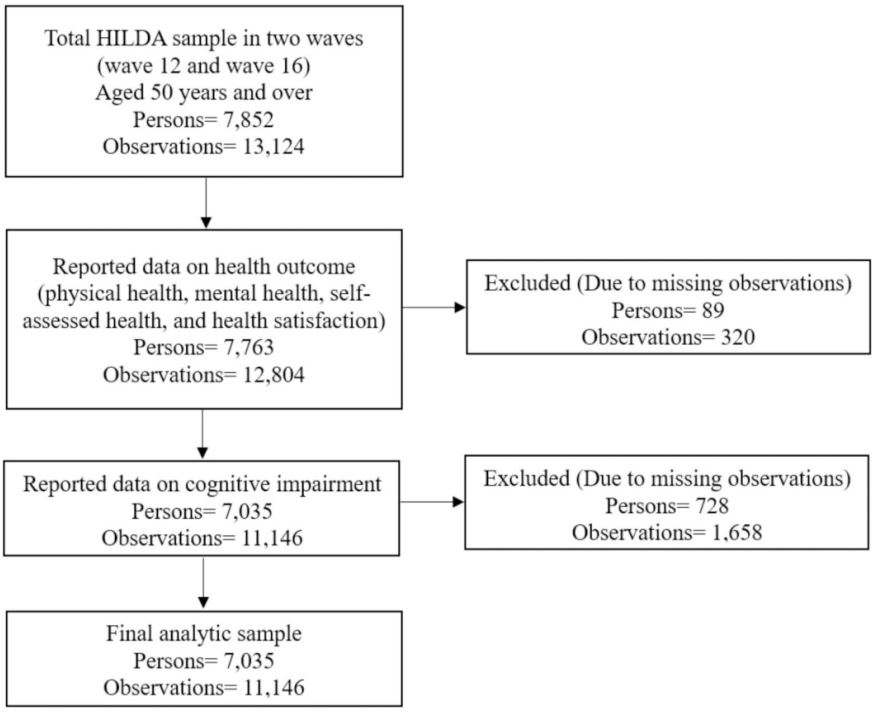

Fig. 1. Participants flow into the analytic sample and missing data.

ranges from 0 to 100, with higher scores indicating better mental health. The study used self-assessed health as the third measure to evaluate health outcomes. This was determined by asking participants the question: "In general, would you say your health is?" In the HILDA Survey, participants' responses were recorded on a scale ranging from "1 = Excellent" to "5 = Poor". The final index used to assess health outcomes was health satisfaction, which was determined by answering the question: "All things considered, how satisfied are you with your health?" Participants rated their health satisfaction on a scale from 0 to 10, with higher scores indicating greater satisfaction.

2.4. Exposure variable

The HILDA Survey evaluates the cognitive capabilities of participants by using validated measures of cognitive function. These tests are simply integrated into the HILDA's in-person survey questionnaires. The survey measured cognitive function of an individual using the Symbol Digit Modalities Test (SDMT) and the Backward Digit Span Test (BDS). While the BDS and SDMT provide valuable information about core cognitive functions, they may not comprehensively assess the cognitive profile of individuals, particularly for determining cognitive impairment without specific cutoff scores. More comprehensive neuropsychological assessments, such as the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005), Mini-Mental Status Examination (MMSE) (Folstein et al., 1985), or Saint Louis University Mental Status (SLUMS) examination (Morley & Tumosa, 2002) offer a more nuanced and reliable assessment of cognitive function. However, due to the unavailability of such tests scores in the HILDA Survey, we relied on the BDS and SDMT to assess a person's cognitive health. The tests have previously been used to detect cognitive impairment in individuals diagnosed with multiple sclerosis (Parmenter et al., 2007; Van Schependom et al., 2014) and those who are currently hospitalized (Leung et al., 2011). The BDS cognitive evaluation exam requires individuals to recite a sequence of numbers in the opposite order (Lamar et al., 2007). The BDS evaluates the cognitive capacity of working memory on a scale of 0 to 8. The SDMT is a cognitive assessment tool that measures processing speed and attention. During the SDMT, participants are instructed to match a list of numbers with corresponding geometric shapes as quickly and accurately as possible (Smith, 1973). The SDMT evaluates the cognitive function of the central brain and provides scores that range from 0 to 110.

The threshold for cognitive impairment in this study was determined based on established criteria from previous literature. Specifically, earlier studies have classified cognitive impairment using the following thresholds: individuals scoring $\geq$1.0 standard deviation (SD) below the mean on either the BDS or SDMT (or both) tests were categorised as having mild cognitive impairment, while those scoring $\geq$1.5 SD below the mean on both tests were classified as having severe cognitive impairment (Aschwanden et al., 2020; Haque et al., 2024a; Keramat et al., 2023). In this study, we combined the categories of mild and severe cognitive impairment and focused on cognitive impairment as a single construct. Accordingly, we defined cognitive impairment as scoring $\geq$1 SD below the mean on both the BDS and SDMT. This approach reflects an empirical threshold used in prior research while ensuring alignment with the study's objectives. Based on this criterion, individuals were classified as cognitively impaired if they scored $\leq$3 on the BDS and $\leq$ 30 on the SDMT.

2.5. Control variables

We included a range of individual-level socio-demographic factors, health-related behaviors, and health characteristics as covariates. The socio-demographic characteristics included age (50–64 years, and $\geq$ 65 years), gender (male, and female), marital status (unpartnered and partnered), highest level of education (year 12 and below, professional qualifications, and university qualifications), annual household disposable income (Quintile 1 [poorest], and Quintile 5 [richest]), participation in the labour force (employed, and unemployed or not in the labour force), Indigenous origin (not of Indigenous origin, and Aboriginal or Torres Strait Islander or both), geographic residency (major city, and regional city or remote area). In addition, three behavioural characteristics that can impact health outcomes were included: smoking habits (non-smoker, and currently smoking), alcohol drinker (non-drinker, and current drinker), and physical activity (less than the recommended level, and recommended level). Furthermore, Body Mass Index (underweight, healthy weight, overweight, and obese) and disability status (no versus yes), were considered as the proxy of participants' health status.

2.6. Estimation strategy

An unbalanced longitudinal data set was constructed, comprising of 11,146 person-year observations from 7035 distinct individuals. The descriptive statistics for continuous variables were presented in the subsequent statistical analysis as means and standard deviations (SD), while frequencies and percentages were utilized for categorical variables. Four distinct regression models were constructed to investigate the associations between cognitive impairment and health outcomes.

The first two outcome variables, general health and mental health, were measured on a continuous scale. Therefore, we applied a longitudinal random-effects GLS regression model to analyse the association between cognitive impairment and general health and mental health. This model is employed to assess the effects of time-varying variables when analysing longitudinal data (e.g., cognitive impairment) and fixed individual characteristics (e.g., gender). This model offers an approximation of the between-person differences in the effects. Furthermore, this model assumes random variability among individuals, which is not influenced by model covariates.

The random-effects GLS regression can be expressed in the following functional form:

$$HO_{it} = \alpha + \beta_1 CI_{it} + \beta_2 Z_{it} + \mu_i + \epsilon_{it} \quad (1)$$

HO denotes the two different types of health outcome variables which were continuous variables in nature: general health, and mental health. CI is exposure variable cognitive impairment. Z_{it} represents the vector consisting of time-varying and time-invariant control variables. The model parameter of interest to be estimated is denoted as β_1, and β_2 indicates the vector of coefficient while α is the model's grand intercept. The analysis considers two parts of the error: individual-specific components, μ, which stays the same over time, and time and person-specific error, ϵ_{it}, which is assumed to be uncorrelated with the independent variables.

The third and fourth outcome variables were self-assessed health and health satisfaction, respectively. These variables were measured on an ordinal scale. Self-assessed health is categorised from "1 = Poor" to "5 = Excellent", while health satisfaction is categorised from 0 to 10, where a higher value indicates a better level of satisfaction with their health. Hence, we applied the random-effects ordered logistic regression model to analyse the association between cognitive impairment and, self-assessed health, and health satisfaction.

The random-effects ordered logistic regression can be expressed in the following functional form:

$$Y_{it}^{*} = \mu + X_{it}^{'}\beta + \varepsilon_{it.}$$

$$= \mu + X_{it}^{'}\beta + \alpha_i + \nu_{it}, i = 1, 2, \ldots\ldots\ldots, N; t = 12, 16 \quad (2)$$

Where the distribution of α_i and ν_{it} are assumed respectively to be $\alpha_i \sim$i.i.d $[0, \sigma_\alpha^2]$ and $\nu_{it} \sim$ i.i.d [0,1]. $X_{it}^{'}$ is a vector of observable time-invariant and time-varying factors including cognitive impairment, socio-demographic characteristics and other control variables. μ is the non-random intercept, β is the vector of coefficients and ε_{it} is the error term.

Statistical significance was determined using a *p*-value threshold of

0.05. Lower *p*-values (<0.01 and < 0.001) were reported to indicate stronger evidence of significance. Stata version 17.0 (StataCorp LLC, College Station, TX: USA) was employed for all statistical analyses.

3. Results

Table 1 provides an overview of the study sample. The mean scores for general health and mental health in the pooled data were 63.72 and 76.18 on a scale of 100, respectively. The mean self-assessed health score was 3.12 on a scale of 1 to 5, whereas the mean health satisfaction score was 6.96 on a scale of 0 to 10. The results also showed that 11.79 % were cognitively impaired. Furthermore, approximately over two-fifths (42.24 %) were aged 65 or older, more than half (53.20 %) were female, nearly two-thirds (64.35 %) were partnered, nearly a quarter (23.50 %) had a university degree, over half (53.37 %) were either unemployed or not in the labour force, the majority (98.08 %) were not of Indigenous origin, and roughly two-thirds (63.74 %) resided in major cities. Table 1 additionally presents the following information regarding the pooled sample: 87.45 % were non-smokers, 81.04 % were current drinkers, 67.47 % does not perform the recommended level of physical activity, 28.67 % were obese, and 42.31 % had a disability (pooled data).

Fig. 2 depicts the mean scores for general health, mental health, self-assessed health, and health satisfaction throughout the study periods. The result indicates a minor variation in the mean general health score, decreasing from 63.89 in 2012 to 63.57 in 2016. The average mental health score of older Australians fell from 76.46 in 2012 to 75.93 in 2016. Furthermore, the mean health satisfaction score of participants declined slightly from 6.97 to 6.96 in 2012 and 2016, respectively. However, the mean self-assessed health score rose marginally from 3.12 (2012) to 3.13 (2016) during the study period.

Fig. 3 illustrates the rate of older Australians with cognitive impairment in the study sample from 2012 to 2016. The figure shows that the percentage of older Australians with cognitive impairment declined from 13.10 % in 2012 to 10.60 % in 2016.

Fig. 4 depicts the mean health outcomes—general health, mental health, self-assessed health, and health satisfaction—stratified by cognitive impairment status among older Australians from 2012 to 2016. The figure illustrates that older Australians with cognitive impairment scored lower across all four health outcomes—general health, mental health, self-assessed health, and health satisfaction—compared to those without cognitive impairment. For instance, in Wave 16, the mean scores for general health, mental health, self-assessed health, and health satisfaction were 64.76, 76.49, 3.19, and 7.03, respectively, among individuals without cognitive impairment, compared to 53.46, 71.14, 2.62, and 6.34 among older adults with cognitive impairment.

Table 2 shows the regression results obtained from the random-effects GLS and random-effects ordered logistic regressions that explicitly showed the relationships between cognitive impairment and different facets of health outcomes. The results showed that participants with cognitive impairment had significantly lower health outcomes (general health, mental health, self-assessed health and health satisfaction) compared to those without cognitive impairment in all four regression models (models 1–4). In the case of general and mental health, participants with cognitive impairment exhibited a decrease of −2.82 points (β = −2.82, SE = 0.56) (model 1) and − 2.93 points (β = −2.93, SE = 0.53) (model 2) compared to those without cognitive impairment. The results from models 3 and 4 showed that participants with cognitive impairment had significantly lower self-assessed health (β = − 0.75, SE = 0.10), and health satisfaction (β = −0.19, SE = 0.09), respectively, compared to those without cognitive impairment. In addition to cognitive impairment, several other socioeconomic, lifestyle, and demographic variables were found statistically significant. For instance, individuals from the poorest household disposable income (quintile 1), unemployed or not in the labour force, smokers, obese, or those with disability had lower general health, mental health, self-

Table 1
Distribution of the analytic sample (outcome, and exposure variable: Baseline, Final, and Pooled across all waves (Persons = 7035, Observations = 11,146).

	Baseline Wave (2012)		Final Wave (2016)		Pooled in all Waves (2012–2016)	
Characteristics	n	mean/ %	n	mean/ %	n	mean/ %
Outcome variables (Self-reported health)						
General health	5410	63.89	5736	63.57	11,146	63.72
Mental health	5410	76.46	5736	75.93	11,146	76.18
Self-assessed health	5410	3.12	5736	3.13	11,146	3.12
Health satisfaction	5410	6.97	5736	6.96	11,146	6.96
Exposure variable						
BDS	5410	4.77	5736	4.84	11,146	4.81
SDM	5410	41.68	5736	42.84	11,146	42.27
Cognitive impairment						
No	4703	86.90	5129	89.40	9832	88.21
Yes	707	13.10	607	10.60	1314	11.79
Covariates						
Age						
50–64 years	3133	57.91	3305	57.62	6438	57.76
65 years and over	2277	42.09	2431	42.38	4708	42.24
Sex						
Male	2518	46.54	2698	47.04	5216	46.80
Female	2892	53.46	3038	52.96	5930	53.20
Marital status						
Unpartnered	1921	35.51	2052	35.77	3973	35.65
partnered	3489	64.49	3684	64.23	7173	64.35
Highest level of education						
Year 12 and below	2407	44.49	2340	40.79	4747	42.59
Professional qualifications	1782	32.94	1998	34.83	3780	33.91
University qualifications	1221	22.57	1398	24.37	2619	23.50
Annual household disposable income						
Quintile 1 (poorest)	1082	20.00	1148	20.00	2230	20.01
Quintile 2	1082	20.00	1147	20.00	2229	20.00
Quintile 3	1083	20.02	1147	20.00	2230	20.01
Quintile 4	1082	20.00	1147	20.00	2228	19.99
Quintile 5 (richest)	1081	19.98	1147	20.00	2229	20.00
Participation in labour force						
Employed	2504	46.28	2693	46.95	5197	46.63
Unemployed or not in the labour force	2906	53.72	3043	53.05	5949	53.37
Indigenous origin						
Not of Indigenous origin	5310	98.15	5622	98.01	10,932	98.08
Aboriginal or Torres Strait Islander or both	100	1.85	114	1.99	214	1.92
Geographic residency						
Major city	3476	64.25	3628	63.25	7104	63.74
Regional city/remote area	1934	35.75	2108	36.75	4042	36.26

(*continued on next page*)

Table 1 (*continued*)

Characteristics	Baseline Wave (2012)		Final Wave (2016)		Pooled in all Waves (2012–2016)	
	n	mean/ %	n	mean/ %	n	mean/ %
Smoking habits						
Non-smoker	4728	87.39	5019	87.50	9747	87.45
Currently smoking	682	12.61	717	12.50	1399	12.55
Alcohol drinking						
Non-drinker	1019	18.84	1094	19.07	2113	18.96
Active drinker	4391	81.16	4642	80.93	9033	81.04
Physical activity						
Less than the recommended level	3634	67.17	3886	67.75	7520	67.47
Recommended level	1776	32.83	1850	32.25	3626	32.53
Body Mass Index (BMI)						
Underweight	79	1.46	74	1.29	153	1.37
Healthy weight	1784	32.98	1802	31.42	3586	32.17
Overweight	2074	38.34	2137	37.26	4211	37.78
Obesity	1473	27.23	1723	30.04	3196	28.67
Disability status						
No	3069	56.73	3361	58.59	6430	57.69
Yes	2341	43.27	2375	41.41	4716	42.31

assessed health, and health satisfaction.

Table 3 presents the average marginal effects of self-assessed health and health satisfaction associated with cognitive impairment, based on the regression results from Models 3 and 4 in Table 2. It is observed that the average marginal effects were positive for the lower categories but negative for the higher categories. The findings indicate that individuals with cognitive impairment were 5.79 percentage points and 2.04 percentage points less likely to fall into the fourth and fifth categories of self-assessed health, respectively, compared to those without cognitive impairment. Similarly, the likelihood of individuals with cognitive impairment experiencing health satisfaction in the eighth, ninth, and tenth categories is reduced by 0.88, 1.11, and 0.59 percentage points, respectively, compared to those without cognitive impairment.

3.1. Robustness check

Table 4 shows the sensitivity analysis, which evaluates the robustness of the pooled findings (Models 1, 2, 3, and 4). The models initially reported in Table 2 were reassessed using the generalised estimating equation (GEE) approach and the random-effects generalised least squares (GLS) technique. The findings of the sensitivity analysis closely matched the baseline values for all the factors of interest. For example, the results from models 1, 2, 3 and 4 in Table 4 showed that participants with cognitive impairment had significantly lower general health ($\beta = -3.55$, SE = 0.56), mental health ($\beta = -3.89$, SE = −7.74), self-assessed health ($\beta = -0.19$, SE = 0.02), and health satisfaction ($\beta = -0.14$, SE = 0.06), respectively, compared to those without cognitive impairment.

3.2. Heterogenous effects

Tables 5, 6, 7, and 8 showed the results of adjusted random-effects GLS and ordered logistic regression models designed to investigate if the results obtained on the relationship between cognitive impairment and various health outcomes (general health, mental health, self-assessed health, and health satisfaction) vary by age and gender. Across both age groups (50–64 years and 65 years and over), individuals

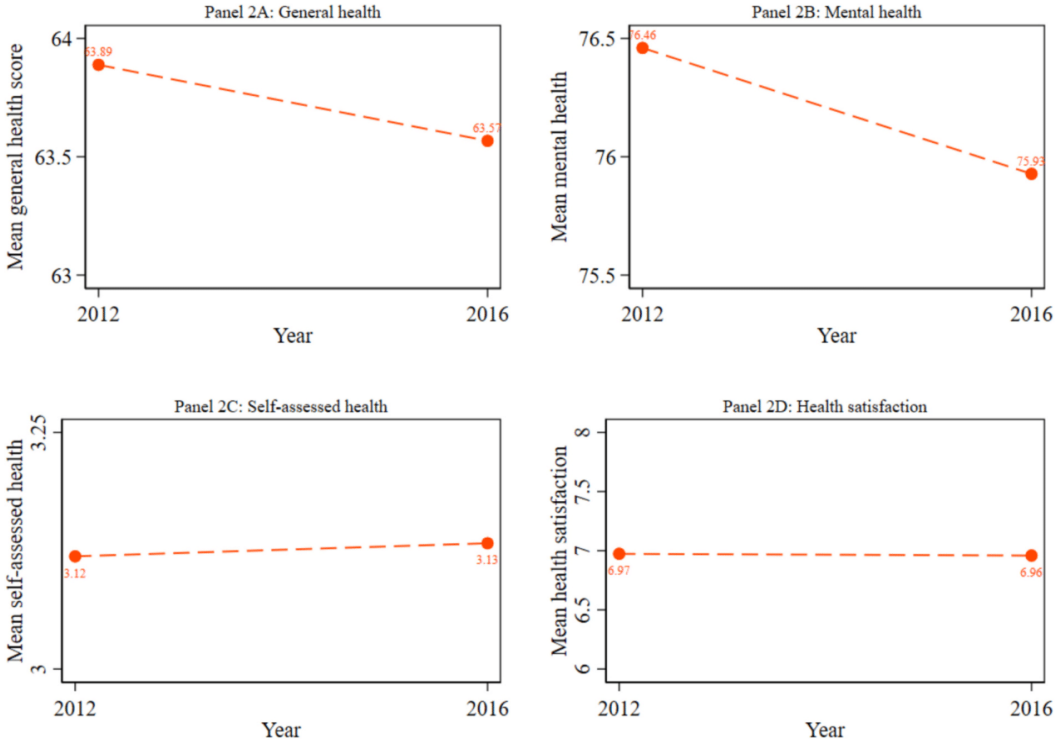

Fig. 2. Distribution of four types of health outcomes (general health, mental health, self-assessed health, and health satisfaction) in older Australians, 2012–2016.

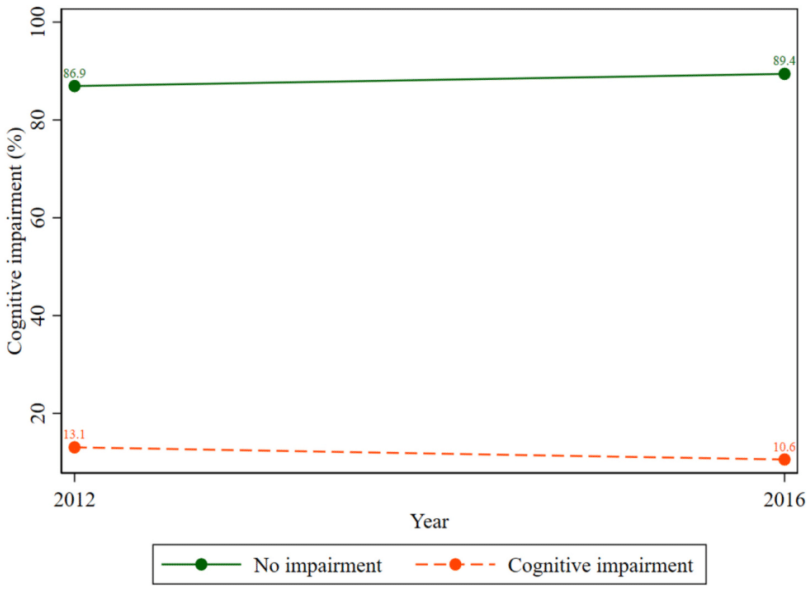

Fig. 3. Rate of cognitive impairment among older Australians, 2012–2016.

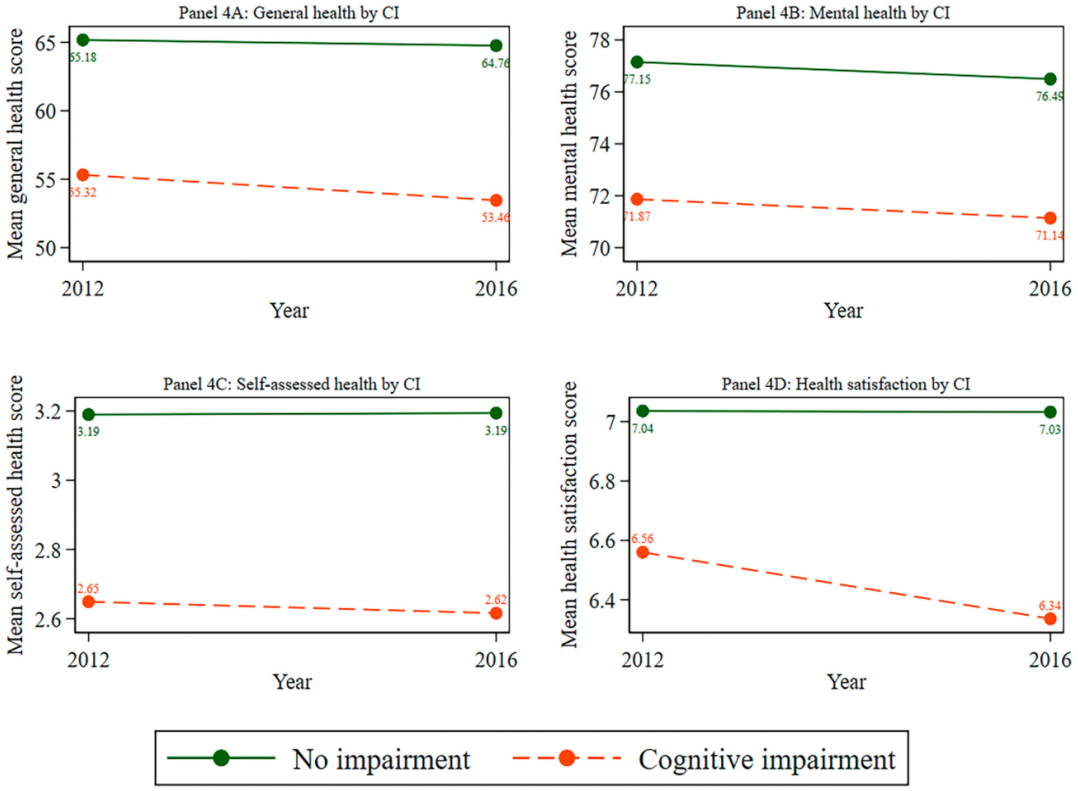

Fig. 4. Mean health outcomes (general health, mental health, self-assessed health, and health satisfaction) by status of cognitive impairment.

with cognitive impairment reported poorer mental health (Table 6), self-assessed health (Table 7) and health satisfaction (Table 8) compared to those without cognitive impairment which is in line with the main regression results. For example, Model 2 of Tables 6, 7, and 8 demonstrate that participants aged 65 years and older with cognitive impairment had significantly lower scores in mental health ($\beta = -3.92$, SE =

Table 2
The relationship between cognitive impairment and four different types of health outcomes (general health, mental health, self-assessed health, and health satisfaction).

Variables	Model 1	Model 2	Model 3	Model 4
	Random-effects GLS	Random-effects GLS	Random-effects Ordered logistic regression	Random-effects Ordered logistic regression
	General health	Mental health	Self-assessed health	Health satisfaction
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	−2.82*** [0.56]	−2.93*** [0.53]	−0.75*** [0.10]	−0.19* [0.09]
Covariates				
Age				
50–64 years (ref)				
65 years and over	1.97*** [0.42]	5.15*** [0.39]	0.15* [0.08]	0.86*** [0.07]
Sex				
Male (ref)				
Female	2.90*** [0.42]	−0.60 [0.38]	0.35*** [0.07]	0.24*** [0.06]
Marital status				
Unpartnered (ref)				
partnered	0.80* [0.41]	1.81*** [0.38]	0.13 [0.07]	0.22*** [0.06]
Highest level of education				
Year 12 and below (ref)				
Professional qualifications	1.03* [0.48]	0.23 [0.44]	0.22** [0.08]	−0.03 [0.07]
University qualifications	0.55 [0.55]	0.43 [0.48]	0.58*** [0.10]	−0.12 [0.08]
Annual household disposable income				
Quintile 1 (poorest)	−2.74*** [0.57]	−2.36*** [0.53]	−0.61*** [0.10]	−0.45*** [0.09]
Quintile 2	−3.06*** [0.52]	−1.49*** [0.48]	−0.55*** [0.10]	−0.45*** [0.08]
Quintile 3	−1.82*** [0.48]	−0.89* [0.44]	−0.29*** [0.09]	−0.20** [0.08]
Quintile 4	−0.77 [0.44]	−0.08 [0.41]	−0.20* [0.08]	−0.14* [0.07]
Quintile 5 (richest) (ref)				
Participation in labour force				
Employed (ref)				
Unemployed or not in the labour force	−4.51*** [0.43]	−2.31*** [0.40]	−0.70*** [0.08]	−0.40*** [0.07]
Indigenous origin				
Not of Indigenous origin(ref)				
Aboriginal or Torres Strait Islander or both	−2.38 [1.57]	−0.05 [1.42]	−0.25 [0.26]	0.09 [0.24]
Geographic residency				
Major city (ref)				
Regional city/ remote area	−0.01 [0.41]	0.28 [0.37]	−0.16* [0.07]	0.04 [0.06]
Smoking habits				
Non-smoker (ref)				
Currently smoking	−4.06*** [0.57]	−3.33*** [0.57]	−0.88*** [0.1]	−0.52*** [0.09]
Alcohol drinking				
Non-drinker (ref)				
Active drinker	3.14*** [0.51]	1.89*** [0.46]	0.58*** [0.08]	0.23*** [0.07]
Physical activity				
Less than the recommended level (ref)				
Recommended level	5.78*** [0.34]	3.73*** [0.30]	1.01*** [0.07]	0.83*** [0.06]
Body Mass Index (BMI)				
Underweight	−5.16*** [1.51]	−4.14** [1.48]	−0.80*** [0.25]	−0.50 [0.27]
Healthy weight (ref)				
Overweight	−1.45*** [0.4]	−0.48 [0.36]	−0.22*** [0.07]	−0.23*** [0.06]
Obesity	−5.70*** [0.49]	−1.28*** [0.43]	−1.07*** [0.09]	−0.89*** [0.07]
Disability status				
No (ref)				
Yes	−14.03*** [0.40]	−5.34*** [0.33]	−2.39*** [0.07]	−2.37*** [0.06]

Notes: 1. Values are rounded off to two decimal places. 2. Ref means reference category. 3. Robust standard errors are in brackets.
4. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.

0.60), self-assessed health (β = −0.92, SE = 0.12), and health satisfaction (β = −0.21, SE = 0.10), respectively, compared to their counterparts aged 65 years and older without cognitive impairment. However, the study revealed a complex interplay between gender and cognitive impairment on various health outcomes. While females with cognitive impairment consistently reported poorer health outcomes across all four domains: general health (Model 4, Table 5), mental health (Model 4, Table 6), self-assessed health (Model 4, Table 7) and health satisfaction (Model 4, Table 8), the results for males were more nuanced. For males, the association between cognitive impairment and health satisfaction

Table 3
Relevant marginal effects results obtained from random-effects ordered logistic regressions.

Overall well-being score	Self-assessed health	Health satisfaction
	Variable of interest-cognitive impairment	
	Marginal effect, *P* value	Marginal effect, P value
0		0.0009; 0.05
1	0.0208; <0.001	0.0013; 0.05
2	0.0494; <0.001	0.0023; 0.04
3	0.0081; <0.001	0.0036; 0.04
4	−0.0579; <0.001	0.0037; 0.04
5	−0.0204; <0.001	0.0063; 0.04
6		0.0047; 0.03
7		0.0029; 0.02
8		−0.0088; 0.04
9		−0.0111; 0.03
10		−0.0059; 0.03

(Model 3, Table 8) was not statistically significant, but a clear inverse association was observed for general health (Model 3, Table 5), mental health (Model 3, Table 6), and self-assessed health (Model 3, Table 7), meaning those with cognitive impairment reported poorer health outcomes. For example, Model 3 of Tables 5, 6, and 7 reveals that male participants with cognitive impairment scored significantly lower in general health (β = −1.88, SE = 0.79), mental health (β = −2.94, SE = 0.77), and self-assessed health (β = −0.62, SE = 0.14), respectively, compared to their male counterparts without cognitive impairment.

Table 9 summarizes the group comparison of interaction effects between cognitive impairment, annual household disposable income, and disability status on four health outcomes: general health, mental health, self-assessed health, and health satisfaction. The results showed that individuals with cognitive impairment and from the lowest household disposable income quintile (quintile 1) had significantly lower scores across all four health outcomes compared to those without cognitive impairment and from the highest disposable income quintile (quintile 5). For instance, those with cognitive impairment and from the lowest disposable income quintile (quintile 1) exhibited significantly lower general health (β = −0.88, SE = 0.15) [model 1], mental health (β = −0.93, SE = 0.16) [model 2], self-assessed health (β = −1.26, SE = 0.16) [model 3], and health satisfaction (β = −0.51, SE = 0.15) [model 4] scores compared to their counterparts. Similarly, individuals with both cognitive impairment and a disability demonstrated markedly lower scores in general health, mental health, self-assessed health, and health satisfaction compared to those without cognitive impairment and no disability. For example, participants with cognitive impairment and a disability showed significantly lower mental health (β = −1.57, SE = 0.12) [model 6], self-assessed health (β = −3.16, SE = 0.13) [model 7], and health satisfaction (β = −2.57, SE = 0.12) [model 8] relative to their counterparts without cognitive impairment and no disability.

4. Discussion

This study investigated the relationship between four health outcomes (general health, mental health, self-assessed health, and health satisfaction) and cognitive impairment among older Australians using nationally representative longitudinal data. The initial hypothesis posited a negative association between cognitive impairment and various health outcomes. The findings indicated that people with cognitive impairment had significantly lower general health, mental health, self-assessed health, and health satisfaction compared to those without cognitive impairment. Furthermore, the study findings unveiled the average marginal effects of health satisfaction and self-assessed health concerning cognitive impairment. The findings indicated that cognitive impairment reduces the likelihood of transitioning into the highest category in both self-assessed health and health satisfaction, provided all other variables remain constant. In addition, heterogeneous effects revealed that individuals with cognitive impairment, regardless of age group (50–64 years or 65 years and older), reported poorer mental health, self-assessed health, and health satisfaction compared to those without cognitive impairment. Furthermore, females with cognitive impairment consistently reported poorer health outcomes across all four domains—general health, mental health, self-assessed health, and

Table 5
Heterogenous Effect: the relationship between cognitive impairment and general health by age and gender.

Variables	Model 1	Model 2	Model 3	Model 4
	Random-effects GLS	Random-effects GLS	Random-effects GLS	Random-effects GLS
	General health (Age 50–64 years)	General health (Age 65 years and over)	General health (Male)	General health (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	−1.59 [1.04]	−3.90 [0.68]	−1.88* [0.79]	−3.61*** [0.81]

Notes: 1. The results of the robustness check are only shown for the cognitive impairment for brevity 2. Values in brackets are robust standard errors. 3. All the models were adjusted for age, sex, marital status, highest level of education, annual household disposable income, participation in labour force, indigenous origin, geographic residency, smoking habits, Alcohol drinking, physical activity, body Mass Index, and disability status. 4. Ref means reference category. 5. The detailed results can be observed in Table A2 in the appendix of the online supplementary material. 6. ***, and * denote significance at the p < 0.001 and p < 0.05 levels, respectively.

Table 4
The relationship between cognitive impairment and four different types of health outcomes (general health, mental health, self-assessed health, and health satisfaction).

	Model 1	Model 2	Model 3	Model 4
	Generalised estimating equation	Generalised estimating equation	Random-effects GLS	Random-effects GLS
	General health	Mental health	Self-assessed health	Health satisfaction
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	−3.55*** [0.56]	−3.89*** [−7.74]	−0.19*** [0.02]	−0.14* [0.06]

Notes: 1. The results of the robustness check are only shown for the cognitive impairment for brevity 2. Values in brackets are robust standard errors. 3. All the models were adjusted for age, sex, marital status, highest level of education, annual household disposable income, participation in labour force, indigenous origin, geographic residency, smoking habits, Alcohol drinking, physical activity, body Mass Index, and disability status. 4. Ref means reference category. 5. The detailed results can be observed in Table A1 in the appendix of the online supplementary material. 6. *** and * denote significance at the $p < 0.001$ and $p < 0.05$ levels, respectively.

Table 6
Heterogenous Effect: the relationship between cognitive impairment and mental health by age and gender.

Variables	Model 1	Model 2	Model 3	Model 4
	Random-effects GLS	Random-effects GLS	Random-effects GLS	Random-effects GLS
	Mental health (Age 50–64 years)	Mental health (Age 65 years and over)	Mental health (Male)	Mental health (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	−2.33* [1.05]	−3.92*** [0.60]	−2.94*** [0.77]	−2.88*** [0.72]

Notes: 1. The results of the robustness check are only shown for the cognitive impairment for brevity 2. Values in brackets are robust standard errors. 3. All the models were adjusted for age, sex, marital status, highest level of education, annual household disposable income, participation in labour force, indigenous origin, geographic residency, smoking habits, Alcohol drinking, physical activity, body Mass Index, and disability status. 4. Ref means reference category. 5. The detailed results can be observed in Table A3 in the appendix of the online supplementary material. 6. ***, and * denote significance at the $p < 0.001$ and $p < 0.05$ levels, respectively.

Table 7
The relationship between cognitive impairment and self-assessed health by age and gender.

Variables	Model 1	Model 2	Model 3	Model 4
	Ordered logit	Ordered logit	Ordered logit	Ordered logit
	Self-assessed health (Age 50–64 years)	Self-assessed health (Age 65 years and over)	Self-assessed health (Male)	Self-assessed health (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	−0.55*** [0.19]	−0.92*** [0.12]	−0.62*** [0.14]	−0.85*** [0.14]

Notes: 1. The results of the robustness check are only shown for the cognitive impairment for brevity 2. Values in brackets are robust standard errors. 3. All the models were adjusted for age, sex, marital status, highest level of education, annual household disposable income, participation in labour force, indigenous origin, geographic residency, smoking habits, Alcohol drinking, physical activity, body Mass Index, and disability status. 4. Ref means reference category. 5. The detailed results can be observed in Table A4 in the appendix of the online supplementary material. 6. *** denote significance at the $p < 0.001$ level.

Table 8
The relationship between cognitive impairment and health satisfaction by age and gender.

Variables	Model 1	Model 2	Model 3	Model 4
	Ordered logit	Ordered logit	Ordered logit	Ordered logit
	Health satisfaction (Age 50–64 years)	Health satisfaction (Age 65 years and over)	Health satisfaction (Male)	Health satisfaction (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	−0.42* [0.17]	−0.21* [0.10]	−0.12 [0.13]	−0.24* [0.13]

Notes: 1. The results of the robustness check are only shown for the cognitive impairment for brevity 2. Values in brackets are robust standard errors. 3. All the models were adjusted for age, sex, marital status, highest level of education, annual household disposable income, participation in labour force, indigenous origin, geographic residency, smoking habits, Alcohol drinking, physical activity, body Mass Index, and disability status. 4. Ref means reference category. 5. The detailed results can be observed in Table A5 in the appendix of the online supplementary material. 6. * denote significance at the $p < 0.05$ levels.

health satisfaction. Similarly, male participants with cognitive impairment reported poorer health outcomes in general health, mental health, and self-assessed health; however, no significant association was observed for health satisfaction. The study finally examined the group comparison of interaction effects between cognitive impairment, household disposable income, and disability status with four distinct health outcomes: general health, mental health, self-assessed health, and health satisfaction. The results showed that individuals with cognitive impairment and from the lowest household disposable income quintile had significantly poorer scores across all health outcomes compared to those without cognitive impairment and from the highest household disposable income quintile. Similarly, individuals with both cognitive impairment and a disability had markedly lower scores across all four health outcomes compared to those without cognitive impairment and disability.

4.1. Cognitive impairment and general health

This study revealed that participants with cognitive impairment tended to have poorer self-reported general health compared to those without cognitive impairment. This finding aligns with the existing body of research, in which there exists an association between mild and non-dementing cognitive impairment and poorer health at the population level (Frisoni et al., 2000). Furthermore, numerous studies have substantiated the longitudinal association between cognitive function and physical performance in older adults, with cognitive assessments being regarded as predictors of the decline in physical performance, including activities of daily living and instrumental activities of daily living (Atkinson et al., 2007; Tabbarah et al., 2002; Wang et al., 2002). The inverse relationship between cognitive impairment and general health, which manifests as difficulties with performing daily tasks and working because of health issues, could be explained as follows: physical performance may necessitate more cognitive monitoring as people get

Table 9
Abridged regression results of group comparison of the interaction effect between cognitive impairment, household disposable income, and disability status on four different types of health outcomes (general health, mental health, self-assessed health, and health satisfaction).

Models	Model 1	Model 2	Model 3	Model 4
Variables	General Health	Mental Health	Self-assessed Health	Health Satisfaction
	Random-effects ordered logistic regression	Random-effects ordered logistic regression	Random-effects ordered logistic regression	Random-effects ordered logistic regression
Group comparison in the interaction effect between cognitive impairment and household disposable income				
No impairment # Quintile 1	−0.46*** [0.10]	−0.39*** [0.10]	−0.65*** [0.11]	−0.50***[0.10]
No impairment # Quintile 2	−0.51*** [0.09]	−0.26***[0.09]	−0.56*** [0.10]	−0.47***[0.09]
No impairment # Quintile 3	−0.29*** [0.08]	−0.15 [0.08]	−0.29*** [0.09]	−0.19** [0.08]
No impairment # Quintile 5	−0.14 [0.08]	0.01 [0.08]	−0.20** [0.09]	−0.13 [0.07]
No impairment # Quintile 5 (ref)	1	1	1	1
Cognitive impairment # Quintile 1	−0.88*** [0.15]	−0.93*** [0.16]	−1.26*** [0.16]	−0.51*** [0.15]
Cognitive impairment # Quintile 2	−0.89*** [0.17]	−0.87*** [0.17]	−1.33*** [0.18]	−0.63*** [0.17]
Cognitive impairment # Quintile 3	−0.82*** [0.19]	−0.57*** [0.21]	−1.15*** [0.21]	−0.59*** [0.18]
Cognitive impairment # Quintile 4	−0.74** [0.31]	−0.65* [0.33]	−1.07*** [0.28]	−0.64* [0.29]
Cognitive impairment # Quintile 5	−0.30 [0.33]	−0.52 [0.29]	−0.94*** [0.35]	−0.36 [0.28]

Model	Model 5	Model 6	Model 7	Model 8
Group comparison in the interaction effect between cognitive impairment and disability status				
No impairment # no disability (ref)	1	1	1	1
No impairment # disability	−2.29*** [0.07]	−0.96*** [0.06]	−2.37*** [0.07]	−2.37*** [0.06]
Cognitive impairment # no disability	−0.36* [0.14]	−0.43*** [0.15]	−0.67*** [0.19]	−0.18 [0.14]
Cognitive impairment # disability	−2.78 [0.12]	−1.57*** [0.12]	−3.16*** [0.13]	−2.57*** [0.12]

Notes: 1. The results only show the interaction effect for brevity 2. Values in brackets are robust standard errors. 3. All the models were adjusted for age, sex, marital status, highest level of education, participation in the labour force, Indigenous origin, geographic residency, smoking habits, Alcohol drinking, physical activity, and body Mass Index. 4. Ref means reference category. 5. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.

older, and when cognitive function deteriorates, the capacity to track physical performance may also decline (Atkinson et al., 2010). Besides, older adults were more vulnerable to comorbid chronic conditions, which caused them to judge their health less positively.

4.2. Cognitive impairment and mental health

The findings provided evidence that participants with cognitive impairment exhibited poorer mental health compared to those without cognitive impairment. A recent Australian study revealed that people with cognitive impairment tended to have a lower HRQoL where older Australians with cognitive impairment had lower mental component summary (MCS) scores compared to those without cognitive impairment (Keramat et al., 2023). Another study found that cognitive deficits have an impact on the ability of individuals with mental illness to accomplish daily tasks, both when they are experiencing acute symptoms and when they are in periods of remission (Clements et al., 2015). Depression, anxiety, and loneliness are possible channels through which cognitive impairment might affect mental health. For example, it was found that cognitive impairment increased the likelihood of experiencing depression and anxiety (Yates et al., 2013), and participants with mild cognitive impairment were more likely to experience symptoms of minor depression, such as feeling low on energy, sluggish, and worse in the mornings (Kumar et al., 2006). Additionally, cognitive decline has been identified as a predictor for self-reported loneliness (Boss et al., 2015; Burholt et al., 2017) which may be detrimental to mental health.

4.3. Cognitive impairment and self-assessed health

This study observed a substantial decrease in self-assessed health among those with cognitive impairment compared to those without cognitive impairment. This result aligns with previous research suggesting a link between lower cognitive function and poorer self-reported health (Kim, 2021). The inverse association between cognitive impairment and poor self-assessed health can be attributed to the fact that cognitive impairment increases the probability of disability in older individuals (Di Carlo et al., 2000; Whitson et al., 2014), and adults with disability tended to report lower self-rated health (Carlson et al., 2013).

4.4. Cognitive impairment and health satisfaction

This study also examined the association between cognitive impairment and health satisfaction. The results showed that people with cognitive impairment had lower levels of health satisfaction than those without cognitive impairment. A prior study provided compelling evidence of an association between moderate and severe cognitive impairment and a decrease in HRQoL. More specifically, a decrease in physical component summary score (PCS) score (Keramat et al., 2023). Poor health satisfaction among people with cognitive impairment can be ascribed to decreased levels of health satisfaction. A recent study found individuals with cognitive disorders, such as autism, attention deficit, and memory loss, exhibit lower levels of satisfaction with their health compared to the general population (Stone et al., 2023). Cognitive impairment is frequently underdiagnosed in hospital settings, and even when found, patients may still face adverse health outcomes due to disparities in care. These disparities might manifest as health-related

symptoms being disregarded because of the patient's impairment, or negative attitudes from healthcare staff (Australian Commission on Safety and Quality in Health Care, 2019).

4.5. Implications for policy and practice

Efforts to tackle health inequalities should focus on attaining fairness in health and health outcomes, rather than just equal allocation of resources in the healthcare system (Whitehead, 1990). The findings indicate that disability prevention strategies for older adults with cognitive impairment should include evaluating the health outcomes of their care and integrating this assessment into their care and support plans. Early detection of cognitive decline might enhance older adults' satisfaction with their health and potentially prevent them from being disabled in the future. The Australian Commission on Safety and Quality in Health Care has developed numerous resources to support the safety and quality improvement systems in Australian health care, including eight National Safety and Quality Health Service (NSQHS) standards, which are a national statement on the type and quality of care that all patients should receive (Australian Commission on Safety and Quality in Health Care, 2023). The standards encompass a wide range of acts that pertain to the provision and enhancement of care for individuals with cognitive impairment. Hospitals need to establish a protocol to identify and provide care for individuals who have or are at risk of cognitive impairment, promptly detect sudden worsening in mental state, and effectively regulate the administration of psychoactive medications (Australian Commission on Safety and Quality in Health Care, 2019). This study proposes that standard healthcare prevention, targeted intervention, and treatment procedures should prioritize older adults with cognitive impairment and other forms of disability. To best address this challenge, a coordinated approach involving clinicians, researchers who can guide interventions, and government support for funding and policy changes is required.

4.6. Strengths, limitations, and avenues for further research

One of the main strengths of this study is the utilization of an extensive population-based longitudinal design with a diverse range of older age cohorts. This is one of the first studies in Australia that examine the relationship between cognitive impairment and four distinct health outcomes using a nationally representative dataset. In addition, to prevent spurious associations, the study incorporated numerous confounding variables, including health-related behavioural characteristics (e.g., smoking habits, alcohol consumption, and levels of physical activity). Moreover, this study employed a longitudinal random-effects regression model to examine the between-person variations in the relationships between self-perceived health outcomes and cognitive impairment among older adults. Furthermore, we have provided evidence that cognitive impairment tests, specifically the SDMT and BDS, have been a validated tool to measure cognitive impairment.

The study has several limitations that warrant mention. Firstly, the reliance on self-reported data for health outcomes, including general health, mental health, self-assessed health, and health satisfaction, inherently introduces potential biases that may influence the validity of our findings. Social desirability bias, where individuals may overstate their health to conform to societal expectations or avoid stigma, is a significant concern, particularly for subjective assessments like mental health and self-assessed health. Recall bias, especially among older adults and those with cognitive impairments, can also distort the accuracy of reported health experiences. These biases may lead to either under- or overestimation of the true association between cognitive impairment and health outcomes. To mitigate these risks, we utilized validated self-report measures with established reliability and validity. Furthermore, statistical adjustments were made to account for potential confounders, including age, gender, socioeconomic status, and coexisting health conditions. Despite the inherent limitations of self-reported data, its feasibility for collecting data from large populations makes it a widely used and practical method in population-based research (Haque et al., 2024a; Haque et al., 2024b). Secondly, the lack of universally agreed-upon cut-off scores for the SDMT and BDS scales poses a limitation in accurately defining and encompassing the full spectrum of cognitive impairment. While these tests provide valuable insights into core cognitive processes, they may not fully capture the memory deficits commonly associated with cognitive impairment or dementia. This could have led to an underestimation of the prevalence of cognitive impairment in this sample. Employing memory-focused assessments, such as the Montreal Cognitive Assessment, Mini-Mental State Examination, or Saint Louis University Mental Status test, might have offered a more targeted approach and enhanced comparability with existing literature. Thirdly, while our findings suggest an association between cognitive impairment and health outcomes, it is important to acknowledge that this study cannot establish a definitive causal relationship. The observational nature of this study limits our ability to establish definitive causal relationships. Finally, the potential of reverse causality, where poorer health may contribute to cognitive decline, cannot be ruled out. Future research employing experimental or quasi-experimental designs could provide greater clarity on the causal pathways underlying these associations.

This study highlights the significant association between cognitive impairment and poor health outcomes among older Australians, pointing to several areas for further investigation. Future studies should explore the mechanisms underlying these associations, such as the role of social determinants, healthcare access, and lifestyle factors in mediating or moderating the relationship between cognitive impairment and health outcomes. Rigorous evaluations of innovative interventions, such as cognitive stimulation therapy, music therapy, and technology-assisted therapy, are needed to identify strategies for improving health outcomes in individuals with cognitive impairment. Such research could inform the development and implementation of effective and cost-efficient interventions within the Australian healthcare system. By expanding the scope of research to incorporate diverse measures of cognitive impairment, particularly those addressing memory deficits (e.g., Montreal Cognitive Assessment or Mini-Mental State Examination), it would be possible to enhance comparability with international studies and provide deeper insights into cognitive health. Additionally, investigating the impact of early interventions, such as physical activity, mental stimulation, or social engagement programs, could yield actionable recommendations for policymakers. Studies with longer follow-up periods and additional waves of the HILDA Survey would offer a more comprehensive understanding of the progression of cognitive impairment and its cumulative effects on health outcomes. Finally, qualitative research capturing the lived experiences of individuals with cognitive impairment and their caregivers could complement quantitative findings, providing a holistic perspective on the challenges faced and potential strategies to enhance their well-being.

5. Conclusions

This paper examined the association between cognitive impairment and four distinct health outcomes among older adults using a nationally representative sample. The findings of our research fill an essential gap in the current body of literature since earlier studies on this topic were limited in scope. The findings suggest a significant association between cognitive impairment and reduced well-being across multiple dimensions. The identified association indicate that cognitive decline presents a significant risk not only to mental health but also to physical and perceived well-being. This holistic understanding underscores the necessity of reviewing and incorporating cognitive assessment into standard clinical protocols for adults, especially in older individuals.

This research underscores the importance of healthcare practitioners prioritizing cognitive assessments during routine patient consultations, particularly for older adults. By incorporating cognitive testing into

standard care, healthcare providers can support primary prevention efforts and improve health outcomes for individuals with cognitive decline. Specifically, we recommend including cognitive screening as part of regular health check-ups for older adults, especially those aged 50 years and above, using validated tools such as the Montreal Cognitive Assessment (MoCA) or Mini-Mental State Examination (MMSE). Additionally, clinical pathways should be established to facilitate early intervention in the event of a diagnosis of cognitive impairment diagnosis, with referrals to multidisciplinary specialists such as occupational therapists, dietitians, and mental health counsellors. To maintain the currency of clinical practice, we recommend the regular update of clinical recommendations informed by growing scientific and clinical evidence, as well as findings from longitudinal research and randomised controlled trials.

Moving forward, further research is essential to explore the mechanisms linking cognitive impairment to various health outcomes. Recognising modifiable risk factors that could inform preventive strategies will be crucial in mitigating the impact of cognitive decline on the health and well-being of older adults.

CRediT authorship contribution statement

Rezwanul Haque: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Khorshed Alam:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Conceptualization. **Jeff Gow:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Christine Neville:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization. **Syed Afroz Keramat:** Writing – review & editing, Supervision, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Ethical approval and consent to participant

This study used secondary data from de-identified existing unit records from the HILDA Survey, so ethical approval was not required. However, the authors completed and signed the Confidentiality Deed Poll and sent it to NCLD (https://ncldresearch@dss.gov.au) and ADA (https://ada@anu.edu.au) before receiving approval for their data application. The datasets analysed and/or generated during the current study are subject to the signed confidentiality deed.

Declaration of Generative Al and Al-assisted technologies in the writing process

During the preparation of this work, the author(s) used Grammarly and OpenAI in order to improve the readability and language of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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Declaration of competing interest

"I have nothing to declare"

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.104770.

Data availability

The data were obtained from the Melbourne Institute of Applied Economic and Social Research (https://melbourneinstitute.unimelb.edu.au/). Though the information is not openly available, appropriately qualified researchers can access the data after following their protocols and meeting their requirements. Their contact address is Melbourne Institute of Applied Economic and Social Research, the University of Melbourne, VIC 3010, Australia.

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7.2 Links and implications

The identified associations suggest that cognitive decline presents a critical risk factor for deteriorating health outcomes. This comprehensive understanding emphasises the need to incorporate cognitive assessments into standard clinical practices, particularly for older adults. Early identification of cognitive impairment offers an opportunity to develop targeted interventions that can mitigate adverse health effects and potentially delay the progression to more severe disability. Given the anticipated rise in dementia and cognitive decline owing to an ageing population, it is crucial to establish effective methods for detecting and addressing cognitive impairment at earlier stages. The research highlights the importance of healthcare practitioners prioritising cognitive assessments during routine patient visits, especially for older individuals. By integrating cognitive screening into regular care, healthcare providers can enhance prevention efforts and improve overall health outcomes for individuals with cognitive decline. The following chapter explores a potential intervention strategy aimed at improving the HRQoL of individuals living with cognitive impairment.

Note: Appendix E provides supplementary material and associated appendix tables, as referenced in this chapter.

CHAPTER 8: PAPER 6 - STAYING ACTIVE, STAYING SHARP: THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND HEALTH-RELATED QUALITY OF LIFE FOR PEOPLE LIVING WITH COGNITIVE IMPAIRMENT

8.1 Introduction

This chapter presents the findings of the sixth and final study, which investigates the association between physical activity and HRQoL in older Australians with cognitive impairment. While the beneficial health effects of physical activity, including its role in cognitive health, are well-established, the specific relationship between physical activity and HRQoL in this population within the Australian context remains under-explored. This study addresses this critical gap in the literature by examining this association within a large population-based cohort. The findings of this research have significant implications for public health policy, informing the development of evidence-based interventions that promote physical activity and enhance the HRQoL of older Australians with cognitive impairment.

Quality of Life Research
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Staying active, staying sharp: the relationship between physical activity and health-related quality of life for people living with cognitive impairment

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Abstract

Background Physical inactivity is a major global health concern and has been identified as a risk factor for cognitive impairment. In Australia, the long-term relationship between physical activity and health-related quality of life (HRQoL) in individuals with cognitive impairment remains under researched. This study aims to address this knowledge gap by using data from a population-based longitudinal study.

Methods We used data from two waves (wave 12 [2012] and wave 16 [2016]) of the Household, Income and Labour Dynamics in Australia (HILDA) Survey. Our final analytic sample consisted of 1,168 person-year observations from 985 unique individuals. To investigate the association between physical activity and HRQoL, we employed random-effects Generalized Least Squares (GLS) model.

Results We found that participants engaging in physical activity, <1 to 3 times per week, showed significant positive associations with the Physical Component Summary (PCS) score [β=4.41, Standard Error (SE)=0.68], Mental Component Summary (MCS) score (β=2.55, SE=0.74), and SF-6D utility value (β=0.05, SE=0.007) compared to those who did not perform any physical activity. Similarly, participants who engaged in physical activity more than three times per week to every day had notably higher scores in PCS (β=7.28, SE=0.82), MCS (β=4.10, SE=0.84), and SF-6D utility values (β=0.07, SE=0.009).

Conclusion There is clear evidence that performing physical activity is positively associated with improved HRQoL in people with cognitive impairment. Our findings underscore the critical role of public health initiatives, such as health education and community-based programs, in promoting physical activity to enhance the HRQoL of older Australians living with cognitive impairment.

Keywords Australia · Cognitive impairment · Health-related quality of life (HRQoL) · Physical activity

Introduction

The rising life expectancy, mostly driven by advancements in medical technology, is contributing to a growing global population of older adults aged 65 years and over [1, 2]. By 2066, the proportion of Australians aged 65 years or over is forecasted to rise to between 21% and 23%, a notable jump from the 16% recorded in 2020 [3]. Older adults are at a higher risk of experiencing cognitive decline, impacting their thinking, memory, concentration, and other brain functions [4]. Cognitive impairment, varying from mild to severe, is a major factor contributing to dependence and disability among older adults [5]. Mild cognitive impairment (MCI) is a condition whereby a person's cognitive function

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is below normal, although they do not meet the criteria for dementia [6, 7]. People with MCI possess a significantly elevated risk of progressing to dementia relative to the general population [8], with an annual progression rate estimated between 10 and 15% [9, 10]. According to a recent meta-analysis, approximately 15% of community-dwelling adults aged 50 years and over are affected by MCI globally [11]. The estimated rate of cognitive impairment among Australians aged 65 years and older ranges from 7.7% to 33.3% [12, 13]. While currently no curative treatments exist for cognitive impairment related to dementia [14], non-pharmaceutical approaches remain a cornerstone of treatment for older adults experiencing cognitive impairment [8]. According to the World Health Organization, non-pharmacological interventions are recommended as the primary strategy for managing dementia symptoms and improving the well-being and quality of life of people living with dementia [15].

People with cognitive impairment have a higher propensity for physically inactive lifestyle [16], which may subsequently increase their risk of developing dementia [17] and aggravate cognitive decline [18]. Moreover, chronic illnesses along with physical inactivity can have a detrimental impact on people's health and well-being, resulting in decreased overall health, reduced physical performance, and lower health-related quality of life (HRQoL) [19, 20]. HRQoL is a key component of assessing the health and well-being of older adults, providing valuable insights into their overall quality of life during the ageing process [21], and can inform decisions about preventing and treating illnesses [22].

Regular physical activity has many positive effects on health, both physical and mental [23]. Existing evidence based on cross-sectional [24–26] and longitudinal data [27, 28] have consistently demonstrated that people who engage in recommended levels of physical activity have better HRQoL compared to those who are less active, particularly among older population. Additionally, a recent systematic review emphasized that engaging in frequent physical activity can benefit older adults by enhancing their functional mobility, independence, reducing anxiety, improving balance, and fostering better social interactions [29]. While some longitudinal studies in Australia have shown a positive relationship between physical activity and HRQoL, these studies have primarily focused on the general population [30] or older people with disabilities [31]. Existing research suggests that physical activity is a strong protective factor against cognitive decline and can have beneficial effects on both cognitive and non-cognitive functions in people with cognitive impairment and dementia [6, 14, 32]. For instance, a meta-analysis of 18 randomized controlled trials suggests that physical activity improved cognitive function and quality of life for individuals living with dementia [33]. The study also revealed a positive effect of physical activity interventions on cognitive function across different population groups [33]. The primary analysis showed a substantial positive effect with a standardized mean difference (SMD) of 0.42 (95% CI: 0.23, 0.62). In individuals with Alzheimer's disease (AD), physical activity interventions also demonstrated a beneficial effects (SMD = 0.38, 95% CI: 0.09, 0.66). A positive effect was also observed in a broader group including individuals with AD or a non-AD dementia diagnosis (SMD = 0.47, 95% CI: 0.14, 0.80). These findings consistently support the notion that physical activity interventions can have a positive impact on cognitive function in individuals living with cognitive impairment and dementia.

Physical activity is an effective intervention for promoting brain health in older adults, as it offers a low-cost and low-risk approach to improve cognitive function [34]. People with disabilities often benefit more from exercise than people without disabilities, especially for overall health and well-being [33, 35]. According to the World Health Organisation, older people may mitigate cognitive decline by performing a minimum of 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic activity, along with strength training per week [36]. Despite numerous efforts to encourage physical activity among Australians, only 18% of the adult population met the recommended guidelines in 2022 [37].

The beneficial effects of physical activity are well-established, particularly in terms of preventing and managing cognitive decline. However, the relationship between physical activity and HRQoL among older Australians with cognitive impairment has not been thoroughly investigated. A significant gap exists in Australian research regarding the relationship between physical activity levels and HRQoL specifically among older adults with cognitive impairment. To address this gap, we explored the relationship between physical activity and HRQoL using a nationally representative longitudinal data. Insights from this research could inform evidence-based policies aimed at improving the HRQoL of people with cognitive impairment.

Methods

Data source

Our empirical analyses utilized data from the Household, Income, and Labour Dynamics in Australia (HILDA) Survey. Since 2001, the survey has been collecting yearly data from a sample of Australians who are representative of the whole country. The study monitors a cohort of almost 17,000 people over their life course, gathering data on a range of topics including family and household dynamics,

employment and earnings, educational attainment, and health outcomes. The HILDA Survey used a mix of face-to-face interviews and self-completion questionnaires to obtain this information [38]. A comprehensive overview of the HILDA dataset can be found elsewhere [39].

Study participants

Our analysis used data from two time points of the HILDA Survey: the year 2012 (wave 12) and 2016 (wave 16). These specific waves were chosen for the study because they are the only waves within the dataset that include questions specifically designed to assess cognitive impairment. The HILDA survey assessed cognitive function of the survey respondents using validated instruments, including the Symbol Digit Modalities Test (SDMT) and the Backward Digit Span Test (BDS). While the scores obtained from the BDS and SDMT provide valuable insights into specific cognitive domains (working memory and processing speed, respectively), they may not fully capture the overall cognitive profile of an individual. A limitation of these tests is the lack of established cut-off scores, which may hinder accurate diagnosis of cognitive impairment. More comprehensive neuropsychological assessments, such as the Montreal Cognitive Assessment (MoCA) [40], Mini-Mental Status Examination (MMSE) [41], or Saint Louis University Mental Status (SLUMS) examination [42], offer a nuanced and reliable evaluation of cognitive function. Due to the unavailability of data measured through these scales, we utilized the BDS and SDMT to assess cognitive impairment for this study. Evidence suggests that the BDS and SDMT have been previously used to detect cognitive impairment, particularly in people with multiple sclerosis [43, 44] and hospitalized patients [45].

The BDS cognitive evaluation exam involves individuals reciting a sequence of numbers in reverse order [45]. The BDS evaluates the cognitive capacity of working memory on a scale of 0 to 8. The SDMT is a cognitive assessment tool that measures a person's ability to process information quickly and accurately. The SDMT requires participants to match a list of numbers with corresponding geometric shapes as quickly and accurately as possible [46]. The SDMT evaluates the cognitive function of the central brain and provides scores that range from 0 to 110. The threshold for identifying cognitive impairment in this study was informed by an established criterion. Previous research has categorized cognitive impairment based on standardized thresholds: individuals scoring ≥ 1.0 standard deviation (SD) below the mean on either the BDS or SDMT (or both) are classified as having mild cognitive impairment, while those scoring ≥ 1.5 SD below the mean on both tests are identified as having severe cognitive impairment [47–49]. This study consolidated mild and severe cognitive impairment into a single category, focusing on cognitive impairment as a unified construct. Cognitive impairment was therefore defined as scoring ≥ 1 SD below the mean on both the BDS and SDMT. This criterion aligns with empirical thresholds reported in prior studies and supports the objectives of this research. Accordingly, participants were considered cognitively impaired if they scored ≤ 3 on the BDS and ≤ 30 on the SDMT. Given that cognitive impairment primarily affects older people, our study focused on Australians aged 50 years and over. Therefore, the inclusion criteria for people in the sample were as follows: (i) being 50 years of age or older; (ii) identified as living with cognitive impairment; and (iii) having valid information on the outcome and key factors of interest. Applying these inclusion criteria resulted in an unbalanced panel of 1,168 yearly observations from 985 unique individuals. Figure 1 depicts the sample selection process and missing data analysis.

Outcome variable

The primary outcome variable in our study was HRQoL, which we measured using the 36-item Short-Form Health Survey (SF-36). The SF-36 is a widely used and reliable instrument that assesses an individual's physical and mental health using a standardized questionnaire [50]. The questionnaire comprises 36 items that evaluate eight specific health domains: physical functioning (PF), role physical functioning (RP), role emotional functioning (RE), social functioning (SF), mental health (MH), vitality (VT), bodily pain (BP), and general health (GH). Each dimension of the SF-36 has a theoretical range of 0 to 100, where 0 indicates the worst possible health and 100 represents the best possible health. The SF-36 data generally yields two summary measures: the physical-component summary (PCS) and the mental-component summary (MCS) [51]. The PCS and MCS were standardised by linear z-score transformations, resulting in a mean of 50 and a standard deviation of 10. The theoretical ranges of PCS and MCS scores are 4.54 to 76.09 and -1.21 to 76.19, respectively, with higher scores indicating improved health [30].

In addition to the PCS and MCS, the SF-36 can also be used to generate the SF-6D, a health-state utility index, which is another internationally recognized measure of HRQoL [52]. The SF-6D utility index is derived from a subset of six subscales of the SF-36 (PF, RP, RE, SF, VT, and BP), with a theoretical range from 0.29 (indicating poor health) to 1 (representing optimal health) [52].

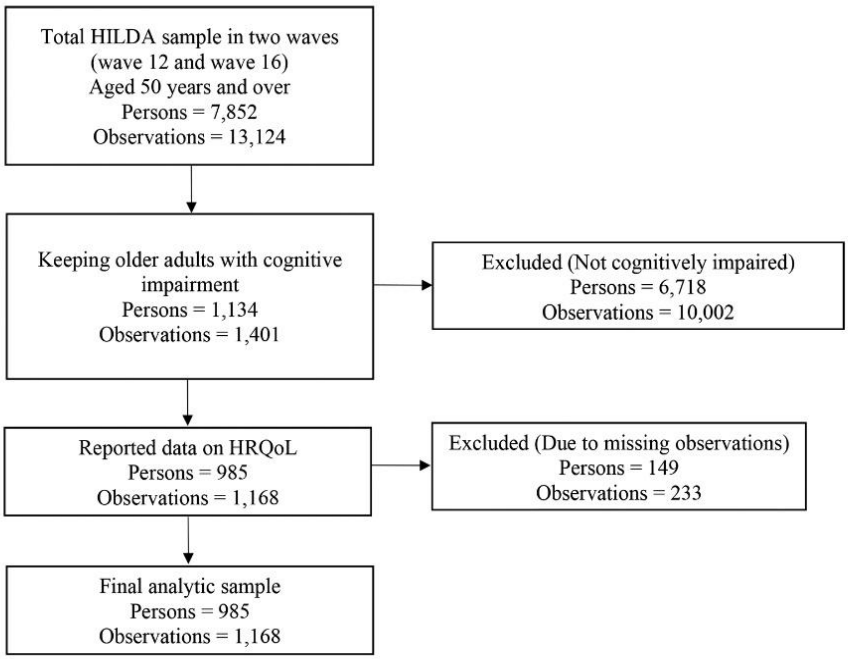

Fig. 1 Participants' flow in the analytic sample and missing data

Exposure variable

This study investigates the frequency of moderate-to-intense physical activity. To assess this, the research relies on a self-administrated question consistently employed across all waves of the HILDA Survey. This question inquires: 'In general, how often do you participate in moderate or intensive physical activity for at least 30 minutes? Moderate physical activity will cause a slight increase in breathing and heart rate such as brisk walking.' The participants' replies were categorised into six pre-determined categories: 'not at all', 'less than once per week', '1 or 2 times per week', '3 times per week', 'more than 3 times per week but not every day', and 'every day'. We simplified the physical activity categories into three groups: 'not at all,' '<1 to 3 times per week' (by merging the groups 'less than once per week', '1 or 2 times per week', and '3 times per week'), and 'more than 3 times per week to everyday' (by merging the groups 'more than 3 times per week but not every day', and 'every day'). The categorization of physical activity in this study adheres to the established criteria of the Australian National Physical Activity Guidelines for Adults [53], demonstrating close concordance with the World Health Organization's guidelines [54]. This methodological approach has been adopted in prior empirical research utilizing the HILDA survey data [31, 55].

Covariates

We incorporated several individual-level socio-demographic, health-related behavioural characteristics, and health-related characteristics as covariates. The socio-economic and demographic characteristics analysed included: age (50–64 years, and ≥65 years), gender (male, and female), marital status (unpartnered and partnered), highest level of education (year 12 and below, professional qualifications, and university qualifications), household yearly disposable income (Quintile 1 [poorest], and Quintile 5 [richest]), participation in the labour force (employed, and unemployed or not in the labour force), Indigenous origin (non- Aboriginal or Torres Strait Islander, and Aboriginal or Torres Strait Islander), geographic residency (major city, and regional or remote area). Additionally, two health-related behavioural characteristics that can impact health outcomes were included: smoking habits (former smoker or never smoked, and currently smoking), and alcohol drinking (former drinker or never drunk, and active drinker). Furthermore, Body Mass Index (underweight, healthy weight, overweight, and obese) and disability status (no versus yes), were considered as the proxy of participants' health-related characteristics.

Estimation strategy

We commence our analysis by calculating descriptive statistics for the study sample. For categorical variables,

frequencies and percentages are calculated to describe their distribution. For continuous variables, means and standard deviations are calculated to summarize their central tendency and variability. These descriptive statistics are calculated separately for baseline, final wave, and pooled data to provide an overview of the data across different time points. We also present a summary of participants' SF-36 component summary scores, and SF-6D utility values according to their physical activity levels.

The outcome variables (PCS, MCS, and SF-6D) used in our study were measured on a continuous scale. Therefore, we employed a longitudinal random-effects GLS regression model to examine the relationship between physical activity and HRQoL, allowing us to identify individual variations in this association. Additionally, the random-effects structure enables us to control for unobserved individual heterogeneity and potential confounders, thereby enhancing the reliability of our findings.

The random-effects GLS regression can be expressed in the following functional form:

$$HRQoL_{it} = \alpha + \beta_1 PA_{it} + \beta_2 Z_{it} + \mu_i + \epsilon_{it}$$

HRQoL denotes the three outcome variables: PCS, MCS and SF-6D. The level of physical activity, PA, is an exposure variable. Z_{it} represents the vector consisting of time-varying and time-invariant control variables. The model parameter of interest to be estimated is denoted as β_1, and β_2 indicates the vector of coefficients while α is the model's grand intercept. The analysis considers two parts of the error: individual-specific components, μ, that stays the same over time, and time and person-specific error, $?_{it}$, which is assumed to be uncorrelated with the independent variables.

Statistical significance was determined using a p-value threshold of 0.05. Lower p-values (<0.01 and <0.001) were reported to indicate stronger evidence of significance. Stata version 17.0 (StataCorp LLC, College Station, TX: USA) was employed for all statistical analyses.

Results

Table 1 displays the socio-economic, demographic, health-related behavioural, and health-related characteristics of the analytic sample at baseline, final wave, and pooled across waves. In the pooled data, most participants were older adults, with 79% aged 65 years or older, 48% were female, and 53% were partnered. Among the study sample, 8% had a university degree, about 16% were employed, just below 2% identified as Aboriginal and Torres Strait Islander, 57% resided in major cities, 11% were smokers, 66% drank alcohol, 26% were obese, and 65% had a disability.

Table 2 displays the summary statistics of key variables, including PCS, MCS, SF-6D utility value, eight dimensions of the SF-36, and levels of physical activity among the study participants. In the pooled data, the mean PCS, MCS, and SF-6D values of the study participants were 37.86, 48.15 and 0.67, respectively. The mean score of the SF-36's eight dimensions were as follows: PF (56.47), RP (46.24), RE (64.14), SF (69.44), MH (71.88), VT (54.27), BP (56.50), and GH (54.46). Regarding physical activity, the pooled data also showed that approximately 30% of the participants do not perform in any physical activity, around 44% participated in moderate or intense physical activity < 1 to 3 times per week, and around 26% engaged in moderate or intense physical activity more than 3 times per week to every day.

Figure 2 depicts the mean PCS scores, MCS scores, and SF-6D utility value among older Australians with cognitive impairment based on their physical activity levels. The results show that those who were physically inactive exhibited lower PCS, MCS, and SF-6D scores compared to their counterparts. For instance, in wave 16, people who never engaged in physical activity had the lowest scores (PCS = 30.69, MCS = 44.79, SF-6D = 0.61), followed by those engaged in moderate or intense physical activity < 1–3 times per week (PCS = 38.95, MCS = 48.19, SF-6D = 0.68), with the highest scores observed in those engaged in moderate or intense physical activity more than 3 times per week to every day (PCS = 44.07, MCS = 51.10, SF-6D = 0.73).

Table 3 presents the results obtained from the random-effects GLS regression models. We found that older Australians with cognitive impairment who engaged in moderate or intense physical activity for at least 30 min had higher PCS, MCS and SF-6D values compared to those who were physically inactive. For example, model 1 demonstrated that people who engaged in moderate or intense physical activity < 1–3 times per week, and more than 3 times per week to everyday had higher PCS scores 4.41 (β = 4.41, SE = 0.68) and 7.28 (β = 7.28, SE = 0.82), respectively, compared to those who were physically inactive. Similarly, model 2 revealed that those who engage in moderate or intense physical activity < 1–3 times per week, and more than 3 times per week to everyday had higher MCS scores 2.55 (β = 2.55, SE = 0.74) and 4.10 (β = 4.10, SE = 0.84), respectively, relative to physically inactive people. Additionally, from model 3, we found that participants engaged in moderate or intense physical activity < 1–3 times per week, and more than 3 times per week to everyday had greater SF-6D utility values 0.05 (β = 0.05, SE = 0.007) and 0.07 (β = 0.07, SE = 0.009), respectively, in comparison to those who did not engage in any physical activity.

Table 1 Distribution of analytic sample (socio-economic and demographic, health-related behavioural characteristics, and health-related characteristics: baseline, final, and pooled across all waves)

Variables	Baseline Wave (2012)		Final Wave (2016)		Pooled data (2012–2016)	
	n	%	*n*	%	*n*	%
Socio-economic, and demographic characteristics						
Age group						
50–64 years	131	20.70	116	21.68	247	21.15
65 years and over	502	79.30	419	78.32	921	78.85
Gender						
Male	325	51.34	286	53.46	611	52.31
Female	308	48.66	249	46.54	557	47.69
Marital status						
Unpartnered	306	48.34	246	45.98	552	47.26
Partnered	327	51.66	289	54.02	616	52.74
Highest level of education						
Year 12 and below	422	66.67	327	61.12	749	64.13
Professional qualifications	167	26.38	161	30.09	328	28.08
University qualifications	44	6.95	47	8.79	91	7.79
Household yearly disposable income (Quintile)						
Quintile 1 (poorest)	168	26.54	66	12.34	234	20.03
Quintile 2	134	21.17	100	18.69	234	20.03
Quintile 3	94	14.85	139	25.98	233	19.95
Quintile 4	118	18.64	117	21.87	235	20.12
Quintile 5 (richest)	119	18.80	113	21.12	232	19.86
Participation in labour force						
Employed	98	15.48	85	15.89	183	15.67
Unemployed or not in the labour force	535	84.52	450	84.11	985	84.33
Indigenous origin						
Non-Aboriginal or Torres Strait Islander	624	98.58	524	97.94	1,148	98.29
Aboriginal or Torres Strait Islander	9	1.42	11	2.06	20	1.71
Geographic residency						
Major cities	356	56.24	309	57.76	665	56.93
Regional/remote	277	43.76	226	42.24	503	43.07
Health-related behavioural characteristics						
Smoking habits						
Former smoker/never smoked	557	87.99	479	89.53	1,036	88.70
Currently smoking	76	12.01	56	10.47	132	11.30
Alcohol drinking						
Former drinker or never drunk	195	30.81	199	37.20	394	33.73
Active drinker	438	69.19	336	62.80	774	66.27
Health-related characteristics						
Body Mass Index (BMI)						
Underweight	24	3.79	13	2.43	37	3.17
Healthy weight	225	35.55	178	33.27	403	34.50
Overweight	233	36.81	189	35.33	422	36.13
Obesity	151	23.85	155	28.97	306	26.20
Disability status						
No	229	36.18	183	34.21	412	35.27
Yes	404	63.82	352	65.79	756	64.73

Notes (1) The pooled study comprised a total of 1,168 person-year observations from 985 distinct individuals. (2) The OECD-modified equivalency scale was used to calculate the equivalised yearly household income, which was then divided into quintiles

Table 2 Summary statistics: subjective health scores, and level of physical activity

Characteristics	Baseline Wave (2012)		Final Wave (2016)		Pooled data (2012–2016)	
	n	% /mean (SD)	*n*	% /mean (SD)	*n*	% /mean (SD)
SF-36 domain scores						
Physical functioning	633	56.76 (29.27)	535	56.11 (29.88)	1,168	56.47 (29.54)
Role physical	633	46.87 (44.88)	535	45.48 (45.27)	1,168	46.24 (45.04)
Role emotional	633	64.01 (43.38)	535	64.30 (43.40)	1,168	64.14 (43.37)
Social functioning	633	70.97 (27.17)	535	67.64 (28.36)	1,168	69.44 (27.76)
Mental health	633	72.22 (18.43)	535	71.48 (17.80)	1,168	71.88 (18.14)
Vitality	633	54.80 (21.44)	535	53.64 (21.08)	1,168	54.27 (21.28)
Bodily pain	633	57.06 (26.37)	535	55.84 (26.75)	1,168	56.50 (26.54)
General health	633	55.31 (23.72)	535	53.46 (22.85)	1,168	54.46 (23.33)
SF-36 component summary score						
PCS	633	38.09 (11.91)	535	37.59 (12.11)	1,168	37.86 (12.00)
MCS	633	48.43 (10.67)	535	47.82 (10.57)	1,168	48.15 (10.62)
SF-6D utility value	633	0.67 (0.13)	535	0.68 (0.13)	1,168	0.67 (0.13)
Levels of physical activity						
Not at all	184	29.07	170	31.78	354	30.31
< 1 to 3 times per week	277	43.76	233	43.55	510	43.66
More than 3 times per week to everyday	172	27.17	132	24.67	304	26.03

Notes (1) The pooled study comprised a total of 1,168 person-year observations from 985 distinct individuals. (2) PCS = physical component summary, MCS = mental component summary, and SF-6D = Short-Form Six-Dimension health utility index

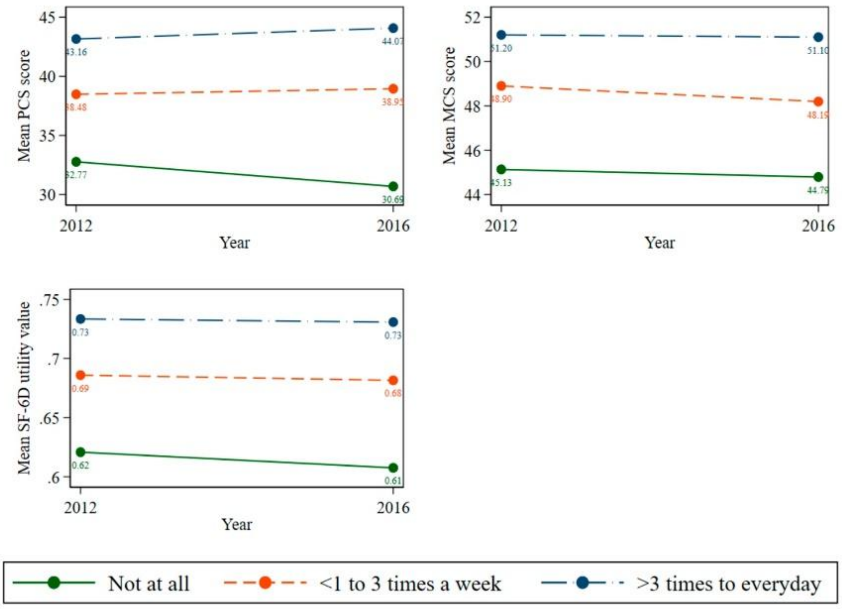

Fig. 2 Mean PCS, MCS, and SF-6D utility values by the status of level of physical activities. Note: 1. Abbreviation: PCS = physical component summary, MCS = mental component summary, and SF-6D = Short-Form Six-Dimension health utility index

Robustness check

We also fitted random-effects generalised estimating equation (GEE) regression model as part of the sensitivity analysis. The model initially reported in Table 3 was re-assessed and presented in Appendix Table A1 in the online supplemental material. The findings of the sensitivity analysis closely matched the baseline values for all the factors of interest. We found that older Australians with cognitive impairment who engaged in moderate or intense physical activity had higher PCS, MCS and SF-6D values compared to those who were physically inactive. For example, participants engaged in moderate or intense physical activity for more than 3 times per week to everyday had greater PCS (β = 7.46, SE = 0.76), MCS (β = 4.61, SE = 0.81) and SF-6D (β = 0.08, SE = 0.008) scores, in comparison to those who did not engage in physical activity.

Table 3 Abridged results from random-effects GLS regression models of HRQoL (MCS, PCS and SF-6D), pooled analysis

Variables	Model 1	Model 2	Model 3
	PCS	MCS	SF-6D
	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value
Levels of physical activity			
Not at all (ref)			
< 1 to 3 times per week	4.41 (0.68), 0.001	2.55 (0.74), 0.001	0.05 (0.007), 0.001
More than 3 times per week to everyday	7.28 (0.82), 0.001	4.10 (0.84), 0.001	0.07 (0.009), 0.001

Notes (1) The sample size is 985 individuals and 1,168 observations. (2) All models were adjusted for age, gender, marital status, highest education level of education, household yearly disposable income, participation in the labour force, Indigenous origin, geographic residency, smoking habits, alcohol drinking, BMI and disability status. (3) PCS = physical component summary, MCS = mental component summary, and SF-6D = Short-Form Six-Dimension health utility index. (4) Ref means reference category. (5) Cluster-robust standard errors (SE) are reported in the parenthesis

Table 4 Abridged results from random-effects GLS regression models of HRQoL (MCS, PCS and SF-6D) by age

Variables	Age (50–64 years)			Age (65 years and above)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	PCS	MCS	SF-6D	PCS	MCS	SF-6D
	Coefficient (SE), P-value	Coefficient (SE), P-value	Coefficient (SE), P-value	Coefficient (SE), P-value	Coefficient (SE), P-value	Coefficient (SE), P-value
Levels of physical activity						
Not at all (ref)						
< 1 to 3 times per week	3.62 (1.69), 0.03	1.18 (1.77), 0.50	0.04 (0.01), 0.03	4.36 (0.75), 0.001	2.94 (0.82), 0.001	0.04 (0.008), 0.001
More than 3 times per week to everyday	6.67 (1.78), 0.001	3.09 (1.88), 0.10	0.06 (0.02), 0.01	7.41 (0.91), 0.001	4.51 (0.96), 0.001	0.07 (0.011), 0.001

Note (1) All models were adjusted for age, gender, marital status, highest education level of education, household yearly disposable income, participation in the labour force, Indigenous origin, geographic residency, smoking habits, alcohol drinking, BMI and disability status. (2) PCS = physical component summary, MCS = mental component summary, and SF-6D = Short-Form Six-Dimension health utility index. (3) Ref means reference category. (4) Cluster-robust standard errors (SE) are reported in the parenthesis

Sensitivity analysis

We conducted a missing data analysis, as presented in Appendix Table A2. With the exception of Indigenous origin, SF-6D utility score, and BMI, the proportion of missing observations for most variables was less than 5%. To address the missing data, we applied the last value carry forward imputation technique. After imputation, we applied the random-effects GLS technique and compared the results with the estimates obtained from the complete case analysis (Table 3). The regression results from the imputed data were consistent in direction with the baseline regression findings. However, the magnitudes of the physical activity estimates varied slightly across the HRQoL measures. For example, participants engaged in moderate or intense physical activity for more than 3 times per week to everyday had greater PCS (β = 7.53, SE = 0.79), MCS (β = 3.97, SE = 0.83) and SF-6D (β = 0.07, SE = 0.009) scores, in comparison to those who did not engage in physical activity. The imputed regression analysis results are detailed in Appendix Table A3.

Heterogenous effect

To further explore the relationship between physical activity and HRQoL, we ran a series of random-effects Generalized Least Squares (GLS) regression models. These models were used to investigate how the association between physical activity and HRQoL might vary across different age and gender subgroups within the study population. The results indicated that, across both age groups (50–64 years and 65 years and older), people who participated in any form of moderate or intense physical activity for at least 30 min had significantly higher PCS, MCS, and SF-6D values compared to those who were physically inactive (see Table 4). For instance, among participants aged 65 years and over, those engaging in moderate or intense physical activity more than 3 times per week to everyday had significantly higher scores in PCS (β = 7.41, SE = 0.91), MCS (β = 4.51, SE = 0.96), and SF-6D (β = 0.07, SE = 0.011) compared to those who did not engage in physical activity (Models 4, 5 and 6 in Table 4). Similarly, irrespective of gender, individuals participating in any moderate or intense physical

Table 5 Abridged results from random-effects GLS regression models of HRQoL (MCS, PCS and SF-6D) by gender

Variables	Male			Female		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	PCS	MCS	SF-6D	PCS	MCS	SF-6D
	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value	Coefficient (SE), *P*-value
Levels of physical activity						
Not at all (ref)						
< 1 to 3 times per week	3.02 (0.97), 0.01	3.43 (1.06), 0.001	0.04 (0.01), 0.001	5.70 (0.95), 0.001	1.93 (0.98), 0.05	0.04 (0.01), 0.001
More than 3 times per week to everyday	6.90 (1.11), 0.001	6.11 (1.09), 0.001	0.08 (0.01), 0.001	7.16 (1.21), 0.001	2.10 (1.23), 0.08	0.05 (0.01), 0.001

Note (1) All models were adjusted for age, gender, marital status, highest education level of education, household yearly disposable income, participation in the labour force, Indigenous origin, geographic residency, smoking habits, alcohol drinking, BMI and disability status. (2) PCS = physical component summary, MCS = mental component summary, and SF-6D = Short-Form Six-Dimension health utility index. (3) Ref means reference category. (4) Cluster-robust standard errors (SE) are reported in the parenthesis

activity showed higher PCS, MCS, and SF-6D scores than those who were inactive (see Table 5). For example, female participants who engaged in moderate or intense physical activity more than 3 times per week to daily had greater PCS (β = 7.16, SE = 1.21), MCS (β = 2.10, SE = 1.23), and SF-6D (β = 0.05, SE = 0.01) scores compared to their inactive counterparts (Models 4, 5 and 6 in Table 5).

Discussion

Our research sought to evaluate the relationship between physical activity and HRQoL among older Australians living with cognitive impairment. We employed a mix of preference-based (SF-6D) and non-preference (SF-36 component summaries) measures to assess HRQoL. Our analysis, utilizing random-effects Generalized Least Squares (GLS) modelling, demonstrated that physical activity acts as a protective factor for HRQoL. We discovered that older Australians with cognitive impairment engaging in moderate or intense physical activity for at least 30 min had substantially greater PCS, MCS, and SF-6D utility values than their physically inactive counterparts.

Our results are consistent with earlier research conducted across various countries among general populations (e.g., had no cognitive impairment) and found a positive association between physical activity and HRQoL [24–27]. An earlier study also reported that consistent physical activity levels, including gradual increases in activity frequency, were linked to preserving or enhancing both physical and mental HRQoL in community-dwelling older adults [28]. Furthermore, two Australian longitudinal studies provided evidence that a higher frequency of moderate-to-vigorous intense physical activity was linked to an improved HRQoL [30, 31].

Our findings also align with one RCT study that demonstrated the benefits of aerobic exercise training in reducing the decline in HRQoL in older adults with mild cognitive impairment [57]. However, another RCT study did not find a significant positive effect of walking on quality of life within a similar cohort [56]. The observed discrepancies between our findings and those of prior studies may be explained by variations in research design, physical activity assessment methods, study populations, and the specific criteria used to diagnose cognitive impairment.

The relationship between physical activity and HRQoL may be explained by its positive effects on functional capacity and physical health, which promote a greater sense of independence and well-being [21]. These improvements are likely to enhance the physical aspects of HRQoL. Moreover, physical activity may benefit people with cognitive impairment by improving sleep quality and reducing depressive symptoms, thereby positively influencing HRQoL [57]. Additionally, physical activity may enhance HRQoL by affecting mood-related brain chemicals, such as neurotransmitters and endorphins [58, 59]. Regular physical activity also improves physical fitness, functionality, and a sense of control [26, 60, 61], and is associated with increased mental stimulation and better psychological health [26]. Social interaction may also be an important factor in explaining the observed relationship between physical activity levels and HRQoL. Many forms of physical activity, such as group exercise classes, walking clubs, or team sports, provide opportunities for social engagement, which has a positive impact on mental health and psychological well-being. Social interactions fostered through physical activity can reduce feelings of isolation and loneliness, particularly among individuals with cognitive impairment, thereby contribute to the improvement of the mental aspects of HRQoL [62, 63]. Furthermore, a history of regular physical activity may have a protective influence on future physical activity levels, HRQoL, and cognitive impairment. Engaging in physical activity throughout earlier life stages can have long-term benefits. These benefits, likely stemming from

the cumulative effects of improved muscle strength, cardiovascular health, and neural plasticity, may contribute to better physical and cognitive health in later years [64, 65]. This cumulative effect of early-life physical activity on physical and cognitive health may create a virtuous cycle. Improved physical and cognitive health can motivate continued engagement in physical activity, which in turn can further enhance HRQoL and create a positive feedback loop that supports overall well-being.

Strengths, limitations, and avenues for further research

Our study's strengths include its use of a comprehensive longitudinal design. To the best of our knowledge, this is the first observational study to examine the association between physical activity and HRQoL among people with cognitive impairment. The use of a validated instrument to measure HRQoL and cognitive impairment ensures the reliability of our findings. However, our study has some limitations that need to be mentioned. Firstly, the HILDA Survey's physical activity frequency measure may not have accurately captured the exact amount of time participants spent on physical activities, which could affect the precision of our results. Secondly, the reliance on self-reported data for physical activity and other covariates may introduce potential biases. Social desirability bias, characterised by the inclination of individuals to overstate their physical activity levels or underreport health limitations, is a significant concern. Recall bias, especially among older adults and those with cognitive impairments, can also distort the accuracy of reported physical activity engagement and HRQoL experiences. These biases may lead to either under- or overestimation of the true association between physical activity and HRQoL. Third, the absence of standardized cut-off scores for the SDMT and BDS limits their ability to accurately define and comprehensively assess the full range of cognitive impairment. Furthermore, while these tests provide valuable insights into specific cognitive domains, they may not adequately capture memory deficits, a core feature of cognitive impairment and dementia. This limitation could have potentially underestimated the prevalence of cognitive impairment in this study. The inclusion of memory-focused assessments, such as the Montreal Cognitive Assessment, Mini-Mental State Examination, or Saint Louis University Mental Status test, could have provided a more targeted approach and improved comparability with findings from other studies. Finally, the analysis did not account for potential confounding factors such as diet, stress levels, and comorbid conditions. These factors can significantly influence both physical activity levels and HRQoL. The unavailability of data on these factors in the HILDA Survey represents a major limitation. By not accounting for these factors, the study may not precisely estimated the relationship between physical activity and HRQoL among people with cognitive impairment. This may lead to confounding bias, distorting the observed relationship between physical activity and HRQoL due to the influence of these unobserved variables. This could result in spurious associations.

Future research could explore the economic implications of physical activity in people with cognitive impairment, including cost savings, work productivity, and reduction of overall health and economic burdens on the healthcare system. These research would provide valuable insights for policymakers and healthcare providers, guiding strategies and investments in initiatives concerning physical activity.

Implications for policy and practice

The findings of this research can be directly utilized by healthcare professionals who work with older adults with cognitive impairment to develop and implement more effective health promotion interventions that emphasize the importance of physical activity. In 2018, Australia became one of the pioneering nations in developing national physical activity guidelines tailored to older adults with cognitive impairment [66]. A narrative review further supported these guidelines, providing evidence that the recommendations for older adults could be adapted to meet the needs of individuals with cognitive impairment [67]. This conclusion was reached after comparing these guidelines with similar Canadian guidelines. Evidence suggests that older Australians today place a higher value on information and advice from healthcare professionals compared to other sources, highlighting their critical role in adopting recommendations [67]. By offering tailored guidance and support, healthcare professionals can assist individuals in achieving the recommended physical activity levels, which can lead to improved well-being. Our findings highlight the necessity of including physical activity in comprehensive care plans through bulk-billed GP services for older adults with cognitive impairment.

Conclusions

Our research provides substantial evidence of the positive relationship between physical activity and HRQoL in older people with cognitive impairment. Using longitudinal data from the HILDA Survey, we found that engaging in moderate to intense physical activity for at least 30 min is associated with improved HRQoL. These results highlight the significance of integrating physical activity into holistic strategies for enhancing the general well-being of

older Australians living with cognitive impairment. Health education and promotion initiatives must be implemented across all demographics to promote physical activity, especially amongst those with cognitive impairments. The SF-6D utility values derived from our research may serve as essential inputs for the forthcoming economic evaluation of intervention concerning physical activity. Thereby, our study findings will help policy makers to identify the cost-effective interventions concerning physical activity aimed at improving the health and well-being of older adults. Further research is needed to investigate the enduring advantages of physical activity on HRQoL in adults with cognitive impairment and to create tailored therapy that encourage physical activity.

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Data availability The data were obtained from the Melbourne Institute of Applied Economic and Social Research (https://melbourneinstitute.unimelb.edu.au/). Though the information is not openly available, appropriately qualified researchers can access the data after following their protocols and meeting their requirements. Their contact address is Melbourne Institute of Applied Economic and Social Research, the University of Melbourne, VIC 3010, Australia.

Declarations

Ethical approval This study used secondary data from de-identified existing unit records from the HILDA Survey, so ethical approval was not required. However, the authors completed and signed the Confidentiality Deed Poll and sent it to NCLD (https://www.dss.gov.au/) and ADA (https://ada@anu.edu.au) before receiving approval for their data application. The datasets analysed and/or generated during the current study are subject to the signed confidentiality deed.

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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8.2 Links and implications

This study has significant implications for healthcare professionals working with older adults with cognitive impairment. It highlights the importance of incorporating physical activity into health promotion interventions to improve HRQoL. Healthcare providers play a crucial role in helping older Australians meet physical activity guidelines, which can enhance overall well-being. The findings emphasise the need for physical activity to be included in comprehensive care plans, particularly through bulk-billed GP services, to ensure equitable access. The positive association between physical activity and HRQoL supports its integration into care strategies, and the SF-6D utility values from this research can inform future economic assessments of physical activity interventions.

This thesis includes six studies focusing on three key themes: (i) the prevalence and risk factors of dementia (Chapters 3 and 4); (ii) the adverse health outcomes (Chapters 5, 6, and 7); and (iii) potential strategies for improving the well-being of individuals with cognitive impairment (Chapter 8). The next chapter provides a concluding discussion and explores the policy implications derived from the findings of these studies.

Note: Appendix F provides supplementary material and associated appendix tables, as referenced in this chapter.

CHAPTER 9: CONCLUSION AND POLICY IMPLICATIONS

9.1 Chapter summary

This chapter provides a synthesis of the findings, conclusions, and policy implications derived from this thesis, which aimed to address critical gaps in understanding dementia and cognitive impairment in Australia. Dementia prevalence continues to rise in Australia, posing a significant public health challenge with substantial direct and indirect costs. To address this growing concern, this thesis focused on investigating the risk factors, adverse health outcomes, and potential improvements in HRQoL of people with dementia and cognitive impairment.

The research began by examining changes in the prevalence of dementia and explored associations with key risk factors, including i) geographic remoteness and ii) chronic pain. The thesis then assessed the relationship between cognitive impairment and dementia with iii) self-care limitations, iv) socio-economic inequalities in HRQoL, and v) health outcomes, such as general health and mental health, self-assessed health, and health satisfaction. Finally, the potential for improving HRQoL among people with cognitive impairment was explored by analysing the relationship between vi) physical activity and HRQoL as a modifiable factor.

This thesis utilised robust, nationally representative data from the cross-sectional SDAC and the longitudinal HILDA survey to provide comprehensive evidence of these associations.

This chapter concludes the thesis by summarising the key findings and discussing their implications for policy and practice. It also highlights how the insights gained from this research can inform strategies to reduce the burden of dementia, promote equity in health outcomes, and improve the quality of life for Australians affected by cognitive impairment and dementia.

9.2 Summary of key findings

- Geographic remoteness and dementia (Paper 1, Chapter 3)

This study examined the most recent national prevalence and trends of dementia in Australia, with a particular focus on geographic remoteness as a potential risk factor. The findings indicated that, between 2015 and 2018, the prevalence of dementia among adults aged 65 years and older increased, rising from 5,099 per 100,000 in 2015 to 5,229 per 100,000 in 2018. The analysis revealed notable variations in dementia prevalence based on geographic remoteness. Specifically, a significant increase was observed in major cities, where the prevalence rose from 5,010 per 100,000 in 2015 to 5,590 per 100,000 in 2018. Conversely, in outer regional and remote areas, the prevalence decreased substantially, from 4,810 to 3,760 per 100,000 over the same period. Furthermore, the results demonstrated that older adults residing in major cities had higher odds of experiencing dementia compared to those in outer regional and remote areas.

- Chronic pain and dementia (Paper 2, Chapter 4)

This study set out to investigate the association between chronic pain and dementia, with a particular emphasis on whether this relationship differs by age and gender. The findings underscored the significant role of chronic pain as a risk factor for dementia among older Australians. Specifically, older individuals experiencing chronic pain were found to have substantially higher odds of developing dementia compared to their counterparts without chronic pain. The analysis further revealed that the association between chronic pain and dementia persisted across all age groups, highlighting the consistent impact of chronic pain on cognitive health irrespective of age. Additionally, gender-specific differences were observed, with women experiencing chronic pain showing notably higher odds of living with dementia compared to women without chronic pain and their male counterparts.

- Dementia, Chronic Pain and Self-care Limitations (Paper 3, Chapter 5)

This study aimed to investigate the complex relationships among dementia, chronic pain, and self-care limitations, while also examining the combined impact of co-occurring dementia and chronic pain on self-care limitations. Using ordered logistic regression analysis, the findings highlighted that people with dementia faced significantly higher odds of experiencing severe self-care limitations compared to those without dementia. Similarly, chronic pain emerged as an independent factor contributing to an increased likelihood of self-care limitations, with individuals suffering from chronic pain demonstrating significantly higher odds of these

challenges than those without such pain. Importantly, the interaction effect analysis provided additional insights, revealing that the coexistence of dementia and chronic pain had a pronounced and synergistic effect on self-care limitations. This combination substantially heightened the probability of severe self-care impairments compared to individuals without either condition.

- Socio-economic inequalities in HRQoL and the contribution of cognitive impairment (Paper 4, Chapter 6)

Using data from the HILDA survey, this research explored socio-economic inequalities in HRQoL among older Australians and examined the specific contribution of cognitive impairment to these disparities. The study revealed that the prevalence of MCI among Australians aged 50 years and over was 11.76% in 2012 and 9.03% in 2016. Across both years, individuals with mild or severe cognitive impairment reported significantly lower HRQoL compared to those without cognitive impairment. The findings highlighted pronounced pro-rich inequalities in HRQoL, with concentration indices of 0.029 and 0.025 for waves 12 and 16, respectively. Notably, MCI accounted for 7.60% and 9.03% of the observed socio-economic inequalities in HRQoL during 2012 and 2016, underscoring its substantial contribution to these disparities. Additionally, factors such as unemployment and low household income were identified as key drivers of overall HRQoL inequalities, alongside the impact of cognitive impairment.

- Cognitive impairment and self-reported health outcomes (Paper 5, Chapter 7)

This study examined four key health outcomes—general health, mental health, self-assessed health, and health satisfaction—among older Australians with cognitive impairment, utilising nationally representative longitudinal data. The initial hypothesis posited that cognitive impairment negatively impacts these health outcomes. The results confirmed that individuals with cognitive impairment reported significantly poorer general health, mental health, self-assessed health, and health satisfaction compared to those without cognitive impairment. Moreover, the findings highlighted the average marginal effects of cognitive impairment on self-assessed health and health satisfaction. Specifically, cognitive impairment was associated with a reduced likelihood of achieving the highest levels of self-assessed health and health satisfaction, assuming all other factors remained constant. The analysis also revealed notable heterogeneity in the effects of cognitive impairment on health outcomes by age and gender. Participants aged 65 years and older with cognitive impairment exhibited worse self-assessed

health, general health, and mental health compared to those aged 50–64 years. Similarly, female participants with cognitive impairment experienced lower self-assessed health, general health, and health satisfaction compared to their male counterparts.

- Physical activity and HRQoL (Paper 6, Chapter 8)

This study explored the long-term relationship between physical activity and HRQoL in people living with cognitive impairment. HRQoL was assessed using both preference-based (SF-6D) and non-preference-based (SF-36) measures to provide a comprehensive evaluation of participants' physical and mental well-being. By applying random-effects modelling, the study confirmed the protective influence of physical activity on HRQoL within this vulnerable population. The findings revealed that participants who engaged in physical activity one to three times per week experienced significant improvements in the Physical Component Summary (PCS), Mental Component Summary (MCS), and SF-6D utility values compared to those who did not engage in any physical activity. Furthermore, people who participated in physical activity more frequently—ranging from more than three times per week to daily—achieved even higher scores across PCS, MCS, and SF-6D utility values, highlighting the dose-response benefits of regular physical activity.

9.3 Contributions to the field of research

This thesis makes a significant contribution to the existing body of literature by providing a comprehensive examination of the risk factors, adverse health outcomes, and potential avenues for improvement in the HRQoL of individuals living with dementia and cognitive impairment within the Australian context. A key strength of this research lies in the utilisation of large and recent nationally representative datasets, ensuring the findings reflect the contemporary epidemiological landscape of dementia in Australia. Furthermore, by controlling for a wide range of socio-demographic factors, this research provides a more nuanced understanding of the relationship among dementia, cognitive impairment, and HRQoL, while mitigating the potential influence of confounding variables. This thesis generates new knowledge, advances theoretical and methodological understanding, and offers valuable policy insights for the Australian health sector. These contributions are outlined below.

9.3.1 Contribution to theory and methods

The thesis extends the human development model by demonstrating its applicability to understanding the complex interplay of personal, environmental, and societal factors in the context of dementia. Specifically, the findings on the association between geographic remoteness and dementia prevalence (Chapter 3) highlight the crucial role of environmental factors, such as access to healthcare and social support, in shaping dementia risk. This contributes to a deeper understanding of how the broader social and environmental context influences health outcomes. Moreover, this research enhances the utility of the ICF by demonstrating its value in analysing the impact of dementia and chronic pain on various aspects of functioning, including ADLs and participation in social life (Chapters 4 and 5). The findings on the impact of co-occurring dementia and chronic pain on self-care limitations provide empirical evidence for the ICF's framework and demonstrate its relevance to understanding the lived experiences of individuals with complex health conditions.

This thesis makes a significant theoretical contribution to distributive justice theories, particularly Rawls' (1971, 2001) social contract theory and egalitarianism, by bridging the gap between their normative prescriptions and positive empirical analysis. While these theories traditionally focus on prescribing policies, structures, and institutions based on normative value judgements, this research applies their principles to real-world data, offering empirical validation and practical relevance. In Chapter 6, the study operationalises egalitarian concepts to investigate socio-economic inequalities in HRQoL and the role of cognitive impairment, thereby advancing the empirical application of these theoretical ideas. By integrating moral concepts into positive economics, this thesis enhances the empirical acceptability of distributive justice theories, contributing to a deeper understanding of their applicability in addressing contemporary health and social inequities.

9.3.2 Contribution to knowledge and policy implication/development

This thesis makes significant contributions to the existing body of knowledge, offering valuable insights and having important policy implications. The contributions of each paper to the field of research are detailed below.

Paper 1 significantly advances the existing literature by analysing dementia prevalence trends in Australia utilising a nationally representative dataset that encompasses both household and institutional care settings. Previous research on dementia prevalence in Australia has primarily relied on data collected from aged care institutions. Notably, this study is the first to investigate the association between geographic remoteness and dementia prevalence within the Australian

context, providing valuable insights into the spatial distribution of dementia across different regions of the country.

Paper 2 contributes significantly to the existing literature by investigating the relationship between chronic pain and dementia. This study represents the first Australian investigation to establish a correlation between these two conditions. Furthermore, this research endeavours to ascertain whether the observed association between chronic pain and dementia exhibits variations across different age and gender groups.

Paper 3 makes a significant contribution to the literature by investigating the association between co-occurring dementia and chronic pain with self-care limitations in older Australian adults. While previous research has established that dementia and chronic pain independently contribute to declines in ADLs, the combined impact of these two conditions on self-care limitations has not been extensively explored in the Australian context. This study, therefore, provides valuable insights for the development of well-informed interventions aimed at supporting the independence of and facilitating healthy ageing among older adults living with both dementia and chronic pain.

Paper 4 significantly contributes to the literature by examining how socio-economic inequalities impact HRQoL, with a specific focus on the contribution of cognitive impairment. This study, the first of its kind, utilises the comprehensive HILDA dataset to decompose the contribution of cognitive impairment to pro-rich inequality in HRQoL. By employing a rigorous methodological approach, including the utilisation of decomposition analysis, this research provides valuable insights into the mechanisms through which cognitive impairment contributes to health disparities across different socio-economic strata within the Australian population.

Paper 5 makes a significant contribution to the literature by exploring the association between cognitive impairment and health outcomes among older Australians. This research is among the first in Australia to investigate the impact of cognitive impairment on health outcomes using nationally representative data, providing valuable insights into an understudied area. The application of a longitudinal random-effects regression model enabled a comprehensive examination of variations in self-perceived health outcomes among individuals with cognitive impairment over time. Additionally, the study utilised validated cognitive assessment tools, including the Symbol Digit Modalities Test (SDMT) and Backward Digit Span (BDS), which are recognised for their effectiveness in capturing critical aspects of cognitive ageing and

impairment. These methodological strengths underscore the study's contribution to advancing the understanding of cognitive impairment and its health implications in older populations.

Paper 6 significantly advances the understanding of the relationship between physical activity and HRQoL in older Australians with cognitive impairment. This study, the first of its kind in Australia, provides valuable insights into the potential benefits of physical activity in enhancing the HRQoL of this population. The findings of this research have important implications for the development of evidence-based policies aimed at improving the HRQoL of individuals with cognitive impairment and optimising the equitable allocation of resources within the healthcare system.

9.4 Policy implications

This thesis provides several policy-relevant insights derived from six interconnected studies, each addressing different aspects of dementia and cognitive impairment in the Australian context. The findings emphasise the importance of targeted interventions, integrated healthcare strategies, and socio-environmental improvements to mitigate risk factors, enhance health outcomes, and improve the quality of life for older Australians. The key policy implications *are outlined below*.

9.4.1 Addressing dementia risk in urban environments

The findings in Chapter 3 (Paper 1) indicate that residents of major cities are at a higher risk of developing dementia. To address this, policymakers should consider expanding urban green spaces and increasing tree coverage in cities to promote physical activity, social interaction, and mental well-being while reducing exposure to air pollution. Local councils can develop dedicated urban forest strategies or embed urban forest conservation within urban planning frameworks to create healthier living environments. Furthermore, state and territory governments should allocate additional funding to enhance vital services for older adults, including memory clinics, geriatric assessments, mental health services, and home care visits. These efforts will not only reduce dementia risk but also improve the quality of life for older Australians.

9.4.2 Prioritising chronic pain management

Chapter 4 (Paper 2) highlights chronic pain as a significant risk factor for dementia, emphasising the need for personalised and proactive healthcare strategies for managing chronic pain. Policymakers should prioritise chronic pain management programs, particularly for high-risk populations, to mitigate its cognitive and psychological impacts. Early intervention strategies can reduce the long-term cognitive decline associated with chronic pain and enhance healthcare decision-making for vulnerable groups.

9.4.3 Mitigating self-care limitations in individuals with dementia and chronic pain

Chapter 5 (Paper 3) reveals that the co-occurrence of dementia and chronic pain significantly exacerbates self-care limitations. Policies should focus on identifying factors contributing to severe self-care limitations and developing prevention and treatment programs to address these challenges. Supporting individuals with dementia and chronic pain can minimise the negative outcomes in their personal, social, and professional lives while improving overall care outcomes.

9.4.4 Reducing socio-economic inequalities in HRQoL

Findings from Chapter 6 (Paper 4) demonstrate that individuals from lower SES groups experience lower HRQoL, with cognitive impairment contributing significantly to this inequality. Policies aimed at reducing these disparities should prioritise support for vulnerable populations, particularly individuals with cognitive impairment from low SES backgrounds. Measures such as targeted social assistance programs, including cash transfers or housing subsidies, can help alleviate the economic burdens and improve HRQoL for these groups.

9.4.5 Improving health outcomes for individuals with cognitive impairment

Chapter 7 (Paper 5) underscores the association between cognitive impairment and poor health outcomes. Disability prevention strategies should incorporate assessments of health outcomes into care and support plans for older adults with cognitive impairment. Policymakers should prioritise early interventions to address cognitive decline, improve satisfaction with health, and prevent future disabilities. A coordinated approach involving clinicians, researchers, and government agencies is essential to implement effective prevention and treatment strategies for this population.

9.4.6 Promoting Physical Activity to Enhance HRQoL

Chapter 8 (Paper 6) identifies the positive relationship between physical activity and improved HRQoL for individuals with cognitive impairment. To leverage this finding, healthcare professionals should play a central role in providing tailored guidance and support to encourage older adults to engage in recommended physical activity levels. Policymakers can include physical activity programs in comprehensive care plans and subsidise them through bulk-billed General Practitioner (GP) services. These initiatives will empower older Australians with cognitive impairment to enhance their physical and mental well-being, contributing to a healthier aging population.

By implementing these policy recommendations, Australian healthcare systems and policymakers can address the growing challenges posed by dementia and cognitive impairment, improve health outcomes, and enhance the quality of life for older adults. The findings of this thesis provide a robust foundation for evidence-based policy development in these critical areas.

In summary, this research presents several novel contributions. It is the first study to investigate the association between geographic remoteness and dementia prevalence in Australia using a nationally representative dataset. It is also the first Australian study to establish a correlation between chronic pain and dementia, examining variations across age and gender. Furthermore, this research is the first in Australia to investigate the combined impact of dementia and chronic pain on self-care limitations. The study is the first to utilise the HILDA dataset to decompose the contribution of cognitive impairment to pro-rich inequality in HRQoL. It is among the first in Australia to investigate the impact of cognitive impairment on health outcomes using nationally representative data. Finally, this research is the first in Australia to explore the long-term relationship between physical activity and HRQoL in older Australians with cognitive impairment.

9.5 Limitations and future work directions

The limitations of this thesis have been discussed in detail in each chapter, but several overarching challenges warrant mention. A key limitation is the potential vulnerability of the findings to self-reporting and proxy reporting biases, particularly among individuals with dementia. Cognitive decline often leads to prolonged and uncertain diagnosis processes, exacerbated by the stigma associated with dementia, which may discourage individuals from

identifying their condition. As a result, cases of mild and moderate dementia may be underestimated, particularly within household populations. Additionally, self-reported measures of HRQoL and other health outcomes (i.e., general health, mental health, health satisfaction, and self-assessed health) may have been subject to social desirability bias, potentially inflating health outcome scores. Furthermore, while cognitive assessments such as the BDS and the SDMT offered valuable insights into core cognitive processes, they may not have fully captured the broader cognitive profiles of individuals with MCI or dementia, which often include significant memory deficits. Finally, the cross-sectional and unbalanced longitudinal study designs limited the ability to establish causal relationships. In particular, the bidirectional nature of the relationship between chronic pain and dementia could not be fully explored, leaving temporality and reverse causality unaddressed. These limitations underscore the need for caution in interpreting the findings and highlight opportunities for further research.

The findings of this thesis underscore several promising directions for future research. First, enhancing pain management in older adults by refining estimates of chronic pain prevalence, uncovering its links to cognitive decline, and developing safer, tailored treatment options is essential. Longitudinal studies should further investigate the bidirectional relationship between chronic pain and dementia to establish temporality and clarify reverse causation, paving the way for early prevention and intervention strategies. Incorporating memory-focused cognitive assessments such as Montreal Cognitive Assessment (MoCA), Mini-Mental Status Examination (MMSE), or Saint Louis University Mental Status (SLUMS) examination could offer a more comprehensive understanding of cognitive impairment and improve comparability with existing literature. Future research should also account for a broader range of socio-economic and contextual factors to elucidate more effectively the complex interplay among cognitive impairment, HRQoL, and health outcomes. Differentiating between neurodegenerative cognitive impairments and other forms, such as lifelong learning disabilities, could provide more generalisable insights and allow an in-depth exploration of varying cognitive trajectories. Finally, identifying modifiable risk factors and underlying mechanisms linking cognitive impairment to health outcomes is vital for developing preventative strategies to improve the health and well-being of individuals at risk of or living with cognitive impairment and dementia. These research directions collectively aim to advance understanding and inform evidence-based interventions.

Building upon the findings and limitations of the research outlined above, several future research directions for Australian policy contexts can be identified:

An important avenue for future research could be to examine the recovery trajectory of HRQoL following the onset of dementia. Rather than estimating average effects, future studies should investigate how HRQoL evolves on a year-by-year basis after a dementia diagnosis. This would enable researchers to quantify the proportion of quality of life loss attributable to dementia during the first, second, third year, and beyond. Such longitudinal insights are essential for understanding whether, and at what point, quality of life begins to stabilise or improve, which in turn has significant implications for the design of cost-effective support strategies. Given the increasing prevalence of dementia and the constraints on healthcare resources, identifying the most critical periods for intervention could help policymakers target support more effectively. Moreover, this approach could inform the evaluation of care models and pharmacological interventions aimed at improving or maintaining HRQoL among individuals living with dementia.

Research can explore the potential impact of climate change-related factors such as extreme heat events, air pollution, and natural disasters on dementia prevalence and progression in Australia. This research can inform policies aimed at climate change mitigation and adaptation, particularly those focused on protecting vulnerable populations and enhancing resilience in the face of climate-related health challenges.

Research can investigate the relationship among social isolation, loneliness, and cognitive decline in the Australian context. This research can help shape policies that promote social connectedness among older adults, such as community engagement programs, social support services, and the use of technologies to combat social isolation.

Research can be undertaken to conduct rigorous evaluations of innovative interventions aimed at improving the quality of life for people with dementia and their caregivers, such as cognitive stimulation therapy, music therapy, and technology-assisted therapy. This research can inform the development and implementation of successful and cost-effective interventions within the Australian healthcare system.

Research can look at the possible role of traditional Indigenous knowledge and practices in dementia prevention and care within Aboriginal and Torres Strait Islander communities. This research can inform culturally appropriate and sensitive dementia care models that respect and incorporate Indigenous knowledge systems.

Research can also explore the broader economic burden of dementia and cognitive impairment in Australia. Beyond healthcare costs, this could include indirect costs such as informal

caregiving, reduced quality of life, and productivity losses—especially among those diagnosed before age 65. A comprehensive cost analysis would better inform policy decisions and support the development of more effective and economically sustainable interventions.

9.6 Conclusions

The prevalence of dementia is rising in Australia, presenting significant challenges for individuals, families, and policymakers. While many factors are associated with the incidence of dementia, few studies have comprehensively explored geographic remoteness and chronic pain as risk factors of dementia using nationally representative data. Furthermore, limited research has examined the adverse health outcomes of dementia and cognitive impairment or identified actionable strategies to improve the HRQoL of affected individuals.

This thesis addresses these gaps through six studies, drawing on data from the nationally representative SDAC and the HILDA survey. Employing both cross-sectional and longitudinal research designs, the thesis is structured into three themes. Theme I explores the prevalence of dementia in Australia, with a particular focus on its association with geographic remoteness. Additionally, it examines the variations in the relationship between chronic pain and dementia across different age groups and genders. Theme II examines the adverse health outcomes associated with dementia and cognitive impairment, emphasising self-care limitations, different health outcomes, and socio-economic inequalities in HRQoL through decomposition analysis. Theme III explores pathways to improving cognitive health, highlighting the role of physical activity in enhancing HRQoL among individuals with cognitive impairment.

The findings presented in this thesis carry substantial policy implications. They provide Australian policymakers with critical evidence on the rising prevalence of dementia, its associated risk factors, and its widely ranging impacts on individuals and communities. Moreover, the research underscores the need for targeted interventions to mitigate the adverse health outcomes of dementia and cognitive impairment and promote better quality of life for affected populations.

It is anticipated that the insights from this thesis will contribute to shaping evidence-based policies aimed at slowing the rising prevalence of dementia, reducing its adverse health impacts, and fostering healthier, more supportive environments for individuals living with cognitive impairment.

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APPENDIX A

This appendix showcases the media coverage received by Paper 1 (Chapter 3) included in this thesis. The study (Paper 1, Chapter 3), entitled *Changes in the Prevalence of Dementia in Australia and its Association with Geographic Remoteness* gained widespread media attention following a media release entitled "People in major cities more likely to develop dementia, study finds" developed by the Media & Communications team, UniSQ which was first offered as an exclusive to AAP. After its publication on 22 November 2023, the story gained significant traction, resulting in over 150 media mentions across electronic (including 7 News Australia), print (including The Daily Mail, The Telegraph, The Herald Sun, The Canberra Times, The Chronicle, The Newcastle Herald, National Seniors Australia, The Border Mail, The Courier, and The New Daily), and other broadcast outlets (including ABC New England North West AM, ABC Riverina, and ABC Central West NSW Radio). It resulted in a potential total reach of **106,907,627**, with an estimated advertising value equivalency (AVE) of **$985,721.50.**

This appendix includes a selection of newspaper clippings and images from television interviews, highlighting the broad public engagement with and impact of this research.

Rezwanul Haque's research findings were featured in 7 News telecasted on 23 November 2023

Australian study reveals city people are more likely to develop dementia 7 News Australia

Rezwanul Haque's research findings were featured in the Daily Mail on 22 November 2023.

Daily Mail AUSTRALIA

Rural residents have lower risk of dementia: study

By AUSTRALIAN ASSOCIATED PRESS
PUBLISHED: 03:36 AEDT, 22 November 2023 | **UPDATED:** 03:36 AEDT, 22 November 2023

People living in country Australia have a lower risk of dementia than their city peers, possibly because they have cleaner air and more green spaces, a study suggests.

An analysis of the most recent national Survey of Disability, Ageing and Carers found adults over 65 living in major cities were 1.12 times more likely to develop the brain disorder.

The University of Southern Queensland study is the first to look at the geography of dementia prevalence using national data from both households and care facilities.

Environmental factors could influence the higher rates in the cities, lead author and PhD student Rezwanul Haque wrote.

"For example, earlier research identified chronic noise exposure, air pollution, and a paucity of green space as probable risk factors for cognition reduction, which are more prevalent in metropolitan areas," the study said.

A 2020 University of Wollongong study of nearly 110,000 NSW adults found increasing urban tree canopy cover could help lower the risk of dementia.

The results of the University of Southern Queensland research, published in the PLOS One science journal, defied expectations in one area of rural health, research

Rezwanul Haque's research findings were featured in the Telegraph on 22 November 2023.

THE Telegraph

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November 22, 2023
Seymour, AU

14°C Scattered Clouds
Wind: 23 Km/h

NATIONAL

Rural residents have lower risk of dementia: study

By AAP Newswire
Nov 22, 2023

Research points to the value of maintaining green space in cities, where dementia risk may be higher -AAP Image

People living in country Australia have a lower risk of dementia than their city peers, possibly because they have cleaner air and more green spaces, a study suggests.

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Environmental factors could influence the higher rates in the cities, lead author and PhD student Rezwanul Haque wrote.

Rezwanul Haque's research findings were featured in the NEWCASTLE Herald on 22 November 2023.

Rural residents have lower risk of dementia: study

By Stephanie Gardiner
Updated November 22 2023 - 2:40am, first published 2:31am

Research points to the value of maintaining green space in cities, where dementia risk may be higher (Bianca De Marchi/AAP PHOTOS)

People living in country Australia have a lower risk of dementia than their city peers, possibly because they have cleaner air and more green spaces, a study suggests.

An analysis of the most recent national Survey of Disability, Ageing and Carers found adults over 65 living in major cities were 1.12 times more likely to develop the brain disorder.

The University of Southern Queensland study is the first to look at the geography of dementia prevalence using national data from both households and care facilities.

Environmental factors could influence the higher rates in the cities, lead author and PhD student Rezwanul Haque wrote.

"For example, earlier research identified chronic noise exposure, air pollution, and a paucity of green space as probable risk factors for cognition reduction, which are more prevalent in metropolitan areas," the study said.

A 2020 University of Wollongong study of nearly 110,000 NSW adults found increasing urban tree canopy cover could help lower the risk of dementia.

The results of the University of Southern Queensland research, published in the PLOS One science journal, defied expectations in one area of rural health, research supervisor Professor Khorshed Alam said.

"The traditional view is that people who are living in rural and remote areas should have more dementia prevalence, but this study is saying the opposite," Prof Alam told AAP.

He said the research could be used to better inform public policy and planning.

"In our traditional decision-making and urban land use planning, we don't pay enough attention to green spaces, playgrounds and urban forestry," Prof Alam said.

"We think converting them into more commercial uses has value, but maintaining forestry spaces, green space or walkways has intrinsic

Rezwanul Haque's research findings were featured in the Chronicle on 23 November 2023.

23 Nov 2023
Article type: Publication
Page: 6
Chronicle, The
Readership: 49000
AVE: $82.63

HEALTH

Dementia risk from city life

Australians who crave city life could be putting themselves at a greater risk of suffering from dementia.

City slickers are 1.12 times more likely to develop the serious brain disorder compared with their regional counterparts, new research by the University of Southern Queensland has found.

The study found dementia rates across Australia increased from 0.84 per cent to 0.89 per cent between 2015 and 2018. For people living in major cities, the prevalence was 5590 per 100,000.

Rezwanul Haque's research findings were featured in the Clifton Courier on 29 November 2023.

Dementia less likely in rural areas

Good news for country folk comes from study that suggests Australians who enjoy life in the bush could be at less risk of suffering from dementia.

New research by the University of Southern Queensland has found city slickers are 1.12 times more likely to develop the serious brain disorder compared to their regional counterparts,

The study published in PLOS One was conducted by PhD student Rezwanul Haque using the latest available data from the Survey of Disability, Ageing and Carers (SDAC), a nationally representative database collected by the Australian Bureau of Statistics about the health of the Australian population.

This is the first study to establish a link between dementia risk and geographic remoteness from an Australian perspective.

Moreover, the study also explores the recent changes in dementia prevalence.

For people living in outer regional and remote areas, the prevalence was 3,760 per 100,000 in 2018 – a 21 per cent decrease from 2015, despite dementia rates across the population increasing from 0.84 per cent to 0.89 per cent.

Conversely, there was an 11 per cent increase in dementia among people living in major cities between 2015 and 2018.

Mr Haque's supervisor and co-author Professor Khorshed Alam said environmental factors could be one of the reasons why people living in the bush are less likely to develop dementia.

University of Southern Queensland's Rezwanul Haque and Professor Khorshed Alam.

"Earlier research identified chronic noise exposure, air pollution and a paucity of green space as probable risk factors for cognition reduction, which are more prevalent in metropolitan areas than rural and remote communities," he said.

The strength of the research was the use of the SDAC dataset which included data on dementia prevalence collected from both households and cared accommodation, whereas previous studies either used data that didn't present geographical differences or were conducted using routinely collected aged care institutional data.

Despite regional areas seeing a decline in dementia prevalence rates, Mr Haque said dementia was a significant health problem among older Australians, with one in 20 people aged over 65 nationally having dementia according to the SDAC dataset.

"There is currently no cure for any form of dementia," he said.

"Diabetes, high blood pressure, obesity, under-nutrition, depression and brain injuries have increased over time in Australia, which may all be a factor in the rise in dementia rates.

"Australia's ageing population is expected to grow even older in the coming decades, which will drive up dementia rates and put more pressure on families, health care systems and communities."

The study 'Changes in the prevalence of dementia in Australia and its association with geographic remoteness' was co-authored with Professor Christine Neville and Professor Jeff Gow from the University of Southern Queensland.

APPENDIX B

This appendix highlights the media coverage and public engagement generated by the second paper (Paper 2, Chapter 4) of this thesis, entitled *Age and Gender Differences in the Relationship Between Chronic Pain and Dementia Among Older Adults.* This paper gained widespread media attention following a media release entitled "Link between Chronic Pain and Increased Risk of Dementia" by the Media & Strategic Communications team, UniSQ in October 2024. Overall, the media release and interviews generated 28 print (including The National Tribune, Australian Senior News, Local Ipswich News, Redland City News, Health Medicine Network, MSN.com, Medical Xpress, and Knowridge), digital, and other broadcast outlets (including 4BC, 2GB Radio, 2NURFM, 2UE, 4KZ, 990 AM 4RO, 2CC Talking Canberra, FIVEaa). It resulted in a potential total reach of **127,297,021**, with an estimated advertising value equivalency (AVE) of **$1,177,497.**

The following section includes selected clippings from newspaper articles illustrating the extensive reach and impact of this research in raising awareness of the association between chronic pain and dementia in older adults.

Rezwanul Haque's research findings were featured in the Local Ipswich News on 17 October 2024.

Study finds chronic pain linked with dementia

OLDER Australians suffering from chronic pain face a significantly increased risk of dementia, according to a new University of Southern Queensland-led study.

About one-third of older people are believed to be living with chronic pain, while the number of people with dementia, which is considered an age-related disease, continues to rise.

In the new study, researchers found that after adjusting for several individual factors, including age and gender, the risk of dementia was almost two times higher in older Australians with chronic pain compared to those without chronic pain. The increase in risk was consistent across all age groups.

The researchers say this is the first study in Australia to establish a correlation between chronic pain and dementia.

Rezwanul Haque, a PhD student in health economics, led the study, which was published in Value in Health.

He said there were several possible reasons why older people with chronic pain were subject to an increased risk of dementia.

These include disruptions in attention and memory, impaired decision-making abilities, decreased processing speed and psychomotor speed, and increased stress levels that may trigger the release of cortisol, which is associated with degeneration of the hippocampus and memory problems, as well as other underlying health conditions.

University of Southern Queensland PhD student Rezwanul Haque was the study's lead.

"During instances of chronic pain, nerve endings provide quick pain signals to the brain to prompt necessary remedial responses, and this process depletes the neuronal resources that are also engaged in cognitive activities," Mr Haque said.

"Furthermore, the existence of chronic pain can disrupt the brain's natural pain-relief system, which may lead to poor cognitive outcomes such as loss of working and long-term memory."

For the study, the researchers analysed data from more than 40,000 adults aged 65 and older who participated in nationally representative surveys in 2015 and 2018.

"While there is a growing recognition of the complex link between chronic pain and cognitive decline, we were absolutely surprised by the magnitude of the difference in the results," Mr Haque said.

"It's a striking reminder that chronic pain may be a more serious dementia risk factor than previously anticipated."

Mr Haque said the results highlighted the urgent need for a comprehensive healthcare approach to chronic pain management in older adults.

"Chronic pain is a common problem among elderly Australians but is not recognised as a national public health priority," he said.

"A continuous, aligned and personalised healthcare strategy is needed to establish chronic pain management priorities, especially in groups with the greatest need.

"Many people who experience chronic pain are unable to access best practices in pain management, either because of financial constraints or a lack of knowledge about available alternatives. The disparity is even more pronounced in rural and remote regions.

"A proactive approach to chronic pain management might not only minimise potential cognitive decline associated with chronic pain, but ultimately inform healthcare decisions by prioritising early interventions to reduce future cognitive complications."

Mr Haque emphasised that more research was needed to understand the underlying processes of pain in the context of aging and dementia, and to foster the development and progression of safer and more effective treatment options.

The study was co-authored with Professor Khorshed Alam, Professor Jeffrey Gow and Professor Christine Neville from the University of Southern Queensland, and Dr Syed Afroz Keramat from The University of Queensland.

Rezwanul Haque's research findings were featured in the Redland Bayside News on 17 October 2024.

Study finds chronic pain linked with dementia

Redland City News

University of Southern Queensland PhD student Rezwanul Haque was the study's lead.

OLDER Australians suffering from chronic pain face a significantly increased risk of dementia, according to a new University of Southern Queensland-led study.

About one-third of older people are believed to be living with chronic pain, while the number of people with dementia, which is considered an age-related disease, continues to rise.

In the new study, researchers found that after adjusting for several individual factors, including age and gender, the risk of dementia was almost two times higher in older Australians with chronic pain compared to those without chronic pain. The increase in risk was consistent across all age groups.

The researchers say this is the first study in Australia to establish a correlation between chronic pain and dementia.

Rezwanul Haque, a PhD student in health economics, led the study, which was published in Value in Health.

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UNCATEGORIZED

Call for greater investment in chronic pain management

October 2, 2024

Older Australians suffering from chronic pain face a significantly increased risk of dementia, according to a new University of Southern Queensland-led (UniSQ) study.

About one-third of older people are believed to be living with chronic pain, while the number of people with dementia, which is considered an age-related disease, continues to rise.

In the new study, researchers found that after adjusting for several individual factors, including age and gender, the risk of dementia was almost two times higher in older Australians with chronic pain compared to those without chronic pain. The increase in risk was consistent across all age groups.

Study author, University of Southern Queensland PhD student Rezwanul Haque.

The researchers say this is the first study in Australia to establish a correlation between chronic pain and dementia.

Rezwanul Haque, a PhD student in health economics, led the study, which was published in *Value in Health*.

He said there were several possible reasons why older people with chronic pain were subject to an excess risk of dementia.

These include disruptions in attention and memory, impaired decision-making abilities, decreased processing speed and psychomotor speed, and increased stress levels that may trigger the release of cortisol, which is associated with degeneration of the hippocampus and memory problems, as well as other underlying health conditions.

"During instances of chronic pain, nerve endings provide quick pain signals to the brain to prompt necessary remedial responses, and this process depletes the neuronal resources that are also engaged in cognitive activities," Mr Haque said.

"Furthermore, the existence of chronic pain can disrupt the brain's natural pain-relief system, which may lead to poor cognitive outcomes such as loss of working and long-term memory."

For the study, the researchers analysed data from more than 40,000 adults aged 65 and older who participated in nationally representative surveys in 2015 and 2018.

"While there is a growing recognition of the complex link between chronic pain and cognitive decline, we were absolutely surprised by the magnitude of the difference in the results," Mr Haque said.

"It's a striking reminder that chronic pain may be a more serious dementia risk factor than previously anticipated."

Mr Haque said the results highlighted the urgent need for a comprehensive healthcare approach to chronic pain management in older adults.

"Chronic pain is a common problem among elderly Australians but is not recognised as a national public health priority," he said.

"A continuous, aligned and personalised healthcare strategy is needed to establish chronic pain management priorities, especially in groups with the greatest need.

APPENDIX C

This appendix includes supplementary materials related to Paper 3 of this thesis, presented in Chapter 5. These documents provide additional details that enhance the main findings of the study and support the methodologies, analyses, and interpretations discussed in the chapter.

Note: The table and figure numbers align with those referenced in the chapter for consistency.

Supplementary document

Appendix Table A1: Bivariate analysis among dementia, chronic pain and other covariates with self-care limitations

Characteristics	2015 Weighted % (95% CI)			P Value	2018 Weighted % (95% CI)			P Value
	No limitation	Moderate or mild	Profound or severe		No limitation	Moderate or mild	Profound or severe	
Dementia								
No	82.26 (81.44-83.04)	8.80 (8.20-9.44)	8.94 (8.41-9.50)	<0.001	82.68 (81.79-83.53)	9.30 (8.63-10.03)	8.02 (7.49-8.58)	<0.001
Yes	17.54 (14.41-21.19)	8.18 (6.07-10.94)	74.28 (70.32-77.88)		22.89 (19.02-27.28)	7.44 (5.50-9.98)	69.68 (65.29-73.73)	
Chronic Pain								
No	89.52 (88.74-90.24)	4.59 (4.08-5.16)	5.90 (5.39-6.44)		89.34 (88.50-90.13)	5.23 (4.63-5.90)	5.43 (4.92-5.99)	<0.001
Yes	57.03 (55.29-58.74)	17.46 (16.10-18.90)	25.52 (24.18-26.90)	<0.001	57.11 (55.24-58.96)	18.32 (16.83-19.91)	24.57 (23.17-26.02)	
Age								
65-69	89.42 (88.26-90.48)	5.48 (4.70-6.38)	5.10 (4.38-5.92)		88.59 (87.26-89.80)	6.39 (5.48-7.44)	5.02 (4.23-5.94)	
70-74	85.20 (83.62-86.66)	7.81 (6.69-9.09)	6.99 (6.04-8.08)		86.95 (85.45-88.32)	7.18 (6.09-8.45)	5.87 (5.03-6.83)	
75-79	80.01 (78.07-81.81)	10.02 (8.60-11.64)	9.98 (8.8-11.29)	<0.001	79.53 (77.39-81.51)	9.87 (8.43-11.53)	10.60 (9.21-12.18)	<0.001
80-84	68.68 (66.04-71.2)	12.61 (10.75-14.73)	18.71 (16.79-20.81)		70.08 (67.33-72.69)	14.42 (12.38-16.72)	15.50 (13.76-17.42)	
85 and above	49.85 (47.19-52.5)	13.34 (11.51-15.41)	36.81 (34.57-39.12)		51.35 (48.43-54.26)	14.22 (12.14-16.59)	34.43 (32.00-36.94)	
Gender								
Male	82.91 (81.80-83.97)	6.67 (5.94-7.49)	10.41 (9.62-11.26)		82.54 (81.33-83.68)	7.71 (6.86-8.66)	9.75 (8.96-10.61)	<0.001
Female	75.50 (74.37-76.59)	10.60 (9.76-11.51)	13.90 (13.13-14.7)	<0.001	76.92 (75.74-78.06)	10.52 (9.64-11.48)	12.56 (11.78-13.38)	
Accessibility and remoteness index								
Major cities in Australia	79.20 (78.20-80.17)	8.30 (7.61-9.05)	12.50 (11.79-13.25)		79.61 (78.52-80.66)	8.88 (8.09-9.74)	11.51 (10.79-12.26)	
Inner regional Australia	77.67 (75.83-79.41)	10.11 (8.79-11.6)	12.22 (11.09-13.46)	<0.001	78.94 (77.05-80.72)	10.4 5(9.05-12.03)	10.61 (9.50-11.83)	<0.001
Outer regional and remote area	79.95 (77.59-82.13)	9.03 (7.44-10.92)	11.02 (9.62-12.59)		80.48 (77.86-82.86)	8.60 (6.93-10.62)	10.92 (9.32-12.76)	
Country of Birth								
Australia	78.60 (77.58-79.59)	9.23 (8.48-10.04)	12.17 (11.49-12.88)		78.60 (77.58-79.59)	9.23 (8.48-10.04)	12.17 (11.49-12.88)	
English Speaking Countries	82.34 (80.38-84.13)	9.09 (7.66-10.77)	8.57 (7.50-9.78)	<0.001	82.34 (80.38-84.13)	9.09 (7.66-10.77)	8.57 (7.50-9.78)	<0.001
Non-English-speaking countries	77.66 (75.74-79.46)	7.11 (6.05-8.34)	15.23 (13.75-16.84)		77.66 (75.74-79.46)	7.11 (6.05-8.34)	15.23 (13.75-16.84)	
State or territory								
New South Wales	79.04 (77.47-80.53)	7.88 (6.85-9.05)	13.08 (11.97-14.28)		80.69 (79.17-82.12)	8.26 (7.23-9.42)	11.06 (10.08-12.12)	
Victoria	76.68 (74.88-78.39)	9.87 (8.60-11.3)	13.45 (12.28-14.72)		79.00 (77.20-80.70)	9.37 (8.14-10.76)	11.63 (10.49-12.88)	
Queensland	81.40 (79.59-83.09)	7.77 (6.57-9.18)	10.82 (9.67-12.09)		79.58 (77.64-81.38)	9.04 (7.72-10.55)	11.39 (10.14-12.77)	
South Australia	76.41 (74.17-78.51)	10.89 (9.23-12.81)	12.70 (11.32-14.22)	<0.001	76.55 (71.78-80.73)	11.42 (8.07-15.92)	12.03 (9.59-14.98)	<0.001
Western Australia	82.53 (80.49-84.41)	8.46 (7.01-10.18)	9.00 (7.82-10.35)		80.61 (78.57-82.49)	9.76 (8.29-11.46)	9.63 (8.40-11.03)	
Tasmania	75.87 (72.50-78.95)	11.27 (8.99-14.05)	12.85 (10.78-15.25)		76.86 (72.02-81.08)	11.80 (8.79-15.66)	11.34 (8.81-14.50)	
Northern Territory	85.41 (79.96-89.57)	4.60 (2.54-8.18)	9.99 (6.59-14.86)		76.55 (60.58-87.40)	10.70 (3.61-27.73)	12.75 (6.01-25.03)	
Australian Capital Territory	79.16 (75.67-82.28)	10.11 (7.74-13.10)	10.72 (8.64-13.24)		78.53 (72.90-83.25)	9.07 (5.88-13.73)	12.40 (9.10-16.69)	

Appendix Table A2: Weighted sample characteristics of the study variables by dementia status

	2015 Weighted % (95% CI) Dementia status			2018 Weighted % (95% CI) Dementia status			Pooled Weighted % (95% CI) Dementia status		
Characteristics	**No**	**Yes**	**P Value**	**No**	**yes**	**P Value**	**No**	**Yes**	**P Value**
Level of self-care limitations									
No limitation	98.87 (98.58-99.10)	1.13 (0.9-1.42)	<0.001	98.50 (98.13-98.79)	1.50 (1.21-1.87)	<0.001	98.50 (98.13-98.79)	1.50 (1.21-1.87)	<0.001
Mild or moderate	95.25 (93.55-96.52)	4.75 (3.48-6.45)		95.78 (94.26-96.91)	4.22 (3.09-5.74)		95.78 (94.26-96.91)	4.22 (3.09-5.74)	
Profound or severe	69.15 (67.20-71.03)	30.85 (28.97-32.80)		67.59 (65.29-69.81)	32.41 (30.19-34.71)		67.59 (65.29-69.81)	32.41 (30.19-34.71)	
Chronic pain									
No	96.83 (96.43-97.18)	3.17 (2.82-3.57)	<0.001	96.54 (96.06-96.96)	3.46 (3.04-3.94)		96.54 (96.06-96.96)	3.46 (3.04-3.94)	
Yes	90.90 (90.15-91.6)	9.10 (8.40-9.85)		90.72 (89.91-91.48)	9.28 (8.52-10.09)		90.72 (89.91-91.48)	9.28 (8.52-10.09)	
Age									
65-69	99.15 (98.78-99.40)	0.85 (0.60-1.22)	<0.001	99.13 (98.72-99.41)	0.87 (0.59-1.28)	<0.001	99.13 (98.72-99.41)	0.87 (0.59-1.28)	<0.001
70-74	97.80 (97.11-98.33)	2.20 (1.67-2.89)		98.01 (97.34-98.51)	1.99 (1.49-2.66)		98.01 (97.34-98.51)	1.99 (1.49-2.66)	
75-79	96.10 (95.28-96.79)	3.90 (3.21-4.72)		94.71 (93.61-95.64)	5.29 (4.36-6.39)		94.71 (93.61-95.64)	5.29 (4.36-6.39)	
80-84	91.19 (89.79-92.42)	8.81 (7.58-10.21)		91.98 (90.58-93.19)	8.02 (6.81-9.42)		91.98 (90.58-93.19)	8.02 (6.81-9.42)	
85 and above	80.93 (79.27-82.48)	19.07 (17.52-20.73)		80.17 (78.14-82.05)	19.83 (17.95-21.86)		80.17 (78.14-82.05)	19.83 (17.95-21.86)	
Gender									
Male	95.88 (95.35-96.36)	4.12 (3.64-4.65)	<0.001	95.26 (94.62-95.83)	4.74 (4.17-5.38)	<0.001	95.26 (94.62-95.83)	4.74 (4.17-5.38)	<0.001
Female	94.04 (93.55-94.50)	5.96 (5.50-6.45)		94.34 (93.82-94.82)	5.66 (5.18-6.18)		94.34 (93.82-94.82)	5.66 (5.18-6.18)	
Accessibility and remoteness index									
Major cities in Australia	94.99 (94.55-95.39)	5.01 (4.61-5.45)	<0.001	94.41 (93.88-94.88)	5.59 (5.12-6.12)	<0.001	94.41 (93.88-94.88)	5.59 (5.12-6.12)	<0.001
Inner regional Australia	94.48 (93.63-95.23)	5.52 (4.77-6.37)		95.16 (94.30-95.9)	4.84 (4.10-5.70)		95.16 (94.30-95.90)	4.84 (4.10-5.70)	
Outer regional and remote area	95.19 (94.12-96.08)	4.81 (3.92-5.88)		96.29 (94.97-97.28)	3.71 (2.72-5.03)		96.29 (94.97-97.28)	3.71 (2.72-5.03)	
Country of Birth									
Australia	94.80 (94.35-95.22)	5.20 (4.78-5.65)	<0.001	95.27 (94.79-95.7)	4.73 (4.30-5.21)	<0.001	95.27 (94.79-95.70)	4.73 (4.30-5.21)	<0.001
English Speaking Countries	96.22 (95.49-96.84)	3.78 (3.16-4.51)		95.12 (93.97-96.07)	4.88 (3.93-6.03)		95.12 (93.97-96.07)	4.88 (3.93-6.03)	
Non-English-speaking countries	94.28 (93.38-95.07)	5.72 (4.93-6.62)		92.99 (91.85-93.98)	7.01 (6.02-8.15)		92.99 (91.85-93.98)	7.01 (6.02-8.15)	
State or territory									
New South Wales	94.64 (93.93-95.28)	5.36 (4.72-6.07)	<0.001	94.41 (93.63-95.10)	5.59 (4.9-6.37)	<0.001	94.41 (93.63-95.10)	5.59 (4.90-6.37)	<0.001
Victoria	95.12 (94.40-95.75)	4.88 (4.25-5.60)		94.36 (93.46-95.15)	5.64 (4.85-6.54)		94.36 (93.46-95.15)	5.64 (4.85-6.54)	
Queensland	94.51 (93.57-95.31)	5.49 (4.69-6.43)		94.86 (93.91-95.67)	5.14 (4.33-6.09)		94.86 (93.91-95.67)	5.14 (4.33-6.09)	
South Australia	94.45 (93.48-95.29)	5.55 (4.71-6.52)		95.50 (93.61-96.85)	4.50 (3.15-6.39)		95.50 (93.61-96.85)	4.50 (3.15-6.39)	
Western Australia	96.05 (95.09-96.82)	3.95 (3.18-4.91)		95.57 (94.71-96.29)	4.43 (3.71-5.29)		95.57 (94.71-96.29)	4.43 (3.71-5.29)	
Tasmania	96.16 (94.92-97.11)	3.84 (2.89-5.08)		96.25 (94.19-97.60)	3.75 (2.40-5.81)		96.25 (94.19-97.60)	3.75 (2.40-5.81)	
Northern Territory	93.69 (89.86-96.13)	6.31 (3.87-10.14)		95.06 (89.08-97.84)	4.94 (2.16-10.92)		95.06 (89.08-97.84)	4.94 (2.16-10.92)	
Australian Capital Territory	95.55 (94.10-96.66)	4.45 (3.34-5.90)		96.91 (95.42-97.93)	3.09 (2.07-4.58)		96.91 (95.42-97.93)	3.09 (2.07-4.58)	

Abbreviation: CI: Confidence Interval

Appendix Table A3: Weighted sample characteristics of the study variables by chronic pain status

	2015 Weighted % (95% CI) Chronic pain status			2018 Weighted % (95% CI) Chronic pain status			Pooled Weighted % (95% CI) Chronic pain status		
Characteristics	**No**	**Yes**	**P Value**	**No**	**Yes**	**P Value**	**No**	**Yes**	**P Value**
Level of self-care limitations									
No limitation	76.53 (75.46-77.56)	23.47 (22.44-24.54)	<0.001	78.19 (77.12-79.22)	21.81 (20.78-22.88)	<0.001	77.40 (76.65-78.14)	22.60 (21.86-23.35)	<0.001
Mild or moderate	35.31 (31.96-38.81)	64.69 (61.19-68.04)		39.55 (35.97-43.25)	60.45 (56.75-64.03)		37.58 (35.09-40.14)	62.42 (59.86-64.91)	
Profound or severe	32.42 (30.15-34.78)	67.58 (65.22-69.85)		33.62 (31.02-36.32)	66.38 (63.68-68.98)		33.02 (31.28-34.81)	66.98 (65.19-68.72)	
Dementia									
Yes	68.87 (67.84-69.88)	31.13 (30.12-32.16)		70.92 (69.86-71.95)	29.08 (28.05-30.14)	<0.001	69.94 (69.20-70.67)	30.06 (29.33-30.80)	<0.001
No	41.99 (38.58-45.46)	58.01 (54.54-61.42)		46.09 (42.28-49.94)	53.91 (50.06-57.72)		44.16 (41.57-46.79)	55.84 (53.21-58.43)	
Age									
65-69	73.01 (71.30-74.66)	26.99 (25.34-28.70)	<0.001	74.71 (72.91-76.43)	25.29 (23.57-27.09)	<0.001	73.88 (72.64-75.08)	26.12 (24.92-27.36)	<0.001
70-74	69.70 (67.67-71.66)	30.30 (28.34-32.33)		72.81 (70.82-74.70)	27.19 (25.30-29.18)		71.39 (69.97-72.76)	28.61 (27.24-30.03)	
75-79	66.91 (64.57-69.17)	33.09 (30.83-35.43)		67.42 (64.98-69.76)	32.58 (30.24-35.02)		67.18 (65.49-68.82)	32.82 (31.18-34.51)	
80-84	62.88 (60.03-65.65)	37.12 (34.35-39.97)		64.09 (61.17-66.91)	35.91 (33.09-38.83)		63.51 (61.48-65.50)	36.49 (34.50-38.52)	
85 and above	54.97 (52.35-57.57)	45.03 (42.43-47.65)		59.14 (56.34-61.88)	40.86 (38.12-43.66)		57.11 (55.19-59.02)	42.89 (40.98-44.81)	
Gender									
Male	72.09 (70.72-73.42)	27.91 (26.58-29.28)	<0.001	73.98 (72.58-75.32)	26.02 (24.68-27.42)	<0.001	73.08 (72.11-74.03)	26.92 (25.97-27.89)	<0.001
Female	63.48 (62.15-64.79)	36.52 (35.21-37.85)		65.78 (64.40-67.14)	34.22 (32.86-35.60)		64.69 (63.73-65.64)	35.31 (34.36-36.27)	
Accessibility and remoteness index									
Major cities in Australia	68.19 (66.96-69.39)	31.81 (30.61-33.04)	<0.001	69.83 (68.56-71.08)	30.17 (28.92-31.44)	<0.001	69.05 (68.17-69.92)	30.95 (30.08-31.83)	<0.001
Inner regional Australia	64.99 (62.73-67.18)	35.01 (32.82-37.27)		69.10 (66.88-71.24)	30.90 (28.76-33.12)		67.20 (65.62-68.74)	32.80 (31.26-34.38)	
Outer regional and remote area	68.16 (65.48-70.73)	31.84 (29.27-34.52)		69.36 (66.36-72.21)	30.64 (27.79-33.65)		68.76 (66.76-70.69)	31.24 (29.31-33.24)	
Country of Birth									
Australia	67.03 (65.78-68.25)	32.97 (31.75-34.22)	<0.001	69.57 (68.30-70.81)	30.43 (29.19-31.70)	<0.001	68.36 (67.47-69.24)	31.64 (30.76-32.53)	<0.001
English Speaking Countries	69.09 (66.54-71.53)	30.91 (28.47-33.46)		70.42 (67.80-72.92)	29.58 (27.08-32.20)		69.78 (67.96-71.54)	30.22 (28.46-32.04)	
Non-English-speaking countries	67.83 (65.65-69.94)	32.17 (30.06-34.35)		69.22 (66.87-71.48)	30.78 (28.52-33.13)		68.56 (66.96-70.12)	31.44 (29.88-33.04)	
State or territory									
New South Wales	66.10 (64.19-67.97)	33.90 (32.03-35.81)	<0.001	70.06 (68.21-71.85)	29.94 (28.15-31.79)	<0.001	68.16 (66.84-69.46)	31.84 (30.54-33.16)	<0.001
Victoria	67.39 (65.33-69.39)	32.61 (30.61-34.67)		70.07 (68.01-72.05)	29.93 (27.95-31.99)		68.80 (67.34-70.22)	31.20 (29.78-32.66)	
Queensland	69.09 (66.71-71.39)	30.91 (28.61-33.29)		68.36 (66.12-70.52)	31.64 (29.48-33.88)		68.71 (67.08-70.29)	31.29 (29.71-32.92)	
South Australia	64.21 (61.57-66.76)	35.79 (33.24-38.43)		70.95 (65.84-75.59)	29.05 (24.41-34.16)		67.72 (64.78-70.52)	32.28 (29.48-35.22)	
Western Australia	72.10 (69.52-74.54)	27.90 (25.46-30.48)		69.34 (66.96-71.62)	30.66 (28.38-33.04)		70.65 (68.91-72.33)	29.35 (27.67-31.09)	
Tasmania	68.84 (65.04-72.40)	31.16 (27.60-34.96)		66.58 (61.44-71.36)	33.42 (28.64-38.56)		67.65 (64.43-70.71)	32.35 (29.29-35.57)	
Northern Territory	64.33 (56.66-71.33)	35.67 (28.67-43.34)		70.84 (56.42-82.01)	29.16 (17.99-43.58)		67.81 (59.54-75.09)	32.19 (24.91-40.46)	
Australian Capital Territory	67.63 (63.22-71.74)	32.37 (28.26-36.78)		68.15 (61.73-73.95)	31.85 (26.05-38.27)		67.90 (63.97-71.60)	32.10 (28.40-36.03)	

Abbreviation: CI: Confidence Interval

Appendix Table A4: Ordered logistic regression examining the association of dementia and chronic pain with self-care limitation, pooled data

	Model 1	Model 2
	Level of self-care limitation	**Level of self-care limitation**
	aOR (95%CI)	aOR (95%CI)
Dementia		
No (ref)		
Yes	15.13** (12.45-17.83)	
Chronic pain		
No (ref)		
Yes	5.91*** (5.45-6.43)	
Group comparison in the interaction between dementia and chronic pain status		
No dementia and no chronic pain (ref)		1.0 (Reference)
No dementia but has chronic pain		6.24*** (5.71-6.81)
Has dementia but no chronic pain		20.18*** (16.08-25.32)
Has dementia and chronic pain		69.58*** (57.01-84.93)

Notes: 1. The outcome variable, self-care limitations, is categorised into five categories (0= "no self-care limitation", 1= "mild self-care limitation", 2= "moderate self-care limitation", 3= "profound self-care limitation", 4= "severe self-care limitation").
2. P-values: ***P < 0.001.
3. Abbreviations: ref Reference; aOR: Adjusted Odds Ratio; CI: Confidence Interval
4. Only exposure variables are reported in the adjusted model. The model is adjusted with age, sex, accessibility and remoteness index, country of birth, and state.

Appendix Table A5: Relevant marginal effects results for ordered logistic regressions

Self-care limitation score	Level of self-care limitation	Level of self-care limitation
	Variable of interest - dementia	**Variable of interest- chronic pain**
	Marginal effect, P value	**Marginal effect, P value**
0	-0.48; 0.001	-0.25; 0.001
1	0.01; 0.001	0.02; 0.001
2	0.08; 0.001	0.07; 0.001
3	0.09, 0.001	0.02; 0.001
4	0.29; 0.001	0.10; 0.001

Note: Self-care limitations score: 0= "no self-care limitation", 1= "mild self-care limitation", 2= "moderate self-care limitation", 3= "profound self-care limitation", 4= "severe self-care limitation".

APPENDIX D

This appendix includes supplementary materials related to Paper 4 of this thesis, presented in Chapter 6. These documents provide additional details that enhance the main findings of the study and support the methodologies, analyses, and interpretations discussed in the chapter.

Note: The table and figure numbers align with those referenced in the chapter for consistency.

Appendix

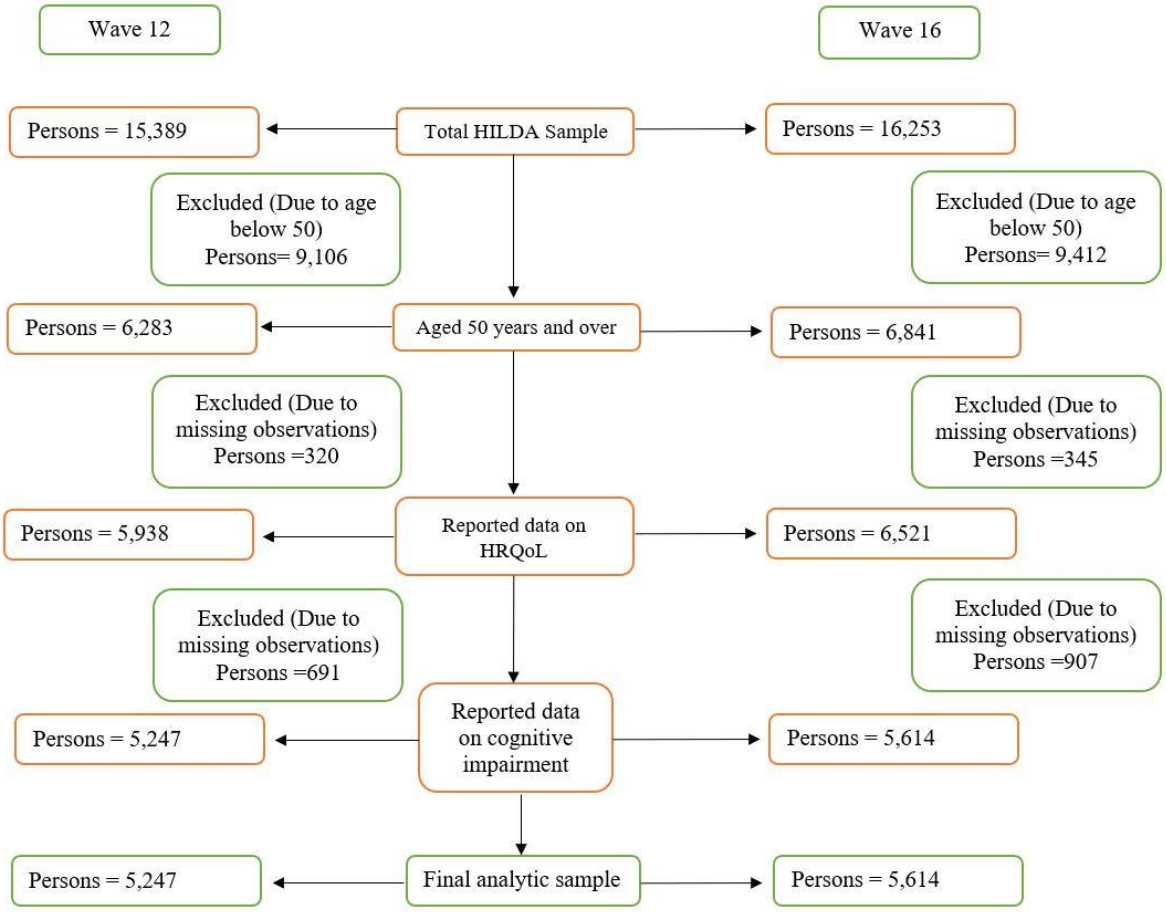


Figure A1. Participant flow into the analytic sample

Table A1: List of covariates and descriptions

Name of the Variable	Measure
Demographic characteristics	
Age (years)	0 = 50 to 64
	1 = 65 years and above
Gender	0 = Male
	1 = Female
Marital Status	0 = Single (not in a relationship or married, widowed, separated)
	1 = Couple (in a marriage or de facto relationship)
Indigenous Origin	0 = Non Aboriginal or Torres Strait Islander
	1 = Aboriginal or Torres Strait Islander
Socio-Economic Status (SES) variables	
Level of education attained	0 = Grade 12 and below
	1 = Advance diploma or certification course
	2 = Degree from university (graduate diploma, honours, masters or doctorate)
Household yearly disposable income of the family	0 = Quintile 1 (Lowest)
	1 = Quintile 2
	2 = Quintile 3
	3 = Quintile 4
	4 = Quintile 5 (highest)
Participation in the labour force	0 = Employed
	1 = Either not in the labour force or unemployed
Geographic residency	0 = Not in remote area (Major city)
	1 = In remote/regional area (Inner regional, outer regional, remote Australia, very remote Australia)
Health-related characteristics	
BMI	0 = BMI < 18.50 (Underweight)
	1 = BMI 18.50–24.99 (Normal)
	2 = BMI 25.00–29.99 (Overweight)
	3 = BMI ≥ 30 (Obese)
Health-related behavioural characteristics	
Smoking habits	0 = Former smoker or never smoked
	1 = Currently smoking
Alcohol drinking	0 = Former drinker or never drunk
	1 = Active drinker (only rarely, 1–2 days, 2–3 days, 3–4 days, 5–6 days per week and every day)

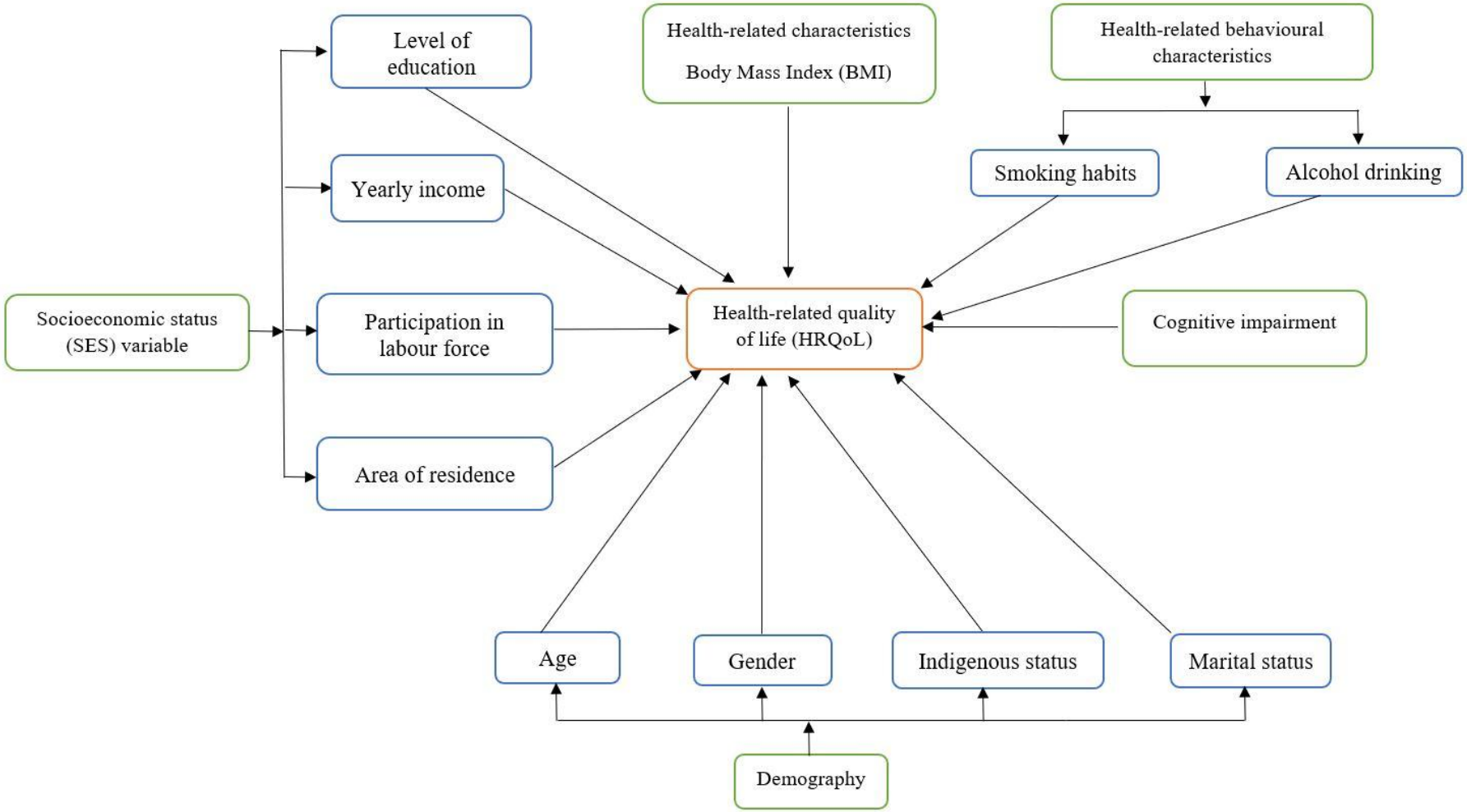
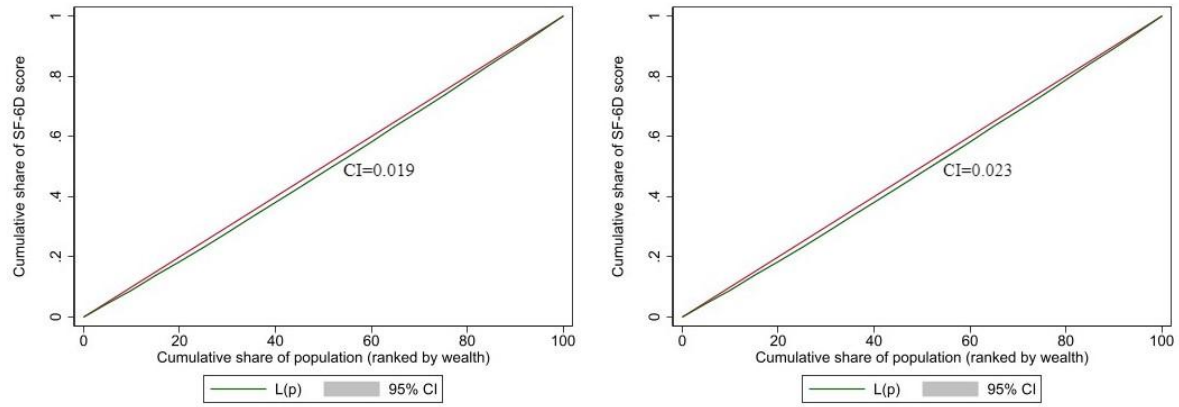


Figure A2: Conceptual framework of HRQoL for older people



Notes: Abbreviation: CI = Concentration Index; 95% CI = 95% Confidence Interval.

Figure A3: Concentration curve of health-related quality of life using standard concentration index with equivalised average household wealth ranking

Table A2: Regression results

	Wave 12		Wave 16	
Cognitive impairment, n (%)	**Coefficient (SE)**	**P-value**	**Coefficient (SE)**	**P-value**
No (ref)				
Mild cognitive impairment	-0.0402(0.0053)	0.001	-0.0469(0.0057)	0.001
Severe cognitive impairment	-0.0568(0.0191)	0.003	-0.0438(0.0181)	0.016
Age (in years)				
50-64 (ref)				
65 and over	0.0157(0.0041)	0.001	0.013(0.0039)	0.001
Gender				
Male (ref)				
Female	-0.0091(0.0034)	0.001	-0.0095(0.0032)	0.003
Indigenous origin				
Non Aboriginal or Torres Strait Islander				
Aboriginal or Torres Strait Islander	-0.0004(0.012)	0.970	-0.0022(0.0112)	0.846
Marital status				
Unpartnered (ref)				
Partnered	0.0136(0.0035)	0.001	0.0151(0.0034)	0.001
Highest level of schooling achieved				
Year 12 and below (ref)				
Professional qualifications	0.0011(0.0038)	0.771	-0.0043(0.0037)	0.241
University qualifications	0.0026(0.0044)	0.552	-0.0027(0.0043)	0.521
Average household wealth (Quintile)				
Quintile 1	-0.0629(0.0067)	0.001	-0.0558(0.0056)	0.000
Quintile 2	-0.0309(0.0063)	0.001	-0.0337(0.0053)	0.000
Quintile 3	-0.0254(0.0063)	0.001	-0.017(0.0051)	0.001
Quintile 4	-0.025(0.0053)	0.001	-0.0269(0.0048)	0.000
Quintile 5 (ref)				
Labour force participation				
Employed (ref)				
Unemployed/Not in the labour force	-0.0634(0.004)	0.001	-0.0623(0.0038)	0.000
Area of residence				
Major Cities (ref)				
Regional/remote	-0.0053(0.0034)	0.114	0.0002(0.0032)	0.951
BMI				
Healthy weight (ref)				
Underweight	-0.0312(0.0137)	0.022	-0.0409(0.0145)	0.005
Overweight	-0.0131(0.0038)	0.001	-0.011(0.0038)	0.003
Obese	-0.043(0.0041)	0.000	-0.0474(0.004)	0.001
Smoking habits				
Former smoker/never smoked (ref)				
Currently smoking	-0.0165(0.005)	0.001	-0.0249(0.0049)	0.001
Alcohol drinking				
Former drinker or never drunk (ref)				
Active drinker	0.0245(0.0042)	0.001	0.0251(0.0041)	0.001

Notes: 1. Standard errors are in the parentheses. 2. Ref indicates reference group

Table A3: Wagstaff - Doorslaer – Watanabe - Decomposition analysis

	wave 12				wave 16			
Variables	**η_k[2]**	**CI[3]**	**Co[4]**	**%Co[5]**	**η_k**	**CI**	**Co**	**%Co**
Mild cognitive impairment	-0.0022	-0.1675	**0.0004**	1.8713	-0.0025	-0.2102	**0.0005**	2.2794
Severe cognitive impairment	-0.0002	-0.2086	**0.0000**	0.2431	-0.0002	-0.3240	**0.0001**	0.2319
Age (in years)								
65 and above	0.0091	-0.0571	**-0.0005**	-2.6473	0.0075	-0.0410	**-0.0003**	-1.3239
Gender								
Female	-0.0066	-0.0233	**0.0002**	0.7852	-0.0069	-0.0267	**0.0002**	0.7956
Indigenous origin								
Aboriginal or Torres Strait Islander	0.0000	-0.0425	**0.0000**	0.0024	-0.0001	-0.1303	**0.0000**	0.0308
Marital Status								
Partnered	0.0120	0.0995	**0.0012**	6.0762	0.0133	0.1081	**0.0014**	6.2120
Highest level of schooling achieved								
Professional qualifications	0.0005	-0.0198	**0.0000**	-0.0514	-0.0020	-0.0396	**0.0001**	0.3407
University qualifications	0.0008	0.2188	**0.0002**	0.9374	-0.0009	0.2653	**-0.0002**	-1.0160
Average household wealth (Quintile)								
Quintile 1	-0.0172	-0.8555	**0.0147**	74.8522	-0.0152	-0.8224	**0.0125**	54.1542
Quintile 2	-0.0084	-0.5517	**0.0047**	23.7288	-0.0092	-0.4595	**0.0042**	18.2548
Quintile 3	-0.0069	-0.2419	**0.0017**	8.5513	-0.0046	-0.0779	**0.0004**	1.5643
Quintile 4	-0.0068	0.3360	**-0.0023**	-11.6994	-0.0073	0.3654	**-0.0027**	-11.6056
Labour force participation								
Unemployed/Not in the labour force	-0.0465	-0.0695	**0.0032**	16.4606	-0.0454	-0.0693	**0.0031**	13.6127
Area of residence								
Regional/remote	-0.0027	-0.0662	**0.0002**	0.9119	0.0001	-0.1013	**0.0000**	-0.0448
BMI								
Underweight	-0.0006	-0.0338	**0.0000**	0.1045	-0.0008	-0.1496	**0.0001**	0.5081
Overweight	-0.0068	0.0036	**0.0000**	-0.1236	-0.0058	0.0466	**-0.0003**	-1.1598
Obese	-0.0169	-0.0636	**0.0011**	5.4706	-0.0186	-0.1353	**0.0025**	10.8935
Smoking habits								
Currently smoking	-0.0028	-0.1475	**0.0004**	2.1197	-0.0043	-0.2468	**0.0010**	4.5397
Alcohol drinking								
Active drinker	0.0269	0.0386	**0.0010**	5.2941	0.0275	0.0454	**0.0012**	5.4044
Total estimate contribution CI of HRQoL (SF-6D)			**0.019**				**0.023**	

Notes: 1. The 0 values do not represent actual zeros. The values are close to zero. 2. η symbolises elasticity. The equation is defined as $\eta_k = \beta_i \frac{\bar{X}_k}{h}$, 3. The concentration index (CI) is calculated by ranking the row variable based on equivalised household income, 4. Co represents the contribution to the concentration index of HRQoL, 5. The contribution is calculated as a percentage by determining the proportion of the contribution to the actual concentration index. The sum of all Co represents the explained portion of the CI of HRQoL in a given wave.

APPENDIX E

This appendix includes supplementary materials related to Paper 5 of this thesis, presented in Chapter 7. These documents provide additional details that enhance the main findings of the study and support the methodologies, analyses, and interpretations discussed in the chapter.

Note: The table and figure numbers align with those referenced in the chapter for consistency.

Appendix

Table A1: Robustness test: The relationship between cognitive impairment and four different types of health outcomes (general health, mental health, self-assessed health, and health satisfaction)

	Model 1	Model 2	Model 3	Model 4
	Generalised estimating equation	Generalised estimating equation	Random effect GLS	Random effect GLS
	General health	Mental health	Self-assessed health	Health satisfaction
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	-3.55*** [0.56]	-3.89*** [-7.74]	-0.19*** [0.02]	-0.14* [0.06]
Covariates				
Age				
50-64 years (ref)				
65 years and over	4.02*** [0.43]	7.38*** [19.07]	0.04* [0.02]	0.57*** [0.04]
Sex				
Male (ref)				
Female	3.09*** [0.36]	-0.54 [-1.68]	0.09*** [0.02]	0.15*** [0.04]
Marital status				
Unpartnered (ref)				
partnered	0.43 [0.36]	1.49*** [4.54]	0.04*** [0.02]	0.16*** [0.04]
Highest level of education				
Year 12 and below (ref)				
Professional qualifications	0.66 [0.40]	0.28 [0.77]	0.06** [0.02]	-0.03 [0.04]
University qualifications	-0.36 [0.47]	-0.02 [-0.05]	0.15*** [0.02]	-0.07 [0.05]
Annual household disposable income				
Quintile 1 (poorest)	-3.35*** [0.62]	-3.36*** [-6.05]	-0.15*** [0.03]	-0.29*** [0.06]
Quintile 2	-3.2*** [0.58]	-2.23*** [-4.26]	-0.13*** [0.02]	-0.29*** [0.05]
Quintile 3	-1.82*** [0.55]	-1.64*** [-3.33]	-0.07*** [0.02]	-0.11** [0.05]
Quintile 4	-1.06* [0.54]	-0.35 [-0.73]	-0.05*[0.02]	-0.07 [0.04]
Quintile 5 (richest) (ref)				
Participation in labour force				
Employed (ref)				
Unemployed or not in the labour force	-5.08*** [0.45]	-2.59*** [-6.43]	-0.18*** [0.02]	-0.36*** [0.04]
Indigenous origin				
Non ATSI (ref)				
Aboriginal or Torres Strait Islander	-2.23 [1.23]	-0.16 [-0.14]	-0.06 [0.07]	-0.09 [0.15]
Geographic residency				
Major cities (ref)				
Regional city/remote area	0.09 [0.36]	0.57 [1.78]	-0.04* [0.02]	0.02 [0.04]
Smoking habits				
Non-smoker (ref)				
Currently smoking	-4.31*** [0.53]	-3.33*** [-7.04]	-0.22*** [0.02]	-0.32*** [0.06]
Alcohol drinking				
Non-drinker (ref)				
Active drinker	3.16*** [0.45]	1.83*** [4.59]	0.15*** [0.02]	0.17*** [0.05]
Physical activity				
Less than the recommended level (ref)				

Recommended level	7.42*** [0.37]	4.36*** [13.2]	0.24*** [0.02]	0.48*** [0.03]
Body Mass Index (BMI)				
Underweight	-6.73*** [1.47]	-4.41*** [-3.34]	-0.20*** [0.06]	-0.42* [0.17]
Healthy weight (ref)				
Overweight	-0.83* [0.41]	-0.45[-1.22]	-0.06*** [0.02]	-0.12*** [0.04]
Obesity	-5.45*** [0.44]	-1.20*** [-3.02]	-0.27*** [0.02]	-0.52*** [0.04]
Disability status				
No (ref)				
Yes	-18.5*** [0.37]	-7.18*** [0.33]	-0.61***[0.02]	-1.48*** [0.04]

*Notes: 1. Values in brackets are robust standard errors. 2. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.*

Table A2: Heterogenous Effect: The relationship between cognitive impairment and general health by age and gender

	Model 1	Model 2	Model 3	Model 4
	Random-effects GLS	Random-effects GLS	Random-effects GLS	Random-effects GLS
	General health (Age 50-64 years)	General health (Age 65 years and over)	General Health (Male)	General Health (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	-1.59 [1.04]	-3.90 [0.68]	-1.88* [0.79]	-3.61*** [0.81]
Covariates				
Age				
50-64 years (ref)				
65 years and over			1.79*** [0.62]	2.08*** [0.59]
Sex				
Male (ref)				
Female	2.25*** [0.52]	3.74*** [0.66]		
Marital status				
Unpartnered (ref)				
partnered	1.23* [0.52]	0.32 [0.64]	0.94 [0.62]	0.65 [0.56]
Highest level of education				
Year 12 and below (ref)	0.92 [0.6]	1.40 [0.74]	1.13 [0.7]	1.24 [0.68]
Professional qualifications	0.45 [0.67]	0.14 [0.87]	1.37 [0.81]	0.09 [0.75]
University qualifications				
Annual household disposable income				
Quantile 1 (poorest)	-4.87*** [0.83]	-2.27** [0.92]	-2.84*** [0.86]	-2.50*** [0.77]
Quantile 2	-3.01*** [0.68]	-3.42*** [0.90]	-4.09*** [0.75]	-2.11*** [0.72]
Quantile 3	-1.61** [0.6]	-2.86*** [0.89]	-2.36*** [0.66]	-1.21 [0.71]
Quantile 4	-0.78 [0.51]	-1.37 [0.94]	-1.26* [0.61]	-0.30 [0.63]
Quantile 5 (richest) (ref)				
Participation in labour force				
Employed (ref)				
Unemployed or not in the labour force	-4.98*** [0.54]	-3.73*** [0.76]	-5.76*** [0.62]	-3.34*** [0.59]
Indigenous origin				
Non-ATSI (ref)				
Aboriginal or Torres Strait Islander	-2.05 [1.77]	-2.10 [2.96]	-0.90 [2.24]	-3.83 [2.17]
Geographic residency				
Major cities (ref)				
In remote/regional area	-0.42 [0.52]	0.49 [0.62]	-0.82 [0.58]	0.69 [0.57]
Smoking habits				
Non-smoker (ref)				
Currently smoking	-4.05*** [0.65]	-3.60*** [1.2]	-4.05*** [0.81]	-4.02*** [0.82]
Alcohol drinking				
Non-drinker (ref)				

Active drinker	2.69*** [0.71]	3.72*** [0.71]	2.78*** [0.85]	3.37*** [0.63]
Physical activity				
Less than the recommended level (ref)				
Recommended level	6.38*** [0.45]	5.37*** [0.54]	6.5*** [0.48]	5.07*** [0.49]
Body Mass Index (BMI)				
Underweight	-4.20* [2.1]	-5.76** [2.17]	-8.49*** [2.93]	-3.82* [1.75]
Healthy weight (ref)				
Overweight	-1.89*** [0.53]	-1.25* [0.62]	-1.00 [0.60]	-1.99*** [0.55]
Obesity	-6.42*** [0.62]	-4.77*** [0.79]	-5.41*** [0.75]	-6.02*** [0.66]
Disability status				
No (ref)				
Yes	-15.18*** [0.57]	-14.00*** [0.58]	-13.69*** [0.58]	-14.27*** [0.56]

*Notes: 1. Values in brackets are robust standard errors. 2. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.*

Table A3: Heterogenous Effect: The relationship between cognitive impairment and mental health by age and gender

	Model 1	Model 2	Model 3	Model 4
	Random-effects GLS	Random-effects GLS	Random-effects GLS	Random-effects GLS
	Mental Health (Age 50-64 years)	Mental Health (Age 65 years and over)	Mental Health (Male)	Health (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	-2.33* [1.05]	-3.92*** [0.60]	-2.94*** [0.77]	-2.88*** [0.72]
Covariates				
Age				
50-64 years (ref)				
65 years and over			4.46*** [0.55]	5.61*** [0.56]
Sex				
Male (ref)				
Female	-1.01* [0.48]	-0.49 [0.57]		
Marital status				
Unpartnered (ref)				
partnered	2.97*** [0.50]	-0.03[0.56]	2.91*** [0.58]	1.03* [0.51]
Highest level of education				
Year 12 and below (ref)				
Professional qualifications	-0.36 [0.57]	1.33* [0.64]	0.40 [0.62]	0.09 [0.63]
University qualifications	-0.61 [0.61]	2.3*** [0.75]	0.50 [0.71]	0.33[0.67]
Annual household disposable income				
Quantile 1 (poorest)	-3.98*** [0.83]	-1.92** [0.76]	-1.78* [0.76]	-2.91*** [0.75]
Quantile 2	-1.84** [0.68]	-1.36 [0.72]	-1.46* [0.65]	-1.61* [0.70]
Quantile 3	-1.50** [0.56]	-0.64 [0.70]	-1.11 [0.58]	-0.77 [0.65]
Quantile 4	0.07 [0.48]	-0.76 [0.78]	-0.26 [0.55]	0.02 [0.61]
Quantile 5 (richest) (ref)				
Participation in labour force				
Employed (ref)				
Unemployed or not in the labour force	-2.85*** [0.53]	-1.68** [0.60]	-2.49*** [0.56]	-2.11*** [0.58]
Indigenous origin				
Non-ATSI (ref)				
Aboriginal or Torres Strait Islander	1.16[1.62]	-3.56 [2.65]	1.62 [1.85]	-1.76 [2.11]
Geographic residency				
Major cities (ref)				
In remote/regional area	-0.18 [0.49]	1.18* [0.53]	0.46 [0.52]	0.15 [0.52]
Smoking habits				
Non-smoker (ref)				
Currently smoking	-2.94*** [0.65]	-3.26*** [1.09]	-2.90*** [0.76]	-3.77*** [0.86]
Alcohol drinking				
Non-drinker (ref)				
Active drinker	1.81** [0.67]	1.69** [0.64]	2.55*** [0.79]	1.49** [0.57]
Physical activity				

Less than the recommended level (ref)				
Recommended level	4.38*** [0.41]	2.91*** [0.46]	4.02*** [0.41]	3.42*** [0.45]
Body Mass Index (BMI)				
Underweight	-6.78** [2.41]	-1.94 [1.69]	-3.85 [2.14]	-4.30* [1.88]
Healthy weight (ref)				
Overweight	-0.92 [0.49]	-0.21 [0.53]	-0.33 [0.52]	-0.73 [0.50]
Obesity	-1.30* [0.56]	-0.95 [0.66]	-1.70**[0.64]	-0.94 [0.59]
Disability status				
No (ref)				
Yes	-6.52*** [0.48]	-4.61*** [0.44]	-5.27*** [0.46]	-5.41*** [0.47]

*Notes: 1. Values in brackets are robust standard errors. 2. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.*

Table A4: Heterogenous Effect: The relationship between cognitive impairment and self-assessed health by age and gender

	Model 1	Model 2	Model 3	Model 4
	Ordered logit	Ordered logit	Ordered logit	Ordered logit
	Self-assessed health (Age 50-64 years)	Self-assessed health (Age 65 years and over)	Self-assessed health (Male)	Self-assessed health (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	-0.55*** [0.19]	-0.92*** [0.12]	-0.62*** [0.14]	-0.85*** [0.14]
Covariates				
Age				
50-64 years (ref)				
65 years and over			0.18 [0.11]	0.13 [0.10]
Sex				
Male (ref)				
Female	0.32*** [0.09]	0.37*** [0.11]		
Marital status				
Unpartnered (ref)				
partnered	0.21* [0.09]	-0.02 [0.11]	0.09 [0.11]	0.14 [0.09]
Highest level of education				
Year 12 and below (ref)				
Professional qualifications	0.13 [0.10]	0.36*** [0.13]	0.20 [0.12]	0.32** [0.11]
University qualifications	0.57*** [0.11]	0.41** [0.16]	0.93***[0.15]	0.32** [0.13]
Annual household disposable income				
Quantile 1 (poorest)	-0.93*** [0.14]	-0.47** [0.17]	-0.71*** [0.16]	-0.47*** [0.14]
Quantile 2	-0.55*** [0.12]	-0.58*** [0.17]	-0.82*** [0.14]	-0.29* [0.13]
Quantile 3	-0.29** [0.11]	-0.36* [0.17]	-0.41*** [0.13]	-0.15 [0.13]
Quantile 4	-0.20* [0.09]	-0.25 [0.18]	-0.33*** [0.12]	-0.05 [0.12]
Quantile 5 (richest) (ref)				
Participation in labour force				
Employed (ref)				
Unemployed or not in the labour force	-0.69*** [0.10]	-0.66*** [0.14]	-0.82*** [0.12]	-0.62*** [0.11]
Indigenous origin				
Non ATSI (ref)				
Aboriginal or Torres Strait Islander	-0.21 [0.28]	-0.25 [0.50]	0.02 [0.35]	-0.50 [0.37]
Geographic residency				
Major cities (ref)				
In remote/regional area	-0.22** [0.09]	-0.06 [0.10]	-0.21* [0.10]	-0.10 [0.09]
Smoking habits				
Non-smoker (ref)				
Currently smoking	-0.86*** [0.11]	-0.79*** [0.19]	-0.86*** [0.14]	-0.87 [0.14]
Alcohol drinking				
Non-drinker (ref)				
Active drinker	0.50*** [0.11]	0.68*** [0.12]	0.39** [0.14]	0.69*** [0.10]
Physical activity				

Less than the recommended level (ref)				
Recommended level	1.08*** [0.09]	0.91*** [0.10]	1.07*** [0.09]	0.93*** [0.09]
Body Mass Index (BMI)				
Underweight	-0.74 [0.40]	-0.81** [0.31]	-1.22** [0.49]	-0.66* [0.29]
Healthy weight (ref)				
Overweight	-0.24** [0.10]	-0.20* [0.11]	-0.11 [0.11]	-0.33*** [0.10]
Obesity	-1.11*** [0.11]	-0.99***[0.13]	-0.99*** [0.13]	-1.14*** [0.11]
Disability status				
No (ref)				
Yes	-2.41*** [0.10]	-2.48*** [0.11]	-2.32*** [0.10]	-2.44*** [0.10]

*Notes: 1. Values in brackets are robust standard errors. 2. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.*

Table A5: Heterogenous Effect: The relationship between cognitive impairment and health satisfaction by age and gender

	Model 1	Model 2	Model 3	Model 4
	Ordered logit	Ordered logit	Ordered logit	Ordered logit
	Health satisfaction (Age 50-64 years)	Health satisfaction (Age 65 years and over)	Health satisfaction (Male)	Health satisfaction (Female)
	β (SE)	β (SE)	β (SE)	β (SE)
Exposure variable				
Cognitive impairment				
No (ref)				
Yes	-0.42* [0.17]	-0.21* [0.10]	-0.12 [0.13]	-0.24* [0.13]
Covariates				
Age				
50-64 years (ref)				
65 years and over			0.87*** [0.10]	0.83*** [0.09]
Sex				
Male (ref)				
Female	0.24*** [0.08]	0.21** [0.09]		
Marital status				
Unpartnered (ref)				
partnered	0.40*** [0.08]	0.01 [0.09]	0.25** [0.09]	0.19* [0.08]
Highest level of education				
Year 12 and below (ref)	-0.07 [0.09]	0.03 [0.10]	0.06 [0.10]	-0.08 [0.10]
Professional qualifications	-0.13 [0.10]	-0.17 [0.12]	0.08 [0.12]	-0.27** [0.10]
University qualifications				
Annual household disposable income				
Quantile 1 (poorest)	-0.80*** [0.14]	-0.33* [0.14]	-0.68*** [0.14]	-0.24* [0.12]
Quantile 2	-0.52*** [0.12]	-0.44*** [0.14]	-0.70*** [0.12]	-0.22 [0.12]
Quantile 3	-0.23** [0.09]	-0.24 [0.14]	-0.33*** [0.11]	-0.06 [0.11]
Quantile 4	-0.18* [0.08]	-0.16[0.14]	-0.27*** [0.1]	0.01[0.1]
Quantile 5 (richest) (ref)				
Participation in labour force				
Employed (ref)				
Unemployed or not in the labour force	-0.56*** [0.08]	-0.13 [0.12]	-0.5*** [0.1]	-0.32*** [0.09]
Indigenous origin				
Non ATSI (ref)				
Aboriginal or Torres Strait Islander	-0.19 [0.25]	0.21 [0.55]	0.12 [0.34]	-0.35 [0.33]
Geographic residency				
Major cities (ref)				
In remote/regional area	0.03 [0.08]	0.07 [0.09]	-0.03 [0.09]	0.12 [0.08]
Smoking habits				
Non-smoker (ref)				
Currently smoking	-0.45*** [0.10]	-0.61 [0.18]	-0.66*** [0.12]	-0.35*** [0.12]
Alcohol drinking				
Non-drinker (ref)				

Active drinker	0.20* [0.10]	0.25** [0.1]	0.13 [0.12]	0.30*** [0.09]
Physical activity				
Less than the recommended level (ref)				
Recommended level	1.02*** [0.07]	0.67*** [0.08]	0.90*** [0.08]	0.78*** [0.08]
Body Mass Index (BMI)				
Underweight	-0.72* [0.35]	-0.36 [0.38]	-1.73*** [0.50]	-0.05 [0.29]
Healthy weight (ref)				
Overweight	-0.20** [0.08]	-0.28*** [0.09]	-0.20* [0.09]	-0.26*** [0.08]
Obesity	-0.95*** [0.09]	-0.83*** [0.11]	-0.9*** [0.11]	-0.90*** [0.09]
Disability status				
No (ref)				
Yes	-2.48*** [0.09]	-2.33*** [0.09]	-2.22*** [0.09]	-2.49*** [0.09]

*Notes: 1. Values in brackets are robust standard errors. 2. ***, **, and * denote significance at the $p < 0.001$, $p < 0.01$, and $p < 0.05$ levels, respectively.*

APPENDIX F

This appendix includes supplementary materials related to Paper 6 of this thesis, presented in Chapter 8. These documents provide additional details that enhance the main findings of the study and support the methodologies, analyses, and interpretations discussed in the chapter.

Note: The table and figure numbers align with those referenced in the chapter for consistency.

Appendix

STROBE Statement—Checklist of items that should be included in reports of ***observational studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	N/A
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	8-9
		(*c*) Explain how missing data were addressed	16
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	16
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for	4

		eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	4-5
		(c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-13
		(b) Indicate number of participants with missing data for each variable of interest	Appendix Table A2
Outcome data	15*	Report numbers of outcome events or summary measures	13-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-20
		(*b*) Report category boundaries when continuous variables were categorized	13
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	15-16
Discussion			
Key results	18	Summarise key results with reference to study objectives	20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21-22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20-21
Generalisability	21	Discuss the generalisability (external validity) of the study results	20
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	30

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Appendix Table A1: Abridged results from random effect GEE regression models of HRQoL (MCS, PCS and SF-6D), pooled analysis

	Model 1	Model 2	Model 3
	PCS	**MCS**	**SF-6D**
	Coefficient (SE), P-value	Coefficient (SE), P-value	Coefficient (SE), P-value
Level of physical activity			
Not at all (ref)			
1 to 3 times a week	4.66 (0.66), 0.001	2.63 (0.70), 0.001	0.04 (0.007), 0.001
More than 3 times a week to everyday	7.46 (0.76), 0.001	4.61 (0.81), 0.001	0.08 (0.008), 0.001

Note: 1. The sample size is 985 individuals and 1,168 observations. 2. All models were adjusted for age, gender, marital status, highest education level of education, household yearly disposable income, participation in the labour force, Indigenous origin, geographic residency, smoking habits, alcohol drinking, BMI and disability status. 3. PCS=physical component summary, MCS=mental component summary, and SF-6D=Short-Form Six-Dimension health utility index. 4. Ref means reference category. 5. Cluster-robust standard errors (SE) are reported in the parenthesis.

Appendix Table A2: Missing observation analysis

Variable	Missing observation	Total observation	Percent Missing
SF-6D utility score	194	1,401	13.85
Backward digit score	0	1,401	0
Symbol-digit modality score	0	1,401	0
Physical functioning	51	1,401	3.64
Role physical	100	1,401	7.14
Role emotional	100	1,401	7.14
Social functioning	8	1,401	0.57
Mental health	26	1,401	1.86
Vitality	26	1,401	1.86
Bodily pain	20	1,401	1.43
General Health	65	1,401	4.64
Age	0	1,401	0
Gender	0	1,401	0
Marital status	0	1,401	0
Highest level of education	0	1,401	0
Participation in labour force	0	1,401	0
Indigenous origin	424	1,401	30.26
Geographic residency	0	1,401	0
Body Mass Index (BMI)	141	1,401	10.06
Disability status	1	1,401	0.07
Smoking habits	52	1,401	3.71
Alcohol drinking	0	1,401	0
Levels of physical activity	21	1,401	1.5

Appendix Table A3: Abridge results from random effect GLS regression models of HRQoL (MCS, PCS and SF-6D) (with imputed value)

	Model 1	Model 2	Model 3
	PCS	**MCS**	**SF-6D**
	Coefficient (SE), P-value	Coefficient (SE), P-value	Coefficient (SE), P-value
Level of physical activity			
Not at all (ref)			
1 to 3 times per week	4.82 (0.65), 0.001	2.38 (0.72),0.001	0.04 (0.008), 0.001
More than 3 times per week to everyday	7.53 (0.79), 0.001	3.97 (0.83), 0.001	0.07 (0.009), 0.001

1. All models were adjusted for age, gender, marital status, highest education level of education, household yearly disposable income, participation in the labour force, Indigenous origin, geographic residency, smoking habits, alcohol drinking, BMI and disability status. 3. PCS=physical component summary, MCS=mental component summary, and SF-6D=Short-Form Six-Dimension health utility index. 4. Ref means reference category. 5. Cluster-robust standard errors (SE) are reported in the parenthesis.

APPENDIX G

List of publications to which I contributed throughout the PhD programme (but not considered part of the thesis)

Journal Articles

Article I: Gow J, Moscovici D, Rana R, Rinaldi A, Ugaglia AA, Valenzuela L ... and **Haque R** (2024) 'Determinants of purchasing sustainably produced wines by Italian wine consumers', *Sustainability*, 16(19):8283, https://doi.org/10.3390/su16198283 **(Q1 journal)**

Article II: Ahsan MN, Mohibbullah M, Gain AK, Khatun F, Rahman MA, Sultana A, **Haque R,** Rahman MM, Rahaman, KR, Vink K and Shaw R (2024) 'We knew a cyclone was imminent': hazard preparedness and disaster management efficiency nexus in coastal Bangladesh', *International Journal of Disaster Risk Reduction*, 102:104240, https://doi.org/10.1016/j.ijdrr.2024.104240 **(ABDC ranking: A; Q1-ranked journal)**

Article III: Keramat SA, Perales F, Alam K, Rashid R, **Haque R**, Monasi N ... and Kondalsamy-Chennakesavan S (2024) 'Multimorbidity and health-related quality of life amongst Indigenous Australians: a longitudinal analysis', *Quality of Life Research*, 33(1):195-206. https://doi.org/10.1007/s11136-023-03500-3 **(ABDC ranking: A; Q1-ranked journal)**

Article IV: Shanto HH, Al-Zubayer MA, Ahammed B, Sarder MA, Keramat SA, Hashmi R, **Haque R** and Alam K (2023) 'Maternal healthcare services utilisation and its associated risk factors: a pooled study of 37 low- and middle-income countries', *International Journal of Public Health*, 68:1606288, https://doi.org/10.3389/ijph.2023.1606288 **(Q1-ranked journal)**

Article V: Rahman SM, Mamoon M, Islam MS, Hossain S, **Haque R** and Zubair ABM (2022) 'Post-displacement status of climate migrants in Rajshahi City, Bangladesh',. *Regional Sustainability*, 3(3):183-187, https://doi.org/10.1016/j.regsus.2022.09.002 **(Q1-ranked journal)**

Article VI: Rahman SM, Ogura Y, Uddin MN, **Haque R** and Rahman SM (2022) 'Economy, commerce, and energy: how do the factors influence carbon dioxide emissions in Japan? An application of ARDL Model', *Statistics, Politics and Policy*, 13(2):219-233, https://doi.org/10.1515/spp-2021-0028

Article VI: Haque R, Alam K, Rahman SM, Mustafa MUR, Ahammed B, Ahmad K ... and Keramat SA (2022) 'Nexus between maternal underweight and child anthropometric status in South and South-East Asian countries', *Nutrition*, 98:111628, https://doi.org/10.1016/j.nut.2022.111628 **(Q1-ranked journal)**

Book Chapter

Rahman SM, Mamoon M, Haque AB, Abedin MJ, **Haque R**, Nahar R ... and Islam MS (2023) 'Information dissemination during the COVID-19 outbreak among the students at the tertiary level in Bangladesh', in Sultan P (ed) *Innovation, leadership and governance in higher education: perspectives on the Covid-19 recovery strategies*, Springer Nature Singapore, Singapore, pp.335-349, https://doi.org/10.1007/978-981-19-7299-7_18