The impact of assistive devices on community-dwelling older adults and their informal caregivers

by

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Author’s Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

In part, this thesis is composed of three manuscripts, one of which has been published (Chapter 3), and two that have been written for publication (Chapter 4 and Chapter 5).

All three manuscripts were written by the doctoral candidate and supervised by Dr. Mark Oremus and Dr. Ashok Chaurasia.

Chapter 3: Marasinghe, K.M., Chaurasia, A., Adil, M. *et al.* The impact of assistive devices on community-dwelling older adults and their informal caregivers: a systematic review. *BMC Geriatr* 22, 897 (2022). https://doi.org/10.1186/s12877-022-03557-8.

Chapter 4: Marasinghe, K.M., Oremus, M., Chaurasia, A. Investigating the association between assistive device use and life satisfaction among community-dwelling older adults: analysis of the Canadian Longitudinal Study on Aging (CLSA).

Chapter 5: Marasinghe, K.M., Chaurasia, A Oremus, M. The association between assistive device use and informal caregiving hours among community-dwelling older adults: analysis of the Canadian Longitudinal Study on Aging (CLSA).

Under Drs. Mark Oremus's and Ashok Chaurasia's supervision, I was responsible for the acquisition, analysis, interpretation of data, and drafting of manuscripts 1 (Chapter 3), 2 (Chapter 4), and 3 (Chapter 5), and submitting manuscript 1 for publication. My supervisors guided and assisted me throughout the process and provided feedback on draft manuscripts.

With supervision from Drs. Mark Oremus and Ashok Chaurasia, I wrote the remaining chapters in this thesis (Chapter 1, Chapter 2, and Chapter 6), which were not intended for publication.

Abstract

Background

Canadians are aging and living longer with chronic conditions, multimorbidity, and disabilities, which can have negative impacts on the health and quality of life of both older adults and their informal caregivers. Assistive devices (AD) can be beneficial to community-dwelling older adults and their informal caregivers; however, researchers have not investigated all outcomes of using AD. Two under-investigated outcomes in aging populations are: (a) the change in life satisfaction (LS) over time, and (b) the change in the number of informal caregiving hours received over time. The Consortium for Assistive Technology Outcome Research (CATOR) framework was used to frame the following objectives, which identifies LS and the amount of informal caregiving hours received as key outcomes of AD use.

Objectives

The objectives of this thesis were addressed via three studies: Study 1 (Chapter 3) examined existing evidence on the associations between (a) AD use and LS, and (b) AD use and informal caregiving hours received; Study 2 (Chapter 4) and Study 3 (Chapter 5) investigated the associations between self-reported AD use within the past 12 months (assessed at baseline) and: (a) the change in LS over time (three-years), (b) the change in informal caregiving hours received over time (three-years), respectively. All studies focused on community-dwelling older adults aged ≥ 65 years.

Methods

Study 1 consisted of a systematic review adhering to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines. Studies 2 and 3 used unweighted data from the Tracking and Comprehensive cohorts of the Canadian Longitudinal Study on Aging (CLSA) and multiple linear regression models to investigate the associations between AD use and the change in LS or informal caregiver time. The regression analyses controlled for comprehensive sets of covariates.

Results

Study 1 suggested AD use was not linked with LS and was associated with reductions in informal caregiving hours. However, due to the scarcity of existing studies, their limitations (e.g., high risk of bias, residual confounding, cross-sectional nature), and very low or moderate strength of evidence, conclusions about the associations of interest could not be drawn with certainty. Results from Study 2 did not find evidence of an association between AD use and increases in LS over time, after accounting for covariates (Tracking: n = 5,502, $\hat{\beta}$ = 1.16, 95% Confidence Interval [CI] = -0.57 to 2.89; Comprehensive: n = 9,760, $\hat{\beta}$ = 0.47, 95% CI = -0.89 to 1.82). Similarly, after controlling for covariates, Study 3 did not find associations between AD use and changes in informal caregiving hours received over time (Tracking: n = 236, $\hat{\beta}$ = 3.10, 95% CI = -77.98 to 84.17; Comprehensive: n = 420, $\hat{\beta}$ = -5.05, 95% CI = -47.19 to 37.09).

Conclusion

In an aging society, empirical evidence regarding the effects of AD on the changes in LS and informal caregiver hours is imperative for evidence-based decision-making and effective recommendations on the provision of AD to older adults. Although the findings of this thesis were non-significant, null findings can be informative because they can contribute to guiding future studies, informing existing theories, and avoiding misleading research conclusions or biased evidence-based practices and policies.

To overcome the limitations of existing studies, future research should aim to extend beyond three years, use large sample sizes, conduct analyses based on the type of AD used (e.g., mobility versus vision-related AD) and the duration of AD use (e.g., short, long, intermittent use), and control for additional potential confounders (e.g., device satisfaction, time-varying confounders). LS questions should be specifically tailored to AD use and informal caregivers should be directly interviewed to promote the accuracy of data on informal caregiving hours. Data sets designed to collect information primarily on AD should be used in future investigations to address the research questions in this thesis. These data sets should ideally be culturally representative and have minimal bias (e.g., selection bias, missing data) to assure reliability and generalizability of the findings.

This thesis further highlighted various implications for future research, theory, policy and practice. These implications included the complexity of research questions and concepts (i.e., life satisfaction, accurate capture of informal caregiving hours from care receivers and caregivers), overcoming limitations of existing studies, the importance of stratified analysis to inform sub-theories in the CATOR framework, integration of evidence from multiple

sources (e.g., experimental studies), funding for improved research, recognition of null findings, and collaborative efforts among stakeholders to make informed decisions related to AD use among community-dwelling older adults.

Acknowledgements

This research was made possible using the data collected by the Canadian Longitudinal Study on Aging (CLSA). Funding for the CLSA is provided by the Government of Canada through the Canadian Institutes of Health Research (CIHR) under grant reference: LSA 94473 and the Canada Foundation for Innovation. This research has been conducted using the CLSA data sets [Tracking and Comprehensive 2.0], under Application Number [2010026]. The CLSA is led by Drs. Parminder Raina, Christina Wolfson, and Susan Kirkland.

I would like to thank my supervisors Drs. Mark Oremus and Ashok Chaurasia for their unwavering support during this journey. My special thanks are extended to Dr. Philip Bigelow, who has been a part of this journey from the beginning, as well as Dr. Jesse Hoey and my mentor at Oxford University, Mr. Kenneth Howse, for their constant feedback on this research. I am also grateful for the time, interest, and feedback provided by the external examiner, Dr. Janet Fast, and the internal/external examiner, Dr. Jennifer Boger. My sincere gratitude goes out to the School of Public Health at the University of Waterloo as well as the Oxford Institute of Population Ageing at the University of Oxford for providing me with the resources to pursue research that is near and dear to my heart.

I want to express my deepest gratitude to the pillars of my life, my Mom and Dad, for their support throughout my Ph.D. journey. A special thanks goes to my Mom for being a tremendous supporter in countless ways. I am deeply grateful to all those who have stood by me in the final stages of the Ph.D., during the difficult time when I had to bid farewell to my dear Dad. His exemplary life has shaped me into the person I am today, and I will continue to

be inspired by the life he lived. Many thanks go out to my friends, colleagues, and friends from @PhDForum, who have been a source of support during this journey. Last but not least, I must mention Buddy, my furry friend of fifteen years who has been my constant companion and source of immense comfort.

Dedication

In loving memory of my Dad,

Upali Marasinghe,

SLAS (Special Grade), Attorney at Law, MPA,

Who was a remarkable and respected public servant in Sri Lanka.

He was known for his practicality, dedication, and reliability in his work.

He was a man of strong principles, integrity, and a deep sense of honor and service.

A gifted writer, teacher, and a leader with humanistic qualities –

a rare personality, and a role model for many.

Despite his seriousness and dedication to his work, he had a great sense of humor

and a beautiful smile that touched the hearts of those who knew him.

He was my friend that I shared countless laughs with.

I dedicate this PhD to my dear Dad with love and gratitude for all that he was

and all that he continues to be in my heart.

(16/02/1959 - 31/10/2022)

"I knew Upali Marasinghe as an enthusiastic colleague in the Sri Lankan public service. He was a reformist and tried his best to institutionalize the concepts of productivity wherever he worked. I have had the privilege of reading some of his publications on productivity and related concepts. His untimely demise has created a void in the realm of public administration in Sri Lanka." - Lalith Weeratunga, Former Secretary to the President of Sri Lanka (2005-2015).

"My first acquaintance with this neatly clad gentleman was on the day I signed my appointment letter as the Chairman of Ceylon Petroleum Cooperation and Ceylon Petroleum Storage Terminal Ltd. No sooner he was introduced, I knew he was someone I could trust.

He spoke very little. But those words mattered because they came out only when it was absolutely necessary - a characteristic of a well experienced, vastly knowledgeable professional civil servant. In our work environment time was of essence, and his was more than mine.

However, he always found time for me when requested. I think this was due to the mutual respect and fondness we had for each other. Most importantly, he was one of the very best human beings I have met in my life. He was a true friend that carried all traits of a good human being, as described in Buddhism. No other words can describe him better than that."

- Dammika Ranatunga, Former Chairman of Ceylon Petroleum Cooperation (CPC) and Ceylon Petroleum Storage Terminal Ltd. (CPSTL), Sri Lanka.

"I will forever remember the time I worked under Mr. Marasinghe, a respected personality who stood up for the truth in any situation and was a great strength to those who served under him." - Thushara Pathiranage, Former Additional Secretary, Ministry of Agriculture, Sri Lanka.

"Indeed, he is someone who deserves our respect. He was an initiator to bring about a transformation in the public service of Sri Lanka. A person who advocated making difficult decisions rather than those that are popular. His memory will always live on in the hearts of those like me who was lucky to have served under him." - Dhammika Ranatunga, Additional Secretary, Ministry of Fisheries, Sri Lanka.

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List of Abbreviations

Abbreviation	**Full Name**
AD	Assistive Devices
ADLs	Activities of Daily Living
AMSTAR	Assessment of Multiple Systematic Reviews
AXIS	Appraisal Tool for Cross-Sectional Studies
CATOR	Consortium for Assistive Technology Outcomes Research
CCHS	Canadian Community Health Survey
CESD	Center for Epidemiologic Studies Short Depression Scale
CI	Confidence Interval
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CLSA	Canadian Longitudinal Study on Aging
COPD	Chronic Obstructive Pulmonary Disease
CSHA	Canadian Study for Health and Aging
DCSs	Data Collection Sites
FSS	Functional Social Support
GRADE	Grading of Recommendation, Assessment, Development, and Evaluation
GSS	General Social Survey
IADL	Instrumental Activities of Daily Living

ISO	International Organization for Standardization
LS	Life Satisfaction
LTCs	Long-Term Care Homes
MEDLINE	Medical Literature Analysis and Retrieval System Online
MOS	Medical Outcomes Study
OARS	Older Americans’ Resources and Services
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews
PwD	Persons with Disabilities
SAS	Statistical Analysis System
SST	Socioemotional Selectivity Theory
SSS	Social Support Survey
SWLS	Satisfaction with Life Scale
WHO	World Health Organization
YLD	Years Lived with Disability

Chapter 1

Overview

1.0 Introduction overview

The world population is aging. In 2050, one in every six persons in the world will be aged 65 years or older and the global population of older adults will increase to about 1.5 billion.[1,2] Not only are populations aging, the number of years spent living in poor health (e.g., chronic illness, multimorbidity, and impairment) is rising across the globe.[3]

The role of assistive devices (AD) in contributing to older adults' overall well-being has gained much attention in recent years. AD are devices and technologies whose primary purpose is to maintain or improve an individual's functioning and independence, to facilitate participation, and to enhance overall well-being.[4] While AD use has been positively associated with multiple aspects of older adults' well-being, not all outcomes of AD use have been investigated in this population.

This thesis studied two outcomes of AD use - life satisfaction (LS) and the number of informal caregiving hours received - that can potentially improve older adults' overall well-being.[5] The rationale for examining these outcomes has been explained theoretically in the Consortium for Assistive Technology Outcomes Research (CATOR) framework;[5] however, little empirical evidence exists to support the framework (see Sections 2.1.4.1 and 2.1.6.1).

LS is a subjective assessment of whether a person's life as a whole and their current situation meet their expectations.[6–9] Although medical advances have increased life expectancy,[10] surviving diseases and living a long life may not necessarily be a satisfying experience. Instead, a satisfying life may be one where individuals can make their own choices and live the life they desire.

Research focusing on LS during later life is important because it reflects an individual's overall sense of well-being (objective and subjective) and fulfillment in later years; promotes better physical and psychosocial health; can reduce healthcare costs and increase productivity resulting in a positive effect on the economy; and provides valuable information for determining public policy and welfare strategies.[11,12] LS has been recognized as a potential short- or long-term outcome of AD use in the CATOR framework.[5]

Another outcome of AD use as outlined in the CATOR framework and a cited benefit of AD use among older adults is AD's potential to reduce the number of caregiving hours received from informal caregivers.[5,13,14] As people age, they may require the assistance of informal caregivers, who are individuals (e.g., friends, family, or neighbors) who provide unpaid assistance with overcoming obstacles related to physical, cognitive, or psychological conditions.[15] The need for informal caregiving will increase along with the rising population of older adults and the concomitant increase in comorbidities.[16] Between 2019 and 2050, the number of older adults in Canada who will require informal care is expected to increase by 1.2 times, from 345,000 to 770,000.[16]

The number of hours of informal care provided by a caregiver is a key indicator of the intensity of informal care and a risk factor for negative health outcomes on the part of caregivers (e.g., caregiving stress, poor health and overall well-being).[17–19] Research indicates that declining caregivers' health negatively impacts the care recipients' mental health as well as the quality of care they receive.[20,21] Through the facilitation of the independence of users, AD may be able to reduce the amount of time caregivers devote to caring for older adults, improve the health and well-being of caregivers, and help promote high-quality care for care recipients.[13,14] Reductions in caregiver time may alleviate the intensity associated with caregiving tasks and responsibilities, enabling informal caregivers to have more independence to do as they please. Therefore, it is valuable to prioritize the health and well-being of informal caregivers to ensure the highest quality of care for caregiver-care recipient dyads.

1.1 Research objectives and dissertation overview

This thesis reviewed the existing literature to identify any gaps in knowledge regarding AD use and LS, and informal caregiver hours among community-dwelling older adults (≥ 65 years). The identified knowledge gap was addressed by analyzing unweighted data from the Canadian Longitudinal Study on Aging (CLSA) Tracking and Comprehensive cohorts to explore two associations among community-dwelling older adults (≥ 65 years): (i) the relationship between AD use within the past 12 months (assessed at baseline) and changes in LS over time (three-years); and (ii) the association between AD use within the past 12 months (assessed at baseline) and changes in the number of informal caregiving hours received over time (three-years). The investigation of these associations was conducted in the three studies described in Chapter 3, Chapter 4, Chapter 5, respectively titled as follows:

- Chapter 3: The impact of assistive devices on community-dwelling older adults and their informal caregivers: a systematic review
- Chapter 4: Investigating the association between assistive device use and the change in life satisfaction among community-dwelling older adults: analysis of the Canadian Longitudinal Study on Aging (CLSA); and

- Chapter 5: The association between assistive device use and the change in informal caregiving hours among community-dwelling older adults: analysis of the Canadian Longitudinal Study on Aging (CLSA).

With an aging population in Canada and around the world, understanding AD's potential to improve the health and well-being of older adults is essential. Developing a better understanding about the prospects of AD allows the promotion of successful aging and underpins the need for evidence-based policies and interventions surrounding the provision of AD for older adults. Together, the three studies examined whether AD can enhance older adults' well-being and assist their informal caregivers (Figure 1 - 1).

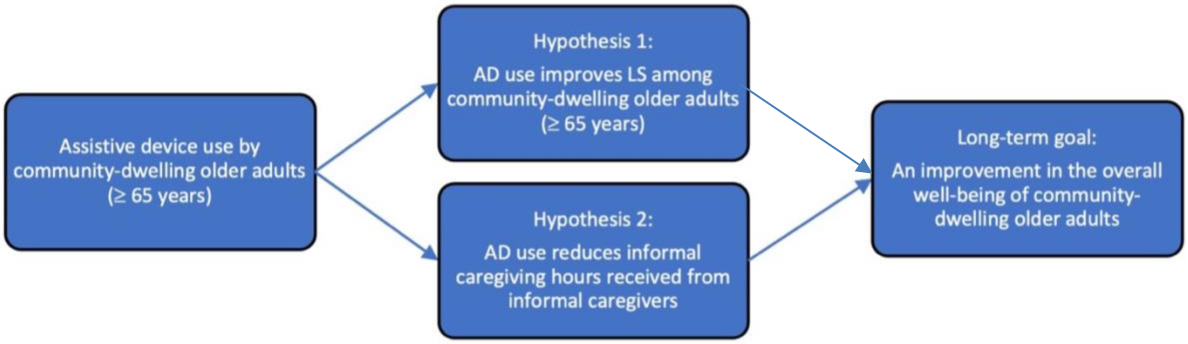

Figure 1 - 1: Overview of research objectives

In addition to the three manuscripts written for publication (Chapter 3, Chapter 4, and Chapter 5), a brief introduction to the thesis was provided in this chapter (Chapter 1), while detailed background information and context for each of the three manuscripts was provided in Chapter 2. Chapter 6 summarizes the dissertation's key findings, discussion, strengths, limitations, implications, future directions, contributions to the field, and conclusions.

Chapter 2

Introduction

2.1 Background

2.1.1 Aging population

With a rapidly aging global population, the year 2019 consisted of 703 million people over the age of 65 years, and this number is estimated to increase to 1.5 billion in 2050.[1] By 2030, the number of Canadian older adults aged 65 years or older is expected to be over 9.5 million, making up 23% of the overall population.[22,23] From 2015-2017, Canadian life expectancy at birth was 82 years, with a life expectancy of 86 years for persons already at the age of 65 years.[24] When considering health-adjusted life-expectancy, out of the 21 more years an average 65-year-old individual is expected to live, only 15 years are expected to be lived in full health, which suggests that while people are living longer, not all years are lived in complete health.[24]

In 2017-2018, 37% of Canadian older adults lived with at least two of the ten most common chronic conditions in Canada,[24] including hypertension with a prevalence of 65.7%, periodontal disease with 52%, osteoarthritis with 38%, ischemic heart disease with 27%, diabetes with 26.8%, osteoporosis with 25.1%, and cancer with 21.5%.[24] Years lived with disability (YLD), which are years of life lived with any short or long-term health loss, increased sharply with age for some diseases.[24] Among Canadian older adults, diabetes, high systolic blood pressure, stroke, heart failure, and Chronic Obstructive Pulmonary Disease (COPD) were all found to be leading causes of YLD.[24] Chronic conditions, multimorbidity, and YLD are known risk factors for increased impairment, functional limitations, and disability among older adults, all of which reduce overall well-being and quality of life in older age.[25–28]

2.1.2 Assistive devices

The International Organization for Standardization (ISO) defines AD as "any product, including devices, equipment, instruments and software, especially produced or generally used by or available for persons with disability to protect, support, train, measure or substitute for body functions, structures, and activities, and to prevent impairments, activity limitations or participation restrictions".[29] Since AD were first developed, they have mainly been linked to persons with disabilities (PwD).[30,31] This linkage aligns with the medical model of disability,[30,31] which regards AD as being developed to help individuals manage or overcome a disability.[31,32] While AD may diminish the impact of disabilities, these devices do not eliminate them.[32] Challenges that many PwD face are not merely due to their disability, but also the physical structures and societal standards that exclude them.[32]

Considering the limited perspective of the medical model of disability, the descriptions of the role of AD have evolved over time to reflect the social model of disability.[29] The social model of disability recognizes that while people may have functional limitations, they do not necessarily define themselves as disabled.[31,32] Rather, the surrounding environment may serve as the source of disability due to a lack of inclusivity (e.g., stairs versus ramps).[31,32] Based on the social model, more recent definitions refer to AD as devices, products, or technologies that preserve and maintain independence.[31]

This thesis embraces the social model and uses the World Health Organization's (WHO, 2022) definition of AD: "devices and technologies whose primary purpose is to maintain or improve an individual's functioning and independence, to facilitate [social] participation, and to enhance overall well-being (para. 1)."[4] AD encompassed by this definition include, but is not limited to, mobility devices such as wheelchairs, walkers, or canes; visual devices such as magnifiers, white canes, electronic magnification aids, or Braille reading materials; audio devices such as hearing aids or amplifiers; or software and apps for communication and information management (also see Appendix A).[29,33]

2.1.2.1 Benefits of assistive devices

For some older adults, AD are necessary for performing crucial activities such as getting out of bed or leaving one's home. AD can facilitate greater mobility, freedom, independence, inclusion, and participation, which can promote positive feelings associated with leading a dignified life.[34] When designed and implemented properly, with equitable and fair access, AD can compensate for impairments and loss of intrinsic capacities, ease the effects of gradual functional deteriorations, reduce the need for caregivers, prevent primary and secondary health outcomes, and lower the costs of health and welfare.[34] Previous studies showed that AD may be useful in preventing further impairment (e.g. fractures caused by falls), or hospitalization, slowing the decline of cognitive and functional abilities, allowing for home health monitoring, tracking and monitoring systems to enhance safety, enhancing social networks, and improving independence, ease of living, social connectivity, safety, mental health, and overall well-being.[4,33,35–43]

2.1.3 Life satisfaction

LS is defined as the subjective judgment of one's life as a whole and current life situation in relation to one's own expectations.[6–9] LS reflects the state and the overall experience of life; a high and positively regarded LS therefore contributes to the well-being of older adults and has been identified as one of the most noteworthy indicators of successful aging.[44–46]

2.1.3.1 Why study life satisfaction?

The advancement of medical sciences has led to an increase in life expectancy,[10] but living a long life may not indicate satisfaction with life. One may wonder whether living a long life with no to minimal choices (e.g., inability to go for a walk by oneself at a time of one's choice) is a life well-lived. Rather, a better life may be one that allows people to live the lives they want (e.g., being able to go for a walk without relying on caregiver help), with a sense of autonomy, independence, and dignity, all of which can contribute to a satisfied life. By improving LS, the experience of living a long life may be enhanced considerably.

Furthermore, LS is associated with greater levels of physical and psychosocial health, and positive health behaviours.[11,47] Greater levels of LS have been associated with lower levels of depression.[11] Left unchecked, depression in older adults is linked to impaired functioning (e.g., cognitive and social), higher prevalence of chronic conditions and physical illnesses, and greater incidence of suicide.[48–50] An aging population with a high level of LS may also reduce healthcare costs as older adults who are satisfied with their lives may be more likely to take better care of their health.[11] Older adults may also be more likely to remain in the labor force for a longer period of time and be more productive, which can contribute to economic growth.[12] Thus, higher levels of LS can benefit both individuals and society at large.

2.1.3.2 Aging and life satisfaction

2.1.3.2.1 Theories regarding life satisfaction

The relationship between age and LS has been debated over the years and is still inconclusive. From an American perspective, the classical theory of LS/bottom-up approach by Diener suggests that LS is dependent on different domains of life such as health, finances, work, and family.[51] In the context of LS later in life, this theory proposes that these domains are expected to decline with age and therefore LS will also decline with age.[51] A study conducted in the United States with 2,306 participants found that LS decreased with age and was largely attributed to health problems, loneliness, and financial difficulties. As confounding variables were not controlled for, conclusions should be interpreted with caution.[52] Additionally, a study conducted in 2001 in Taiwan with 3,151 older Taiwanese adults found that LS decreased with age. In this population, income declines and living arrangements explained much of the variance in LS.[53] In contrast, top-down theories suggest that life circumstances have little influence on LS. Some notable top-down theories are discussed next.

Essentialist theory suggests that LS is largely associated with one's temperament or personality traits.[54–56] Based on the essentialist theory, researchers have suggested that LS should not be affected by objective factors such as age or health deteriorations.[57] In the context of LS later in life, essentialist theory suggests that the average LS level of an individual is likely to remain stable over time.[58] Previous research has found that subjective well-being variables (e.g., life satisfaction) are moderately to strongly associated with personality characteristics (e.g., neuroticism, extraversion, and self-esteem).[56]

Headey and Wearing proposed the Dynamic Equilibrium Theory or Set Point Theory and view changes in subjective well-being (e.g., life satisfaction) as being influenced by life events that are dependent on individual personality traits.[59] For example, those who are high in extraversion and low in neuroticism are more likely to experience positive life events and better LS.[60] On the other hand, those who are low in extraversion and high in neuroticism may experience more negative events and lower LS.[60] A 2008 study found that people with high levels of extraversion and neuroticism reported large changes in LS.[61] Extroverted individuals showed greater improvements in LS over 20 years, while those with high levels of neuroticism showed greater declines in LS.[61]

The Socioemotional Selectivity Theory (SST) posits that, across the lifespan people engage with fewer people as they purposely withdraw from social interactions with insignificant relationships, while maintaining or growing relationships with close friends and family.[62] Through self-regulation of participation in social activities, older adults learn to improve the ratio of their positive and negative emotions.[62] In the context of LS later in life, this theory assumes that as persons transition into older adulthood, they become increasingly aware of the time they have left to live and therefore focus on making the rest of their lives enjoyable by choosing their preferred social circles, which can lead to higher LS.[58] Carstensen et al. found more older adults than younger adults preferred smaller social networks over larger ones, and as people age, they interact less with acquaintances and close friends, and interact more with spouses, siblings, and close friends, supporting the SST.[63,64]

The literature suggests that both bottom-up and top-down perspectives explain LS later in life and why we do not always see a direct decline of LS with age.[65,66] These diverse theories portray the complexity of LS later in life and should be acknowledged when studying LS of older adults.

2.1.3.3 Life satisfaction among older adults in Canada

Findings from the Canadian Community Health Survey (CCHS, 2003-2011), which comprised 65,000 Canadians over the age of 12 years living in all provinces and territories reported that in 2003, Canadians aged 65 years or over were the least satisfied with their lives compared to all other age groups.[67] This observation continued to 2011, with a further decline in LS among older Canadians.[67] Increasing anxiety and uncertainties about employment opportunities and pensions caused by the then-financial crisis may have contributed to the decreasing LS among persons responding to the CCHS, particularly those aged 65 years and over.[67]

In the 2015 CCHS data, 9 out of 10 Canadians reported high levels of satisfaction with life; however, this proportion decreased with increasing age.[68] A similar trend was seen in the 2016 and 2017 CCHS data.[69,70] In 2015, persons who were retired, experiencing long-term disease, or caring for someone other than children had the lowest levels of LS.[68] In 2016 and 2017, respondents who rated their health as fair or poor reported lower levels of LS.[69,70] As people age, they are more likely to experience events that lower LS, such as retirement, long-term illnesses, and involvement in caregiving activities for people other than children (e.g., spouse or friends).[53] This may have contributed to lower levels of LS among older adults.

Results from the 2016 data from the General Social Survey (GSS), with a total sample size of 19,609 found that Canadian older adults in the age groups between 65 to 69 years were less satisfied with their lives compared to persons in older age groups.[71] One explanation for this finding is that those between 65 and 69 years may be in adjustment periods following crucial life transitions such as retirement or the death of a spouse, which can be challenging and impact the overall satisfaction with their lives.[53]

Despite the variations in past LS trends, a 2017 - 2018 report suggested that Canadian older adults were satisfied with their lives.[24] These findings should be interpreted with caution due to the heterogeneity of geriatric populations. Heterogeneity within geriatric populations can be especially large given varying functional limitations, multimorbidity, and different living arrangements, all of which must be considered when comparing across studies. As such, the results may not be applicable to all geriatric populations.

2.1.3.4 Risk and protective factors of life satisfaction

Researching ways to improve LS in older adults requires understanding factors that influence LS later in life. Past studies show that multiple factors are associated with LS in later stages of life.

2.1.3.4.1 Risk Factors

Among Canadian older adults, age, marital status (divorced, separated, widowed, or never married), stress related to family, poor health, and limited finances, the receipt of care, caregiving status, and living alone were negatively associated with LS.[67,71,72] A study by Statistics Canada, using 2016 GSS data, found that older adults who were separated or divorced were less satisfied with their lives compared to those who were married or living common law.[71] Family, health, and financial stress were associated with lower levels of LS in older adults compared to those who did not report any stresses.[71] Older adults who reported insufficient retirement incomes were less satisfied with their lives than those who reported sufficient (self-assessed) retirement incomes.[71] In addition, older adults who received care from others, or who received and provided care, experienced lower LS.[72] Thus a higher level of dependence or caregiving responsibilities may adversely influence one's LS.

Further, a Canadian-Australian study found that older Canadians with multimorbidity felt less satisfied with their lives compared to Australians.[73] Previous American and Swedish studies reported associations between poor functional ability, as measured by Activities of Daily Living (ADLs) impairment levels, and lower LS levels among older adults.[74,75] In addition, a Swedish study revealed that older adults with injuries such as falls and hip fractures, as well as those reporting depressive symptoms, had lower LS scores compared to other respondents.[76–78]

2.1.3.4.2 Protective Factors

A study by Statistics Canada reported that among Canadian older adults, high self-rated physical and mental health, standard of living, social class, resiliency, greater time spent with family and personal relationships were positively associated with LS. For example, older adults who rated their general and mental health as "excellent" had higher LS levels than those who ranked their health as "poor".[71] Older adults who felt they belonged to a relatively higher social class also reported greater levels of LS.[71] Older adults who were able to perform ADLs and had more internal "locus of control" (i.e., "when I make plans, I am almost certain that I can make them work") tended to have higher levels of LS.[79]

2.1.4 Assistive devices and life satisfaction

2.1.4.1 Theoretical framework: assistive device use and life satisfaction

The CATOR framework developed by Jutai et al. is a well-established and comprehensive framework developed to guide the evaluation of AD outcomes.[5] The study of the association between AD and LS is anchored in the CATOR framework, which reflects the social model of disability (see Section 2.1.2).[5] The CATOR framework recognizes five groups of short- and long-term AD outcomes that are relevant from the time an individual acquires an AD to its continued use or disuse: effectiveness, social significance, device satisfaction, psychological functioning, and subjective well-being.[5] Subjective well-being comprises the cognitive and emotional impacts of AD on users' lives; it includes a domain called satisfaction, under which LS is found.[5] Within this framework, LS refers to how users value AD and believe these devices influence their LS.[5] CATOR indicates AD use has the potential to improve LS in older adults over time.[5]

AD may have the potential to provide older adults a life with a sense of autonomy, independence, and dignity (see Section 2.1.3.1) by helping them maintain their independence (e.g., hearing aids enabling independent communication), safety (e.g., walking aids preventing falls), and providing opportunities to enjoy activities they may otherwise forgo (e.g., mobility devices enabling older adults to go for a walk without relying on others' assistance, or the use of glasses to watch television); thereby, improving LS later in life.[43] While AD use may theoretically improve LS in older adults, there is a lack of substantial empirical evidence to support this hypothesis.[80] It is crucial to test the association proposed in the framework using empirical data, as this can provide insights into novel approaches to promoting LS among older adults through AD.

The next part of this thesis focuses on concepts and literature related to Objective 3, which investigates the association between care recipients' AD use and the change in the amount of informal caregiving hours received over time.

2.1.5 Informal caregiving hours

Informal care and support is defined as unpaid help provided by a close relative or close acquaintance (e.g., family, friend, neighbor) to someone who is impacted by physical, cognitive, or psychological factors.[15] Informal care is often provided for one or more activities, such as ADLs, Instrumental Activities of Daily Living (IADLs), and household activities.[15]

Informal caregiving hours is an important marker of the intensity of informal caregiving; longer hours increase the risk of adverse health outcomes for caregivers (see Section 2.1.5.1).[17,18,81–84] Among Canadian informal caregivers who provided 1 to 3 hours of informal care per week, 19% reported caregiving-related stress, while 54% of those who provided 20 or more hours per week reported caregiving-related stress.[81]

2.1.5.1 Care recipient-related factors associated with informal caregiving hours

The number of informal caregiver hours required by older adults depends on their health. Canadian and American literature report that caregivers are more likely to expend higher quantities of informal care hours if the care-recipients suffer from chronic conditions such as multiple sclerosis, memory problems, Parkinsonism, stroke, cancer, Alzheimer's disease or another form of dementia, or they suffer from greater ADLs/IADLs impairment, higher disability status, self-care and mobility needs, injuries (e.g., falls), or depression.[18,85–93]

On the other hand, previous research from the United States, Canada, and Southern Europe has found that receipt of formal care, use of AD and home modifications, and built environments in public spaces can reduce the demand for informal caregiving time.[13,14,94–97]

2.1.5.2 Impacts of high caregiving hours on informal caregivers

Despite long hours, informal caregivers report that helping loved ones brings personal satisfaction, purpose in life, joy in assisting, and closeness to the care recipient.[19,81] While informal caregiving can be rewarding, high numbers of caregiving hours can create physical, emotional, financial, and social challenges for informal caregivers, resulting in a deterioration of caregivers' overall health and well-being.[19]

Previous studies found that among Canadian informal caregivers, those who provided greater numbers of caregiving hours were most likely to report detrimental impacts on overall health, including lack of exercise, less healthy eating, and increased consumption of alcohol.[98] Caregivers who provided more hours of care reported greater feelings of stress and a greater sense that their own health was suffering as a result of caregiving obligations.[99] Other studies from Canada, America, Australia, and the United Kingdom also reported positive associations between high informal caregiving hours and caregiver stress, mobility limitations, depression, anxiety, long-term back problems, pain or discomfort, low quality of life, lack of time for themselves and/or family, reductions in educational and employment opportunities, and overall poor health among informal caregivers.[19,100–104]

2.1.5.3 Aging populations and the expected increases in informal caregiving hours

As populations age, the need for at-home assistance is estimated to grow in the upcoming years. The prevalence of health conditions that demand extensive informal caregiving (see Section 2.1.5) tends to increase with age, placing a greater burden on those who provide care for older adults. Consequently, caregivers of older adults are at a heightened risk of providing substantial amounts of informal care.[16] In 2016, already 75% of the home-care hours received by older Canadians were from informal sources.[16] By 2050, the number of older adults needing informal care is projected to increase by 20%.[16] Changes in family dynamics (e.g., children moving away from intergenerational families to single parent families or living alone) and demographics (e.g., low fertility rates and delayed childbearing) are expected to increase demand for informal caregivers.[105,106] This will reduce the ratio of caregivers to care receivers, resulting in an increase in the amount of work expected from available informal caregivers.[105,106]

2.1.6 Assistive devices and informal caregiving

Previous studies have found that AD can support informal caregivers by reducing task difficulty, energy spent on caregiving activities, fear and anxiety, and safety risk for tasks demanding physical support.[107] Also, AD may reduce the amount of caregiver time by allowing AD users to perform activities without the need for assistance (e.g., moving around the home, walking to the car, grocery shopping). According to the GSS - Caregiving and Care Receiving, among informal caregivers providing assistance to older adults in 2018, transportation was the most common type of assistance (e.g., running errands, shopping, or attending medical appointments), followed by meal preparation and housekeeping.[108] Based on earlier GSS findings, the most time-consuming informal caregiving tasks in descending order included meal preparation, housekeeping, maintenance/repair, grocery shopping, transportation, bills and banking, and personal care.[109] Various types of AD, including modified kitchen utensils and appliances, flashing kitchen timers, and heat detectors, can assist AD users with meal preparation, while robotic cleaning systems, modified lighting may assist with housekeeping, and mobility devices may assist with transportation and grocery shopping tasks, which may have the potential to reduce the demand for informal caregiving and care hours.[43] Potential reductions in caregiver time may give informal caregivers more independence and flexibility in their own lives.[17] However, limited research has investigated the association between care receivers' use of AD and its influence on informal caregiving hours, especially in the Canadian context.[80]

2.1.6.1 Theoretical framework: AD use and informal caregiving hours

The CATOR framework, which was introduced in Section 2.1.4 provides the theoretical underpinning behind the third research question. Among the five categories of AD outcomes (see Section 2.1.4), social significance refers to the impact of AD on society and other people (e.g., caregivers),[5] which includes the nature and amount of effort put into caring for persons who use AD.[5,110] CATOR indicates that AD may have the potential to reduce informal caregiving hours over time.

2.2 Gaps in the literature

A recent systematic review by Marasinghe et al. (included as Chapter 3) found that a scarcity of published literature existed for the two associations addressed in research questions 2 and 3.[80] Therefore, the current knowledge about the associations remains inconclusive. Detailed findings of the systematic review are discussed in Chapter 3.

2.3 Methods

2.3.1 Study 1

The impact of assistive devices on community-dwelling older adults and their informal caregivers: a systematic review.

Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines were followed to conduct and report the systematic review and the study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (identification number: CRD42021248929).[111] Full information about the methodological approach for Study 1 can be found in Chapter 3.

2.3.2 Study 2 and Study 3

Study 2: The impact of assistive device use on the change in life satisfaction among community-dwelling older adults (≥ 65 years): analysis of the Canadian Longitudinal Study on Aging (CLSA), and

Study 3: The association between assistive device use and the change in informal caregiving hours among community-dwelling older adults (≥ 65 years): analysis of the Canadian Longitudinal Study on Aging (CLSA)

2.3.2.1 Data source for Studies 2 and 3

Canadian Longitudinal Study on Aging (CLSA)

The CLSA is a large, national study that aims to better understand the aging process and how it affects the health and well-being of Canadians.[112] The study collects a wide range of information on participants, including their health status, lifestyle behaviors, social and economic factors, and cognitive function.[112] Participants also undergo physical and cognitive tests, as well as provide biological samples for analyses.[112] The CLSA is a collaborative effort involving researchers from universities and research institutions across Canada.[112] It is funded by the Canadian Institutes of Health Research, the Canada Foundation for Innovation, and several provincial and territorial partners.[112]

The doctoral candidate used unweighted data from the CLSA in Studies 2 and 3. The CLSA recruited 51,338 community-dwelling adults between the ages of 45 and 85 years from across Canada.[113] The CLSA consists of two cohorts: a Comprehensive cohort (n = 30,097) and a Tracking cohort (n = 21,241). The Tracking cohort used computer-assisted telephone interviews to randomly collect data, while the Comprehensive cohort obtained data through in-home interviews and Data Collection Sites (DCSs) visits to randomly select participants from catchment areas ranging 25 to 50 kilometers.[113] Baseline data were collected between 2011 and 2015 and first follow-up data were collected between 2015 and 2018.[113]

People living in the three Canadian territories, or on First Nations reserves or other provincial First Nations settlements were excluded from the CLSA. Those who were full-time members of the Canadian Armed Forces, residents of institutions such as long-term care homes (LTCs), persons unable to communicate in French or English, and individuals who showed signs of cognitive impairment at the recruitment interview were also excluded.[113] The CLSA employed stratified random sampling based on age, sex, province, DCSs versus non-DCSs, and low-education versus non-low-education.[114] Complete details of the CLSA and its recruitment procedures may be found elsewhere.[113–115]

2.3.2.2 Data analysis for Studies 2 and 3

Using multiple linear regression analysis and the change score method, which examines the relationship between an exposure variable and a change in an outcome variable over time, the doctoral candidate regressed the change in outcomes from baseline to follow-up on the exposure variable in both studies. The change score method is a technique used in longitudinal studies with non-experimental data when the goal is to understand the effect of an intervention or an exposure on an outcome variable over time.[116,117] Specifically, in Study 2, the doctoral candidate regressed the change in LS from baseline to first follow-up (three-years) on self-reported AD use within the past 12 month (assessed at baseline), while accounting for a set of covariates. In Study 3, the change in informal caregiving hours received from baseline to first follow-up (three-years) was regressed on self-reported AD use within the last 12 months (assessed at baseline), while controlling for a set of covariates. Both studies used unweighted CLSA data because the weights were only defined for the full data set at baseline.[114] Therefore, the weights were no longer accurate when data from follow-up one (i.e., outcome variables at follow-up one) were included in the analyses and missing data were excluded. Data analyses were conducted using SAS version 9.4 (SAS Institute, Cary, N.C., USA).

2.3.2.3 Ethics and data access

The required data were obtained from the CLSA (data access file #2010026) and the University of Waterloo’s Office of Research Ethics gave ethics clearance to Studies 2 and 3 (ORE #42761). Ethics clearance was unnecessary for Study 1 because it did not involve participant-level data.

Chapter 3

The impact of assistive devices on community-dwelling older adults and their informal caregivers: a systematic review

Status: Published

Marasinghe, K.M., Chaurasia, A., Adil, M. *et al.* The impact of assistive devices on community-dwelling older adults and their informal caregivers: a systematic review. *BMC Geriatr* 22, 897 (2022). https://doi.org/10.1186/s12877-022-03557-8.

3.1 Abstract

Objective: The purpose of this systematic review is to assess the impact of assistive devices on the life satisfaction of (Research Question 1), and informal caregiving hours received by (Research Question 2), community-dwelling older adults (≥ 65 years).

Methods: The doctoral candidate searched CINAHL, MEDLINE, and Scopus from database inception to March 2022. For each question, two reviewers independently screened citations, extracted and narratively synthesized the data, and assessed article quality and strength of evidence.

Results: Of the 1,391 citations screened, the doctoral candidate found two articles pertaining to each question, for a total of four articles. In general, assistive device use was not associated with life satisfaction, while it was positively associated with informal caregiving hours. However, the risk of bias was serious across the two studies for Research Question 1, and the overall quality of evidence was "very low". The risk of bias was not serious across the two studies included in Research Question 2 and the overall quality of evidence was "moderate".

Conclusion: Due to the scarcity of studies, the limitations of existing studies (e.g., risk of bias), and the evidence being moderate or very low quality, the doctoral candidate could not draw firm conclusions about the associations. Additional research will produce a better understanding of the two relationships and provide further evidence to inform policy decisions regarding the provision and funding of assistive devices for community-dwelling older adults.

Registration: This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database of systematic reviews (identification number: CRD42021248929).

Keywords: Assistive devices, community-dwelling older adults, informal caregivers, systematic review

3.2 Background

3.2.1 Assistive devices

The World Health Organization (WHO) defines assistive devices (AD) as "devices and technologies whose primary purpose is to maintain or improve an individual's functioning and independence, to facilitate participation, and to enhance overall well-being."[4] Examples of AD include, but are not limited to, mobility devices such as wheelchairs, walkers, canes; visual devices such as magnifiers, white canes, Braille reading materials; audio enhancement devices such as hearing aids and amplifiers, and communication and information management devices such as software and apps.[33]

Previous studies have found that AD contribute to the overall well-being of community-dwelling older adults by preventing impairment, delaying hospitalization, slowing the decline of functional and cognitive abilities, and improving independence and ease of living, social connectivity, safety, and mental health. However, not all features of AD have been extensively investigated across different populations and settings.[4,33,35–42] Two such features are the potential of AD in improving life satisfaction of, and reducing informal caregiving hours received by, community-dwelling older adults.

3.2.2 The aging population

The world population is aging. In 2050, one in every six persons in the world will be above the age of 65 years, with the absolute number of older persons reaching approximately 1.5 billion.[1,2] One reason for the increasing global population of older adults is simply that people are living longer. By 2040, global life expectancy is expected to rise by 4.4 years.[118] In the years 2015-2020, a person aged 65 years could live an additional 17 years on average, which is predicted to rise to 19 years by 2045-2050, globally.[1] However, while people are living longer, not all years are lived in full health. The average number of years of healthy life lost to poor health has risen from 8.62 in 1995 to 9.72 in 2017, and is expected to increase in the majority of countries.[3]

3.2.3 Life satisfaction

Life satisfaction (or ‘satisfaction of life, ‘satisfaction with life’ referred to as LS from now on) is defined as “cognitively oriented, subjective judgment of one’s life as a whole and current life situation in relation to one’s own expectations”.[6–9] LS is a key indicator of a person’s normative opinion about their overall well-being.[119,120] The concepts of LS and quality of life are sometimes used interchangeably in the literature. Although related, they are separate, with quality of life pertaining to a holistic conception of one’s state of life that encompasses physical and psychological health, degree of independent functioning, social engagement, personal views on health, and the relationship between individuals, their health, and the environment.[121,122] Diener’s classical theory of LS suggests that LS is expected to decline with age, in tandem with other elements of life such as health, finances, work, and family.[51] According to this theory, reductions in LS are likely to occur as adverse health conditions become more prevalent among populations that are rapidly aging and living longer.

While it may not be immediately possible to eliminate or improve health challenges that appear in later life, one can take steps to minimize the impact of these challenges through adaptation, (e.g., using AD to reduce the impact of mobility impairment). Such steps can improve the state and experience of living as an older adult, thereby enhancing LS.

Previous research has also found that greater LS is associated with positive health outcomes (e.g., better physical/psychosocial health, and health behaviors), whereas lower LS is linked with negative outcomes (e.g., high incidence of chronic conditions, hospitalization, and mortality).[11,47]

3.2.4 Assistive devices and life satisfaction

The link between AD and LS is recognized in the CATOR framework.[5] CATOR identifies subjective well-being as an outcome. Within this framework, LS refers to how persons who use AD, value AD and believe these devices influence their LS.[5] According to this framework, AD may have the potential to improve LS in older adults.

3.2.5 Informal caregiving hours

The second research question examines the existing evidence on the association between AD use among community-dwelling older adults and informal caregiving hours received by these adults. Informal care refers to unpaid care and assistance provided by family, friends, or neighbors to those who require assistance due to physical, cognitive or mental conditions.[15] Amid populations that are aging and living longer with comorbidities, requirements for such assistance are growing and the number of older adults who will require informal care in Canada is expected to increase by 1.2 times between now and 2050.[16]

Caregiving hours is an important marker of the intensity of informal care and is a risk factor for caregiving stress/burden.[17,18] While other factors besides caregiving hours contribute to caregiver stress/burden (e.g., care recipient’s dependency level), these factors were beyond the scope of the review.[123] Research has shown that stress related to informal caregiving is positively associated with the number of care hours provided.[81–84] Higher numbers of caregiving hours may also pose physical, emotional, financial, and social challenges for informal caregivers, leading to an accelerated deterioration of their overall health and well-being.[19] Furthermore, high informal caregiving hours have been associated with and lack of exercise, unhealthy eating, alcohol consumption, mobility limitations, caregiver stress, depression, anxiety, long-term back problems, pain/discomfort, low quality of life, lack of personal or family time, and overall poor health.[19,98,100–103]

3.2.6 Assistive devices and informal caregiving hours

According to CATOR, social significance refers to the impact of AD on society and other people (e.g., caregivers),[5] including the nature and amount of effort put into caring for persons who use AD.[5,110] The CATOR framework lays the foundation for investigating the relationship between AD use and informal caregiving hours.

The doctoral candidate undertook this systematic review to examine the existing literature on AD use and: 1) the LS of community-dwelling older adults (≥ 65 years of age) who use AD (Research Question 1); and 2) informal caregiving hours received by community-dwelling older adults (≥ 65 years of age) who use AD (Research Question 2).

3.3 Methods

3.3.1 Protocol registration

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (See Appendix B) and registered in the International Prospective Register of Systematic Reviews (PROSPERO) database of systematic reviews (identification number: CRD42021248929).[111]

3.3.2 Database search and search strategy

The database search and search strategy were developed in consultation with a health sciences librarian. Keywords related to four concepts (AD, LS, informal caregiving hours, and older adults) were used for the database search, which covered the Cumulative Index to Nursing and Allied Health Literature (CINAHL) (1961 to March 2022), Medical Literature Analysis and Retrieval System Online (MEDLINE) (1950 to March 2022), and Scopus (1966 to March 2022) (See Appendix C). The search strategy syntax was developed for Scopus and adapted to the other databases.

After removing a total of 47 and 38 duplicates for Research Question 1 and Research Question 2 respectively, two reviewers independently screened the titles and abstracts of the remaining citations, as well as the full texts of papers that passed title and abstract screening. The reviewers resolved discrepancies by consensus. The references of included articles were examined to identify other relevant articles, which were put through the screening process.

3.3.3 Inclusion criteria

Reviewers searched for peer-reviewed, quantitative articles that included a parallel comparison group and used the following eligibility criteria to screen these articles for relevance to the research questions:

Objectives 1 and 2 included articles that focused on: any AD that falls under the International Organization for Standardization (ISO) defined 12 classes of AD, including a wide range of devices such as mobility and sensory aids, mHealth devices (e.g., software applications to enhance memory), among others (See Appendix A); community-dwelling older adults who use AD and are 65 years of age or older; and articles written in any language. Research Question 1 considered articles that investigated the impact of AD on the LS of persons who use devices, whereas Research Question 2 included articles that explored the association between AD use and informal caregiving hours among carers aged 18 years or older.

3.3.4 Exclusion criteria

The doctoral candidate excluded commentaries, letters to the editor, pre-post studies, case series, abstracts, and animal studies.

3.3.5 Data extraction, analysis, and quality assessment

At least two reviewers independently extracted the following information from each study: general (e.g., year, country, follow-up duration, authors, intervention), characteristics of the sample (e.g., mean age, sample size, sex, setting, population), and outcome measures (e.g., LS scores and the number of informal care hours (See Appendix D).

A meta-analysis was not conducted due to the heterogeneity of included studies. Heterogeneity arose from variations in tools used to measure exposure and different methods of reporting quantitative results, e.g., p-values, test statistics, regression coefficients. The components necessary to convert the results into a common metric were not reported in all the included studies. Instead of a meta-analysis, the doctoral candidate narratively synthesized the data. The doctoral candidate used the ‘esc’ package in R v 4.2.0 (The R Foundation for Statistical Computing, Vienna, Austria) to calculate Hedges’ g in one study. Results from all included articles were covered in the narrative synthesis.

Risk of bias was assessed with the Appraisal Tool for Cross-Sectional Studies (AXIS).[124,125] All AXIS questions can be answered with “yes”, “no”, or “don’t know” and 1 point was awarded for each ‘yes’ response. In addition to the traditional scoring of AXIS, a choice was made to award 0.5 points for a ‘partial yes’ following a previous study from the literature.[126] Question 14 (describing non-responders) was not scored and instead it was classed as a sub-question of question 13 (concerns about non-response bias), resulting in a maximum score of 19 points (See Appendix E).[126,127]

The quality and strength of evidence of the included articles was rated using the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) approach.[128] GRADE creates evidence summaries and builds refined recommendations transparently and systematically.[128] The certainty of evidence is evaluated based on factors such as risk of bias, indirectness, inconsistency, imprecision, publication bias, and confounding.[128]

Upon completion of the review, the quality of the review was self-rated using the Assessment of Multiple Systematic Reviews (AMSTAR) 2,[129] omitting the randomized controlled trial portion of question 9 (no trials were included in the review) and the questions related to meta-analysis (e.g., 11, 12, 15). Among the remaining questions, the doctoral candidate assigned a score of 1 to each “yes” response and a score of 0.5 to each “partial yes” response, resulting in a maximum score of 13.

3.3.6 Departures from the protocol

The doctoral candidate assessed risk of bias using AXIS because all of the included articles were cross-sectional. AMSTAR 2 was added to assess the methodological quality of the systematic review.

3.4 Results

A total of 1,391 records were retrieved for both research questions. Four eligible articles (two per research question) were ultimately included in the systematic review. Detailed results are discussed below. Examples of excluded articles would be “Satisfaction with rollators among community-living users: a follow-up study”, which examined AD yet did not measure LS and “We have built it, but they have not come: Examining the adoption and use of assistive technologies for informal family caregivers” that did not investigate caregiving hours.[130,131]

For Research Question 1, a total of 963 citations were retrieved by searching the databases CINAHL, MEDLINE, and Scopus. After removing 47 duplicates, 916 proceeded to title and abstract screening. Seven hundred and sixty-four (83%) articles were removed during the title and abstract screening, leaving 152 articles for full-text screening. One hundred and fifty articles were omitted for not meeting the eligibility criteria. A list of excluded studies is available upon request. The systematic review includes two studies that met the eligibility criteria. Searching through reference lists did not yield any additional articles.

For Research Question 2, a total of 428 articles were retrieved by searching the same databases as in Research Question 1. After removing 38 duplicates, 390 studies remained eligible for title and abstract screening. Three hundred and fifty-four (91%) studies were removed during title and abstract screening and 36 studies advanced to full text screening. Thirty-four studies were excluded because they did not meet the eligibility criteria. A complete list of excluded studies is available upon request from the authors. Two studies met the eligibility criteria and were included in the systematic review. Figure 3 - 1, depicts the flow of articles through the screening process.

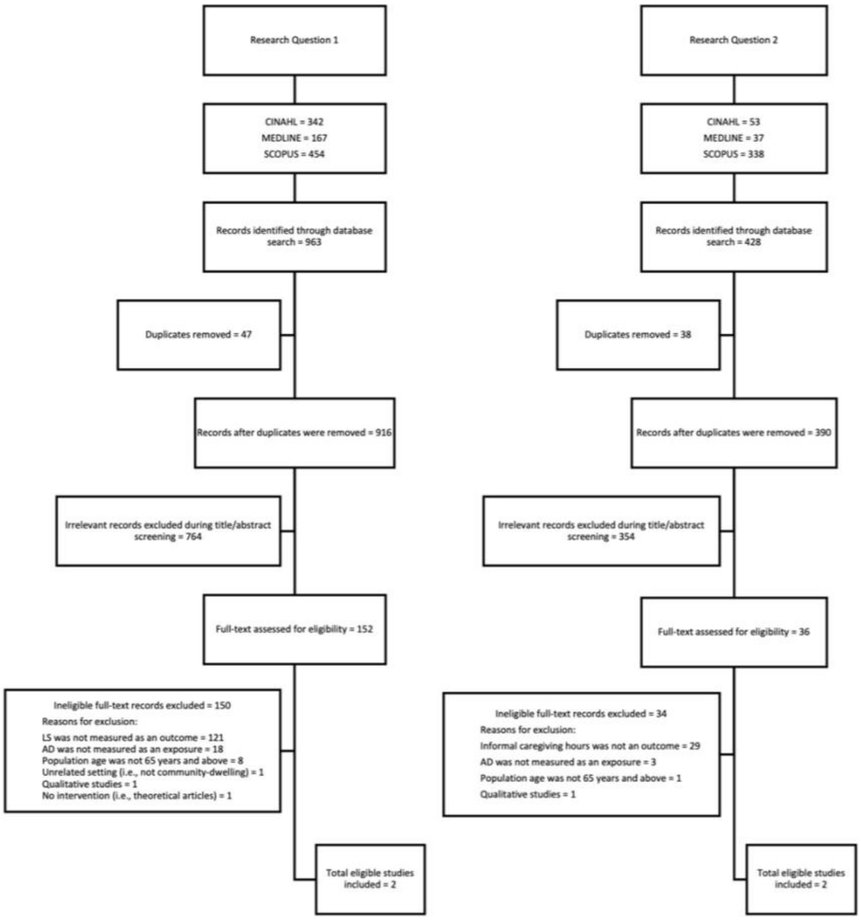

Figure 3 - 1: PRISMA flow chart for Research Questions 1 and 2

3.4.1 Study characteristics

3.4.1.1 Research Question 1: Assistive device use and life satisfaction

The two eligible articles were cross-sectional.[132,133] One article was published in English and the other in Korean, which was translated with the assistance of a native Korean speaker. The two articles defined the outcome, LS, as an individual’s subjective experience of fulfillment in life or one’s global degree of contentment with life,[132,133] and measured with the Elderly LS Scale and the Andrew and Withey LS Scale adapted by Alex Michalos.[132,133] Both articles reported on community-dwelling adults aged 65 years and older and treated the exposure (AD use) as dichotomous (AD use versus no use).

The first article, by In-sook et al., investigated the association between the use of devices for walking, bathing, daily living, healthcare, physiotherapy, and health monitoring among 601 community-dwelling, older Korean adults.[132] After adjusting for age, income, gender, marital status, living arrangements, subjective health, activities of daily living (ADLs)/IADLs, health related quality of life, and satisfaction with AD, the authors reported no association between AD use and LS ($\hat{\beta} = 0.014$ - not significant; note the authors did not report a p-value or standard error).

The second article, by Leung et al., used data from the Canadian Study for Health and Aging (CSHA) to investigate whether wheelchair use was associated with LS in a group of 5,395 community-dwelling persons aged 65 years or older who were not diagnosed with dementia.[133] The authors reported that the rating of life as a whole among persons with a wheelchair was lower than that of persons without a wheelchair ($X^2 = 68.5$, $p < 0.0001$), suggesting older adults using wheelchairs experienced less satisfaction with life compared to those who did not use wheelchairs. However, this paper did not report any results besides the chi-square test statistic and p-value.

3.4.1.2 Research Question 2: Assistive device use and informal caregiving hours

The two included articles for Research Question 2 were cross-sectional and published in English.[13,14] Both articles defined informal care similarly: that is, unpaid care provided by family and friends. Both articles measured time spent on informal caregiving in hours as the outcome measure. One article collected data on informal caregiving hours received in the week before data collection,[14] while the other looked at informal caregiving hours received in the two weeks prior to data collection.[13] In Agree et al.'s study, respondents were asked how many numbers of hours of hands-on assistance they received for ADLs.[13] Hoenig et al. asked respondents how many hours of assistance they received to perform basic ADLs (e.g., eating, getting in and out of bed, getting around inside, dressing, bathing, and getting to the bathroom or toilet).[14] Both articles obtained data on informal caregiving hours from the care recipients.[13,14] The common exposure investigated by both articles was AD use (versus non-use) and the samples included community-dwelling adults aged 65 years or older.

Agree et al. investigated whether AD use for mobility (e.g., cane, walker, wheelchair), bathing (e.g., bath seat and rail), or toileting (e.g., raised seat, toilet rail, portable toilet) was associated with reductions in informal caregiving hours among 4,006 community-dwelling, older American adults, who had any pathology, impairment limitation, or disability.[13] Their study used the method of multivariate regression analysis, where interdependent outcomes of AD use, formal care, and informal care were simultaneously regressed on variables covering health needs, resources, access, and demographic characteristics. Using this methodology, the authors identified factors (independent variables) that were associated with increased likelihood of AD use, while simultaneously associated with decreases in hours used in informal or formal care. Specifically, AD use was significantly associated with fewer informal care hours, particularly among the unmarried (AD use: $\hat{\beta} = 0.14$, $p < 0.01$; Informal care hours: $\hat{\beta} = -40.17$, $p < 0.01$), better educated (AD use: $\hat{\beta} = 0.12$, $p < 0.05$; Informal care hours: $\hat{\beta} = -15.36$, $p < 0.01$) or had better cognitive abilities (AD use: $\hat{\beta} = -0.17$, $p < 0.01$; Informal care hours: $\hat{\beta} = 83.77$, $p < 0.01$).[13] These findings adjusted for the number of ADLs that were severely difficult to perform; cognitive impairment measured by the use of a proxy for poor memory; senility and confusion due to having Alzheimer's disease; insurance; poverty; marital status; living environment; access to healthcare; and demographics such as age, gender, education, and race.[13]

In addition, the doctoral candidate calculated a small Hedges' g of 0.22 (95% confidence interval [CI] = 0.15 to 0.28) when comparing informal care hours in persons who used AD (n = 2,712) with those who did not (n = 1,294), suggesting no difference between the two groups among all participants in the study. Among only respondents who used care, Hedges' g coefficient for informal care hours among persons with AD and persons without AD was 0.11 (95% CI = 0.04 to 0.17), again indicating a very small difference between the two groups, suggesting no significant difference between groups.[13]

The study by Hoenig et al., examined 2,638 community-dwelling, American older adults with at least one basic ADLs limitation. These individuals reported using any technological aid to help ameliorate ADLs impairments in areas such as eating, getting in and out of bed, dressing, bathing, toileting, indoor mobility, and outdoor mobility.[14] After controlling for ADLs impairment, missing hours of help, cognitive impairment, health, hospitalizations, age, gender, race, education, income, and insurance, the study found that those who used any technological assistance reported 3.8 fewer hours of help per week ($\hat{\beta} = -3.8$, 95% CI = -6.54 to -1.06) than those who did not.[14]

In Research Question 1, one study found an inverse association between AD use and LS, while the other did not find an association. In Research Question 2, both studies found an association between AD use and reduction in informal caregiving hours received by community-dwelling older adults.

3.4.2 Risk of bias: Research question 1

In the two studies in Research Question 1, one article scored 16 out of 19,[133] and the other scored 14 (See Appendix F).[132] One article had several limitations associated with the study design (Question 2), justification of results (Question 17), and discussion of limitations (Question 18).[133] The other article had several limitations associated with justification of sample size (Question 3), addressing non-responders and non-response bias (Questions 7 and 13), and reporting funding sources (Question 19).[132] Both articles failed to report ethics approval and informed consent processes (Question 20).[132,133] In addition, one study did not report any results besides the chi-square test statistic and p-value, and also did not account for confounding or provide distributions of results.[133] Overall, the risk of bias was serious across the two studies.

GRADE Assessment: Research Question 1

3.4.3 GRADE assessment: Research question 1

Certainty assessment							Certainty	Importance
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**		
2	observational studies	serious[a]	serious[b]	not serious	serious[c]	none	⊕◯◯◯ Very low	CRITICAL

Table 3 - 1: GRADE assessment for Research Question 1

a. See Risk of Bias section in results and Appendix F.

b. The results of the two studies were not consistent.

c. The study by Leung et al.[133] had a large sample size (n = 5,395) and unbalanced exposure groups (exposed = 295, 5.5% versus unexposed = 4,949, 92.5%). The study by In-sook et al. had a medium sample size (n = 601); this study did not report the number of persons with AD and persons without AD.[132]

All observational studies were graded as low quality at the start of the GRADE assessment, as per GRADE guidelines. Inconsistency was graded as being serious because one study[132] found no association and the other reported an inverse association between AD use and LS.[133] The results of the latter study should be interpreted with caution because the study did not perform any analysis beyond a chi-square test. All studies directly compared the exposure and outcome of interest. Studies with a large sample size, but only a small number of exposed subjects compared to unexposed subjects, as well as studies with a lack of information on exposed versus non-exposed groups, could potentially be indicative of less precise estimates, as described by Carlson et al.[132–134] Confounding was not assessed in both studies as per GRADE guidelines, which state that the impact of plausible confounding should only be assessed in observational studies that have not been downgraded for any reason. The overall quality of evidence of the included studies in Research Question 1 was very low (Table 3 - 1).

3.4.4 Risk of bias: Research question 2

In the two studies in Research Question 2, both studies scored 18 out of 19 (See Appendix F). One study had a response rate of 51% for the outcome variable and raised concerns about non-response bias (Question 13).[14] This study also failed to report funding sources.[14] The two studies did not mention if ethics approval was obtained. The risk of bias was not serious across the two studies.

3.4.5 GRADE assessment: Research question 2

Certainty assessment							Certainty	Importance
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**		
2	observational studies	not serious	not serious	not serious	serious[a]	none	⊕⊕⊕◯ Moderate	CRITICAL

Table 3 - 2: GRADE assessment for Research Question 2

a. One study had a large sample size (n = 2,638), but consisted of unbalanced exposure (n = 2,199, 83.4%) versus non-exposure groups (n = 169, 6.41%).[13,14] Although the other study had a large sample size, the number of exposed versus unexposed participants was unclear.[13]

Inconsistency was graded as not serious because both studies found a positive association between AD use and a reduction in informal caregiving hours.[13,14] Indirectness was not serious because both studies directly examined the exposure and outcome of interest. Imprecision was serious due to unbalanced exposure versus non-exposure groups.[13,14] As per GRADE guidelines mentioned above, plausible confounding was not assessed. The overall quality of evidence of the included studies was moderate (Table 3 - 2).

3.5 Discussion

Of the 1,391 citations screened, the doctoral candidate found two articles pertaining to each question, for a total of four. In relation to Research Question 1, one study showed no association between AD use and LS and one study found an inverse relationship.[132,133] In Research Question 2, two studies showed a positive finding for the association between AD use and the reduction in informal caregiving hours.[13,14] The dearth and limitations of published literature on both research questions prevented us from drawing firm conclusions about the associations under study.

A few limitations of the studies included in this review should be noted. The two studies included in Research Question 1 had inconsistent results, possibly due to heterogeneity across studies. One study adjusted for a wide range of covariates[132] and the other study did not control for any covariates, presenting varying degrees of confounding effects.[133] Additionally, each study investigated the use of different AD (e.g., wheelchairs, and devices for walking, bathing, daily living, healthcare, physiotherapy, and health monitoring), therefore limiting the comparison of findings across studies.[132,133] Furthermore, the two studies occupied different statistical analyses and tools to measure LS.[132,133]

In Research Question 2, the two studies controlled for different mixes of covariates, which may have contributed to differences in the strength of the results across studies. Both sets of study authors acknowledged the potential presence of residual confounding because they did not control for comorbid health conditions.[13,14] Both studies had further limitations such as concerns around non-response bias and imprecision (See Table 3 - 2, footnote ‘a’), further biasing the results. Non-response bias can be suspected when non-responders in a study are different from responders on prognostic characteristics.[124] For example, in the study by Hoenig et al., participants who did not respond to questions relating to ADLs impairment reported using significantly more hours of help, possibly shifting the results toward the null. One study investigated those who used AD for only ADLs difficulties; therefore, the findings cannot be generalized to community-dwelling older adults who use other types of AD.[13] The quality of evidence in Research Question 2 was moderate, along with only two studies, making it difficult to draw firm conclusions or make recommendations.

A common limitation across studies was that many types of AD were grouped together under “AD use”, thus obscuring the differences between AD in terms of their individual impacts on the two outcomes (LS and informal caregiving hours).[13,14,132] Researchers should stratify their analyses by specific types of AD (e.g., mobility versus hearing-related AD, high-tech versus low-tech AD) when possible, to understand whether device-specific differences exist. Such analyses would require large sample sizes and future research could perhaps power their studies to explore differences between multiple devices. In addition, existing evidence may lack internal validity due to the very low (Research Question 1) and moderate (Research Question 2) strength of evidence. All four studies were cross-sectional, which prevents inferences about temporality and changing relationships over time. The cross-sectional nature, and the strength evidence of existing studies creates uncertainty around whether the results of existing studies present true associations. Lastly, findings may be only relevant to populations from areas similar to where the studies were carried out (e.g., Canada, South Korea, and United States) and therefore may not be generalizable to all countries.

This systematic review identified important gaps in the literature. Future studies can overcome the aforementioned knowledge gaps by first, conducting further research (e.g., longitudinal, stratified by AD) to overcome the knowledge and methodological gaps. Through attempting to reduce limitations observed in existing studies (e.g., risk of bias, residual confounding, non-response bias), by controlling for appropriate confounding variables, having balanced exposure versus non-exposure groups, and reducing other biases such as those that are mentioned under 'Risk of Bias', future studies can improve the quality and strength of evidence, increasing their reliability for decision-making.

3.6 Strengths and limitations of the review

This systematic review is the first to assess the impact of AD on LS and informal caregiving hours received among community-dwelling older adults. Furthermore, this systematic review considered articles that were published in other languages besides English to minimize the possibility of language bias. This review also followed the PRISMA criteria for systematic reviews and used GRADE and AXIS for assessing the quality of articles. Finally, a self-rating using AMSTAR 2 scored this review 12 out of 13, indicating high methodological quality. Question 4 and 7 of AMSTAR received a 0.5, or "partial yes", because the doctoral candidate did not search grey literature and trial/study registries and the list of excluded publications was not provided in an appendix due to length.

Limitations of the review included an inability to conduct a meta-analysis due to the heterogeneity of the articles, as well as a lack of commonly reported outcome statistics. The doctoral candidate was also unable to assess publication bias due to the absence of a meta-analysis and the small number of studies included in the review.

3.7 Conclusion

The scarcity of studies and moderate to very low strength of existing evidence prevented us from drawing conclusions about the two associations investigated in this review. AD play an important role in improving the overall well-being of community-dwelling older adults. This review considers the potential of AD in improving LS of, and reducing informal caregiving hours received by, community-dwelling older adults. Greater

LS levels can enhance the state and experience of living as an older adult, while reductions in informal care hours can ease the negative outcomes associated with greater hours of informal caregiving (e.g., caregiver stress, depression). More research and high-quality evidence are required for evidence-based decision-making and effective recommendations regarding the provision and funding of AD for community-dwelling older adults.

Chapter 4

Investigating the association between assistive device use and the change in life satisfaction among community-dwelling older adults: analysis of the Canadian Longitudinal Study on Aging (CLSA)

4.1 Abstract

Objective

To investigate whether self-reported assistive device (AD) use within the last 12 months preceding baseline data collection is associated with a change in life satisfaction (LS) between baseline and three years of follow-up among community-dwelling older adults (≥ 65 years) compared to those who did not use AD at all.

Methods

Using multiple linear regression models, the change in LS (follow-up - baseline), measured with the Satisfaction with Life Scale (SWLS), was regressed on AD use (yes/no) and a series of sociodemographic, health, functionality, psychological, and support covariates. Complete cases from the Tracking (n = 5,502) and Comprehensive (n = 9,760) cohorts of the Canadian Longitudinal Study on Aging (CLSA) were used in the analyses.

Results

The results did not provide evidence for an association between self-reported AD use and changes in LS over time (Tracking cohort: $\hat{\beta}$ = 1.16, 95% CI = -0.57 to 2.89; Comprehensive cohort: $\hat{\beta}$ = 0.47, 95% CI = -0.89 to 1.82).

Conclusions

The non-significant findings may partly be explained by the fact that a majority of the study sample reported high LS scores and low usage of AD. Nonetheless, null findings are valuable as they can guide future research and prevent biased policies and practices. Future research can employ longer follow-up periods, collect data on additional confounding factors such as device satisfaction, conduct analyses by specific device type (e.g., mobility devices versus vision-related devices), and use refined LS questions related to AD use to structure future studies toward investigating LS in the context of AD use.

4.2 Introduction

The world's population is getting older, with an estimated one in six individuals being 65 years or older by 2050.[1,2] Additionally, people are living longer, but not necessarily in good health, as the number of years lost due to chronic illnesses, multiple health issues, and impairments is increasing worldwide.[3]

4.2.1 Assistive devices

The World Health Organization defines assistive devices (AD) as devices or technologies designed to enhance an individual's independence, participation, and overall well-being.[4] AD can have a pivotal role in addressing healthcare challenges for aging populations by enabling older adults to perform daily functions such as leaving their homes or getting out of bed. Studies have shown that some AD can prevent further impairments, delay hospitalization, slow functional and cognitive decline, enhance independence, social connectivity, safety, mental health, and overall well-being.[4,33,35–42] Older adults use a wide range of AD that are divided into 12 classes, including mobility, vision, hearing, communication, and information management-related devices (see Appendix A).[29]

4.2.2 Life satisfaction

Life satisfaction (LS) is defined as the subjective judgment of one's life as a whole and their current life situation in relation to expectations.[6–9] It serves as an indicator of overall well-being and reflects an individual's life experiences. LS has gained interest among researchers as a health outcome because increases in life expectancy following medical advancements over the last 50 years are not necessarily accompanied by fulfillment in life.[10]

The question remains as to whether a life prolonged by medical advances, but devoid of the ability to make choices like going for a walk on one's own, is a fulfilling life. A more satisfying life would include the capability of leading a dignified, independent, and autonomous life.[135–137] AD could enhance LS by giving older adults the tools to undertake hitherto restricted activities, thereby optimizing independence and freedom.

LS has been identified as one of the most important indicators of successful aging in the current literature[44–46] because it is associated with improved physical and psychosocial health, and positive health behaviors.[11,47] Exploring LS and targeting interventions and policy changes to maintain or improve the LS of older adults may produce several benefits for the health of aging populations. These benefits include healthier populations which can lead to reduced healthcare expenses and increased productivity, resulting in a positive impact on the economy.[11,12] Furthermore, LS experienced during the later years of life can be informative for policymaking, effective resource allocation, and social welfare planning.[138] Therefore, it is crucial to prioritize the maintenance and improvement of LS of older adults to promote their well-being and contribute to the betterment of society as a whole.

This study aims to investigate whether AD use can improve LS among community-dwelling older adults. According to a systematic review by Marasinghe et al., the published articles in the area are characterized by biased and low quality evidence, thereby presenting an opportunity for further research.[80] To the best of the doctoral candidate's knowledge, this is the first study to examine the association between AD use and LS longitudinally, with a national-level data set that is comprehensive enough to enable adjustment for multiple, relevant confounders.

4.2.3 Theoretical framework

This study was anchored in the CATOR framework developed by Jutai et al.[5] This CATOR framework identifies five AD outcomes: effectiveness, social significance, device satisfaction, psychological functioning, and subjective well-being.[5] Subjective well-being comprises the cognitive and emotional assessments of AD's impact on users' lives and includes a domain called satisfaction, under which LS is found. Within this framework, LS refers to how users value AD and believe these devices influence their LS.[5] CATOR posits that AD has the potential to improve LS in older adults.

4.3 Methods

4.3.1 Design and study sample

The CLSA enrolled community-dwelling adults aged between 45 and 85 years in Canada.[113] The study randomly collected baseline data from 51,338 participants, out of which 21,241 were interviewed through computer-assisted telephone interviews in the Tracking cohort, and the remaining 30,097 were randomly chosen from catchment areas within 25 to 50 kilometers of 11 Data Collection Sites (DCSs) across Canada to form the Comprehensive cohort.[113] The Comprehensive cohort's data were collected through in-home interviews and DCSs visits.[113] Baseline data collection began in 2011 and lasted until 2015, and the first follow-up data collection started in 2015 and ended in 2018.[113]

The CLSA excluded who: lived in the three Canadian territories, on First Nations reserves or other provincial First Nations settlements, were full-time members of the Canadian Armed Forces, were residents of institutions such as long-term care homes (LTCs), were persons unable to communicate in French or English, or showed signs of cognitive impairment at the recruitment interview.[113] More information of the CLSA and its recruitment methods may be found elsewhere.[113–115]

4.3.2 Study sample

The analyses contained CLSA participants aged 65 years or over from both the Tracking and Comprehensive cohorts. Participants with missing data for the exposure variable (AD use), outcome variable (change in LS), or any covariate were excluded. In the Tracking and Comprehensive cohorts, the final sample sizes for all descriptive and regression analyses were 5,502 and 9,760 participants, respectively (see Figure 4 - 1Figure 4 - 2).

4.3.3 Measures

4.3.3.1 Dependent variable - change in life satisfaction

LS was measured using the Satisfaction with Life Scale (SWLS).[31] SWLS is a five question instrument with seven response levels per question (1 = strongly disagree; 7 = strongly agree).[6,139] Responses were summed to generate overall scores between scores of 5 and 35 for each participant, with scores ≥ 20 considered as being satisfied with life.[139] Following the advice of the SWLS's developers, the doctoral candidate used the continuous scores in all analyses to avoid information loss during classification (e.g., categorical).[140,141] The change in LS was computed by subtracting the baseline score from the follow-up score.

The SWLS has shown high internal reliability and consistency, construct validity, and moderate temporal stability.[60,61] The SWLS has undergone validation studies and testing of its psychometric features in a number of populations (e.g., Spain, Chile, Peru, and Argentina) and has demonstrated favorable characteristics for usage across different populations and age groups.[142] Specifically, it has been demonstrated that the SWLS is reliable, valid, and reproducible when used to assess LS among older adults in community-settings.[143] Several studies have previously used the SWLS to evaluate LS among community-dwelling older adults who were aged 65 years and above.[144–146]

4.3.3.2 Independent variable - AD use

The CLSA gathered data on AD use, including those related to mobility, hearing, and vision. Participants were asked: “During the past 12 months, have you used any of the following assistive devices?” (mobility); “Do you use any aids, specialized equipment, or services for persons who are deaf or hard of hearing, for example, a volume control telephone or TV decoder?” (hearing); “Besides glasses or contact lenses, do you use any aids or specialized equipment for persons who are blind or visually impaired, for example, magnifiers or Braille reading materials?” (vision). In this study, a participant was considered as an AD user if they reported using at least one device of any type. The doctoral candidate dichotomized the AD use variable as the aim of the study question was to evaluate the connection between AD use and LS among those who used AD versus those who did not, as has been done in previous studies.[13,14,132,133]

4.3.3.3 Confounding variables

4.3.3.3.1 Sociodemographic domain

Consistent with the existing literature, this study controlled for baseline values of age (65-74 or 75-89 years),[132,147] sex (male or female),[132] education (at most secondary education or at least some post-secondary education),[132] annual household income,[132,40] marital status (married or other - other included single, never married or never lived with a partner, widowed, divorced, separated),[132,40] living arrangement (living alone or not alone), and race

(White only and other).[132,148,149] The income variable in Canadian dollars was categorized as follows: < $20,000, $20,000 to < $50,000, $50,000 to < $100,000, $100,000 to < $150,000, or ≥ $150,000.

4.3.3.3.2 Health Domain

This study controlled for self-perceived health[132,147] and chronic conditions.[150–152] Self-perceived health included general health ("In general, would you say your health is excellent, very good, good, fair, or poor?") and mental health ("In general, would you say your mental health is excellent, very good, good, fair, or poor?"). However, only physical health was included in the regression models due to issues relating to multicollinearity with mental health (further discussed in Section 4.4.3).

The doctoral candidate adjusted for a dichotomous chronic conditions variable coded as 'yes', if participants self-reported being told by a doctor that they had at least one of the following conditions: osteoarthritis, arthritis, respiratory, cardiovascular, neurological, gastrointestinal, or vision-related diseases, cancer, mental health conditions, infections, back problems, bone, thyroid, kidney-related conditions, or any other chronic condition.[15] Participants were coded as 'no' if they did not report any of these conditions.

4.3.3.3.3 Functionality domain

The doctoral candidate controlled for the ability to carry out activities of daily living (ADLs) and instrumental activities of daily living (IADLs) with or without assistance (from another person or device),[132] as well as injury (yes or no).[74–77,153–158] The CLSA assessed ADLs and IADLs using a modified version of the Older Americans' Resources and Services (OARS) Multidimensional Functional Assessment Questionnaire.[159] Participants were asked about their ability to carry out seven ADLs and seven IADLs; the CLSA employed an algorithm to combine these responses into a 5-point scale ranging from no functional impairment to total impairment.[159] This variable is an overall classification of one's capacity to perform ADLs and IADLs.[159] Injury was coded as 'yes' or 'no' in response to the following question: "In the last 12 months, have you had any injuries that were serious enough to limit some of your normal activities? For example, a broken bone, a bad cut or burn, a sprain or a poisoning."

4.3.3.3.4 Psychosocial domain

Participants self-reported the presence of depressive symptoms via the Center for Epidemiologic Studies Short Depression Scale (CESD-10), which contained 10 questions about items such as feelings of depression, loneliness, hopefulness for the future, and restless sleep. Each question consisted of four possible responses (all of the time, occasionally, some of the time, rarely, or never) and an algorithm was used to generate a score between 0 and 30, with higher scores indicating more severe depressive symptoms. The doctoral candidate dichotomized the variable that divided the score into two categories: positive (≥ 10) or negative screen for depressive symptoms.[160]

4.3.3.3.5 Support domain

Two variables were assessed under this domain: (i) the receipt of formal/informal home care was a three-level variable identifying whether participants received formal home care, informal home care, or both during the past 12 months; (ii) functional social support (FSS) was the degree to which one perceives they will receive assistance or support from their social network when needed.[124,135,136,137] FSS was measured using the 19-item, self-administered Medical Outcomes Study (MOS) Social Support Survey, and scored using an algorithm that converted questionnaire responses into a 0 to 100 score (higher scores indicated better FSS).[164–166]

4.3.4 Data analysis

4.3.4.1 Descriptive analysis

Data analysis was conducted using SAS version 9.4 (SAS Institute, Cary, N.C., USA). Summary statistics were reported via frequency tables for categorical variables, and using means, and standard deviations for continuous variables.

4.3.4.2 Regression analysis

The doctoral candidate employed multiple linear regression for the analysis because of the presence of several predictor variables (i.e., independent variable and covariates) and a continuous outcome variable in the research question.[167] She employed a general linear model (PROC GLM in SAS) and regressed the change in continuous LS score from baseline to first follow-up on the baseline value of AD use in the past 12 months. She adjusted for the baseline values of the covariates described above by including them in the model (see Appendix G).

4.3.4.3 Model diagnostics and missing data

The fit of regression was assessed utilizing residual versus predicted plots, observed versus predicted plots, and influential observations (i.e., Cook’s Distance, studentized residual versus leverage graph).[168] An adequacy plot should show a random scatter around the horizontal axis (y = 0) without any discernible patterns, while a plot indicating good model fit should show data points clustering tightly around a diagonal line of 45°.[169]

Multicollinearity was assessed through Type II tolerance values generated from PROC GLM procedures to identify highly correlated variables in the model and resolve conflicts. A Type II tolerance value of ≥ 0.1 indicated no issues with multicollinearity.[170]

The doctoral candidate used bivariate analysis to compare responses to LS questions across participants with complete and missing data on AD use. She also investigated whether responses to AD use differed between participants with complete and missing LS data. Comparisons were conducted with the Rao-Scott chi-square test for AD use, which is a statistical test designed for categorical or binary variables and Mann-Whitney U test for LS, which is a statistical test used to compare variables including continuous variables.[171,172] The doctoral candidate studied the distributions of AD use and LS among participants included in the analysis versus those excluded from the analysis, using side-by-side boxplots and overlay of histograms.

4.3.5 Ethics and data access

All data for this study were obtained via a data access request to CLSA (file #2010026); the University of Waterloo's Office of Research Ethics approved this study **(**file #42761**).**

4.4 Results

4.4.1 Descriptive results

Table 4 - 1Table 4 - 2 displays the sociodemographic and health characteristics of the study samples in the Tracking and Comprehensive cohorts. Across the two population cohorts, close to two-thirds of the population were older adults between the ages 65 and 74 years, and one-third were between 75 and 89 years. The population was equally distributed

across the two sexes and a majority self-identified as White; most reported incomes less than $50,000, were married, and lived with at least one other person.

Though the aim of this study was not to investigate the association of interest by type of AD use, but rather by AD use versus non-use, understanding the range and nature of AD used by participants in this study was beneficial (see Section 4.4.3). Table 4 - 4 provides an overview of the types of AD used by participants in the Tracking and Comprehensive cohorts. A majority of AD used in this study included those that compensate for a physical limitation (e.g., mobility, hearing, or vision-related constraints), which reflects the CLSA's exclusion of participants with cognitive impairment.[113]

4.4.2 Regression results

4.4.2.1 Tracking cohort

The results did not find a significant difference in the change in LS over three years among community-dwelling older adults who reported of AD use, compared to those who did not report any AD use, while controlling for all covariates ($\hat{\beta}$ = 1.16, 95% CI = -0.89 to 1.82 [see Table 4 - 3]).

4.4.2.2 Comprehensive cohort

Results did not find evidence of a significant association between AD use versus no AD use and changes in LS over three years among community-dwelling older adults compared to those who did not use AD, after controlling for all covariates ($\hat{\beta}$ = 0.47, 95% CI = -0.89 to 1.82) (see Appendix G).

4.4.3 Model diagnostics

In both cohorts, residual plots did not indicate model violations or model inadequacy, while model fit plots depicted weak linear patterns that generally followed a 45° line, indicating that the model has some ability to predict the actual observed values (see Appendix H). The studentized residual versus leverage graph showed potential outliers (values outside of two horizontal lines) and some influential observations outside of the vertical reference line in both cohorts. These outliers and influential observations were kept in the analyses because though extreme, they were valid observations. Cook's distance graph showed observations with Cook's distances less than the 50th percentile, indicating an absence of influential observations that can influence the findings in both Tracking and Comprehensive cohorts. The linear trend in the Q-Q plot and histogram suggests that the normality assumption was met (see Appendix H).

For both cohorts, multicollinearity assessment showed high correlations between self-perceived physical and mental health. The doctoral candidate omitted self-perceived mental health and retained self-perceived physical health in the models because most of the AD captured in this study were related to physical health limitations rather (see Table 4 - 4).

4.4.4 Missing data

One thousand two-hundred sixty-six (19%) and 1,584 (14%) participants were excluded from the eligible samples in the Tracking and Comprehensive cohorts, respectively, due to missing data (see Figure 4 - 1 andFigure 5 - 2). In the Tracking cohort, among participants with missing data on LS at follow-up, a higher proportion reported AD use at baseline, compared to participants with no missing data (47% versus, 38%, respectively) (see

Appendix I). A similar observation was apparent in the Comprehensive cohort (46% versus 38%, respectively) (see Appendix I).

Among Tracking cohort participants with missing versus complete data on AD use at baseline, a small and statistically non-significant difference in mean LS at follow-up was observed, indicating no clinically important difference in LS distributions based on incomplete or complete data on AD use at baseline. The difference between mean LS at baseline among those with missing and complete data on AD use at baseline was greater though statistically non-significant (see Appendix J). Similar findings were observed in the Comprehensive cohort (see Appendix J). In both Tracking and Comprehensive cohorts, no evidence was found to suggest a difference in the distributions of LS across participants who were included in the analysis versus participants excluded from the analysis (see Appendix J). Turning to AD use, the probability of AD use in the excluded group was significantly higher than in the included group (Tracking: 45% versus 37% respectively; Comprehensive: 41% versus 38% respectively, p-value <.0001) (see Appendix K). These observations regarding AD use indicate possible bias toward the null (discussed further in Section 4.5).

4.5 Discussion

This study did not find evidence of significant associations between self-reported AD use and changes in the LS over three years in the Tracking and Comprehensive cohorts of the CLSA. Since this study employed a complete case analysis, which is a statistical method that only includes participants with complete data on the variables of interest, these findings are only applicable to populations mirroring the characteristics of the analytical sample.

In terms of comparisons of the study findings to the existing literature, no previous studies have investigated the relationship between AD use and the change in LS over time; therefore, the doctoral candidate did not have studies of the same nature to compare results. However, through the search for a recent systematic review (see Chapter 3),[80] she found three cross-sectional analyses that investigated the relationship between AD use and LS. A South Korean study, with a similar aging population to this study (community-dwelling older adults aged 65) did not find a significant association between AD use and LS ($\hat{\beta}$ = 0.014 - not significant; p-value or standard error unreported), after adjusting for a similar set of covariates as in this study.[132] Although non-significant, the South Korean study results indicated a small and positive association and aligned with the findings of this study from both Tracking and Comprehensive cohorts. The types of AD used by participants in the South Korean study (see Section 3.4.1.1) were similar to the AD used by participants in this study (see Table 4 - 4). Additionally, compared to the South Korean study (n = 601), this study had large sample sizes (Tracking cohort: n = 5,502 and Comprehensive cohort: 9,760), yet both studies produced similar results. It is possible that the types of devices included in these two studies may not play a role in improving LS in older adults, though results from merely these two studies are not sufficient to draw firm conclusions.

A second study by Squires investigated the association between hearing aid use and LS among 33 community-dwelling older adults aged 65 years or older in the United States.[147] The author did not find a significant association (Kruskal-Wallis Test Statistic (H) = 1.12) in a bivariate analysis without any adjustment for covariates.[147] Despite being found through the systematic review search, the Squires study was not included as part of the review due to not meeting the review's eligibility criteria. A third study using Canadian data reported that 5,395 older adults using wheelchairs experienced less satisfaction with life compared to those who did not use wheelchairs (X^2 = 68.5, p < 0.0001), though the authors did not report any results adjusted for covariates.[133] While the sample ages and settings in the two studies were similar to that of the sample of this study, differences in the types of AD examined in each study (only hearing aids or only wheelchairs versus the inclusion of several types of AD)[133,147] and variations in the use of statistical methods (e.g., covariate adjustments) limited comparisons of study findings with earlier publications.

This study's null findings may be explained by several factors. First, the CLSA contains a largely healthy subsample of the population because healthier people were more likely to join the study.[173] This healthy-participant effect was evident in both cohorts, as the majority of participants self-reported excellent, very good, or good physical and mental health; no functional impairment or injuries; low or few depression symptoms; few reported receiving informal or formal care; high FSS and LS scores; and approximately two-thirds did not use AD (see Table 4 - 1Table 4 - 2). A healthy sample may require less AD; therefore, AD may not be seen as beneficial in this sample. The healthy nature of the population may have biased the findings of the thesis toward the null, thereby underestimating the true association between AD use and changes in LS. In the Comprehensive cohort, participants were required to travel to a CLSA data collection site.[174] This requirement may have further exacerbated the enrolment of healthy volunteers because persons who were dependent on AD for mobility restrictions may have been less likely to join the study, thereby biasing results further toward the null (see Table 4 - 3).

Secondly, a healthy sample such as the one used in the thesis may begin the study with higher baseline LS scores than the average in the population. Over three years of follow-up, these scores are less likely to exhibit drastic declines because of the healthy sample, thereby reducing variability in the data and leading to very small mean changes in LS from baseline to follow-up. Therefore, three years may not have been sufficient time to detect changes in LS over time.

Thirdly, in both cohorts persons excluded from the analysis due to missing data had a significantly higher proportion of AD use compared to included individuals (see Section 4.4.4). This may also have contributed to biasing the results towards the null because fewer persons who used AD were included in the analyses. Overall, this study failed to identify a significant finding likely due to biases imposed by the broad nature and variations of AD types included in the study, self-selection, missing data, and limited follow-up time.

Theoretically, according to CATOR framework, AD can be seen as devices that have the potential to help improve older adults' LS over time and contribute to overall well-being, yet the findings of the current study did not find evidence to support this theory.[5] Findings also do not refute the CATOR framework as results merely indicate that the evidence in the given sample is insufficient for a firm conclusion about the association of interest. These null findings are still informative as they can contribute to informing theory, guide future research, and avoid policies and practices based on biased research.[175,176]

4.5.1 Strengths

This is the first study to investigate the association between AD use and the change in LS over time among community-dwelling older adults, aged 65 years or over. This study controlled for a comprehensive set of covariates to minimize the impact of residual confounding. Existing studies did not account for any covariates or adjusted for a few but not all relevant covariates (e.g., depressive symptoms).[132,133,147]

4.5.2 Limitations

All types of AD were grouped together under "AD use" and dichotomized by AD use versus no AD use in this analysis, thereby could not examine the differential impacts of specific types of AD on changes in LS. Furthermore, the sample of this study mainly consists of AD that compensate for physical impairments (see Table 4 - 4). The CLSA's exclusion of participants who have cognitive impairments, may explain this limited representation of AD in this sample. The lack of sub-analysis by device type, analysis by AD use versus no AD use, and limited representation of AD in the sample may have masked the granularity of AD use. As such, the results could not identify whether some AD were associated with greater changes in LS than others. The findings only apply to a subset of AD and cannot be extended to all types of AD, such as those not captured in this study.

Furthermore, as discussed in Section 4.5, the healthy participant effect observed in the CLSA, loss of information due to missing data, and the availability of only two time-points across three years are further limitations of this study. The limitations associated with the analytical sample (e.g., the use of unweighted data and complete case analysis) restricts the applicability of findings only to populations that mirror the study sample and creates implications for population-wide policy and practices. While the CLSA intended to be representative of the Canadian population, most of its sample self-identified as White, which may be attributable to self-selection bias or language barriers. The requirement that CLSA participants must be able to respond in English or French may have played a role in the language barrier. In the current study, participants of visible minorities made up around 2.5-4% of the sample, while they make up 22.3% of the entire Canadian population.[177] This may further restrict the applicability of the findings to the entire Canadian population from a sociocultural perspective.

4.5.3 Implications and future directions

LS is influenced by multiple aspects of human life (see Section 2.1.3.2.1). More direct and refined LS questions in the context of AD use may provide better insight into the association between AD use and the change in LS. In the CLSA, LS was measured using the SWLS and it asks questions about LS independent of AD use.[31] For example, it does not ask questions regarding how an individual's LS has changed as a result of AD use. This means the evaluation of LS with this scale does not take into account how AD use may affect an individual's LS. Without such questions, the study may miss important nuances in how AD use affects LS. Using scales that specifically structure its LS-related questions within the context of AD use or adding such questions to studies may be more suitable when investigating the association of interest to understand the relationship more closely. Therefore, future studies are encouraged to include AD use-specific LS questions in their approach to measuring LS.

LS may be perceived differently across different cultures and countries.[178] Although the available data indicates that the SWLS has the ability to assess LS across different cultures, its developers acknowledge that more research is necessary to fully understand how the scale should be interpreted in different cultures and subcultures.[178] Therefore, LS scales should be validated in different cultures prior to use in research. Furthermore, in some cultures, AD use are viewed as a sign of weakness rather than a support; therefore, future researchers should note cultural contexts in future investigations.[179]

To assess whether AD have differential impacts on LS, researchers should attempt to stratify their analyses by specific types of AD (e.g., mobility versus hearing-related AD, high-tech versus low-tech AD), keeping in mind the larger sample size requirements to conduct subgroup analyses. Other approaches used to manage missing data (e.g., imputation) may be used to avoid drawbacks of employing complete case analysis (e.g., applicability of results to target populations), where appropriate. While the doctoral candidate controlled for a comprehensive set of confounders, controlling for context relevant confounders (e.g., satisfaction with device) would reduce potential residual confounding in future studies.

4.6 Conclusion

As the population ages, evidence of AD’s effect on LS is essential to inform future interventions, evidence-based decision-making, and effective recommendations on the provision of AD to community-dwelling older adults. This study builds on previous research by investigating the relationship between AD use and the change in LS over time, while controlling for a comprehensive set of variables in sociodemographic, health, functionality, psychological, and support domains. Results did not find evidence for statistically significant associations between AD use and the change in LS among community-dwelling older adults aged 65 and above in the CLSA. While study limitations may have contributed to null findings, it cannot be ruled out that AD use is unassociated with changes in LS among older adults. Future research is required to further elucidate this relationship. Future research should investigate the association of interest further using more representative samples (e.g., minimal selection bias or missing data, and culturally representative), longer follow-up periods than three-years, controlling for context-relevant confounders, stratifying AD use by type, and designing studies more explicitly structured towards investigating LS in the context of AD use (e.g., the use of more refined LS questions directly related to AD use).

Table 4 - 1: Sample characteristics in the Tracking and Comprehensive cohorts (categorical variables)

Characteristic	Tracking cohort	Comprehensive cohort
	Frequency (n) and Percent (%)	Frequency (n) and Percent (%)
Sample size (n)	5502	9760
Age		
65-74	3218 (58.49)	5983 (61.30)
75-89	2284 (41.51)	3777 (38.70)
Sex		
Female	2721 (49.45)	4753 (48.70)
Male	2781 (50.55)	5007 (51.30)
Education		
At most secondary education	1373 (24.95)	1858 (19.04)
At least some post-secondary education	4129 (75.05)	7902 (80.96)
Income		
Less than 20,000	1031 (18.74)	1597 (16.36)
20,000 or more, but less than 50,000	2822 (51.29)	4509 (46.20)
50,000 or more, but less than 100,000	1328 (24.14)	2906 (29.77)
100,000 or more, but less than 150,000	207 (3.76)	474 (4.86)
150,000 or more	114 (2.07)	274 (2.81)
Ethnicity		
White only	5358 (97.38)	9374 (96.05)
Other	144 (2.62)	386 (3.95)
Marital status		
Married	3591 (65.27)	6306 (64.61)
Other	1911 (34.73)	3454 (35.39)
Living arrangement		
Alone	1655 (30.08)	2912 (29.84)
Not alone	3847 (69.92)	6848 (70.16)
Physical health		
Excellent	1078 (19.59)	2043 (20.93)
Very Good	2187 (39.75)	4098 (41.99)
Good	1645 (29.90)	2849 (29.19)
Fair	510 (9.27)	669 (6.85)

Poor	82 (1.49)	101 (1.03)
Chronic conditions		
Yes	5281 (95.98)	9507 (97.41)
No	221 (4.02)	253 (2.59)
Functional impairment - ADLs/IADLs		
Impairment	738 (13.41)	1300 (13.32)
No impairment	4764 (86.59)	8460 (86.68)
Injury		
Yes	529 (9.61)	1089 (11.16)
No	4973 (90.39)	8671 (88.84)
Symptoms of depression		
Yes	752 (13.67)	1342 (13.75)
No	4750 (86.33)	8418 (86.25)
Formal/informal care		
Received at least one type of care	884 (16.07)	1419 (14.54)
Did not receive care	4618 (83.93)	8341 (85.46)
AD Use		
Yes	2042 (37.11)	3668 (37.58)
No	3460 (62.89)	6092 (62.42)

Table 4 - 2: Sample characteristics in the Tracking and Comprehensive cohorts (continuous variables)

Characteristics	**Tracking cohort**			**Comprehensive cohort**		
	Mean	Std	P - value	Mean	Std	P - value
Change in LS	-0.28	4.95	<.0001	0.21	4.83	<.0001
FSS (MOS-SSA Score range 0-100)	83.20	17.20	N/A	80.71	17.27	N/A

Notes: SWLS = Satisfaction with Life Scale, MOS-SSA = Medical Outcomes Study Social Support Survey.

Table 4 - 3: Regression coefficients for the association between assistive device use and the change in life satisfaction in the Tracking and Comprehensive cohorts

	Cohort	**Tracking cohort (n = 5,502)**		**Comprehensive cohort (n = 9,760)**	
	Parameter	**Estimate**	**95% Confidence Interval**	**Estimate**	**95% Confidence Interval**
Adjusted	AD use	1.16	-0.57 to 2.89	0.47	-0.89 to 1.82

Notes: The adjusted model controlled for several confounding variables from sociodemographic, health, functionality, psychological, and support domains (see Section *Measures*).

Table 4 - 4: Types of AD used in the Tracking and Comprehensive cohort

Tracking cohort			**Comprehensive cohort**		
Assistive device	**N**	**%**	**Assistive device**	**N**	**%**
Cane or walking stick	709	34.72	Cane or walking stick	1155	31.49
Grab bars	658	32.22	Hearing aids	1055	28.76
Visual aids	507	24.83	Grab bars	1046	28.52
Hearing aids	498	24.39	Visual aids	1030	28.08
Bathroom aids	329	16.11	Bathroom aids	441	12.02
Walker	261	12.78	Walker	400	10.91
Grasping tools or reach extenders	195	9.55	Leg braces or supportive devices	261	7.12
Leg braces or supportive devices	134	6.56	Grasping tools or reach extenders	242	6.6
Wheelchair	104	5.09	Wheelchair	165	4.5
Hand or arm brace	75	3.67	Hand or arm brace	147	4.01
Personal alarm	52	2.55	Motorized scooter	89	2.43
Bath or bed lifts or other lifting devices	49	2.4	Bath or bed lifts or other lifting devices	77	2.1
Motorized scooter	45	2.2	Respiratory ventilation	76	2.07
Crutches	17	0.83	Personal alarm	70	1.91
Supportive bandages, clothing, or footwear	15	0.73	Crutches	54	1.47
Respiratory ventilation	14	0.69	Other	40	1.09
Other	12	0.59	Neck or back brace	26	0.71
Special eating utensils	11	0.54	Supportive bandages, clothing, or footwear	25	0.68
Neck or back brace	7	0.34	Other orthotics	14	0.38

Dressing aids	5	0.24	Dressing aids	8	0.22
Other orthotics	2	0.1	Special eating utensils	5	0.14
Prosthetic limb	0	0	Prosthetic limb	4	0.11
Lid/can openers	0	0	Lid/can openers	3	0.08

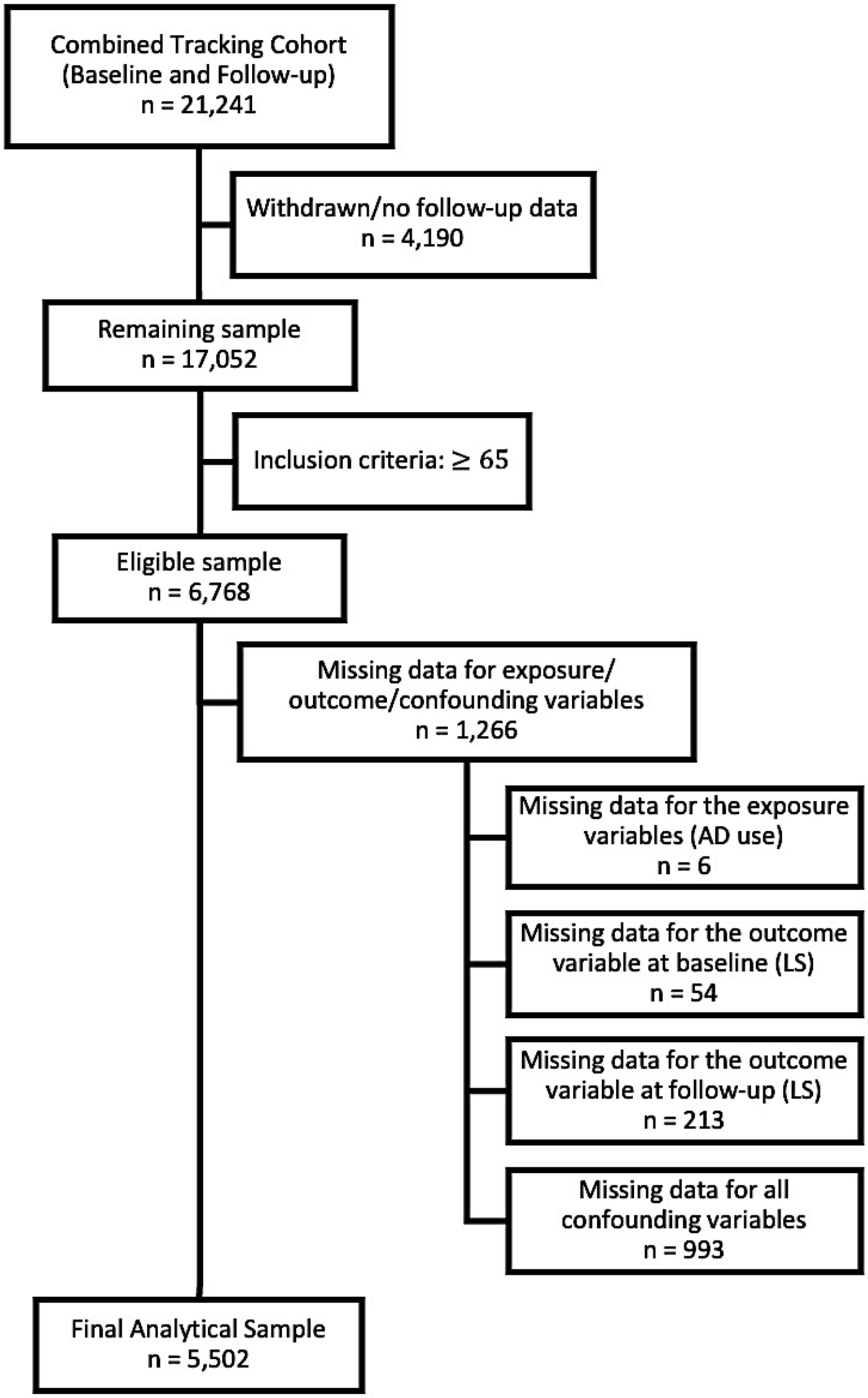

Figure 4 - 1: Exclusion of missing data in the Tracking cohort

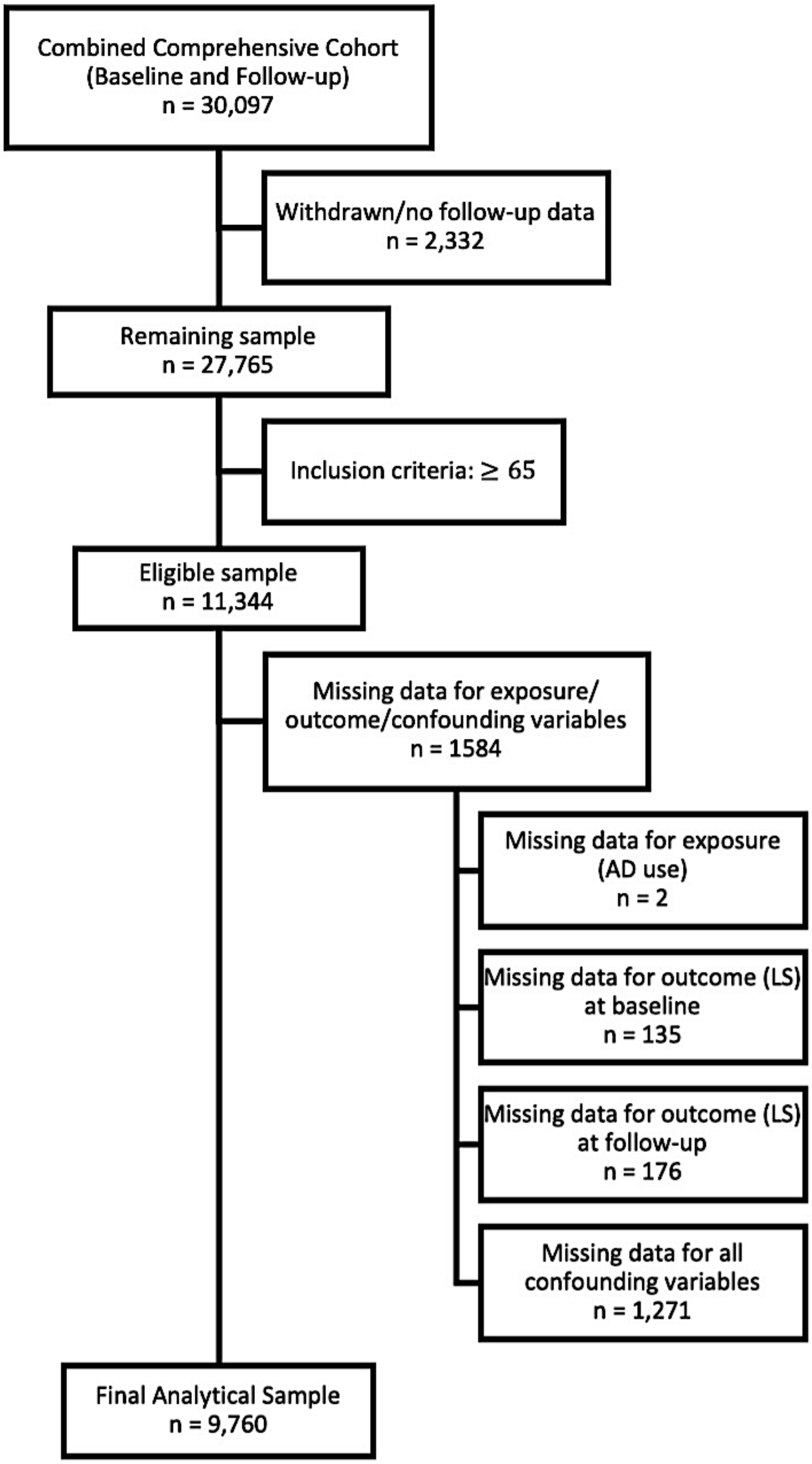

Figure 4 - 2: Exclusion of missing data in the Comprehensive cohort

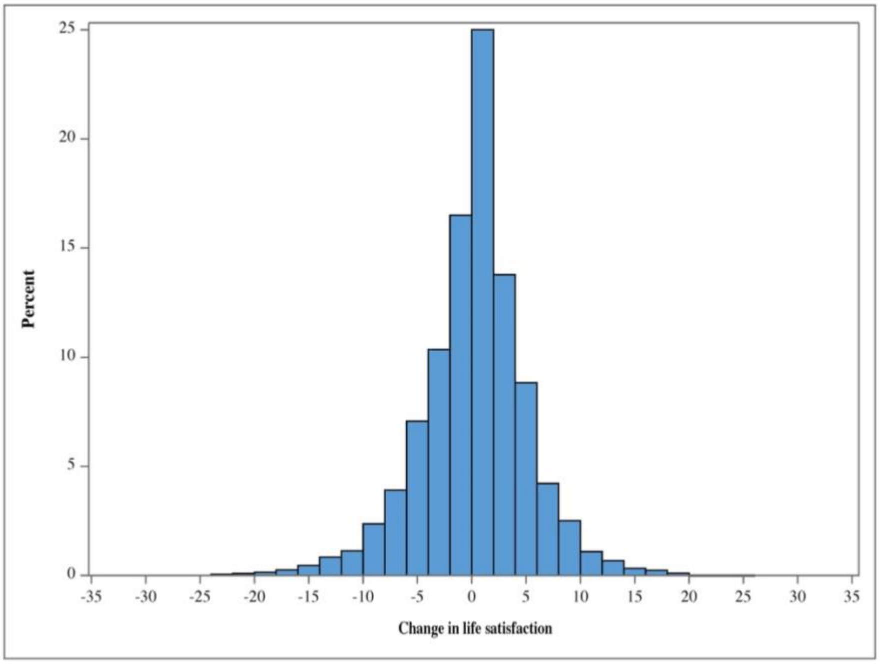

Figure 4 - 3: Distribution of the change in life satisfaction in the Tracking cohort

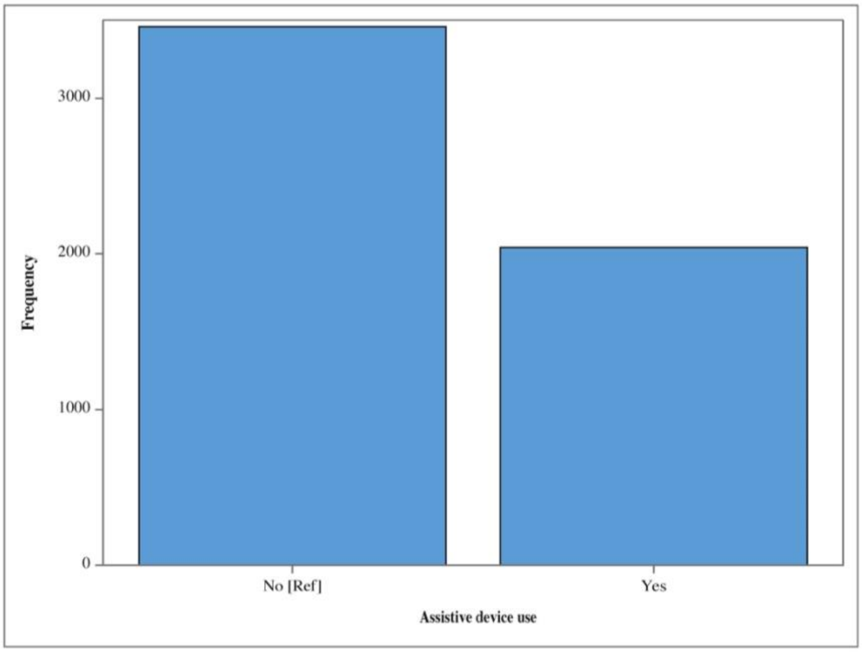

Figure 4 - 4: Distribution of assistive device use in the Tracking cohort

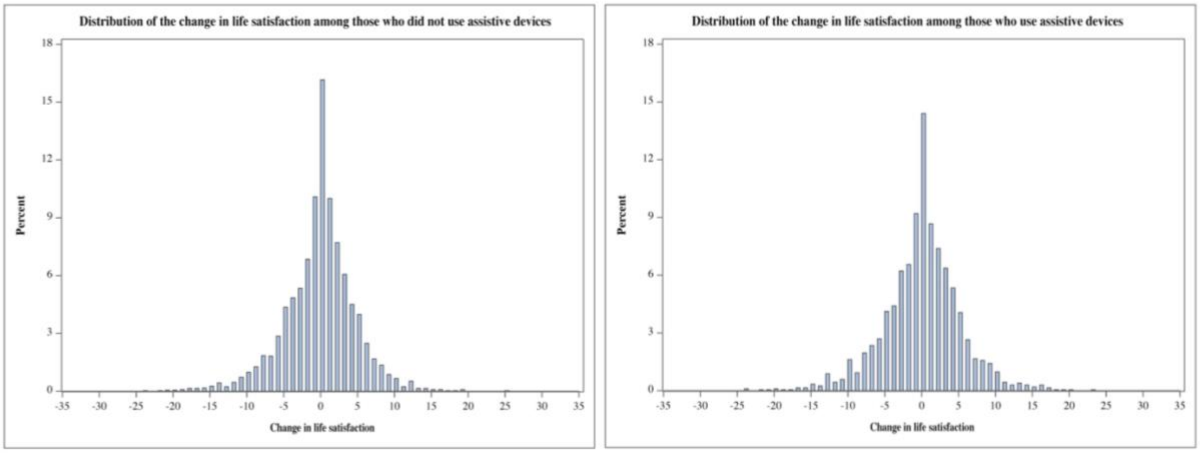

Figure 4 - 5: Distributions of the change in LS across those who used AD versus those who did not use AD in the Tracking cohort

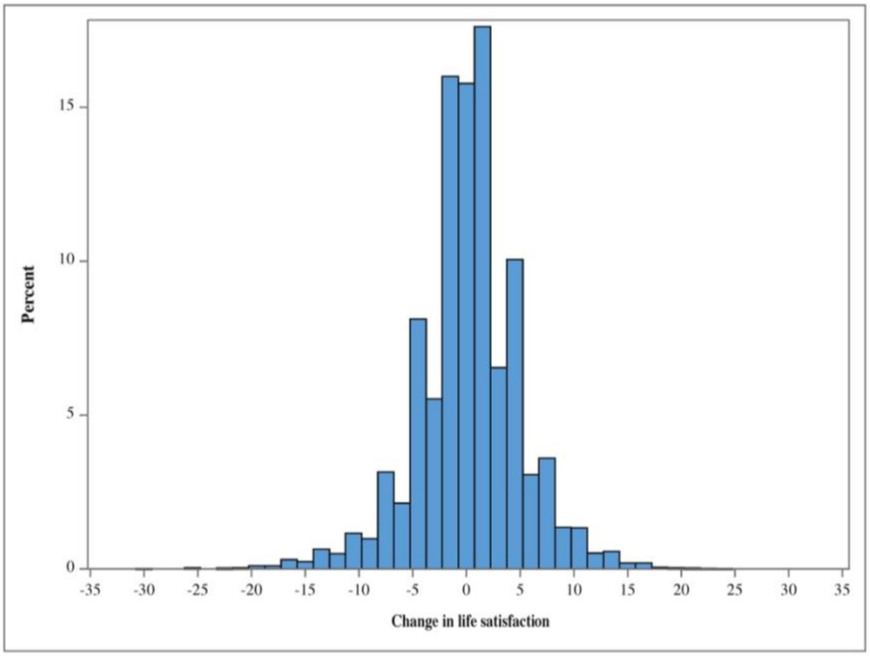

Figure 4 - 6: Distribution of the change in life satisfaction in the Comprehensive cohort

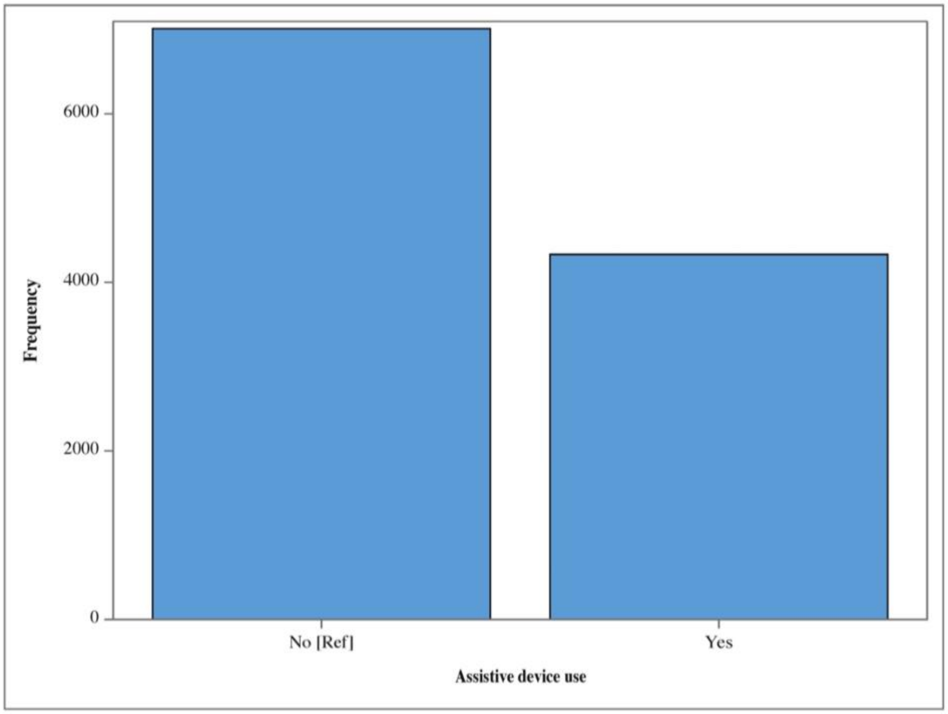

Figure 4 - 7: Distribution of assistive device use in the Comprehensive cohort

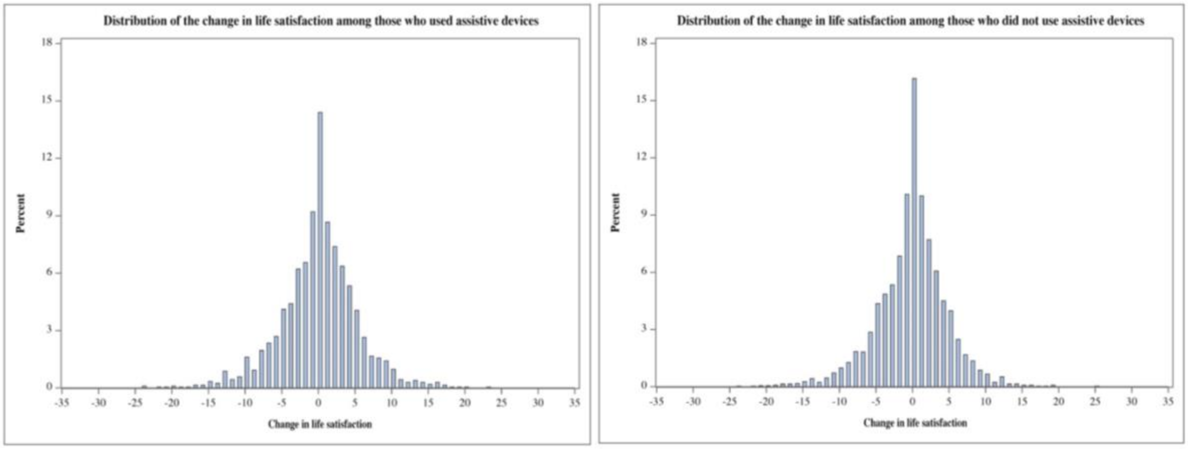

Figure 4 - 8: Distributions of the change in LS across those who used AD versus those who did not use AD in the Comprehensive cohort

Chapter 5

The association between assistive device use and the change in informal caregiving hours among community-dwelling older adults: analysis of the Canadian Longitudinal Study on Aging (CLSA)

5.1 Abstract

Objective

To investigate whether assistive device (AD) use within the past 12 months (self-reported at baseline) affects the change in the amount of informal caregiving hours received over time (three-years), among community-dwelling older adults (≥ 65 years) in comparison to those who did not use AD at all.

Methods

Data from the Tracking (n = 236) and Comprehensive (n = 420) cohorts of the Canadian Longitudinal Study on Aging (CLSA) were analyzed using multiple linear regression models to regress the changes in the amount of informal caregiving hours received (follow-up - baseline) on AD use (yes/no) while accounting for a set of sociodemographic, health, functionality, psychological, and support covariates.

Results

The doctoral candidate did not find significant associations between AD use and changes in the amount of informal care hours received among older adults (Tracking cohort: $\hat{\beta}$ = 3.10, 95% CI = -77.98 to 84.17; Comprehensive cohort: $\hat{\beta}$ = -5.05, 95% CI = -47.19 to 37.09).

Conclusions

The wide confidence intervals which included the null value of zero, suggested the possibility of either a positive or negative association, or potentially no association between AD use and informal caregiver time. However, inconclusive findings are still valuable for informing future research directions, prompting re-examination of existing theories, and guiding evidence-based decisions. Future studies should aim to account for shortcomings of this study where possible by using longer follow-up periods, larger sample sizes, and sub-analyze by device types (e.g., hearing-related AD versus mobility devices). They should also use more representative data sets and avoid biases (e.g., volunteer bias, missing data). Additionally, obtaining caregiving hours directly from informal caregivers is necessary to assess the association between AD use and changes in informal caregiving hours over time.

5.2 Introduction

The world's population is experiencing a significant shift toward aging. By 2050, one out of every six people will be 65 years old or older.[1,2] While people are living longer lives, many are not experiencing good health, with chronic diseases, multimorbidity, and disabilities leading to increases in the number of years lost due to poor health.[3] At least 48 million people are expected to die from chronic conditions by 2060, with older adults bearing the greatest burden of disease.[180]

5.2.1 Assistive devices

Assistive devices (AD) are increasingly being used to address health challenges associated with aging. AD are designed to improve an individual's independence, functioning, and well-being, and promote their participation.[4] Examples of AD used by older adults include but does not limit to mobility devices like wheelchairs, canes, and walkers, visual aids such as magnifiers, Braille reading materials, and white canes, audio devices like hearing aids and amplifiers, and software and apps for information management and communication.[33] The International Organization for Standardization (ISO) 9999 and the World Health Organization (WHO) have classified AD into 12 categories that are most relevant to aging, and these can be found in Appendix A.[29]

Some studies have found that AD can directly benefit informal caregivers.[107] AD can support informal caregivers by reducing the difficulty of caregiving tasks, energy and effort spent on caregiving activities, fear and anxiety, and safety risks associated with tasks that require physical assistance.[107] However, little research has been conducted to investigate how care receivers' use of AD influences informal caregiving hours, especially in Canada.[80]

5.2.2 Informal caregiving hours

The term “informal care” refers to unpaid care and assistance provided by family, friends, or neighbors to those who require assistance due to physical, cognitive or psychological impairments.[15] Requirements for such assistance are growing among aging populations and the number of older adults who will require informal care in Canada is expected to increase by 1.2 times between now and 2050.[16]

The amount of hours spent providing informal care is an important indicator of the intensity of informal care, as well as a risk factor for adverse health outcomes among caregivers.[17,18] A greater number of caregiving hours is associated with increased stress and may result in physical, emotional, financial, and social challenges for informal caregivers, resulting in accelerated declines in health and well-being.[19,81–84] Previous studies have linked informal caregiving hours to poor health, unhealthy eating, alcohol consumption, mobility restrictions, caregiver stress, depression, anxiety, long-term back pain, discomfort, low quality of life, a lack of personal or family time, a reduction in educational and employment opportunities, and overall poor health, among other factors.[19,98,100–104]

In a recent systematic review, Marasinghe et al. found limited and moderate-quality evidence for a positive association between AD use and reduced informal caregiving hours among community-dwelling older adults (see Chapter 3).[80] However, the evidence from these two studies was inconclusive due to their cross-sectional nature and the suspected presence of residual confounding, non-response bias, and imprecision (see Chapter 3).[80] Therefore, this study expanded upon previous studies by being the first longitudinal study to investigate the association between AD use and the change in informal caregiving hours received over time among community-dwelling older adults, while accounting for a robust set of potential confounders.

5.2.3 Theoretical framework

The CATOR framework served as the theoretical underpinning of this research.[5] Five AD outcomes defined by the CATOR framework are: effectiveness, social significance, device satisfaction, psychological functioning, and subjective well-being.[5] Social significance refers to the impact of AD (short- or long-term) on society and other people (e.g., caregivers),[5] in terms of the nature and amount of effort put into caring for persons who use AD.[5,110] Therefore, according to CATOR, AD use among care recipients may reduce the amount of time informal caregivers spend providing care.[5] In promoting the independence of individuals using AD, potential reductions in caregiving time may reduce the intensity of caregiving obligations and duties, thereby allowing informal caregivers greater independence and flexibility in their lives.[181]

5.3 Methods

5.3.1 Design

The Canadian Longitudinal Study on Aging (CLSA) collected baseline data from community-dwelling adults between the ages of 45 and 85 years across Canada.[113] A computer-assisted telephone interview was used to randomly collect data from 21,241 individuals in the Tracking cohort.[113] A total of 30,097 individuals were randomly selected within 25 to 50 kilometers of 11 Data Collection Sites (DCSs) across Canada and interviewed in their homes and at the DCSs as part of the Comprehensive cohort.[113] After collecting baseline data from 2011 until 2015, the first follow-up data collection began in 2015 and concluded in 2018.[113]

The CLSA excluded several groups of people: persons who lived in the three Canadian territories, on First Nations reserves or other provincial First Nations settlements; full-time members of the Canadian Armed Forces; residents of institutions such as long-term care homes (LTCs); persons unable to communicate in French or English; and individuals who showed signs of cognitive impairment at the recruitment interview.[113] A stratified random sample was employed in the CLSA which took into account age, gender, province, catchment area of DCSs versus non-DCSs, as well as low-education versus non-low-education.[114] A detailed description of the CLSA recruitment process can be found elsewhere (see following citations).[113–115]

5.3.2 Study sample

The analysis included participants aged 65 years or older from both the Tracking and Comprehensive cohorts of the CLSA. Participants were excluded if they had missing data on the exposure variable (AD use), outcome variable (the change in informal caregiving hours received), or any confounding factor to obtain the final analytical samples (n = 236 and 420 for the Tracking and Comprehensive cohorts, respectively [see Figure 5 - 1Figure 5 - 2]).

5.3.3 Measures

5.3.3.1 Dependent variable - change in informal caregiving hours received

CLSA participants who reported receiving informal care were asked to estimate the number of hours per week on average that a caregiver helped them with the caregiving activity that required the most assistance. These activities included assistance with eating, dressing, bathing, or toileting; help taking medicines or help with nursing care (for example, dressing changes or foot care; managing care such as making appointments; help with activities such as housework, home maintenance, or outdoor work; provision of transportation (e.g., trips to the doctor or shopping); meal preparation or delivery; and, miscellaneous items not covered in this list. For the outcome variable in the regression models, the doctoral candidate computed the change in informal care hours by subtracting hours of care received at baseline from hours received at follow-up.

5.3.3.2 Independent variable - AD use

As part of the CLSA study, information was collected about AD use, including mobility, hearing, and vision-related questions. Information on the use of mobility and any other types of devices was collected by asking participants: “During the past 12 months, have you used any of the following assistive devices?”. Similarly, information on hearing and vision-related AD were collected by asking: “Do you use any aids, specialized equipment, or services for persons who are deaf or hard of hearing, for example, a volume control telephone or TV decoder?”; or “Besides glasses or contact lenses, do you use any aids or specialized equipment for persons who are blind or visually impaired, for example, magnifiers or Braille reading materials?”. Individuals who reported using at least one device of any type were considered as those who use AD. Since the comparison group was AD use versus no AD use, the doctoral candidate chose to dichotomize AD use.[13,14,132,133]

5.3.3.3 Confounding variables

5.3.3.3.1 Sociodemographic domain

This study accounted for baseline values of care recipients' age (65-74 or 75-89 years) and caregivers' age (18 and above), [82–84,144] sex (male or female),[13,14,96] education (at most secondary education or at least some post-secondary education),[13,14,96] annual household income (< \$20,000, \$20,000 to < \$50,000, \$50,000 to < \$100,000, \$100,000 to < \$150,000, or ≥ \$150,000),[13,14,96] marital status (married or other - single, never married or never lived with a partner, widowed, divorced, separated),[13] living arrangement (living alone or not alone),[13] and race (White only and other).[13,14,96]

5.3.3.3.2 Health Domain

Self-perceived health and chronic conditions were adjusted for in this study.[14,86,87,96,151,152] Self-perceived health consisted of general health ("In general, would you say your health is excellent, very good, good, fair, or poor?") and mental health ("In general, would you say your mental health is excellent, very good, good, fair, or poor?").[15] General and mental health were entered into the regression model as two separate variables.

Chronic conditions were assessed by asking if the participants had been told by a doctor that they had at least one of the following conditions (versus none of these conditions): osteoarthritis, arthritis, respiratory, cardiovascular, neurological, gastrointestinal, or vision-related diseases, cancer, mental health conditions, infections, back problems, bone, thyroid, kidney-related conditions, or any other chronic condition.[15] If none of these conditions were reported by participants, they were coded as 'no'.

5.3.3.3.3 Functionality domain

This study controlled for the ability to carry out activities of daily living (ADLs) and instrumental activities of daily living (IADLs),[13,14,96] and injury (yes or no).[90,91,153–156,183] ADLs and IADLs represent an individual's ability to perform these activities with or without assistance (from another person or device) and was measured in the CLSA through the modified version of the Older Americans' Resources and Services (OARS) Multidimensional Functional Assessment Questionnaire.[159] The ability to carry out seven ADLs and seven IADLs was assessed using a 5-point scale ranging from no impairment to total impairment.[159] Injury was assessed by asking participants, "In the last 12 months, have you had any injuries that were serious enough to limit some of your normal activities? For example, a broken bone, a bad cut or burn, a sprain or a poisoning" with two possible responses: yes or no.[15]

5.3.3.3.4 Psychosocial domain

Depressive symptoms: The doctoral candidate accounted for depressive symptoms that were measured by using the CESD-10, a questionnaire that contained 10 questions about items such as feelings of depression, loneliness, hopefulness for the future, and restless sleep.[78,148] A score between 0 and 30 was generated based on four possible responses to each question (all of the time, occasionally, some of the time, rarely, or never), with higher scores indicating more severe depression. The score was dichotomized into two categories: positive (cut-off of a score of 10 or more) or negative screen for depressive symptoms.[160]

5.3.3.3.5 Support domain

Functional social support (FSS) was controlled for under the support domain.[94,151,162] The receipt of formal care was considered as a potential confounder however, due to concerns related to confounding, this variable was excluded from the analysis (see Section 5.5.3). FSS indicates the degree to which one perceives they will have help or support when needed in four areas: tangible, affection, positive social interaction, and emotional/informational and was assessed using the 19-item, self-administered Medical Outcomes Study-Social Support Survey (MOS-SSS); an overall FSS score between 0 and 100 was obtained using a published scoring algorithm.[164,165] Higher FSS levels were indicated by higher scores.

5.4 Data analysis

5.4.1 Descriptive analysis

SAS version 9.4 (SAS Institute, Cary, N.C., USA) was used for all data analyses. The doctoral candidate employed frequency tables for categorical data, and means and standard deviations for continuous variables, to generate descriptive statistics.

5.4.2 Regression analysis

Using multiple linear regression via SAS's PROC GLM procedures, the doctoral candidate regressed the change in informal care hours from baseline to first follow-up on AD use in the past 12 months (assessed at baseline). The five domains of covariates (sociodemographic, health, functionality, psychological, and support domains - see Section 5.3.3.3) were accounted for by including them in the model as predictor variables (see Appendix L).

5.4.3 Missing data and model diagnostics

The analyses excluded observations with missing data for the exposure, outcome, and any confounding variables. By employing bivariate analysis and Mann-Whitney U test - a statistical test for comparing binary and continuous variables - the doctoral candidate compared responses to informal caregiving hours across participants with complete versus missing data on AD use.[171] She also investigated the differences in the responses to AD use using Rao-Scott chi-squares - a statistical test for comparing categorical or binary variables - between participants with complete versus missing data on informal caregiving hours received.[171,172]

To assess the fit of the regression models, diagnostic methods such as residual versus predicted plots, observed versus predicted plots, and influential observations (i.e., Cook's Distance, Studentized Residual versus Leverage graph) were used. As a general rule, an adequacy plot should display a random scatter around the horizontal axis ($y = 0$) without any discernible pattern, whereas a plot indicating good model fit should exhibit dense clusters of data points around a 45° diagonal line.[169] According to the recommendations of a statistician, in order to identify strongly correlated variables in the model and resolve conflicts, multicollinearity was tested using Type II tolerance values for PROC GLM procedures. It was determined that there were no issues with multicollinearity if Type II tolerance values did not fall below 0.1.[170]

Existing literature suggests that the receipt of formal care and informal care can be interdependent.[184] Therefore, the doctoral candidate assessed whether the receipt of formal care was a confounder before deciding whether or not to control for it. The final model was run with and without the formal care variable, which was retained in the analysis if the regression coefficient for AD use changed by at least ±10% after its addition to the model, which indicates confounding.[185]

5.4.4 Ethics and data access

All data for this study were obtained via a data access request to CLSA (file #2010026); the University of Waterloo's Office of Research Ethics approved this study **(**file #42761**).**

5.5 Results

5.5.1 Descriptive results

Sample characteristics for the Tracking and Comprehensive analytical samples are shown in Table 5 - 1

Table 5 - 2. Across the two time points and cohorts, older adults aged 65 to 74 made up about half of the overall sample, with the other half aged 75 and 89. Most people in both cohorts were female, self-identified as White, and reported total annual household incomes of less than $50,000.

Table 5 - 4 summarizes the types of AD used by individuals in the study. These devices mostly compensated for physical limitations (e.g., mobility, hearing, vision etc.), which reflects the CLSA's exclusion of persons with evident cognitive impairment at baseline.[113]

5.5.2 Regression results

This study did not find evidence for associations between AD use and changes in informal caregiving hours over time among older adults who used AD compared to those who did not use AD at all, while controlling for all covariates (Tracking: $\hat{\beta}$ = 3.10, 95% CI = -77.98 to 84.17; Comprehensive: $\hat{\beta}$ = -5.05, 95% CI = -47.19 to 37.09) (see Table 5 - 3).

5.5.3 Model diagnostics

For both the Tracking and Comprehensive cohorts, residual plots indicated slight negative trends and the model fit plots displayed largely clustered patterns around zero (see Appendix M). These patterns seemed to be influenced by outliers, which were ultimately retained in the analysis because they were still valid observations (see Appendix N). In both cohorts, the Studentized Residual versus Leverage graph displayed probable outliers (values outside of two horizontal lines) as well as several influential data outside of the vertical reference line. Cook's distances for both the Tracking and Comprehensive cohorts were below the 50th percentile, indicating the absence of highly influential observations. In both the Q-Q plots and histograms, the observed trends satisfied the assumption of normality (see Appendix J). No multicollinearity issues were detected in both cohorts.

5.5.4 Missing data

Due to missing data, 6,532 (97%) and 10,924 (96%) participants were excluded from the eligible samples in the Tracking and Comprehensive cohorts, respectively (see Figure 5 - 1Figure 5 - 2). In the Tracking cohort, the difference in mean hours of informal care received at follow-up was twice as great (although non-significant) among participants with complete data on AD use, compared to participants with missing data on AD use at baseline (see Appendix O). The doctoral candidate was unable to compare the means of informal care hours received at follow-up among those with missing and complete data on AD use at baseline due to participants missing data on both variables at the same time (n = 12) (see Appendix O).

Among participants with missing data on informal caregiving hours at follow-up in the Tracking cohort, a higher proportion reported not using AD at baseline, compared to participants with complete data (65% versus 47%, respectively). This was also the case in the Comprehensive cohort (66% versus 45%, respectively), indicating possible bias away from the null (see Appendix O). A significantly higher probability of AD use was observed among Tracking participants who were included in the analysis compared to those who were excluded from the analysis (74.15% versus 37.27%, respectively, p-value <.0001). A similar trend was seen in the Comprehensive cohort: 78.10% AD use in the included group versus 36.65% in the excluded group, p-value <.0001 (see Appendix Q). These observations indicate bias away from the null in both cohorts. The distributions of the change in informal caregiving hours among participants included in the regression analysis versus those excluded were not substantively different in both cohorts (see Appendix P). However, observations with extreme negative values can be seen among participants excluded from the analysis in the Comprehensive cohort (Figure P - 1). As these boxplots do not represent the change in distributions including the impact of covariates that were included in the model, it cannot be determined if the exclusion of these values influenced the results of the study.

5.6 Discussion

This study did not find significant associations between AD use and the change in informal caregiving hours received over three years of follow-up among community-dwelling older adults aged 65 years and above in the CLSA. As the 95% confidence intervals included the null value of zero for the association studied, the doctoral candidate was unable to draw conclusions about the true nature of the association (i.e., positive or negative). Due to the larger 95% CI in the Tracking cohort (95% CI = -77.98 to 84.17), it is possible to expect more uncertainty around the effect size than in the Comprehensive cohort (95% CI = -47.19 to 37.09). The doctoral candidate could not compare her findings with other longitudinal studies because this research was the first examination of the link between AD use and informal caregiver hours using longitudinal data.

Using complete case analysis, only participants with complete data were included in this study. As a result, these findings are applicable only to populations with characteristics similar to the sample used in the analysis. Furthermore, this study captured only subsets of AD (see Table 5 - 4). Consequently, findings do not apply to AD that were not included in the study.

Only two previous cross-sectional studies have investigated the association between AD use and informal caregiving hours.[80] A study by Agree et al., which consisted of a similar population (community-dwelling older adults aged 65 and above) and controlled for few of the covariates as in this study found that AD use was significantly associated with fewer informal care hours among the unmarried, better educated, or those with higher cognitive function.[13] Agree et al. also captured similar AD as in the current study, which comprised of devices that mainly compensated for physical impairment (see Section 3.4.1.2 and Table 5 - 4, respectively). The direction of the effect of findings of Agree et al.'s study aligned with the current study findings in the Comprehensive cohort, although not significant. The study by Agree et al. consisted of a larger sample size compared to the current study (n = 4,006 versus n = 236 and n = 420), which may have contributed to significant findings.[13]

The second study by Hoenig et al, which also consisted of a similar population to that of this study (community-dwelling older adults aged 65 years and above) found that those who used any technological assistance reported 3.8 fewer hours of help per week ($\widehat{\beta}$ = - 3.8, 95% CI = - 6.54 to -1.06) compared to those who did not, after controlling for many of the covariates controlled for in this study.[14] As in the current study, similar AD were captured by Hoenig et al. (see Table 5 - 4 and Section 3.4.1.2, respectively). Hoenig et al.'s findings aligned with the direction of effect of the findings of this study (in the Comprehensive cohort), although the findings were not significant in this study. The study by Hoenig et al., also consisted of larger sample size (n = 2,638), which may have lead to significant findings as having a larger sample size can increase the power of the study and chances of finding statistically significant results.[117]

The null findings in this study may be attributed to several factors. For example, in both cohorts, a majority of participants reported having good physical and mental health (see Table 5 - 1

Table 5 - 2). This healthy participant effect may have biased the findings toward the null, underestimating the true association between AD use and the change in informal caregiving hours received. In healthy populations, the use of AD may be less necessary, leading to a lower perceived benefit of such devices. The healthy participant effect observed in the CLSA samples can be attributed to self-selection or volunteer bias, as people who were in better health may have been more likely to volunteer for the study.[173]

It has been suggested that some AD for older adults can be burdensome to informal caregivers, such as devices that pose privacy concerns (e.g., monitoring devices), cause accidents, or require repairs or caregiver assistance to operate.[186,187] Some AD that were captured in this study could have displayed some of the above characteristics, thereby adding to caregiver burden. Though, it is not possible to confirm this assumptions as the CLSA does not investigate detailed characteristics of the AD that were used. This phenomenon may also have contributed to the null findings of this study.

While some researchers argue that some AD may substitute for caregiver time, others argue that AD may only complement caregiver time or do both.[96,188,189] AD may act as a substitute, complement, or do both, depending on the type of device.[96] It is possible that this study included AD that complemented caregiver time and not those that substituted for it, which may have contributed to obtaining non-significant results. Further research with stratification by device type (see Section 5.6.3) is highly encouraged as it can help researchers understand which types of devices can add to or reduce caregiver burden (e.g., time), and substitute, complement, do neither or both, potentially reducing the increased likelihood of detecting null findings.

Furthermore, smaller sample sizes and an insufficient follow-up period may not have been adequate to detect significant findings. In both cohorts, participants included in the analysis had a significantly higher probability of using AD than those excluded from the analysis, which might have biased the results away from the null, leaving the effect size greater than what it would be otherwise (see Appendix Q). The CLSA collected information about informal caregiving hours from the care receiver, not the caregiver (see Section 5.6.3), which may have led to an underestimation of informal caregiving hours as suggested in the current literature, exerting further bias away from the null.[190]

Although study findings did not provide evidence to support the CATOR framework, the null results in the Tracking and Comprehensive cohorts cannot be used to definitively conclude that AD use is unassociated with the number of informal caregiver hours received; rather, the findings do not provide evidence for an association because results may have been subjected to volunteer bias, low power, missing data, lack of granularity in device types, under-reporting of caregiving hours, and insufficient follow-up time to detect differences in the outcome. This lack of evidence does not preclude that AD use may have potential for substituting for informal caregiving hours. These findings should inform theory, existing data sets like the CLSA, and encourage future research.

5.6.1 Strengths

This is the first study to use data from a national study to investigate the relationship between AD use and the change in informal caregiving hours received over three-years by community-dwelling older adults. Existing studies are cross-sectional, which only provides an overview of a single point in time; the doctoral candidate examined data from two time points to alleviate this issue and assess changes in the outcome over time. Furthermore, this study controlled for relevant covariates that were excluded from existing studies (e.g., chronic conditions, injury, depression, caregiver’s age, and FSS), thereby minimizing confounding bias.

5.6.2 Limitations

This study was limited by several factors including self-selection bias that could have led to the inclusion of a healthier subset of the target population, a relatively short follow-up that may not have been long enough to detect large changes in informal care hours received over time, missing data that appeared to exert bias away from the null, low power that might have prevented the detection of small effects due to small sample sizes, a proxy measure of caregiver time leading to possible under-reporting of caregiver hours, and the grouping of all AD together into a single group.

Additionally, the CLSA excluded individuals with cognitive impairment, which precluded the assessment of cognitive status as a possible effect modifier and may have led to under-representation of those who received higher numbers of informal caregiving hours.[191] Furthermore, this exclusion may also have led the CLSA to include more of a certain type of AD (e.g., AD for physical impairment rather than AD for cognitive impairment - see Table 5 - 4), limiting the applicability of study findings to all types of AD.

The CLSA was designed to be representative of the Canadian population, however most of its sample self-identified as White, perhaps due to self-selection bias or language barriers (i.e., English or French language requirements). Visible minorities constituted 2-4% of the sample in this study, but they make up 22.3% of the total Canadian population.[177] This may limit the relevance of the findings to the overall Canadian population from a sociocultural perspective.

5.6.3 Implications and future directions

While obtaining precise caregiving hours from caregivers is a challenge, recording caregiving hours received from the care-recipient is even more challenging. The reporting of caregiving hours by care recipients may contribute to a discrepancy between the actual hours of care received and number of care hours reported.[190] Previous literature has found that caregivers reported providing more hours of care, compared to what the care recipients within the same dyad reported.[190] To mitigate the latter limitation, the CLSA may include an additional questionnaire for informal caregivers to report caregiving hours. To avoid recall bias associated with reporting caregiving hours, future studies can request caregivers to use a time diary to record hours.

Bringing all types of AD under one term prevents researchers from clearly identifying their individual effects, which can create barriers for policymakers and stakeholders in making informed decisions about which types of AD to distribute, fund, and further investigate. To understand if AD have varied effects on informal caregiving hours, researchers should try to stratify their analyses (given there are no small cell counts) by specific types of AD, while keeping in mind the larger sample sizes required for subgroup analyses. Future analyses with stratification by AD type is further encouraged due to complexities associated with AD's impact on caregiving hours (e.g., substitution, complementation, both, or neither). By conducting focused analyses by AD type, future research, policy, and practices can target more tailored approaches to understanding the benefits of AD (e.g., if evidence suggests that wheelchairs are effective in reducing caregiver time, funding and distribution can be prioritized for wheelchairs).

Three-year follow-up periods may not provide sufficient time to evaluate the change in informal caregiving hours received on a long-term basis, particularly in healthy samples in which the participants' health status may be less likely to change significantly over time. As this was a limitation of the present study, longer follow-up periods should be used in future research to better address the research question. Additionally, employing qualitative research methods in future studies would be beneficial to understand *how* AD use can help reduce informal care hours because these methods permit more in-depth explorations of the complexities associated with the research question.

Furthermore, it is important to note that while non-significant findings may not support the original hypotheses, they can nonetheless be valuable in informing future research (e.g., avoiding past and present shortcomings), re-evaluating theories (e.g., supporting, or disconfirming theories), and contributing to a comprehensive body of evidence, facilitating strong evidence-based decision-making.

5.7 Conclusion

Understanding AD's potential in helping informal caregivers is critical to alleviate negative impacts of informal caregiving. This study builds on a small amount of limited existing research by investigating the relationship between AD use and the change in informal caregiving hours received over time, while controlling for a comprehensive set of variables in sociodemographic, health, functionality, psychological, and support domains. Results did not find statistically significant associations between AD use and the change in informal caregiving hours received over time, among community-dwelling older adults aged 65 and above in the CLSA. However, non-significant findings can guide future research, offer re-evaluation of theories, and guide strong evidence-based decisions. Further research should investigate the relationship between AD use and the change in informal caregiving hours received over time by using longer follow-up periods, larger sample sizes, stratifying AD use by type, using more representative populations, avoiding biases (e.g., volunteer bias, missing data), and gathering more precise information through informal caregivers rather than care recipients to avoid misreporting of caregiving hours.

Table 5 - 1: Sample characteristics in the Tracking and Comprehensive cohorts (categorical variables)

Characteristic	Tracking cohort Frequency (n) and Percent (%)	Comprehensive cohort Frequency (n) and Percent (%)
Sample size (n)	236	420
Age (Care recipient)		
65-74	107 (45.34)	194 (46.19)
75-89	129 (54.66)	226 (53.81)
Age (Caregiver)		
Less than 50 years	61 (25.85)	128 (30.48)
51-60 years	76 (32.20)	75 (17.86)
61-70 years	60 (25.42)	109 (25.95)
70-93 years	39 (16.53)	108 (25.71)
Sex		
Female	152 (64.41)	272 (64.76
Male	84 (35.59)	148 (35.24)
Education		
At most secondary education	73 (30.93)	87 (20.71)
At least some post-secondary education	163 (69.07)	333 (79.29)
Income		
Less than 20,000	65 (27.54)	103 (24.52)
20,000 or more, but less than 50,000	123 (52.12)	204 (48.57)
50,000 or more, but less than 100,000	35 (14.83)	89 (21.19)
100,000 or more, but less than 150,000	8 (3.39)	13 (3.10)
150,000 or more	5 (2.12)	11 (2.62)
Ethnicity		
White only	231 (97.88)	405 (96.43)
Other	5 (2.12)	15 (3.57)
Marital status		
Married	107 (45.34)	235 (55.95)
Other	129 (54.66)	185 (44.05)
Living arrangement		
Alone	113 (47.88)	145 (34.52)
Not alone	123 (52.12)	275 (65.48)

Physical health		
Excellent	15 (6.36)	43 (10.624)
Very Good	41 (17.37)	97 (23.10)
Good	100 (42.37)	164 (39.05)
Fair	64 (27.12)	88 (20.95)
Poor	16 (6.78)	28 (6.67)
Mental health		
Excellent	49 (20.76)	101 (24.05)
Very Good	90 (38.14)	141 (33.57)
Good	84 (35.59)	138 (32.86)
Fair	12 (5.08)	37 (8.81)
Poor	1 (0.42)	3 (0.71)
Chronic conditions		
Yes	234 (99.15)	418 (99.52)
No	2 (0.85)	2 (0.48)
Functional impairment - ADLs/IADLs		
Impairment	109 (46.19)	224 (53.33)
No impairment	127 (53.81)	196 (46.67)
Injury		
Yes	45 (19.07)	96 (22.86)
No	191 (80.93)	324 (77.14)
Symptoms of depression		
Yes	174 (73.73)	118 (28.10)
No	62 (26.27)	302 (71.90)
AD Use		
Yes	175 (74.15)	328 (78.10)
No	61 (25.85)	92 (21.90)

Table 5 - 2: Sample characteristics in the Tracking and Comprehensive cohorts (continuous variables)

Characteristics	**Tracking cohort (Weighted)**			**Comprehensive cohort (Weighted)**		
	Mean	**Std**	**P-value**	**Mean**	**Std**	**P-value**
Change in informal caregiving hours	1.80	42.93	0.52	2.15	23.34	0.06
Functional social support (MOS-SSA Score range 0-100)	81.32	17.54	N/A	80.53	16.16	N/A

Notes: MOS-SSA = Medical Outcomes Study Social Support Survey.

Table 5 - 3: Regression coefficients for the association between assistive device use and the change in informal caregiving hours in the Tracking and Comprehensive cohorts

		Tracking cohort (n = 236)		Comprehensive cohort (n = 420)	
	Parameter	**Estimate**	**95% Confidence Interval**	**Estimate**	**95% Confidence Interval**
Adjusted	**AD use**	3.10	-77.98 to 84.17	-5.05	-47.19 to 37.09

Notes: The adjusted model controlled for several confounding variables from sociodemographic, health, functionality, psychological, and support domains (see Section *Measures*).

Table 5 - 4: Types of AD used by participants in the Tracking and Comprehensive cohort

Tracking cohort			Comprehensive cohort		
Assistive device	**N**	**%**	**Assistive device**	**N**	**%**
Cane or walking stick	103	58.86	Cane or walking stick	187	57.01
Grab bars	90	51.43	Grab bars	167	50.91
Walker	65	37.14	Hearing-related devices	111	33.84
Bathroom aids	59	33.71	Walker	103	31.4
Hearing-related devices	41	23.43	Bathroom aids	97	29.57
Wheelchair	33	18.86	Grasping tools or reach extenders	61	18.6
Grasping tools or reach extenders	33	18.86	Visual aids	56	17.07
Visual aids	29	16.57	Wheelchair	52	15.85
Motorized scooter	13	7.43	Leg braces or supportive devices	32	9.76
Leg braces or supportive devices	13	7.43	Bath or bed lifts or other lifting devices	25	7.62
Bath or bed lifts or other lifting devices	12	6.86	Personal alarm	21	6.4
Personal alarm	12	6.86	Motorized scooter	17	5.18
Hand or arm brace	5	2.86	Hand or arm brace	17	5.18
Crutches	3	1.71	Other	9	2.74
Special eating utensils	2	1.14	Crutches	5	1.52
Other	2	1.14	Respiratory ventilation	4	1.22
Respiratory ventilation	1	0.57	Neck or back brace	3	0.91

Neck or back brace	0	0	Other orthotics	3	0.91
Dressing aids	0	0	Special eating utensils	2	0.61
Prosthetic limb	0	0	Supportive bandages, clothing or footwear	2	0.61
Supportive bandages, clothing or footwear	0	0	Dressing aids	1	0.3
Other orthotics	0	0	Prosthetic limb	1	0.3
Lid/can openers	0	0	Lid/can openers	0	0

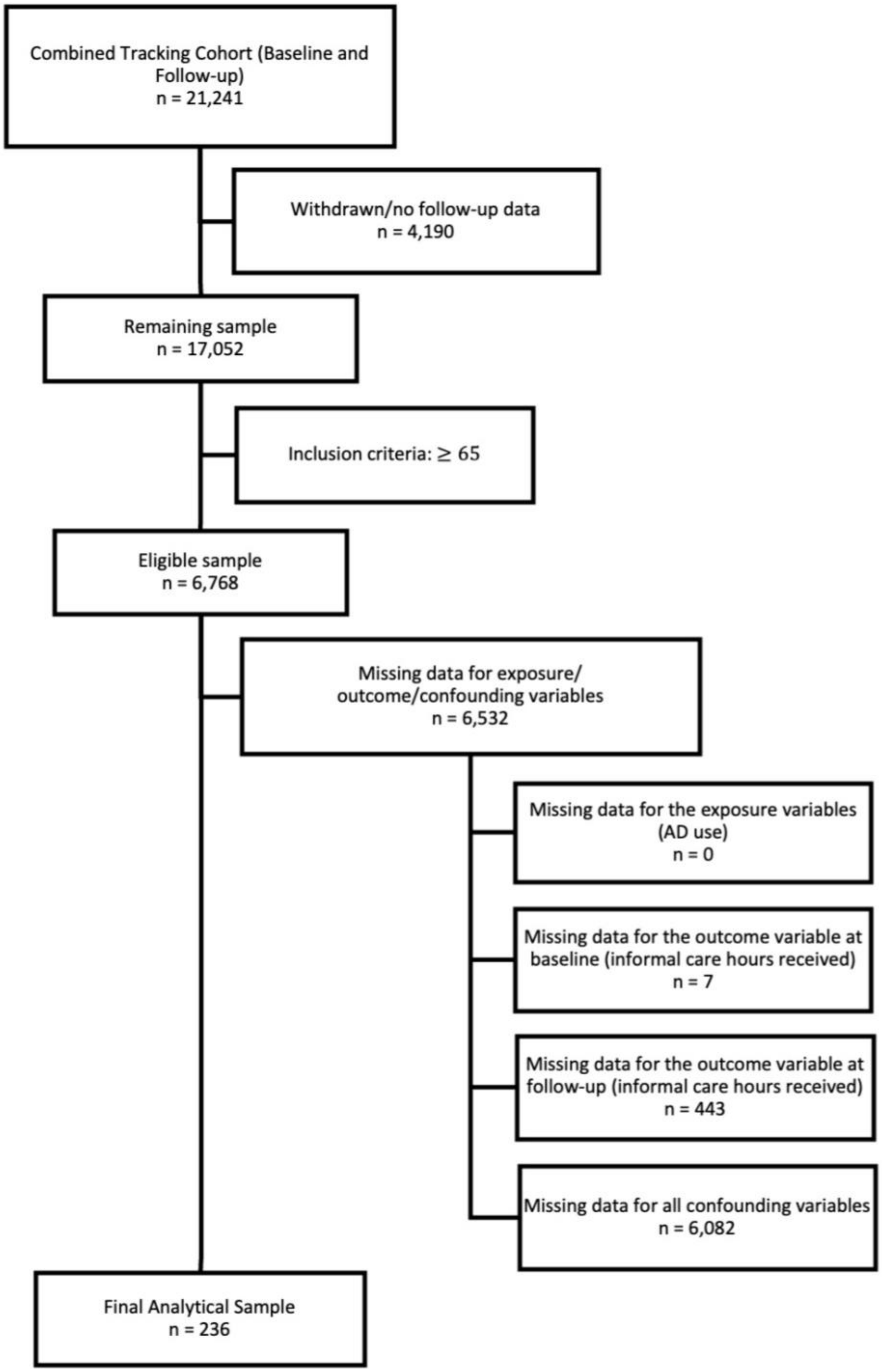

Figure 5 - 1: Exclusion of missing data in the Tracking cohort

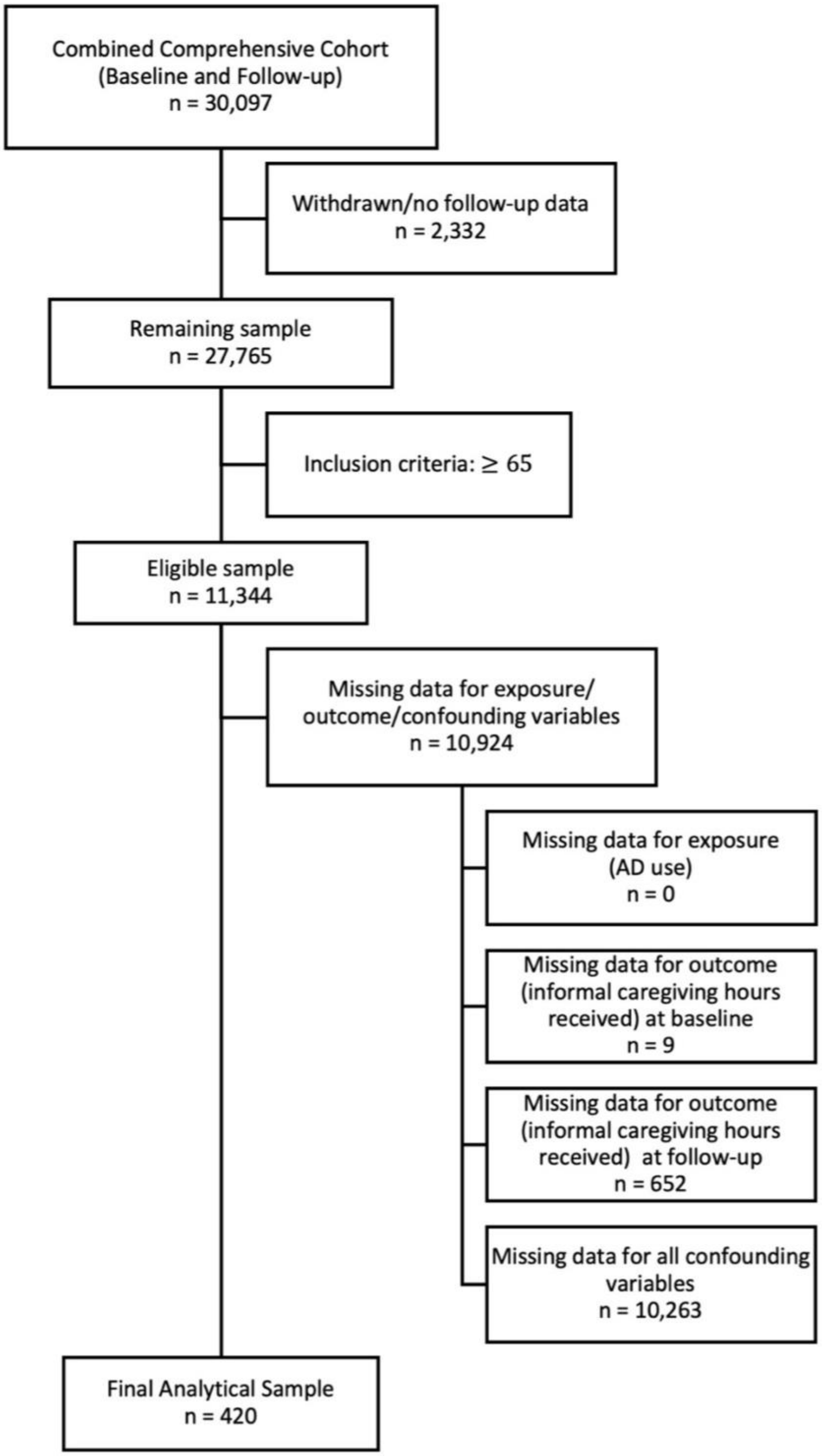

Figure 5 - 2: Exclusion of missing data in the Comprehensive cohort

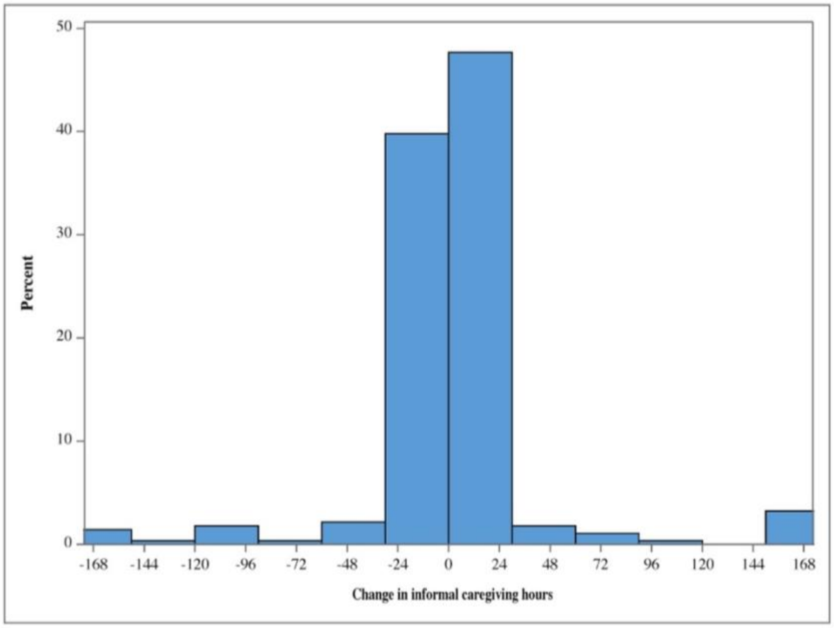

Figure 5 - 3: Distribution of the change in informal caregiving hours received in the Tracking cohort

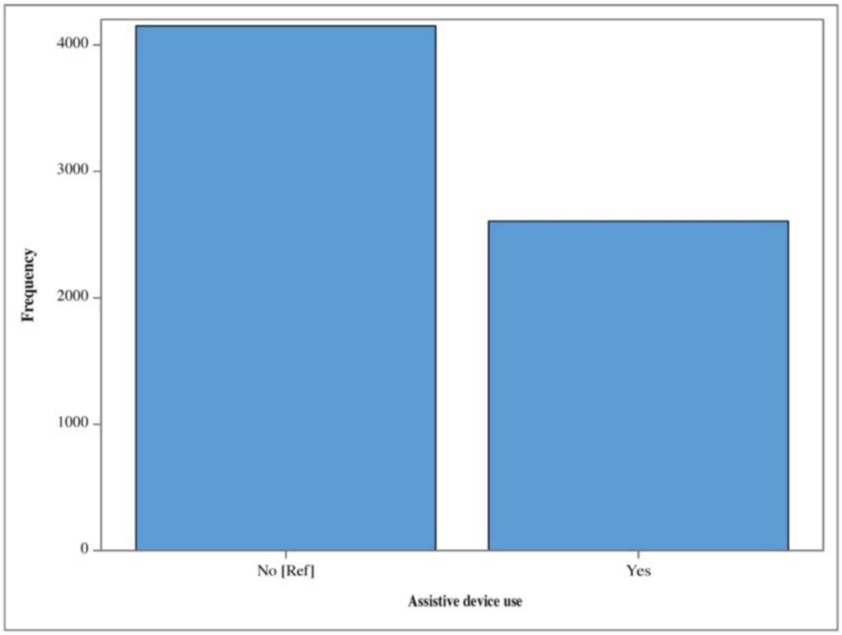

Figure 5 - 4: Distribution of assistive device use in the Tracking cohort

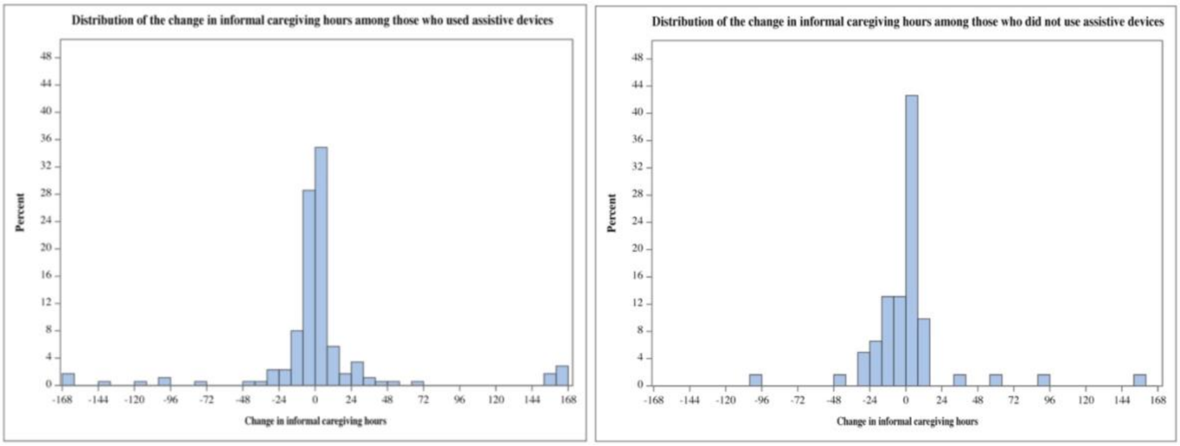

Figure 5 - 5: Distributions of the change in informal caregiving hours across those who used AD versus those who did not use AD in the Tracking cohort

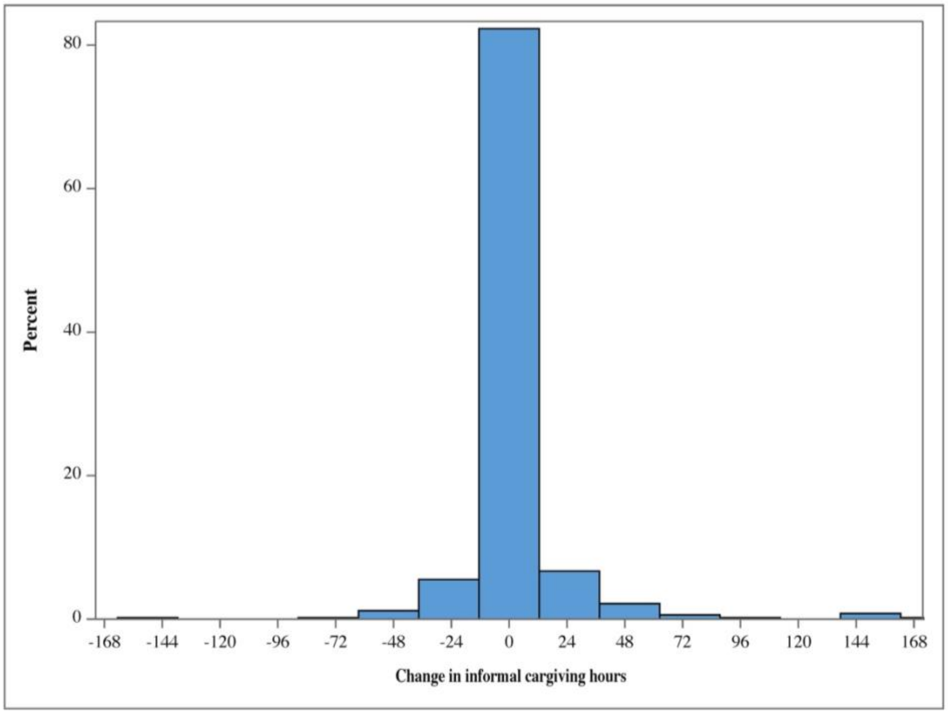

Figure 5 - 6: Distribution of the change in informal caregiving hours received in the Comprehensive cohort

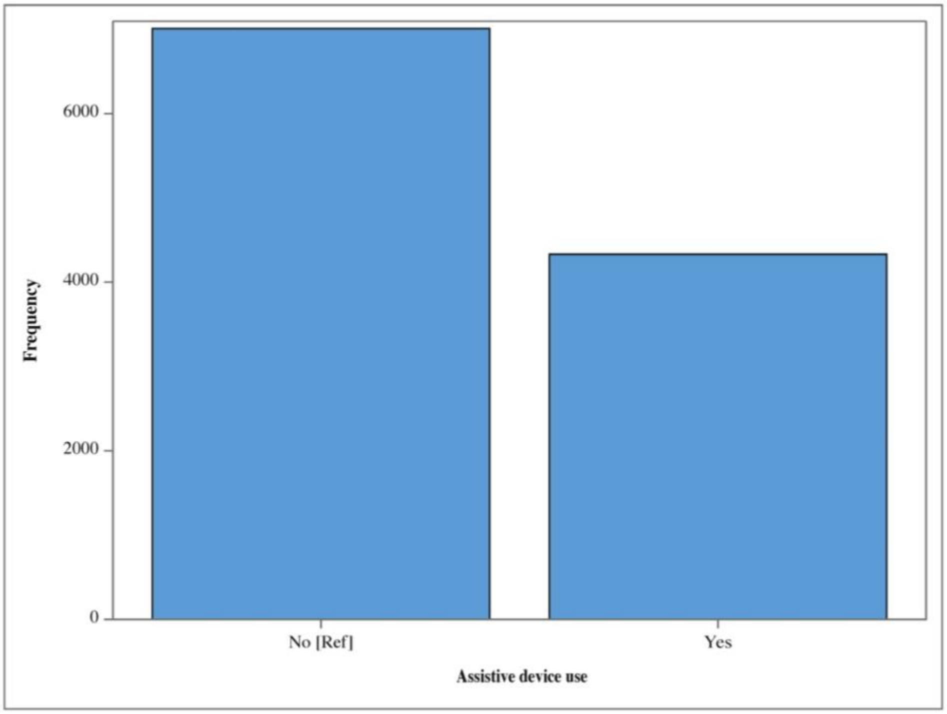

Figure 5 - 7: Distribution of assistive device use in the Comprehensive cohort

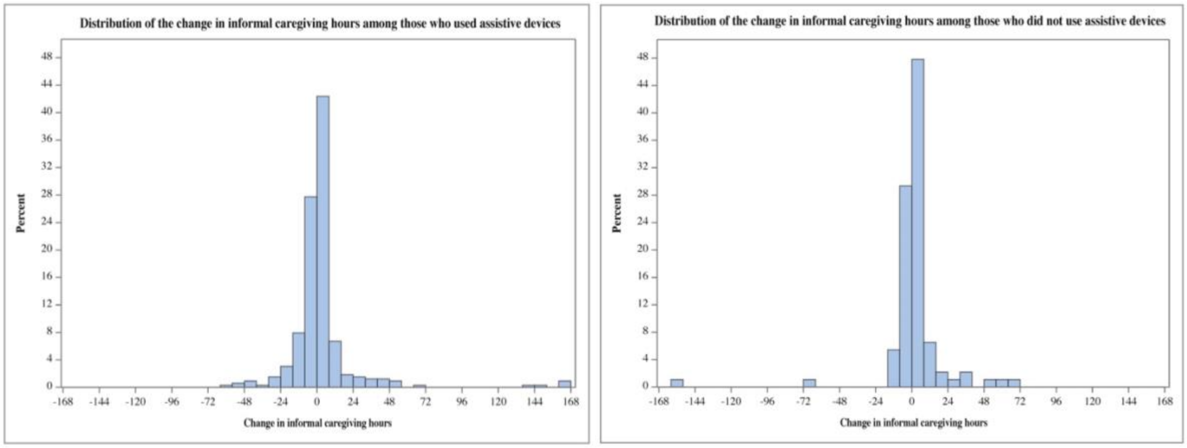

Figure 5 - 8: Distributions of the change in informal caregiving hours across those who used AD versus those who did not use AD in the Comprehensive cohort

Chapter 6

Final discussion and concluding remarks

6.1 Overview

Based on the CATOR framework, AD use is theorized to affect LS and the amount of informal caregiving hours received from others.[5] This thesis was undertaken to empirically explore these theoretical relationships via three specific objectives: (i) to investigate the existing literature for evidence of these associations; (ii) to examine the association between AD use and LS; and (iii) to investigate the association between AD use and the amount of informal caregiving hours received. For objectives ii and iii, the thesis used baseline and three-year follow-up data from a national-level sample of community-dwelling older adults (≥ 65 years) in Canada. This dissertation's key findings, discussion, strengths, limitations, implications and future directions, contributions, and conclusion are presented in this chapter.

6.2 Summary of key findings

Chapter 3, which searched the literature for existing studies on the two associations, concluded that there was minimal evidence (two studies for each association) that ranged from very low to moderate quality on the two relationships.[80] The existing literature provided weak evidence to support the notion that LS can be a negative outcome of AD use.[80] Only one study suggested so and had several notable limitations therefore results should be interpreted with caution and the remaining literature did not detect any significant findings.[132,133] Therefore, the understanding of the relationship between AD use and LS remains uncertain. On the other hand, the existing literature provided some evidence that AD use may influence the amount of informal caregiving hours received, based on two moderate-quality cross-sectional studies.[13,14] However, due to the scarcity of evidence and quality of the studies, the understanding of the two relationships remains open for further investigation. Chapter 3 highlighted that no previous studies had investigated whether these two outcomes could be long-term outcomes of AD use, highlighting the need for further research.

These findings inspired the following two chapters of this thesis, Chapter 4 and Chapter 5, explored the LS and the amount of informal caregiving hours received as long-term outcomes of AD use, respectively, utilizing a longitudinal, population-level data set - the CLSA, adjusting for a robust set of confounding variables in the analyses.

Chapter 4 hypothesized that there would be a positive change in LS over time among those who used AD compared to those who did not use AD at all, as a reflection of the theorized possibility in the CATOR framework that AD use could have positive long-term effects on one's subjective well-being (e.g., life satisfaction).[192] Functional declines associated with aging and related outcomes (e.g., social isolation, reduced mobility) can lead to lower levels of LS among older adults, and AD use can compensate for some of these restrictions by promoting independence, safety, and providing older adults a sense of purpose, dignity, and autonomy, thereby contributing to improved LS.[34,51,193] However, results of this study did not find evidence to suggest a significant positive change in LS over time among older adults who used AD compared to those who did not use AD and did not provide evidence to support the CATOR framework.

Chapter 5 investigated whether AD use was associated with changes in the amount of informal caregiving hours received over three-years. Based on the CATOR framework's premise that AD use may have positive long-term effects on society and others (e.g., caregiving hours), Chapter 5 hypothesized that older adults who used AD in the past 12 months would receive fewer informal caregiving hours.[5] The doctoral candidate did not find statistically significant results to support the CATOR framework.

Overall, this thesis revealed a knowledge gap in the field of AD use and its benefits for community-dwelling older adults and their informal caregivers. However, it did not find empirical evidence to support or refute the investigated associations theorized in the CATOR framework. Results were not definitive on account of limitations associated with each study (see Sections 4.5.2, 5.6.2, and 6.5). Therefore, further research is required to assess the associations of interest. Possible explanations for the findings of this thesis are summarized next.

6.3 Discussion

Several factors may explain the findings of the studies presented in this thesis. Although a comprehensive search strategy was employed for the systematic review to capture as many relevant articles as possible, including those published in languages other than English, Chapter 3 found relatively little existing literature on the two topics. This is mainly because subjective well-being (e.g., life satisfaction) and informal caregiving time have been largely understudied as outcomes of AD use.[5,107] This may be partially due to the perception that AD are primarily intended to improve physical function, with subjective well-being seen as a secondary outcome.[5] The scarcity of research around informal caregiving hours as an outcome of AD may be attributed to the difficulties associated with accurately capturing informal caregiving hours, as this type of caregiving is often provided by family or friends without being formally recorded or tracked.[190]

In Chapter 4Chapter 5, where the samples consisted of healthy samples due to self-selection/volunteer bias in the CLSA (see Sections 4.5 and 5.6), volunteer bias may have influenced the findings toward the null hypothesis, underestimating the true associations between AD use and the two outcomes.[173] Additionally, changes in the outcomes between baseline and follow-up were barely different from zero, indicating minimal or no changes between the two timepoints. At the time of these two studies, the doctoral candidate had access to data from only two timepoints of data spaced three years apart, which may not have been long enough to observe clinically relevant changes in the outcomes, especially among a healthy subset of the overall population. However, there is no clear consensus in the current literature about the amount of time required to detect a change in LS or informal caregiving in healthy populations.

Furthermore, “AD use” indicated the use of any type of AD, which may have diluted the effects AD may have had on the outcomes (see Section 4.5.2 and 5.6.3). The specific type of AD used should be considered when evaluating AD’s effects because different devices (e.g., hearing aids or glasses versus wheelchairs or walking aids) may not have the same effect on the outcomes. Additionally, as acknowledged in Chapter 5, care recipients may have been unable to accurately know and report all care hours they received, resulting in an underestimation of the informal caregiving hours, which may have biased the findings away from the null, providing unreliable estimates (see Section 5.6.3).[190]

Further bias may have been imparted on the findings through missing data in both chapters. Analyses conducted in this thesis handled missing data through complete case analysis, which analyzed only observations that had complete data at baseline and three-year follow-up waves of data collection. In Chapter 4, among participants who were excluded from the analysis, the probability of AD use was significantly higher than in the included group, indicating possible bias towards the null hypothesis. In Chapter 5, participants included in the analysis had a significantly higher probability of using AD than those excluded, indicating bias away from the null hypothesis. Therefore, effect sizes in both studies may have been influenced by missing data, providing less precise results, though non-significant.

Methods for dealing with missing data include multiple imputation, maximum likelihood, and weighted (for an observation being missing or observed) analysis.[194] These methods could be used to mitigate issues of missing data in the CLSA. However, their adoption is complicated as these methods make their respective assumptions about missing data patterns, (probabilistic) missing data mechanisms, and imputation models, probability weights model etc.[194] Such methods are beyond the scope of this thesis and would serve as investigation topics for future researchers. For example, current CLSA projects are exploring missing data patterns and missing data mechanism (personal communication, M. Oremus, March 9, 2023). Findings from such current projects will inform aforementioned methods of dealing with missing data. Until then, complete case analyses with CLSA data seem to be method of choice with their conclusion being generalizable only to sub-populations that mirror the complete case analysis samples.

6.3.1 Take-away points from the three studies

While the findings of this thesis were inconclusive, possibly as a result of the above explanations, three important insights emerged from the findings. First, most existing studies, including those conducted in this thesis, investigating the two associations of interest, share the common limitation of grouping all AD types together rather than sub-analyzing them by more refined groups (e.g., devices for mobility separated from devices for monitoring falls, or even analyses by specific device [wheelchairs versus walkers]). This thesis highlights that this approach has failed to capture the nuances of the various types of devices and their potential impacts on outcomes in studies that have been conducted on the topics so far. As discussed in earlier chapters, this may be due to the lack of large enough sample sizes. Such sub-analyses can inform frameworks such as the CATOR framework to examine how theories outlined within the framework may differ for different types of AD. A comprehensive evaluation of which devices can enhance LS and reduce informal caregiving hours is critical before they are promoted, funded, and distributed to older adults. Such classification can play an important role in decision-making regarding interventions and policy recommendations.

Secondly, this thesis highlights the knowledge gap that still exists regarding the two topics investigated. Including the research presented in this thesis, there are only four studies that investigated the association between AD use and LS: three cross-sectional and one longitudinal;[132,133,147] and only three studies that investigated the relationship between AD and informal caregiving hours: two cross-sectional and one longitudinal study.[13,14] The limited number of studies, each with its own limitations (see Sections 4.5.2 and 5.6.2), may still not be sufficient to provide accurate and comprehensive information about the associations between AD use and the two outcomes. While this thesis built upon existing studies by examining the two associations between AD use and the outcomes *over time*, much still remains unknown regarding the associations. For example, lack of longitudinal studies available for comparative purposes, the question of whether the thesis findings are the ‘truth’ (i.e., no associations exist in the population) or an artifact of the CLSA (i.e., self-selection bias, missing data) remains unanswered. Further research is necessary to advance our understanding of the relationships identified in this thesis, support or refute current findings, and better inform evidence-based decision making and policy decisions accordingly.

Thirdly, while findings in Chapter 4 and Chapter 5 were not statistically significant, non-significant findings can still be informative as they can help to further refine research questions, suggest alternative methods or hypotheses, and provide insight into the underlying mechanisms and complexities of the research questions under investigation. For example, non-significant findings of this thesis lead the doctoral candidate to think about alternatives beyond her hypotheses (e.g., considering the possibility that AD might add to caregiver time or not reduce caregiving time [see Section 5.6]). Additionally, repeated non-significant findings can help inform existing theories by ruling out certain hypotheses over time and providing insight into whether refinement of the theories is necessary. In contrary to what is outlined in the CATOR framework, it is possible that LS may not be a long-term positive outcome associated with AD use among older adults. This might be the case if older adults feel stigmatized or self-conscious when using AD, which can negatively impact their LS.[195] Considering much remains unknown about the two associations, it is possible that AD might improve LS or reduce informal caregiving hours received only theoretically. Therefore, it is important to consider non-significant results, as they may help evaluate and inform prevailing theories for use in future research, and potentially offer new perspectives and avenues for exploration.

6.4 Strengths

First, this thesis included the first ever systematic review with strong methodological approaches to investigate the existing evidence on the two associations of interest, thereby uncovering novel insights, filling a current knowledge gap, and providing a foundation for the research undertaken in Chapter 4 and Chapter 5 and future research. Methodological approaches of this review included adhering to PRISMA guidelines and used GRADE and AXIS to assess the articles' quality and risk of bias. PRISMA provided standardized and transparent ways to report methods and results, increasing the rigor, quality, and credibility of the review.[111] GRADE, which has been designed to rate the quality of scientific evidence in systematic reviews as well as to develop evidence-based guidelines helped to ensure that the review is comprehensive and reliable.[196] AXIS, which is a tool used to rate cross-sectional studies for methodological quality and bias risks offered several advantages, including comprehensive evaluation, reliability, and credibility to the systematic review.[124,125] Furthermore, the review received a self-rating of 12 out of 13 on AMSTAR 2, a quality checklist for systematic reviews. AMSTAR 2 evaluates various aspects of the review process, including the selection of studies, data extraction, analysis, and synthesis of findings to ensure validity and reliability.[197]

Secondly, this thesis provides the first longitudinal analyses of the two associations, allowing for a more detailed understanding of the relationships than simply focusing on the relationships at a particular point in time. Furthermore, the doctoral candidate drew upon a large, national data set to conduct the first investigations of the above-mentioned relationship, which provided access to multiple variables (e.g., comprehensive confounders); and allowed for longitudinal studies, which facilitated the tracking of outcomes over time.

Thirdly, the doctoral candidate adjusted for multiple and relevant covariates that had been unaccounted for in previous research. Previously published studies on the relationship between AD use and LS, either did not account for confounders at all or did not adjust for all relevant confounders such as depressive symptoms which was accounted for in this thesis.[132,133] When investigating the association between AD use and the amount of informal caregiving hours received, the doctoral candidate accounted for additional relevant confounders such as chronic conditions, injury, depression, the receipt of formal care, caregiver's age, and FSS, none of which were included in existing studies.[13,14] Adjusting for multiple covariates that were previously unaccounted for may have contributed to strengthening the findings of studies included in this thesis by reducing confounding bias, increasing precision, validity, and interpretability of the results, thereby strengthening the conclusions of both studies.

6.5 Limitations

This thesis has several limitations. Due to the small number articles included in Study 1, as well as sources of heterogeneity in these articles, the doctoral candidate was unable to perform a meta-analysis. Sources of heterogeneity included different instruments to measure exposure and different ways of reporting quantitative results (e.g., regression coefficients, p-values, test statistics). When defining AD for Studies 2 and 3, small numbers of some types of AD reported by CLSA participants required the doctoral candidate to group all types of

AD under the single banner of “AD use” for analytical purposes, preventing the examination of the differential effects of individual types of AD on the outcomes (see Section 6.3). As explained in each chapter, the findings are therefore limited to the types of AD captured in each study sample. Furthermore, the CLSA had released only two timepoints of data during the thesis research period, which restricted the ability to assess the associations over a longer period of time (see Section 6.3).

As a result of the CLSA’s self-selection bias, the thesis samples represented a healthy subset of the Canadian population (see Section 6.3); consequently, biasing the findings toward the null and underestimating the true associations between AD use and the outcomes over time. Further limitations were imposed by choices made in the CLSA, such as the exclusion of individuals with cognitive impairment at baseline.[191] This exclusion criterion may have lead to an underestimation of the number of people who received higher hours of care in Study 3, as older adults with cognitive impairment have higher caregiving demands. Additionally, the reporting of caregiving hours relied on the care recipients’ memory of the amount of care they received, which may have underestimated the hours reported by the care recipient. According to previous literature, caregivers within the same dyad reported providing more hours of care in comparison to what the care recipients reported they received.[190]

One of the main limitations observed in this thesis was that the CLSA was not primarily designed to collect data on AD. Questions about AD were a subsection of the CLSA. This research could have benefited from a data set designed specifically to address AD use and related areas to the outcomes (e.g., AD questions directly related to LS). Without data specifically geared towards AD, it can be difficult to fully understand their impact and effectiveness. Therefore, it is imperative to develop data sets that are specifically designed to collect information on AD use.

In addition, the CLSA did not ask participants about the duration of their AD use. AD use can be short-term, long-term, or intermittent, and the duration of AD use can influence the outcomes.[5] For example, a participant who has recently started using an AD may not have fully experienced its full impact on their LS yet. On the other hand, an individual who used an AD for only a short duration may still have required significant assistance from their caregivers, despite the use of the device. Therefore, the absence of this information may have limited the accuracy of the findings.

Furthermore, studies in this thesis only controlled for confounders from baseline and did not consider changes in confounders over time (time-varying confounders); the changes in the confounders over three years may have biased the results. Adjusting for time-varying confounders requires more complex statistical models, which can be computationally intensive and require larger sample sizes, which expands beyond the resources that were available to the doctoral candidate.[198] It has been acknowledged in the literature that using conventional regression methods such as those used in this thesis to account for time-varying confounders can lead to over-control and endogenous selection bias.[198] Future studies should consider controlling for time-varying confounders when relevant resources are available.

Lastly, as noted in individual chapters, most participants self-identified as White in both studies, which may be due to self-selection bias, as participants had to respond in either English or French. According to the CLSA samples used in this thesis, visible minorities made up around 3-5% of the sample, whereas they represent 22.3% of the entire population of Canada.[177] As a result, findings may not be applicable to the entire population of Canada.

6.6 Implications and future directions

6.6.1 Implications and directions for future research

LS in later years is influenced by a variety of factors (see Section 2.1.3.2.1). As a result of the complexity and multi-dimensionality of LS, it may be more effective to ask direct and refined questions regarding LS in the context of AD use to gain a more comprehensive understanding of how AD impact LS (e.g., Has using an AD improved your LS?). Therefore, it may be more appropriate to use scales that specifically frame LS-related questions within the context of AD use, or to incorporate such questions into studies.

Furthermore, in different cultures and countries, LS may be perceived differently due to varying norms, values, and beliefs.[178] This makes it difficult to measure accurately the same concept across various cultures and subcultures. In general, the SWLS scale has been found to be capable of measuring LS across cultures.[178] However, further research is needed in order to understand how the scale should be applied to different cultures and subcultures.[178] Therefore, the validity of LS scales should be examined in different cultures before being used in future research. A second factor to consider is that some cultures may view AD use as a sign of weakness rather than support, which could have an impact on studies conducted in different contexts.[179] Therefore, future studies investigating AD use and LS should recognize that results may vary depending on the cultural contexts.

With regard to the second outcome (Chapter 5), informal caregiving hours, sometimes it is difficult to differentiate between informal caregiving obligations and day-today responsibilities. For example, if an informal caregiver prepares meals for themselves and the care recipient simultaneously, it may be difficult to report the exact number of hours spent preparing meals just for the care recipient. Thus, it is likely that caregiving hours can be underreported, particularly when they are reported from memory, affecting the support and resources available to caregivers.

Additionally, while obtaining precise caregiving hours from the caregiver is a challenge, collecting caregiving hours received from the care-recipient also poses challenges. The number of caregiving hours reported by the care recipient may differ from the actual number of care hours received, underestimating the caregiving hours used in this thesis.[190] To overcome the recall bias and discrepancies associated with reporting informal caregiving hours, future studies can collect data on caregiving hours directly from informal care providers and compare with caregiving hours reported by care-recipients.

In light of the limitations of grouping all AD types under “AD use” discussed in previous chapters, future studies should consider obtaining sufficient sample sizes before investigating these relationships in different populations to minimize the implications associated with conducting sub-analyses. Further stratification by level of impairment or level of health could also provide insights into how the associations may change depending on the participants’ health. This can help researchers and policymakers better understand how a particular intervention may be effective or not depending on the health status of people. However, the same challenge lies in acquiring large sample sizes for such stratification. Furthermore, future studies should consider the duration of AD use (intermittent, short-term, or long-term use) to gain a more comprehensive understanding of the two relationships as the nature of AD use can impact the changes in the outcomes as described in Section 6.5.

As a final point, representative samples are needed for future research on the two longitudinal relationships. For example, the observational studies conducted in this thesis contained samples that were typically healthier, which may have resulted in little or no impact of AD due to the lower need for AD in these populations. Selecting appropriate samples is critical for conducting valid and reliable research, and for ensuring that the findings can be applied to real-world situations.

Overall, implications for future research include complexities related to the outcomes, such as the construct of LS, the variation in perceptions of LS across cultures, as well as accurately capturing informal caregiving hours by both care recipients and caregivers, determining the impact of AD based on its type, duration of use, and level of impairment, and using representative samples.

6.6.2 Implications and directions for theory

The thesis did not yield empirical evidence either confirming or refuting the CATOR framework's assertion that LS and informal caregiving hours can be long-term outcomes of AD use.[5] Overall limited and mixed evidence exists to evaluate the credibility of the CATOR framework (including the studies undertaken as part of this thesis) (see Section 6.3.1). Repeated findings, including non-significant results can be useful in providing insight into the validity of certain theories over time and can inform researchers about the limits and boundaries of existing theories. The creators of CATOR should consider and monitor future research on the two associations to build on, update, or revise current theories.

While the CATOR framework accommodates a wide variety of AD applications, and combinations of user populations, AD types, services, and contexts for use, the framework does not extend its theories to different possible contexts.[5] For example, changes in informal caregiving hours may depend on the nature of AD use but no insight into it has been discussed in detail as part of the framework. It is possible that only long-term use of AD can improve LS over time. Therefore, this perspective should be considered in the CATOR framework including sub-theories based on the nature of AD use and its effect on theorized relationships.

Similarly, the theorized associations can vary depending on the type of AD. For example, mobility devices may reduce caregiving hours and hearing aids might not. Neither the CATOR framework nor existing studies explored this possibility. Therefore, this aspect could also be considered in the CATOR framework when developing sub-theories. Furthermore, the theories outlined in the CATOR framework may differ for different population (e.g., older adults). Older adults often have different needs than younger adults and may use technology in different ways.[199] For example, they may be less likely to use certain apps or technologies, or they may require more assistance in using them.[199] The CATOR framework should take into account and discuss how its theories may change based on the population under study.

6.6.3 Implications and directions for policy and practice

While highlighting a knowledge gap, findings of this thesis were inconclusive, therefore, little objective evidence is available to guide policy decisions regarding AD use, LS and informal caregiving. However, inconclusive evidence does not imply that such associations do not exist; findings could be attributed to reasons outlined in Sections 4.5 and 5.6. When findings are inconclusive, policymakers should be cautious about developing new policies or making changes to existing policies regarding the provision of AD to community-dwelling older adults. It is recommended that policymakers monitor future research over time to better understand how evidence related to the two relationships evolves and identify new research and policy areas.

Inconclusive findings may indicate that the issue being studied is complex and multifaceted, which may require more nuanced and comprehensive approaches to addressing the research questions at hand effectively. For example, the development of policy and recommendations may be enhanced by gaining a better understanding of the complexities associated with caregiver outcomes resulting from AD use by care recipients. Policy makers should recognize that complex issues require long-term commitments and continuous evaluations to ensure the policies are effective, consider alternative approaches, and adjust policies as new information becomes available.

Additionally, observational studies cannot establish causality and can have important implications for policy and practice. Policymakers and stakeholders should consider multiple sources of evidence, including both observational and experimental studies, when making decisions. Continued funding, resources, and support for well-designed randomized controlled trials and longitudinal studies are needed to determine the effectiveness of AD in improving caregiving hours and LS over time.

Furthermore, unweighted data may not accurately represent the population being studied, resulting in over- or under-representation of certain groups, which can lead to policies or practices that are not effective or equitable. To increase the generalizability of study findings and inform population-wide policy and practices, future research should use weighted data with weighted missing data analysis, if possible.

Despite inconclusive evidence, policymakers can shape policies and practices pertaining to the two relationships explored in this thesis by monitoring and evaluating new research, recognizing the complexity of the research questions, evaluating evidence from multiple sources, ensuring funding for improved research, and promoting education and collaboration between stakeholders.

6.7 Contributions

First, this thesis filled a gap in knowledge by conducting a systematic review of the existing literature on the two associations for the first time. Second, as a result of this systematic review, the doctoral candidate identified a second gap in the literature, namely the lack of research on the above two relationships. Third, in the subsequent Chapter 5 and Chapter 6, the thesis addressed the identified gaps by conducting two novel and improved studies aimed at exploring the relationships between AD use and the two outcomes over time among community-dwelling older adults. Fourth, the thesis provided recommendations for further research by identifying challenges and common limitations observed in existing studies and emphasizing how future research should address them. Fifth, the thesis based its research on the CATOR framework and suggested directions for the enhancement and modification of the CATOR framework, which can guide future research on AD use and its relationship with LS and informal caregiving hours. Last, this thesis examined the implications for future research, theory, policies, and practices involved in studying these two relationships, which can help advance the field and inform recommendations for future decisions. Overall, this thesis contributed to the existing body of knowledge in the field by identifying new gaps, filling existing gaps, challenging existing theories, and presenting directions for new insights.

6.8 Conclusion

In an aging society, research on the use of assistive devices, life satisfaction, and informal caregiving hours received by community-dwelling older adults is essential because it can inform evidence-based policies and interventions aimed at improving older adults' independence, while supporting their informal caregivers. Empirical evidence of AD's impact on LS and informal caregiving hours is essential to make evidence-based decisions and effective recommendations regarding the provision of AD to older adults.

Considering the lack of existing literature on the two investigated topics and the findings of this thesis, further research into the two associations is highly recommended. Future research on these research questions should aim to overcome limitations observed in existing studies by extending follow-up periods beyond three years, having large sample sizes, conducting analyses based on AD type (e.g., mobility versus vision-related AD), and AD duration (short-term, long-term, intermittent use), while controlling for additional confounders (e.g., satisfaction with the device, time-varying confounders). Future data collection methods should include more refined LS questions tailored specifically to AD use, along with surveying caregivers directly to increase accuracy of caregiving hours, unlike the CLSA, which derives caregiving hours from care recipients. It is recommended that future research utilize data sets designed to collect information primarily on assistive device use to better answer the research questions addressed in this thesis. Further, future research should use representative samples that are weighted, culturally representative, and have minimal biases (e.g., selection bias, missing data).

This thesis emphasizes the importance of further research on the topics studied, identifies limitations in existing studies, and provides recommendations for overcoming these limitations. The importance of null findings was recognized, along with their potential to contribute to the development of future research theories, policies, and practices. Lastly, this thesis acknowledges implications for future research including the complexity of the research questions and concepts (e.g., life satisfaction, cultural differences, accurate capture of informal caregiving hours from care receivers and caregivers), the importance of stratified analysis to inform sub-theories in the CATOR framework (e.g., by AD types, duration of AD use), integrating evidence from multiple sources (e.g., experimental studies), using representative samples, fostering funding for improved research, the importance of null findings, and promoting educational and collaborative efforts among stakeholders.

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Appendix A

Classes of assistive devices

Table A-1: 12 classes of AD classified by the ISO 9999 in collaboration with the WHO.

ISO 9999 (2016) - 12 classes	
04	Assistive products for measuring, supporting, training, or replacing body functions
05	Assistive products for education and for training in skills
06	Assistive products attached to the body for supporting neuromusculoskeletal or movement related functions (orthoses) and replacing anatomical structures (prostheses)
09	Assistive products for selfcare activities and participation in selfcare
12	Assistive products for activities and participation relating to personal mobility and transportation
15	Assistive products for domestic activities and participation in domestic life
18	Furnishings, fixtures and other assistive products for supporting activities in the indoor and outdoor human-made environment
22	Assistive products for communication and information management
24	Assistive products for controlling, carrying, moving, and handling objects and devices
27	Assistive products for controlling, adapting or measuring elements of the physical environment
28	Assistive products for work activities and participation in employment
30	Assistive products for recreation and leisure

Appendix B

PRISMA checklists

Table B - 1: PRISMA checklist for the abstract.

Section and Topic	**Item #**	**Checklist item**	**Reported (Yes/No)**
TITLE			
Title	1	Identify the report as a systematic review.	Yes
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	No. Mentioned elsewhere.
Information sources	4	Specify the information sources (e.g., databases, registers) used to identify studies and the date when each was last searched.	Yes
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	No. Mentioned elsewhere.
Synthesis of results	6	Specify the methods used to present and synthesise results.	Yes
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	Yes
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e., which group is favoured).	Yes. Number of participants not mentioned.
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g., study risk of bias, inconsistency, and imprecision).	Yes
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
OTHER			
Funding	11	Specify the primary source of funding for the review.	No. Mentioned elsewhere.
Registration	12	Provide the register name and registration number.	Yes

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. Doi: 10.1136/bmj.n71

Table B - 2: PRISMA checklist

Section and Topic	Item #	Checklist item	Location where item is reported (In the published manuscript)
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	N/A
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	5-7
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	7
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	8
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	7
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	7
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	7-8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	7-8

	10b	List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	7-8
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	9
Effect measures	12	Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.	8-9
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	8
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	8-9
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	9
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	9
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	9
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	10-11
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	N/A

Study characteristics	17	Cite each included study and present its characteristics.	11-14
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	14-16
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	11-14
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	11-16
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	13
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	14-16
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	14-16
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	14-16
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	16-17
	23b	Discuss any limitations of the evidence included in the review.	17-18
	23c	Discuss any limitations of the review processes used.	19
	23d	Discuss implications of the results for practice, policy, and future research.	19-20
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	3,7
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	7
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	10
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	22
Competing interests	26	Declare any competing interests of review authors.	22

Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	N/A

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. Doi: 10.1136/bmj.n71

Appendix C

Search terms

Table C - 1: Search terms and results for Research Question 1

	Scopus	PubMed	CINAHL
(TITLE-ABS-KEY ((“assistive device*” AND mobility) OR “assistive technology*” OR “assistive device*” OR “assistive product*” OR gerontechnolog* OR “self-help device*” OR “self-help device*” OR “selfhood device” OR “home modification*” OR “mobility aid*” OR “prosth*” OR “ortho*” OR wheelchair* OR cane* OR stick* OR seat* OR walker* OR “walking frame*” OR scooter* OR rollator* OR chair* OR bath* OR detector* OR gps OR “supportive device*” OR “brace*” OR crutch* OR “motorized scooter*” OR “hip protector*” OR “mobility device*” OR “mobility product*” OR “grab bar*” OR rail* OR ramp* OR “bathroom aid*” OR “bath lift*” OR “bed lift*” OR “lifting device*” OR “lifting product*” OR “lifting technolog*” OR “grasping tool*” OR “reach extender*” OR “eating utensil*” OR “personal alarm*” OR “pencil grip*” OR “pill organizer*” OR footwear* OR tricycle* OR seat* OR toilet* OR bathroom* OR cushion* OR pillow* OR bed* OR shower* OR door* OR (device AND dressing*) OR doorway* OR hallway* OR electrotherapy OR (“assistive device*” AND pen) OR (“assistive device*” AND print) OR (“assistive device*” AND hearing) OR “hearing aid*” OR “cochlear implant*” OR amplifier* OR “volume control telephone” OR “TTY” OR teletype OR “TTD” OR “telecommunications device for the deaf” OR “text telephone*” OR “message relay service*” OR (“hearing AND loop”) OR flasher* OR decoder* OR “closed caption” OR “closed caption television” OR “fm amplifier*” OR (“assistive device*” AND “infra-red”) OR (“assistive device*” AND infrared) OR acoustic OR “visual alarm*” OR “vibrating alarm*” OR “closed caption*” OR software* OR (“assistive device*” AND vision) OR magnifier* OR braille OR “talking book*” OR “portable note-taker*” OR “screen reader*” OR “voice recognition” OR daisy OR “communication software*” OR spectacle* OR glass* OR “contact lens*”) AND TITLE-ABS-KEY (“older adult*” OR “aging population*” OR elder* OR senior* OR “old people” OR “older people” OR aged OR “frail elder*”) AND TITLE-ABS-KEY (“satisfaction of life” OR	454		

“life satisfaction” OR “self-satisfaction” OR “satisfaction with life”))			
“Self-Help Devices” AND (Aged OR “Frail Elderly”) AND satisfaction		167	
AB (“assistive device*” AND mobility) OR “assistive technolog*” OR “assistive device*” OR “assistive product*” OR gerontechnolog* OR “self-help device*” OR “self help device*” OR “selfhood device” OR “home modification*” OR “mobility aid*” OR “prosth*” OR “ortho*” OR wheelchair* OR cane* OR stick* OR seat* OR walker* OR “walking frame*” OR scooter* OR rollator* OR chair* OR bath* OR detector* OR gps OR “supportive device*” OR “brace*” OR crutch* OR “motorized scooter*” OR “hip protector*” OR “mobility device*” OR “mobility product*” OR “grab bar*” OR rail* OR ramp* OR “bathroom aid*” OR “bath lift*” OR “bed lift*” OR “lifting device*” OR “lifting product*” OR “lifting technolog*” OR “grasping tool*” OR “reach extender*” OR “eating utensil*” OR “personal alarm*” OR “pencil grip*” OR “pill organizer*” OR footwear* OR tricycle* OR seat* OR toilet* OR bathroom* OR cushion* OR pillow* OR bed* OR shower* OR door* OR (device AND dressing*) OR doorway* OR hallway* OR electrotherapy OR (“assistive device*” AND pen) OR (“assistive device*” AND print) OR (“assistive device*” AND hearing) OR “hearing aid*” OR “cochlear implant*” OR amplifier* OR “volume control telephone” OR “TTY” OR teletype OR “TTD” OR “telecommunications device for the deaf” OR “text telephone*” OR “message relay service*” OR (“hearing AND loop”) OR flasher* OR decoder* OR “closed caption” OR “closed caption television” OR “fm amplifier*” OR (“assistive device*” AND “infra-red”) OR (“assistive device*” AND infrared) OR acoustic OR “visual alarm*” OR “vibrating alarm*” OR “closed caption*” OR software* OR (“assistive device*” AND vision) OR magnifier* OR braille OR “talking book*” OR “portable note-taker*” OR “screen reader*” OR “voice recognition” OR daisy OR “communication software*” OR spectacle* OR glass* OR “contact lens*”) AND AB (“older adult*” OR “aging population*” OR elder* OR senior* OR “old people” OR “older people” OR aged OR “frail elder*”) AND AB (“satisfaction of life” OR “life satisfaction” OR “self-satisfaction” OR “satisfaction with life”))			342
Total	963		

Table C - 2: Search terms and results for Research Question 2

	Scopus	PubMed	CINAHL
TITLE-ABS-KEY ((“assistive device*” AND mobility) OR “assistive technolog*” OR “assistive device*” OR “assistive product*” OR gerontechnolog* OR “self-help device*” OR “self help device*” OR “selfhood device” OR “home modification*” OR “mobility aid*” OR “prosth*” OR “ortho*” OR wheelchair* OR cane* OR stick* OR seat* OR walker* OR “walking frame*” OR scooter* OR rollator* OR chair* OR bath* OR detector* OR gps OR “supportive device*” OR “brace*” OR crutch* OR “motorized scooter*” OR “hip protector*” OR “mobility device*” OR “mobility product*” OR “grab bar*” OR rail* OR ramp* OR “bathroom aid*” OR “bath lift*” OR “bed lift*” OR “lifting device*” OR “lifting product*” OR “lifting technolog*” OR “grasping tool*” OR “reach extender*” OR “eating utensil*” OR “personal alarm*” OR “pencil grip*” OR “pill organizer*” OR footwear* OR tricycle* OR seat* OR toilet* OR bathroom* OR cushion* OR pillow* OR bed* OR shower* OR door* OR (device AND dressing*) OR doorway* OR hallway* OR electrotherapy OR (“assistive device*” AND pen) OR (“assistive device*” AND print) OR (“assistive device*” AND hearing) OR “hearing aid*” OR “cochlear implant*” OR amplifier* OR “volume control telephone” OR “TTY” OR teletype OR “TTD” OR “telecommunications device for the deaf” OR “text telephone*” OR “message relay service*” OR (“hearing AND loop”) OR flasher* OR decoder* OR “closed caption” OR “closed caption television” OR “fm amplifier*” OR (“assistive device*” AND “infra-red”) OR (“assistive device*” AND infrared) OR acoustic OR “visual alarm*” OR “vibrating alarm*” OR “closed caption*” OR software* OR (“assistive device*” AND	338		

vision) OR magnifier* OR braille OR “talking book*” OR “portable note-taker*” OR “screen reader*” OR “voice recognition” OR daisy OR “communication software*” OR spectacle* OR glass* OR “contact lens*”) AND TITLE-ABS-KEY (“older adult*” OR “aging population*” OR elder* OR senior* OR “old people” OR “older people” OR aged OR “frail elder*”) AND TITLE-ABS-KEY (informal OR “informal care” OR “informal caregiv*” OR “caregiver burden”) AND TITLE-ABS-KEY (hour* OR time)			
((“Self-Help Devices”) AND Caregivers AND (Aged OR “Frail Elderly”) AND (hour* OR time OR “time spent”))		37	
AB ((“assistive device*” AND mobility) OR “assistive technolog*” OR “assistive device*” OR “assistive product*” OR gerontechnolog* OR “self-help device*” OR “self help device*” OR “selfhood device” OR “home modification*” OR “mobility aid*” OR “prosth*” OR “ortho*” OR wheelchair* OR cane* OR stick* OR seat* OR walker* OR “walking frame*” OR scooter* OR rollator* OR chair* OR bath* OR detector* OR gps OR “supportive device*” OR “brace*” OR crutch* OR “motorized scooter*” OR “hip protector*” OR “mobility device*” OR “mobility product*” OR “grab bar*” OR rail* OR ramp* OR “bathroom aid*” OR “bath lift*” OR “bed lift*” OR “lifting device*” OR “lifting product*” OR “lifting technolog*” OR “grasping tool*” OR “reach extender*” OR “eating utensil*” OR “personal alarm*” OR “pencil grip*” OR “pill organizer*” OR footwear* OR tricycle* OR seat* OR toilet* OR bathroom* OR cushion* OR pillow* OR bed* OR shower* OR door* OR (device AND dressing*) OR doorway* OR hallway* OR electrotherapy OR (“assistive device*” AND pen) OR (“assistive device*” AND print) OR (“assistive device*” AND hearing) OR “hearing aid*” OR “cochlear implant*” OR amplifier* OR “volume control telephone” OR “TTY” OR teletype OR “TTD” OR “telecommunications device for the deaf” OR “text telephone*” OR “message relay service*” OR (“hearing AND loop”) OR flasher* OR decoder* OR “closed caption” OR “closed caption television” OR “fm			53

amplifier*” OR (“assistive device*” AND “infra-red”) OR (“assistive device*” AND infrared) OR acoustic OR “visual alarm*” OR “vibrating alarm*” OR “closed caption*” OR software* OR (“assistive device*” AND vision) OR magnifier* OR braille OR “talking book*” OR “portable note-taker*” OR “screen reader*” OR “voice recognition” OR daisy OR “communication software*” OR spectacle* OR glass* OR “contact lens*”)) AND AB (“Older adult*” OR “Aging population*” OR Elder* OR Senior* OR “Old people” OR “Older people” OR Aged OR “frail elder*”) AND AB (Informal OR “Informal care” OR “Informal caregiv*” OR “caregiver burden”) AND AB (hour* OR time)			
Total	528		

Appendix D

Data extraction tables

Table D - 1: Data extraction table for Research Question 1

Table 1: Characteristics of eligible studies for Question 1, AD and LS						
Author, year	Population characteristics	Study Design	Exposure Assessment	Outcome Assessment	Covariates	Results
In-sook, L., 2008[133]	n = 601 Male: 43.6% Female: 56.4% Mean age: 74.2, SD = 34.71 Location: Gyeongnam, South Korea Setting: Community Funding: Not reported.	Cross-sectional	The use of assistive devices	Life Satisfaction Elderly Life Satisfaction Scale	Age Sex Income Marital status Education Region of residence Living arrangements (living alone versus with others) Subjective health ADLs/IADLs Health related quality of life Satisfaction with device	No association between the use of assistive devices and life satisfaction ($\hat{\beta} = 0.014$, $p < 0.05$, not significant).
Leung, V. et al., 2005[133]	n = 5,395 Male: Not reported. Female: Not reported. Mean age: Not reported. Location: Canada Setting: community Funding: The National	Cross-sectional	Wheelchair use	Life satisfaction Andrew and Withey Life Satisfaction Scale adapted by Alex Michalos	None	Life satisfaction levels Among persons with wheelchair was lower than the persons without-wheelchair ($X^2 = 68.5$, $p<0.0001$).

	Health Research and Development Program (NHRDP) of Health Canada, Pfizer Canada Inc., NHRDP, Bayer Inc., The British Columbia Health Research Foundation, CIHR					

Table D - 2: Data extraction table for Research Question 2

Table 2: Characteristics of eligible studies for Question 2, AD and Informal caregiving hours						
Author, year	Population characteristics	Study Design	Exposure Assessment	Outcome Assessment	Covariates	Results
Agree et al., 2005[14]	n = 4,006 Male: 53.4% Female: 64.6% Mean age: Not reported. Location: United States Setting: Community Source of Funding: National Institute on Aging	Cross-sectional	Assistive device use	Informal caregiving hours	Number of ADLs with severe difficulty Insurance Poverty Cognitive impairment Age Education Race Gender Marital status Living environment Access to healthcare	AD use was significantly associated with reductions in informal care hours, especially for those who were unmarried (AD use $\hat{\beta} = 0.14$, $p < 0.01$; Informal care hours $\hat{\beta} = -40.17$, $p < 0.01$), better educated (AD use $\hat{\beta} = 0.12$, $p < 0.05$; Informal care hours $\hat{\beta} = -15.36$, $p < 0.01$) or had better

						cognitive abilities (AD use $\hat{\beta} = -0.17$, $p < 0.01$; Informal care hours $\hat{\beta} = 83.77$, $p < 0.01$).
Hoenig et al., 2003[14]	N= 2,638 Male: Not reported. Female: Not reported. Mean age: Not reported. Location: United States Setting: Community Funding: American Federation for Aging Research; National Institutes of Health, National Institute on Aging, Duke University, Claude D. Pepper Older Americans Independence Center	Cross-sectional	The use of assistive devices	Informal caregiving hours	ADLs impairment Insurance Income Cognitive impairment Chronic conditions Age Education Race Gender Missing hours of help Hospitalizations	Those who used any technological assistance, either for some or for all of basic ADLs impairments, reported 3.8 fewer hours of help per week ($\hat{\beta} = - 3.8$, $p = 0.008$) than did those who used no technological assistance.

Appendix E

AXIS scoring

In this scoring directly adapted from Moskalewicz et al., the maximum total score achievable is 19 instead of 20.[126] The minimal score of zero, on the other hand, remains unchanged.[126]

Table E - 1: AXIS Scoring adapted from Moskalewicz et al.[126]

Questions 1 - 9, 10-12, 15-19, 20	Yes = 1 point each No or Don't Know = 0 points each
Question 9	Yes or not applicable = 1 No = 0
Question 13 and 14	If 13 is No, then 14 is considered not applicable/not scored = 1 point If 13 is Yes, and 14 is Yes = 1 point If 13 is Yes, and 14 is No = 0 point If 13 is Don't Know then 14 is deemed not applicable/not scored = 0 point
Question 19	No = 1 point each Yes or Don't Know = 0 points each

Appendix F

AXIS assessment

Table F - 1: AXIS Assessment

	#	Questions	Studies from Research Question 1		Studies from Research Question 2	
			Leung et al.	In-sook et al.	Agree et al.	Hoenig et al.
Introduction	1	Were the aims/objectives of the study clear?	Y - 1	Y - 1	Y - 1	Y - 1
Methods	2	Was the study design appropriate for the stated aim(s)?	PY - 0.5	Y - 1	Y - 1	Y - 1
	3	Was the sample size justified?	Y - 1	N - 0	Y - 1	Y - 1
	4	Was the target/reference population clearly defined? (Is it clear who the research was about?)	Y - 1	Y - 1	Y - 1	Y - 1
	5	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	Y - 1	Y - 1	Y - 1	Y - 1
	6	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	Y - 1	Y - 1	Y - 1	Y - 1

	7	Were measures undertaken to address and categorize non-responders?	Y - 1	N - 0	Y - 1	Y - 1
	8	Were the risk factor and outcome variables measured appropriate to the aims of the study?	Y - 1	Y - 1	Y - 1	Y - 1
	9	Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialled, piloted, or published previously?	Y - 1	Y - 1	N/A - 1	N/A - 1
	10	Is it clear what was used to determined statistical significance and/or precision estimates? (e.g., p-values, confidence intervals)	Y - 1	Y - 1	Y - 1	Y - 1
	11	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	Y - 1	Y - 1	Y - 1	Y - 1
Results	12	Were the basic data adequately described?	Y - 1	Y - 1	Y - 1	Y - 1
	13	Does the response rate raise concerns about non-response bias?	N - 1*	DK - 0	N - 1*	Y - 1
	14	If appropriate, was information about non-responders described?	N	N	N	Y

	15	Were the results internally consistent?	Y - 1	Y - 1	Y - 1	Y - 1
	16	Were the results presented for all the analyses described in the methods?	Y - 1	Y - 1	Y - 1	Y - 1
Discussion	17	Were the authors' discussions and conclusions justified by the results?	N - 0	Y - 1	Y - 1	Y - 1
	18	Were the limitations of the study discussed?	PY - 0.5	Y - 1	Y -1	Y - 1
Other	19	Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?	N - 1*	DK - 0	N - 1*	DK - 0
	20	Was ethical approval or consent of participants attained?	DK - 0	DK - 0	DK - 0	Y - 1
Total			16	14	18	18
Mean appraisal score			Research Question 1	16	Research Question 2	18
Key: Y = "Yes", N = "No", DK = "Don't know"						
*Item is reverse scored (i.e., no is a positive)						

Appendix G

Chapter 4: Full model examining the association between AD use and the change in life satisfaction over time

$$\begin{aligned}(LS\ Follow\ up_{i,j} - LS\ Baseline_{i,j})\\ &= \beta_0 + \beta_1 ADuse_i + \beta_2 Sex_i + \beta_3 Age_i + \beta_4 Education_i + \beta_5 Income_i\\ &+ \beta_6 Ethnicity_i + \beta_7 Marital\ status_i + \beta_8 Living\ arrangement_i\\ &+ \beta_9 Physical\ health_i + \beta_{10} Chronic\ conditions_i + \beta_{11} ADLs/IADLs_i\\ &+ \beta_{12} Injury_i + \beta_{13} Depressive\ symptoms_i + \beta_{14} Formal/Informal\ care_i\\ &+ \beta_{15} FSS_i + \varepsilon_i\end{aligned}$$

Where:

Y_i is unknown and observed continuous outcome "LS Follow up - LS Baseline" for the ith subject;

X_{1i} is the observed predictor variable for "ADuse" for the ith subject;

$X_{2i}, X_{3i}, X_{4i}, X_{5i}, X_{6i}, X_{7i}, X_{8i}, X_{9i}, X_{10i}, X_{11i}, X_{12i}, X_{13i}, X_{14i}, X_{15i}$ are the observed predictor variables for "Age", "Education", "Income", "Ethnicity", "Marital status", "Living arrangement", "Physical Health", "Chronic conditions", "ADLs/IADLs", "Injury", "Depressive symptoms", "Formal/informal care", and "FSS"for the ith subject;

β_0 is the fixed unknown intercept;

β_1 is the fixed unknown slope of "ADuse";

ε_i is the unknown random noise where $\varepsilon_i \overset{iid}{\sim} N(0, \sigma^2)$ with constant variance σ^2; and for any $i \neq j, (X_i, Y_i) \perp (X_j, Y_j)\ and\ \varepsilon_i \perp X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}$

Appendix H

Chapter 4: Model diagnostics of the multiple linear regression model in the Tracking and Comprehensive cohorts

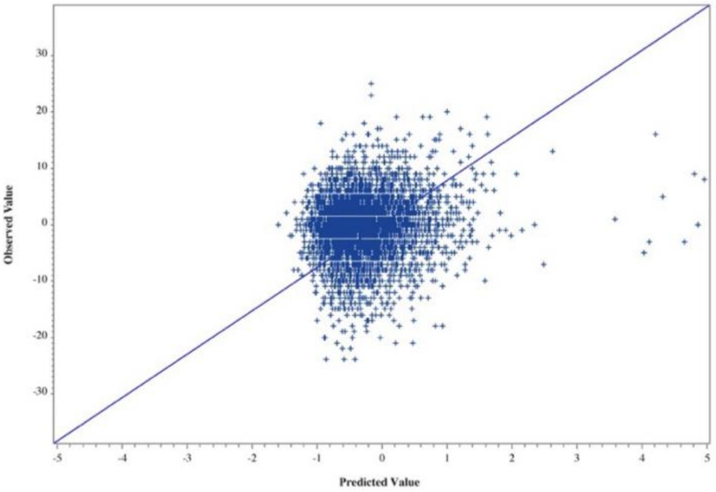

Figure H - 1: Model fit plot for predicted versus observed outcome in the Tracking cohort

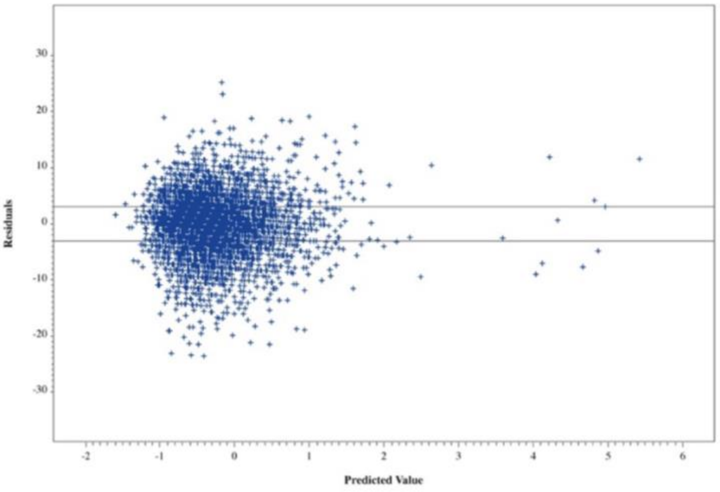

Figure H - 2: Residuals plot for residuals versus predicted outcome in the Tracking cohort

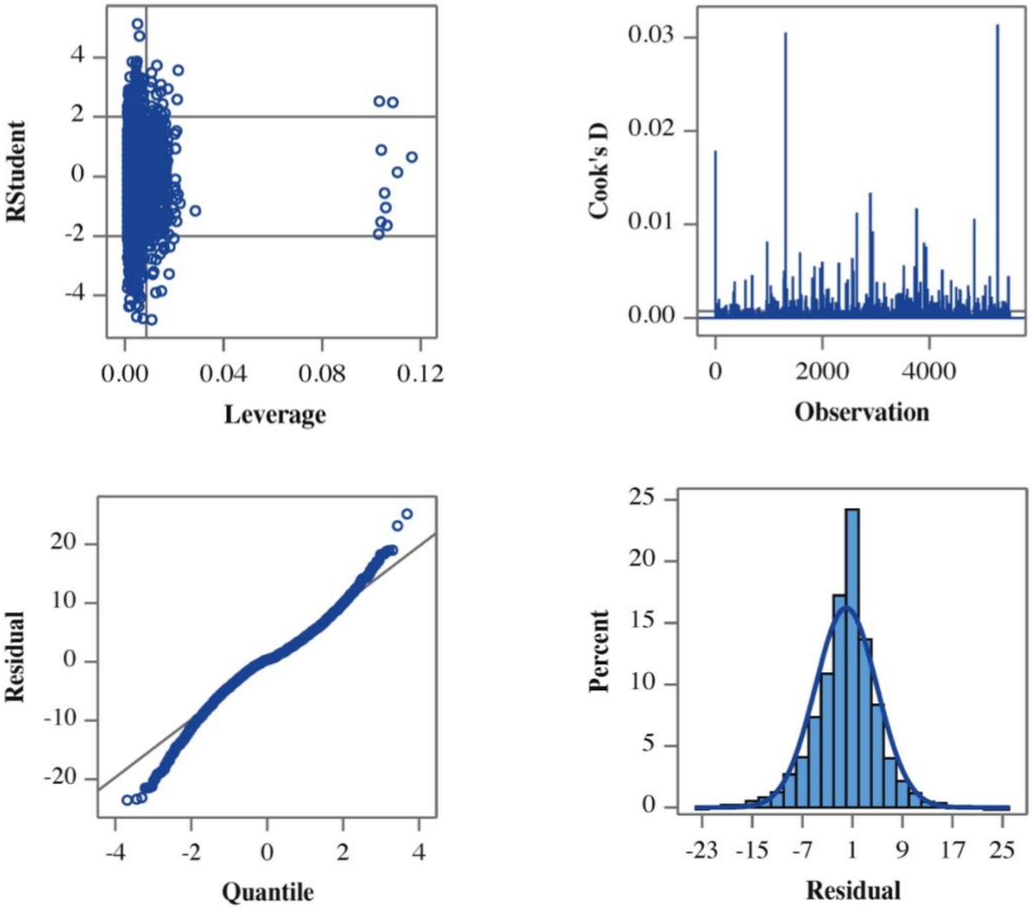

Figure G - 3: Influential observations and normality plots in the Tracking cohort

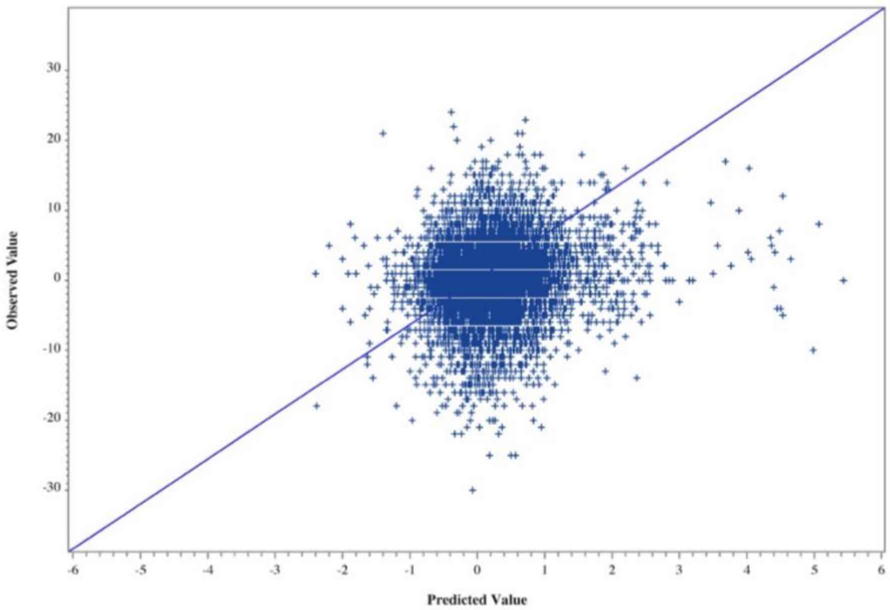

Figure H - 4: Model fit plot for predicted versus observed outcome in the Comprehensive cohort

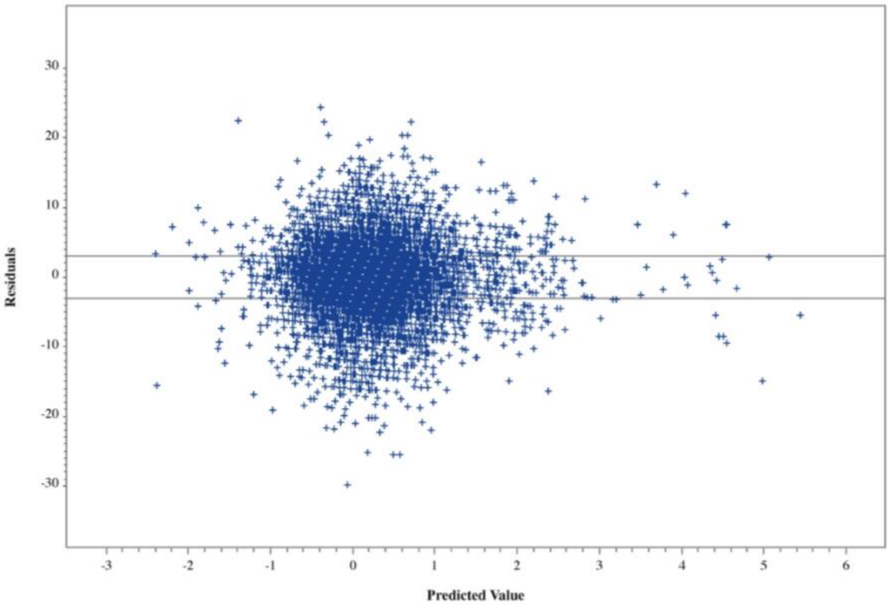

Figure H - 5: Residuals versus predicted outcome plot in the Comprehensive cohort

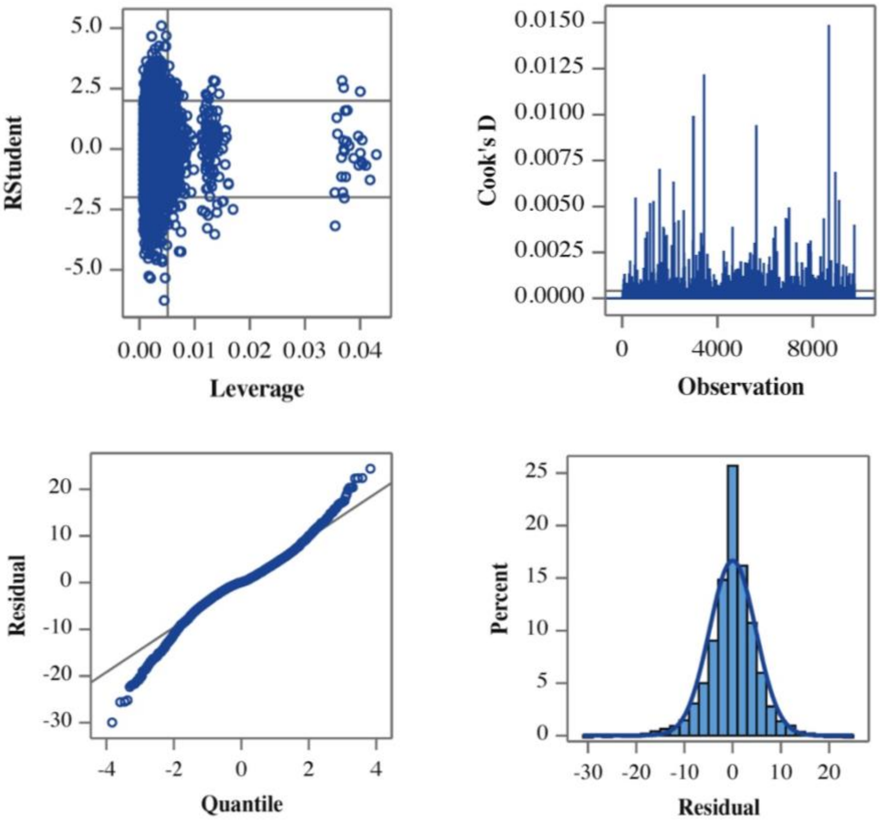

Figure G - 6: Influential observations and normality plots in the Comprehensive cohort

Appendix I

Chapter 4: Bivariate analysis of missing data in the Tracking and Comprehensive cohorts

Table I - 1: Proportions of participants with missing and complete data on life satisfaction (follow-up) and assistive device use (baseline) in the Tracking cohort

	Life satisfaction at follow-up (%)			
Assistive device use at baseline	Missing data	Complete data	X^2	P-value
Assistive device use	47.14	38.16	9.65	0.0019
No assistive device use	52.86	61.84		

Table I - 2: Proportions of participants with missing and complete data on assistive device use (baseline) and life satisfaction (follow-up) in the Tracking cohort

	Assistive device at baseline Mean (SD)		
	Missing data	Complete data	P-value
Life satisfaction at baseline	4512.83 (6622.80)	3325.86 (6622.80)	0.03
Life satisfaction at follow-up	3282.71 (6440.28)	3235.91 (6440.28)	0.93

Table I - 3: Proportions of participants with missing and complete data on life satisfaction (follow-up) and assistive device use (baseline) in the Comprehensive cohort

	Life satisfaction at follow-up (%)			
Assistive device use at baseline	Missing data	Complete data	X^2	P-value
Assistive device use	46.15	38.02	6.4215	0.0113
No assistive device use	53.85	61.98		

Table I - 4: Proportions of participants with missing and complete data on assistive device use (baseline) and life satisfaction (follow-up) in the Comprehensive cohort

	Assistive device at baseline Mean (SD)		
	Missing data	Complete data	P-value
Life satisfaction at baseline	8182.00 (4542.58)	5580.03 (4542.58)	0.25
Life satisfaction at follow-up	5600.33 (5536.51)	5555.49 (5536.51)	0.98

Appendix J

Chapter 4: Comparison of LS distributions among participants included in the analysis versus participants not included in the analysis in Tracking and Comprehensive cohorts

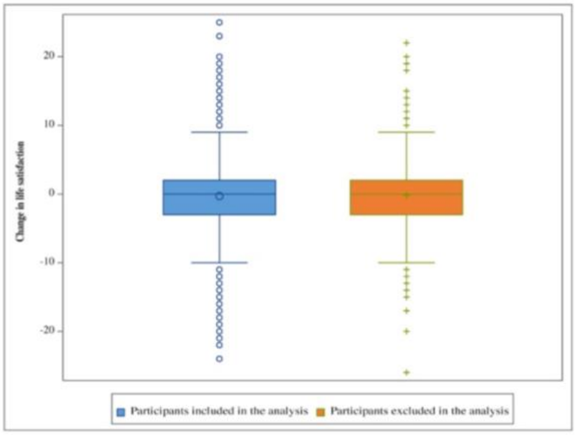

Figure J - 1: Comparison of LS distributions (boxplot) across participants included in the analysis versus participants excluded in the analysis in the Tracking cohort

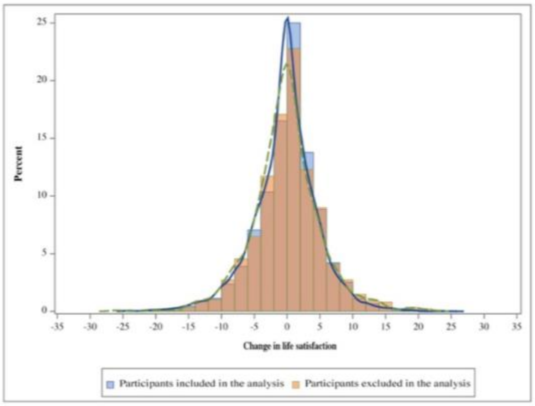

Figure J - 2: Comparison of LS distributions (overlay of histograms) across participants included in the analysis versus participants excluded in the analysis in the Tracking cohort

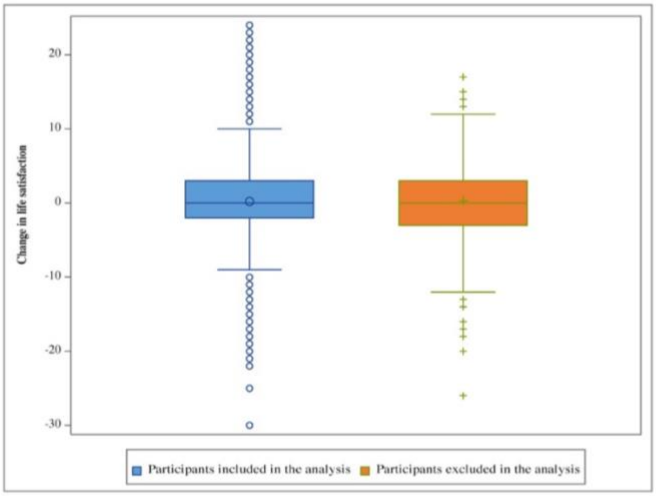

Figure J - 3: Comparison of LS distributions (boxplot) across participants included in the analysis versus participants excluded in the analysis in the Comprehensive cohort

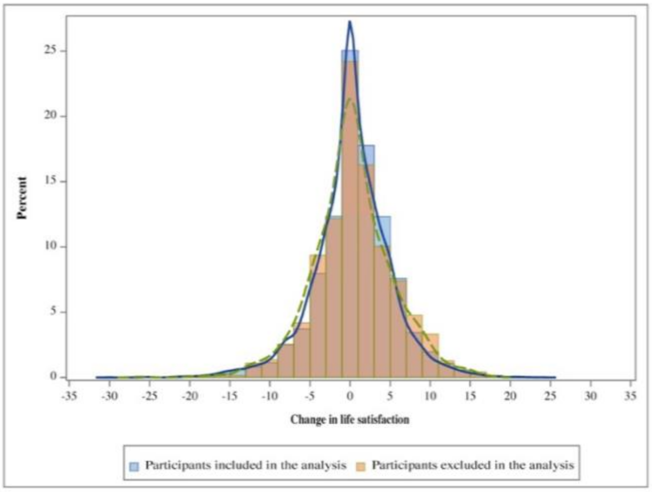

Figure J - 4: Comparison of LS distributions (overlay of histograms) across participants included in the analysis versus participants excluded in the analysis in the Comprehensive cohort

Appendix K

Chapter 3: Comparison of AD use distributions among participants included in the analysis versus participants excluded from the analysis in Tracking and Comprehensive cohorts

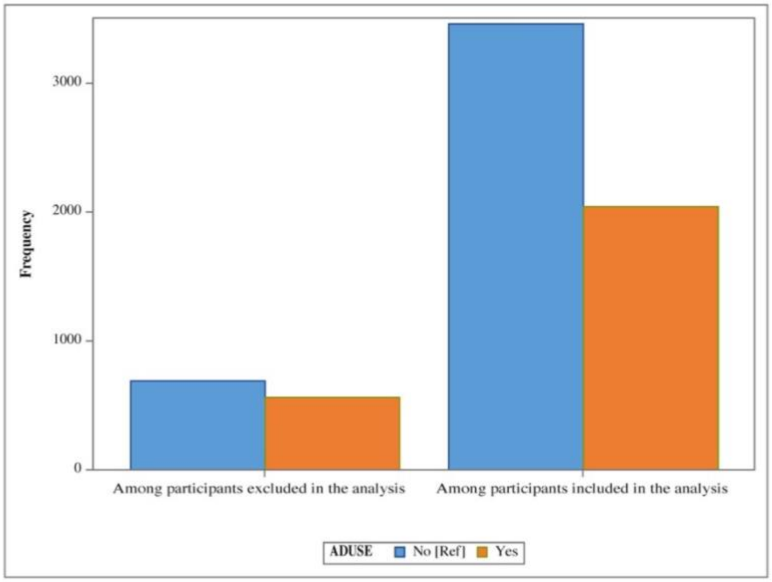

Figure K - 1: AD use among participants included in the analysis versus those excluded from the analysis in the Tracking cohort

AD use	Participants included in the analysis (%)	Participants excluded in the analysis (%)	X^2	P-value
Yes	37.11	44.90	26.11	<.0001
No	62.89	55.10		

Table K - 1: Data table for the distributions of AD use among participants included in the analysis versus those excluded from the analysis in the Tracking cohort

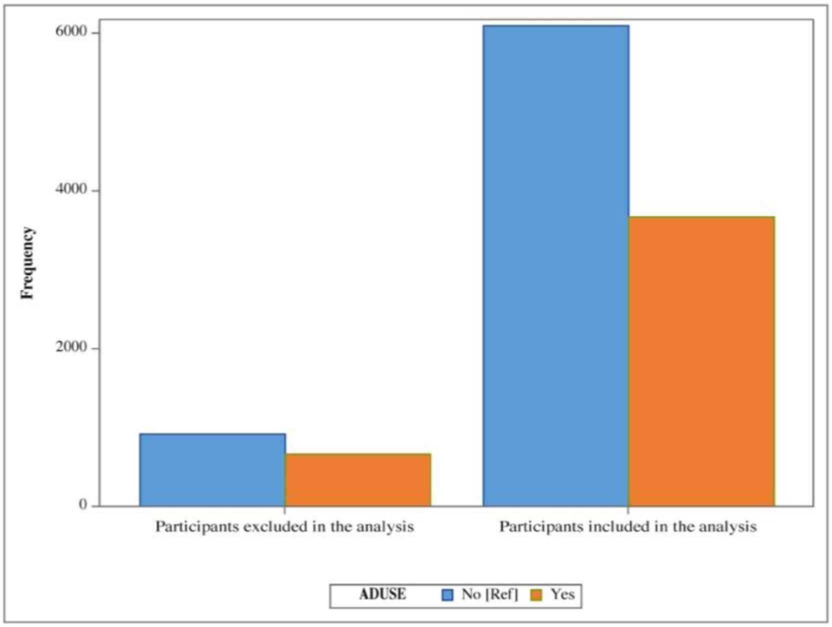

Figure K - 2: AD use among participants included in the analysis versus those excluded from the analysis in the Comprehensive cohort

AD use	Participants included in the analysis (%)	Participants excluded in the analysis (%)	X^2	P-value
Yes	37.58	41.94	10.92	0.0009
No	62.42	58.06		

Table K - 2: Data table for the distributions of AD use among participants included in the analysis versus those excluded from the analysis in the Comprehensive cohort

Appendix L

Chapter 5: Full model examining the association between AD use and the change in informal caregiving hours received

$$\begin{aligned}(Change\ in\ informal\ caregiving\ hours_{i,j})\\ &= \beta_0 + \beta_1 ADuse_i + \beta_2 Sex_i + \beta_3 Age_i + \beta_4 Education_i + \beta_5 Income_i\\ &+ \beta_6 Ethnicity_i + \beta_7 Marital\ status_i + \beta_8 Living\ arrangement_i\\ &+ \beta_9 Physical\ health_i + \beta_{10} Chronic\ conditions_i + \beta_{11} ADLs/IADLs_i\\ &+ \beta_{12} Injury_i + \beta_{13} Depressive\ symptoms_i + \beta_{14} FSS_i + \varepsilon_i\end{aligned}$$

Where:

Y_i is unknown and observed continuous outcome “Change in informal caregiving hours$_{i,j}$” for the ith subject;

X_{1i} is the observed predictor variable for “ADuse” for the ith subject;

$X_{2i}, X_{3i}, X_{4i}, X_{5i}, X_{6i}, X_{7i}, X_{8i}, X_{9i}, X_{10i}, X_{11i}, X_{12i}, X_{13i}, X_{14i}$ are the observed predictor variables for “Age”, “Education”, “Income”, “Ethnicity”, “Marital status”, “Living arrangement”, “Physical Health”, “Chronic conditions”, “ADLs/IADLs”, “Injury”, “Depressive symptoms”, and “FSS” for the ith subject;

β_0 is the fixed unknown intercept;

β_1 is the fixed unknown slope of “ADuse”;

ε_i is the unknown random noise where $\varepsilon_i \overset{iid}{\sim} N(0, \sigma^2)$ with constant variance σ^2; and for any $i \neq j, (X_i, Y_i) \perp (X_j, Y_j)\ and\ \varepsilon_i \perp X_{1,} X_{2,} X_{3,} X_{4,} X_{5,} X_{6,} X_{7,} X_{8,} X_{9,} X_{10,} X_{11,} X_{12,} X_{13,} X_{14}$

Appendix M

Chapter 5: Model diagnostics in the Tracking and Comprehensive cohorts

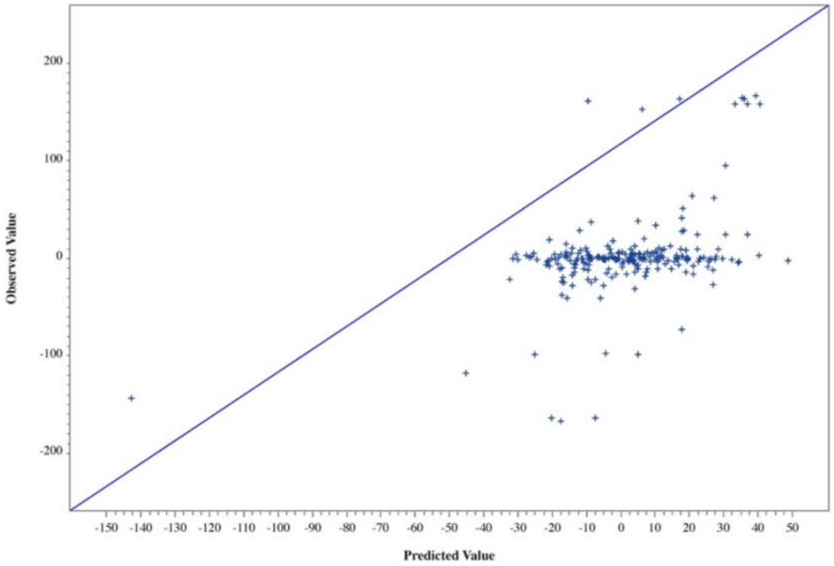

Figure M - 1: Predicted versus observed outcome in the Tracking cohort

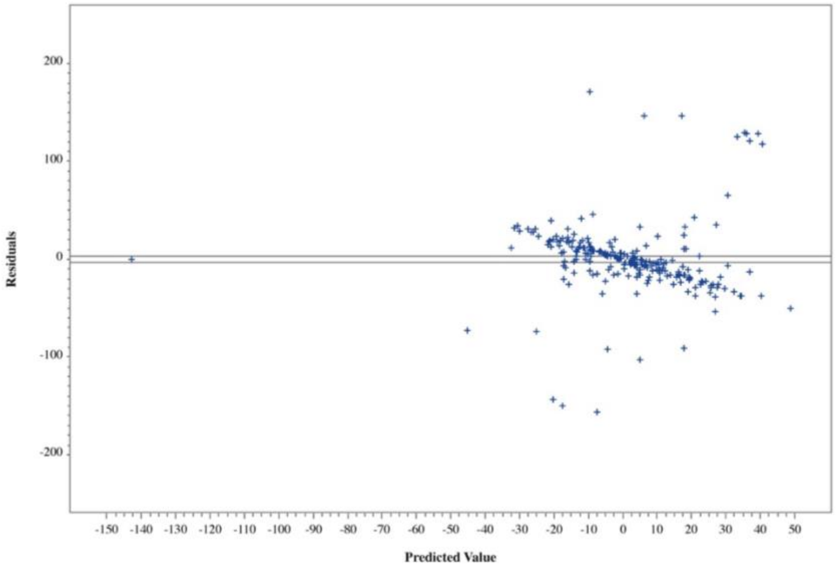

Figure M - 2: Residuals versus predicted outcome in the Tracking cohort

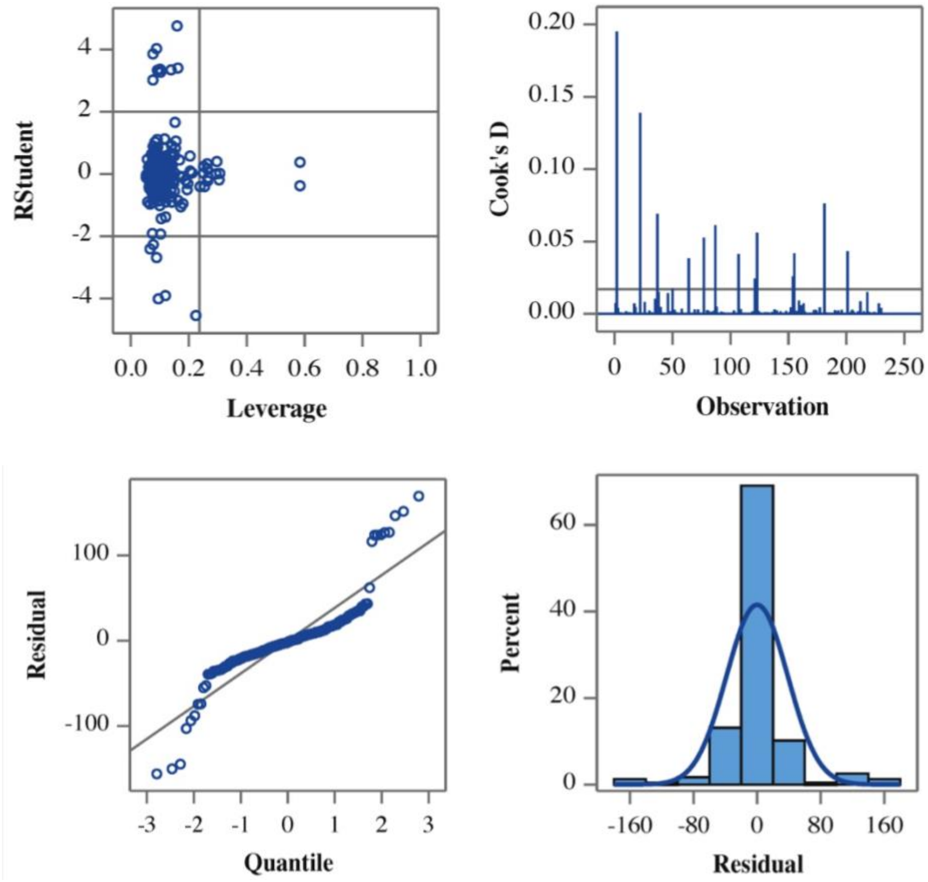

Figure M - 3: Influential observations and normality plots in the Tracking cohort

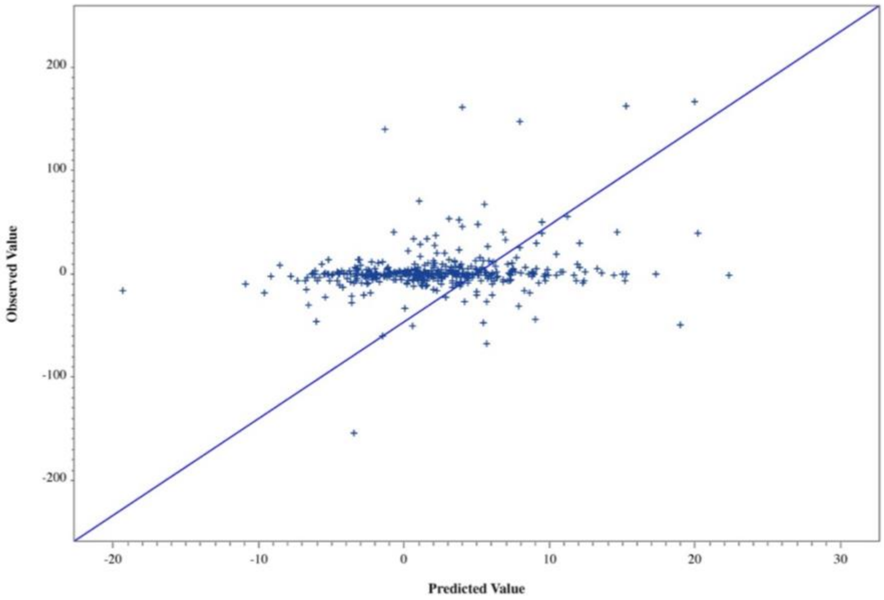

Figure M - 4: Predicted versus observed outcome in the Comprehensive cohort

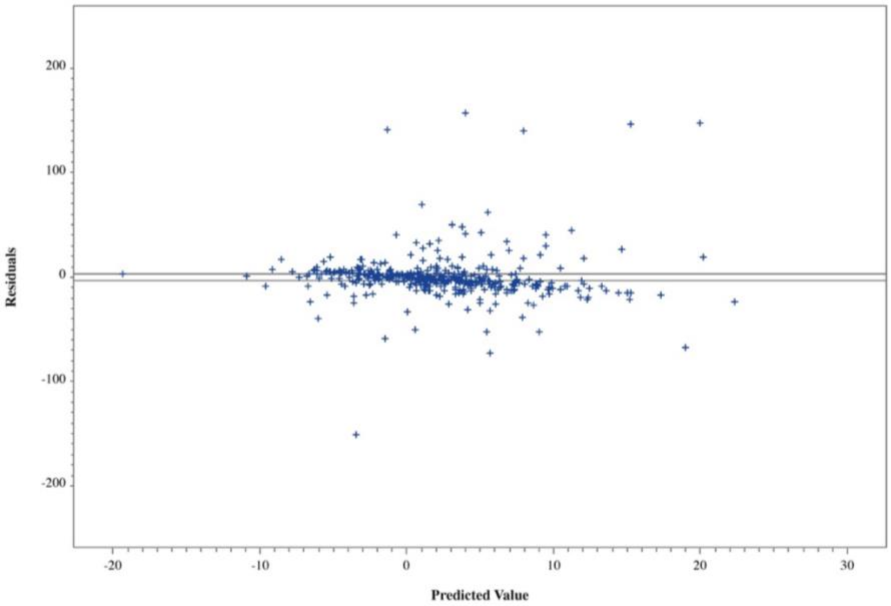

Figure M - 5: Residuals versus predicted outcome plot in the Comprehensive cohort

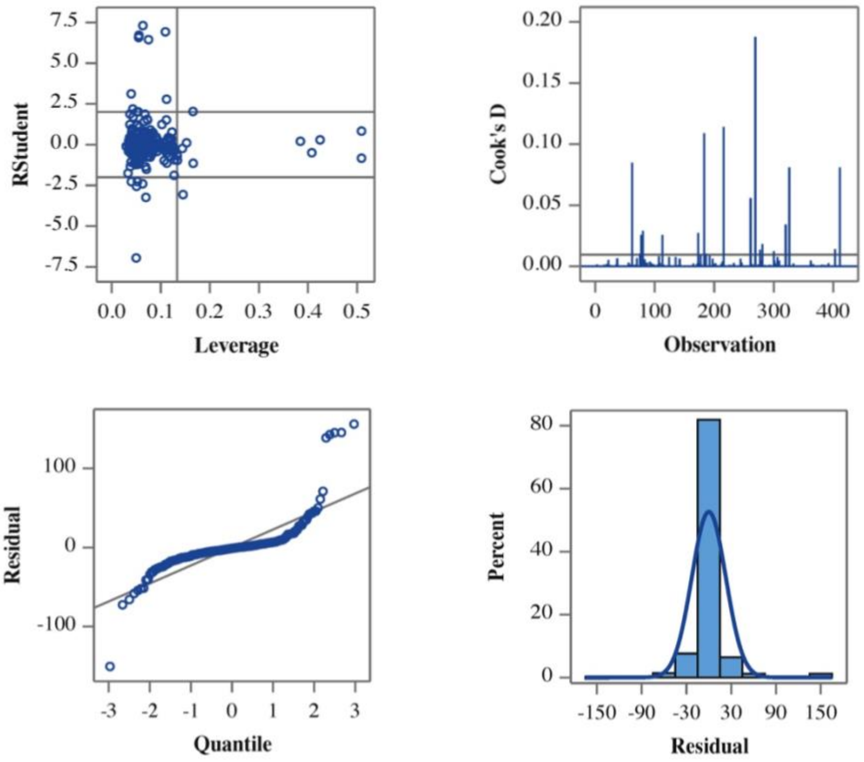

Figure M - 6: Influential observations and normality plots in the Comprehensive cohort

Appendix N

Chapter 5: Model diagnostics in the Tracking and Comprehensive cohorts with the exclusion of outliers

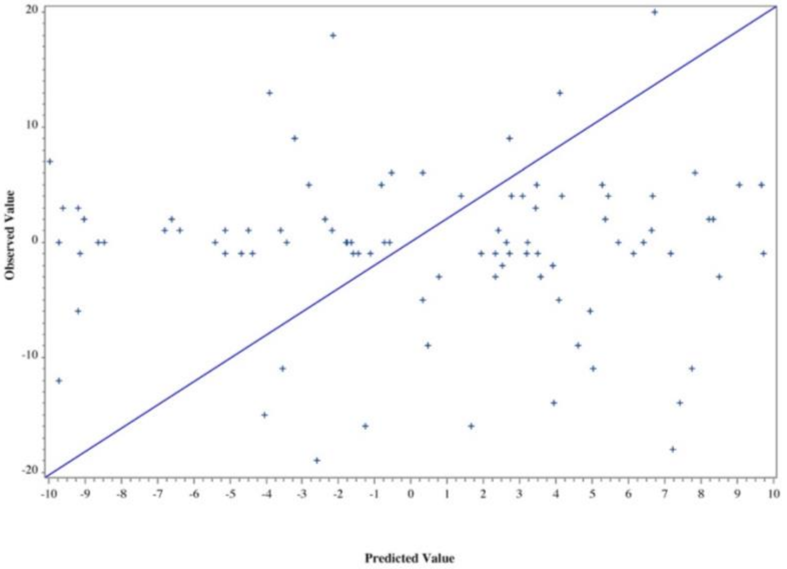

Figure N - 1: Predicted versus observed outcome in the Tracking cohort

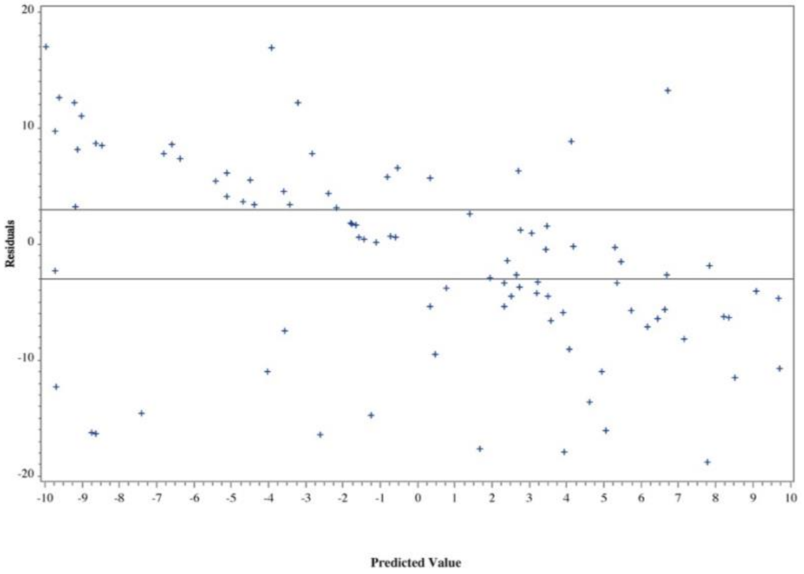

Figure N - 2: Residuals versus predicted outcome in the Tracking cohort

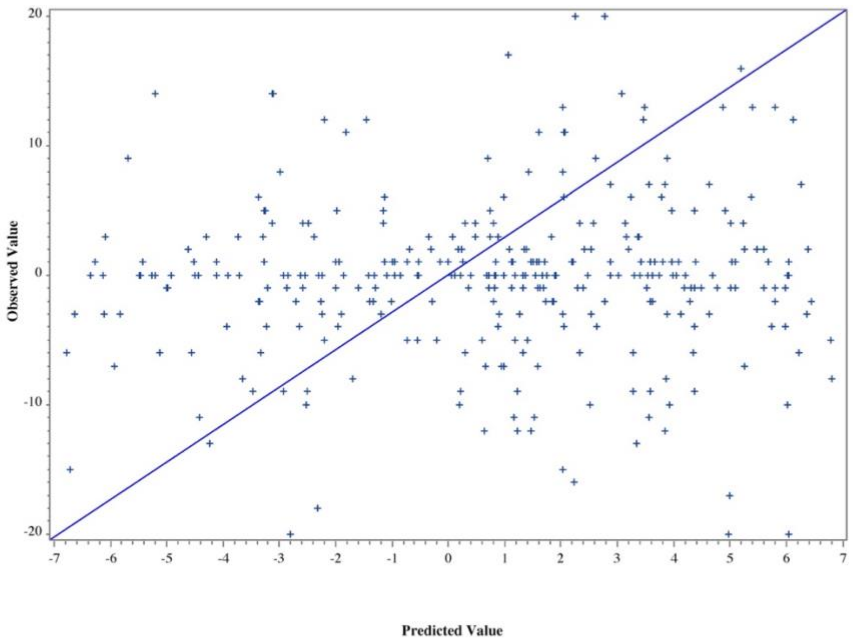

Figure N - 3: Predicted versus observed outcome in the Comprehensive cohort

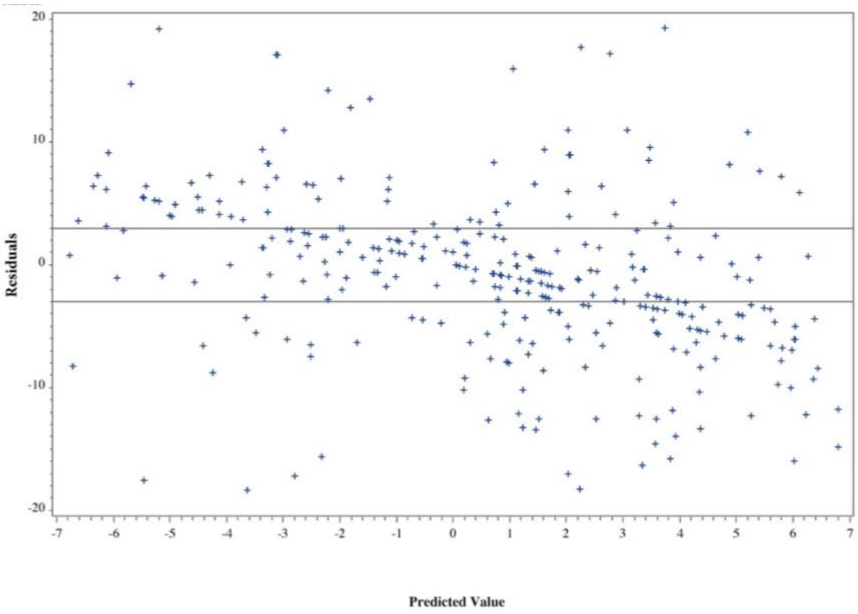

Figure N - 4: Residuals versus predicted outcome plot in the Comprehensive cohort

Appendix O

Chapter 5: Bivariate analysis of missing data in the Tracking and Comprehensive cohorts

Table O - 1: Proportions of participants with missing and complete data on informal caregiving hours (follow-up) and assistive device use (baseline) in the Tracking cohort

	Informal caregiving hours received at follow-up (%)			
Assistive device use at baseline	Missing data	No Missing data	X^2	P-value
Assistive device use	35.24	52.92	135.86	<.0001
No assistive device use	64.76	47.08		

Table O - 2: Proportions of participants with missing and complete data on assistive device use (baseline) and informal caregiving hours (follow-up) in the Tracking cohort

Mean (SD)	Assistive device at baseline		
	Missing data	No Missing data	P-value
Informal caregiving hours received at follow-up	302.17 (629.33)	636.78 (629.33)	0.11

Table O - 3: Proportions of participants with missing and complete data on informal caregiving hours (follow-up) and assistive device use (baseline) in the Comprehensive cohort

	Informal caregiving hours received at follow-up (%)			
Assistive device use at baseline	Missing data	No Missing data	X^2	P-value
Assistive device use	34.36	55.28	314.17	<.0001
No assistive device use	65.64	44.72		

Appendix P

Chapter 5: Comparison of the distributions of the change in informal caregiving hours among participants included versus excluded from the analysis in Tracking and Comprehensive cohorts

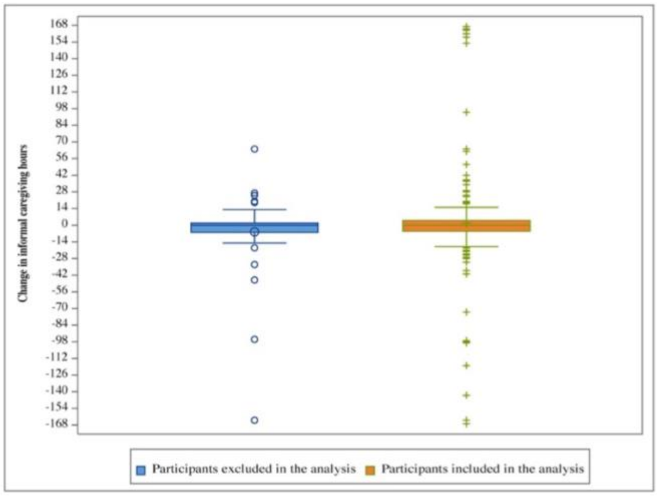

Figure P - 1: Boxplots comparing the distributions of the change in informal caregiving hours across participants included versus excluded from the analysis in the Tracking cohort

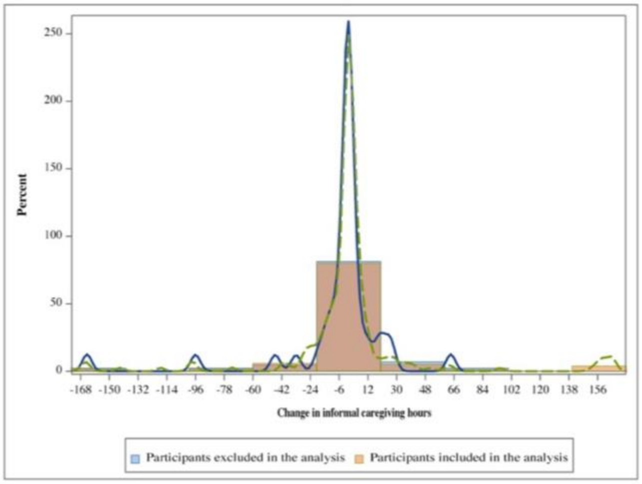

Figure P - 2: Overlay of histograms comparing the distributions of the change in informal caregiving hours across participants included versus excluded from the analysis in the Tracking cohort

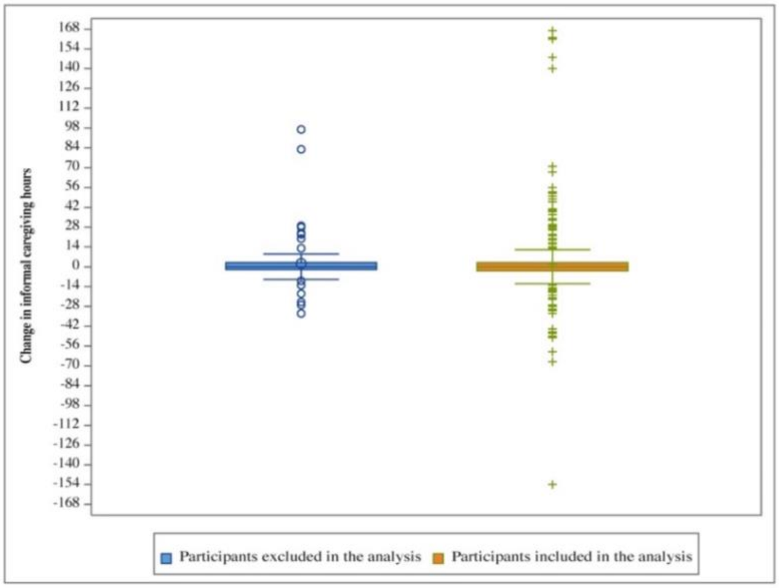

Figure P - 3: Boxplots comparing the distributions of the change in informal caregiving hours across participants included versus excluded from the analysis in the Comprehensive cohort

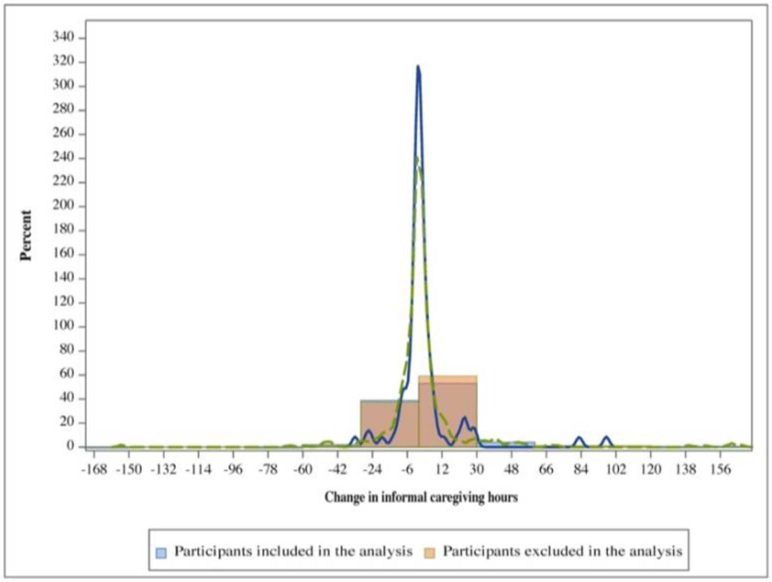

Figure P - 4: Overlay of histograms comparing the distributions of the change in informal caregiving hours across participants included versus excluded from the analysis in the Comprehensive cohort

Appendix Q

Chapter 5: Comparison of the distributions of AD use among participants included versus excluded from the analysis in Tracking and Comprehensive cohorts

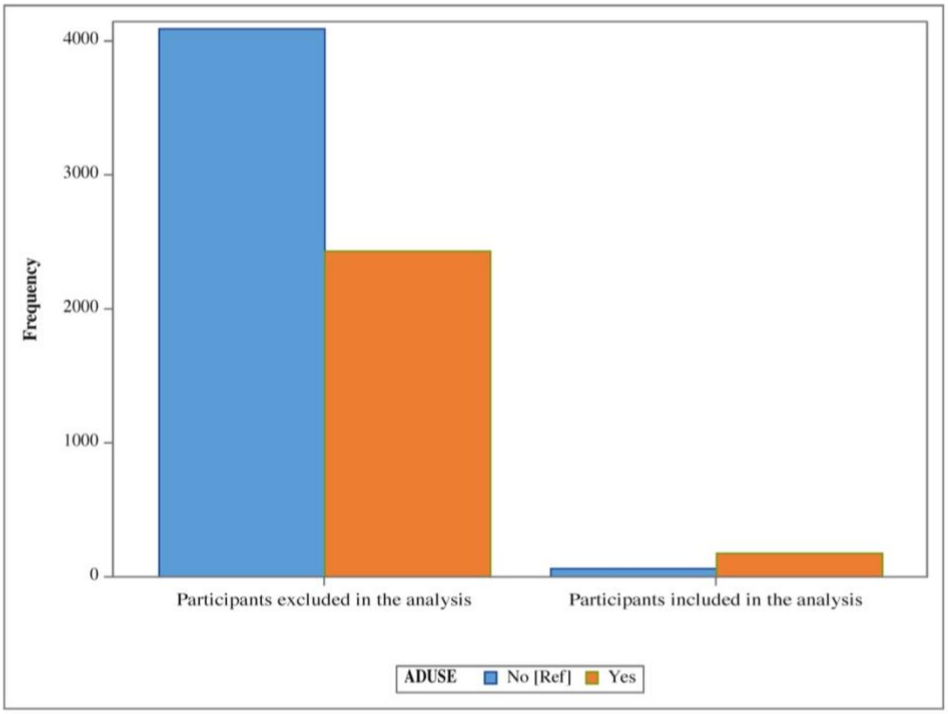

Figure Q - 1: AD use among participants included in the analysis versus excluded from the analysis in the Tracking cohort

AD use	Participants included in the analysis (%)	Participants excluded in the analysis (%)	X^2	P-value
Yes	74.15	37.27	130.78	<.0001
No	25.85	62.73		

Table Q - 1: Data table for the distributions of AD use among participants included in the analysis versus excluded from the analysis in the Tracking cohort

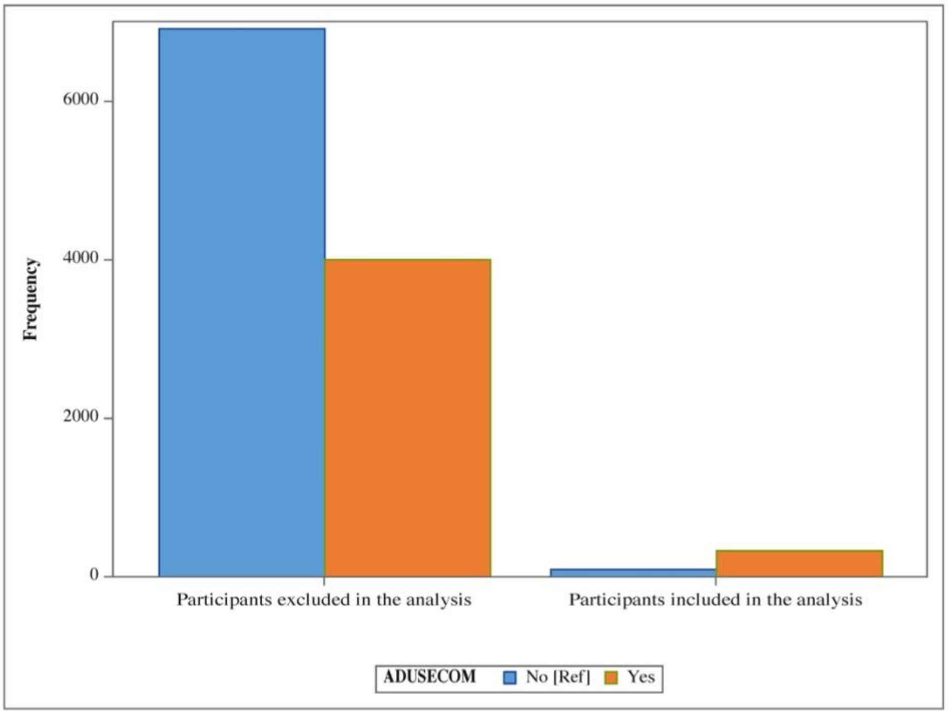

Figure Q - 2: AD use among participants included in the analysis versus those excluded from the analysis in the Comprehensive cohort

AD use	Participants included in the analysis (%)	Participants excluded in the analysis (%)	X^2	P-value
Yes	21.90	63.35	294.25	<.0001
No	78.10	36.65		

Table Q - 2: Data table for the distributions of AD use among participants included in the analysis versus those excluded from the analysis in the Comprehensive cohort