Understanding Longitudinal Changes in The Performance of Activities of Daily Living in Long-Term Care Settings: Trajectories, Transition Patterns, Predictors and Associated Health Outcomes

by

Bonaventure Amandi Egbujie

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Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner:	Dr. Julie Richardson Professor, School of Rehabilitation Science McMaster University
Supervisor(s):	Dr. John Hirdes University Professor, School of Public Health Sciences University of Waterloo
Internal Members:	Dr George Heckman Professor, School of Public Health Sciences University of Waterloo
	Dr Luke Turcotte Assistant Professor, Department of Health Sciences Brock University
Internal-External Member:	Dr Stan Woo Professor, School of Optometry & Vision Science University of Waterloo

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

Bonaventure Amandi Egbujie was the sole author for Chapters 1, 2, 4, 5, 6 and 7 which were written under the supervision of Professor John Hirdes and were not written for publication.

This thesis consists in part of five manuscripts written for publication. Exceptions to sole authorship of material is as follows:

Research presented in Chapter 3

As the lead author, I conceptualized the study question, design, and methodology with guidance from Professor Hirdes. I performed all data analysis and led the interpretation of findings and drafted the initial manuscript with guidance and contribution from Professor Hirdes. My co-authors contributed to interpreting the findings and writing the final manuscript.

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Abstract

With rapid global growth of the aging population and the associated "expansion of morbidity", more people live to experience challenges with performing the usual daily living activities resulting in an increasing need for long-term care (LTC). Understanding the complexities of changes in physical function is essential for the planning and delivery of person-level care that would promote healthy aging and enhance quality of life. This thesis explores the diverse trajectories of change in functional level that occur among LTC residents. It examines the role of individual level factors in these complex changes, with a view to identifying early markers of adverse trajectories and enablers of beneficial trajectories. The ultimate goal of this is to generate evidence that could be used for person-level care planning, health management, and policy development. The thesis is comprised of five empirical studies representing different steps toward the main goal.

Study 1 is a scoping review of existing literature for approaches used to examine longitudinal trajectories of change in physical function. It summarizes evidence of how trajectories of physical function have been modeled over the past 20 years, showing the most frequently applied methods and their outputs. This chapter presents an easy to use, concise summary of the existing functional change modeling approach, highlighting the benefits of each method and the situations where they would most likely be more appropriate. It contributes to our understanding of how physical function trajectory modeling evolved over the years and highlights current gaps in research.

Study 2 provides evidence based on generalized estimating equations to quantify the marginal effect of the COVID-19 pandemic on ADL performance in LTC settings in Canada. This chapter which has already been published with the title, "Functional Decline in Long-Term Care Homes in the First Wave of the COVID-19 Pandemic: A Population-based Longitudinal Study in Five Canadian Provinces", provides an aggregate level comparative analysis of functional decline between the pandemic and pre-pandemic periods. It contributes to the literature on the actual "additional" functional decline that occurred during the pandemic, differentiating this effect from the decline that usually occurs among residents in the setting.

Study 3 presents an analysis of three-year longitudinal trajectories of functional decline in LTC settings using Group-Based Trajectory Modeling (GBTM) technique, which is as form of latent class growth analysis. GBTM was identified through the scoping review in study 1 to be the most appropriate method for answering the research question addressed in this chapter. Four distinct functional decline trajectory subgroups were identified with this modeling approach for the overall population and the sub analytic samples are presented in the associated chapter. Predictors of trajectory group membership were determined as well using binary logistic regression. The study also highlights the value of identifying functional decline trajectory by showing that it predicts future health outcomes like mortality and resource utilization. Prior to this study, there has not been any characterization of the pattern and predictors of longitudinal trajectory of functional decline in among LTC residents in Canada. This study therefore contributes new

knowledge about the multiyear trajectory of functional change followed by residents upon entry into care homes.

Study 4 highlights the multifaceted and complex transition between the different ADL functional levels and transitions out of LTC settings. Study 2 of this thesis provides the aggregate analysis of functional changes associated with a widespread health crisis and, study 3 reports trajectory patterns. However, both do not address the complex dynamic multidirectional changes that occur among residents. This study fills this gap by using multistate Markov transition analysis to capture the complex multidirectional transition between different functional levels (including improvement, decline and remaining unchanged), and transition out of the setting observed during each assessment. The novel contribution of this study is in expanding our knowledge about the transient and terminal transitions that occur concurrent between ADL functional levels and to other health outcomes in LTC setting.

Last, the **5th study** further deepens our understanding of COVID-19's effect on LTC setting. Multistate Markov transition analysis was used to produce evidence of the transitions between ADL functional levels and out of the LTC setting that occurred during COVID-19 pandemic compared to similar transitions in the pre-pandemic period. It advances our previous chapter on Functional Decline in Long-Term Care Homes in the First Wave of the COVID-19 Pandemic, by providing a disaggregated, multidirectional analysis. The study therefore improves existing

knowledge by providing a more granular analysis of the complex effect of the COVID-19 pandemic on the physical function of LTC home residents.

Through evidence generated from this comprehensive series of studies, this thesis expands existing knowledge about changes in the performance of activities of daily living in LTC setting. It adds a nuanced understanding of the complex multidirectional transitions between ADL functional levels and transitions out of the setting. By examining both aggregated and disaggregated measures of functional status, the thesis provides various perspectives with evidence that would allow care providers, health administrators and policy makers to make better decisions about care planning and service provision in LTC. Further, by generating evidence of ADL and other health outcome changes during the COVID-19 pandemic, the thesis contributes additional knowledge that would be useful in planning for future pandemics or similar widespread health crisis. Future work should focus on utilizing this evidence to develop decision support tools to inform personalized care planning, promote healthy aging and enhance the quality of life of older adults.

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This dissertation was made possible through the collective efforts of many, and I am grateful for the support from the individual mentioned and those who may not be explicitly named.

Dedication

To the loving memory of my late parents, Christopher Nnebedum, and Anastasia Akuejeozi Egbujie and sister Jovita Nkiru Okereke. Although you are gone, your life principles and love continue to inspire and motivate me.

Next, to Kachi and Odi who had to endure critical parts of life without me for a while, I hope that this will serve as an inspiration for both of you to always reach greater heights. I love you.

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List of Abbreviations

AB	Alberta
ACP	Advanced care planning
ADL	Activities of Daily Living
ADLH	Activities of Daily Living Hierarchy
ALC	Alternate Level of Care
ALS	Amyotrophic Lateral Sclerosis
ANOVA	Analysis of Variance
APP	Average Posterior Probability
BC	British Columbia
BIC	Bayesian Information Criteria
BMI	Body Mass Index
CAP	Clinical Assessment Protocol
CCRS	Continuing Care Reporting System
CHESS	Changes in Health, End Stage Disease and Signs and Symptoms
CHF	Congestive Heart Failure
CI	Confidence Interval
CIHI	Canadian Institute for Health Information
CINHAL	Cumulated Index to Nursing and Allied Health Literature
CMI	Case-Mix Index
COMPRI	Care complexity prediction instrument
COPD	Chronic Obstructive Pulmonary Disease
COVID-19	Coronavirus Disease 2019
CPS	Cognitive Performance Scale
CTD	Catastrophic Decline
DAD	Discharge Abstract Dataset
DRG	Diagnosis Resource Group
DRS	Depression rating Scale

ED	Emergency Department
ER	Emergency Room
FAQ	Frequently Asked Question
FD	Functional Decline
FIM	Functional Independent Measure
GBTM	Group-Based Trajectory Modeling
GDP	Gross Domestic Product
GEE	Generalized Estimating equation
GMM	Growth Mixture Modeling
HARP	Hospital Admission Risk Prediction
HMTD	Hidden Mixture Transition Distribution
HRS	Health and Retirement Study
IADL	Instrumental Activities of Daily Living
ICF	International Classification of Functioning
ISAR-HP	Identification of Seniors at Risk—Hospitalized Patients
ISE	Index of Social Engagement
LCGA	Latent Class Growth Analysis
LGCA	Latent Growth Class Analysis
LMIC	Low-and-Middle-Income
LSOA	longitudinal study of aging
LTC	Long-term Care
MAPLe	Method for Assigning Priority Levels
MDS	Minimum Data Set
MM	Mixture Model
MS	Multiple Sclerosis
NACRS	National Ambulatory Care Reporting System
NLD	No/Little Decline
OARS	Old American Resources and System
OCC	Odds of Correct Classification

OECD	Organization for Economic Development
ON	Ontario
ORE	Office of Research Ethics
OT	Occupational Therapy
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
PT	Physical Therapy
RAI	Resident Assessment Instrument
RDR	Rapid Decline With recovery
RECORD	Reporting of studies Conducted using Observational Routinely collected health Data
RUG	Resource Utilization Group
SF-36	Short Form Health Survey
SHERPA	Score Hospitalier d'Evaluation du Risque de Perte d' Autonomie
SMAF	Functional Autonomy Measurement System
SOCENG	Social Engagement Scale
SPD	Slow Progressive Decline
SPPB	Short Performance Physical Battery
SSA	Sub Saharan Africa
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TBI	Traumatic Brain Injury
TIA	Transient Ischemic Attack
TRST	Triage Risk Screening Tool
TUG	Time Up and Go
US	United States
UTI	Urinary Tract Infection
WHO	World Health Organization
WHODAS	World Health Organization Disability Assessment Schedule

Chapter 1: General Introduction

1.1. Introduction

As individuals age, they face many challenges that pose substantial threats to healthy aging, affecting their quality of life and the ability to do things they usually enjoy. One such challenge is the loss of functional independence due to a decline in the ability to perform activities of daily living (ADL), clinically described as "*functional decline."* Functional decline is widespread in aging populations, especially long-term care (LTC) residents, partly because the loss of physical function is one of several reasons older adults are placed in institutional care settings (Covinsky, Palmer, et al., 2003; Fortinsky et al., 1999; Sager & Rudberg, 1998; Wolinsky et al., 1993; Yeh et al., 2014). The condition is characterized by the inability to perform basic activities of daily living (ADL) like eating, dressing, and bathing, or instrumental activities of daily living (IADL) like meal preparation and grocery shopping, as a result of decrements in physical, cognitive as well as psychosocial capabilities(Fried et al., 2004; R. Hébert, 1997; Hoogerduijn et al., 2014; Katz et al., 1970; Katz & Akpom, 1976).

Residents typically enter LTC homes with impairment in the performance of ADL(Fong et al., 2012; Gaugler et al., 2007; Hirdes, Poss, et al., 2008; Jette et al., 1992; Palese et al., 2016; Qureshi et al., 2020; Tanuseputro et al., 2017), and over time, worsen, remain the same, or improve with or without intervention(Fedecostante et al., 2016, 2021; Jerez-Roig, de Brito Macedo Ferreira, et

al., 2017; Palese et al., 2016). These multidirectional transitions between different ADL functional states are dynamic and add difficulty to the ongoing management of residents and their future care planning. Positive transitions to better ADL function are infrequent in LTC homes but possible. Negative transitions resulting in a decline to worsened ADL function are more common and predispose residents to harmful consequences that include a higher risk of early mortality, increased hospital admissions, and higher care costs. There is evidence that for particular residents, ADL decline could be delayed, prevented, or even improved sometimes with interventions(Martínez-Velilla et al., 2019; Oida et al., 2003). Strategies that promote positive transitions while mitigating the negative ones will augur well for the residents and the entire health system, including the care providers who often experience burnout associated with the care burden(D. G. Morgan et al., 2002; Pekkarinen et al., 2004; Rai, 2010).

Understanding these dynamic multidirectional transitions and their associated factors is critical to implementing effective strategies to support person-centered care planning and service delivery. Yet very little is documented in the literature about these multidirectional transitions in ADL function in LTC. Also lacking is knowledge of the longitudinal trajectory of change in this ADL function that will allow care planners to anticipate future transitions and apply appropriate health interventions. Residents' ADL function might be improved if future trajectories could be predicted to inform the design of effective early interventions.

A comprehensive study of the complex transitions in ADL function that considers resident and provider-level factors is needed. In addition, there is a need for a systematic method of forecasting and identifying the longitudinal patterns of physical function trajectories that would enable early intervention. This dissertation addresses these knowledge gaps related to ADL transitions and the longitudinal trajectory of functional decline in LTC settings.

1.2. Why Does this Matter?

1.1.1. Consequences of Functional Decline

A decline in physical function is usually associated with several consequences for older adults, irrespective of the setting where they live or receive care. Drame et al. found that a decline in the ability to use the toilet was the most important predictor of the risk of nursing home admission for continuing care(Dramé et al., 2012). Similarly, Hirdes et al. showed that ADL impairment ranked among key predictors of nursing home placement and caregiver distress among home care clients using the Method for Assigning Priority Levels (MAPLe) algorithm(Hirdes, Poss, et al., 2008). Covinsky *et al.* found a significant association between the level of ADL impairment and risk of hospital mortality (0.9% with 0 ADL impairment vs.17.4% with impairment in all ADL items); ADL impairment and nursing home use (3% no ADL impairment vs.33 all ADL impairment); as well as a 50% higher DRG-adjusted hospital cost for patients dependent on all ADL(Covinsky et al., 1997).

Hirdes *et al.* used the Changes in Health, End-Stage Disease, and Signs and Symptoms (CHESS) scale, which included ADL decline, to predict mortality among nursing home residents and other institutionalized older adults(Hirdes et al., 2019). Similarly, Heckman et al. showed that the effect of heart failure on mortality among nursing home residents was strongest for those with low baseline health status that reflected both functional decline and poor cognition(Heckman et al., 2019a).

Decline in ADL performance is also associated with an escalation in the cost of care, especially in LTC settings. Guralnik *et al.* reported a four-fold increment in the annual US healthcare cost for older adults who developed a dependence on at least 1 ADL and received care at home and an almost 10-fold increase in care cost for those who transitioned to institutionalized care(Guralnik et al., 2011). Dai *et al.*(Dai et al., 2017) showed that transitions to more severe ADL states are associated with significantly higher average annual care costs and that those who transition from severe to moderate ADL states cost substantially less to care for (-US$6,045) compared to persons who remain in extreme states of ADL impairment. Available reports show that a substantial percentage of many countries' gross domestic product (GDP) is already spent on long-term care, and it is expected to rise further over the coming years(Crawford, Stoye, and Zaranko, 2021; OECD, 2021). The Figure ranged from 4.1% of GDP in the Netherlands spent on long-term care to 0.1% and 0.2% in Mexico, Chile, Greece, and Turkey(OECD, 2021). These represent substantial expenditures, and a further escalation of these costs would invariably lead to cuts to other equally crucial societal needs. In addition, ADL measures are major factors

included in the Resource Utilization Groups (RUG-III) case-mix system, which predicts resource intensity in LTC homes(B. E. Fries et al., 1994; L. A. Turcotte et al., 2019).

1.1.2. Rising Global Aging Population with Increasing Demand for Long-Term Care

People live longer globally(Kassebaum et al., 2016), and fertility rates are falling in many countries(CIA, 2023; The World Bank, 2023; UNFPA, 2023) combined, contributing to populations aging faster than ever before(Kinsella & Velkoff, 2002; United Nations, Department of Economic and Social Affairs, 2020; United Nations Department of Economic and Social Affairs Population Division, 2019; World Health Organization (WHO), 2015). The number of older adults aged 60 or over doubled in size under 40 years from 382 million in 1980 to about 962 million in 2017(Nations, 2017; United Nations, Department of Economic and Social Affairs, 2017). By 2050, this number will double to 2.1 billion from the current 1.2 billion(United Nations, Department of Economic and Social Affairs, 2017). Although there are contrary opinions (**compression of morbidity**)(Doblhammer & Kytir, 2001; J. F. Fries, 2009), some studies suggest that rising longevity will increase the number of older adults living with chronic conditions, the so-called "**expansion of morbidity**"(Gruenberg, 1977; Kassebaum et al., 2016; Olshansky et al., 1991). With the pervasive expansion of morbidity, the increasing pool of older adults living with ADL limitations in areas such as dressing, bathing, or eating will find it challenging to live independently for as long as they wish (age in place). Such a scenario will most

likely escalate the high demand for long-term care (LTC) or nursing home services(World Health Organization (WHO), 2015). Lakdawalla *et al.* predicted that the previously observed decline in the institutionalization of older adults would reverse, with a massive jump in older adults needing facility-based care(Lakdawalla et al., 2003). They attributed this to rising disability. Canada has also seen a growing demand for LTC beds due to the aging population, with the supply of such beds not keeping pace with the demand(Deloitte, 2021; Gibbard, 2017).

1.1.3. Changing Residents' Composition with Rising Prevalence of ADL Impairment

Long-term care was projected to become a significant global public health challenge over time as a result of rising disability (functional impairment) burden(Katz et al., 1970; Katz & Akpom, 1976). Not only is a decline in performing ADL a substantial driver of the cost of caring for residents in LTC homes, but its prevalence is also anticipated to rise over time. The prevalence of functional decline is projected to grow by approximately 120% worldwide between 2016 and 2026, increasing the number of persons receiving institutionalized care over the same period by about 130%(Palese et al., 2016). In addition, an analysis of the 30-year trend in nursing home composition in the US reported an overall increase in "average ADL dependency score" between 2000 and 2015, with a further breakdown showing that this dependency cuts across most ADL items(Fashaw et al., 2020). Sahyoun *et al.* reported a changing profile of nursing home residents in the US, showing that between 1985 and 1997, the average number of ADL items in which residents

required assistance rose to 4.4/6.0 from 3.8/6.0(Sahyoun et al., 2001). A higher prevalence of ADL impairment will exert additional pressure on the available resources within LTC settings, magnifying the burden on care providers and potentially compromising care quality. Preventing the rising demand for LTC placement would be an ideal solution, but it remains almost implausible. With the prevention of LTC care demand not likely achievable, other options for intervening to ensure optimal care for residents who eventually get admitted into nursing homes would be needed.

1.3. What is Known About Functional Change Patterns and Trajectories?

1.3.1. Pattern and Longitudinal Trajectory of Change in ADL Function:

Understanding the course of ADL function has become increasingly important as part of the tools that could be utilized to develop strategies for mitigating the consequences of functional decline on individuals and the health system. Available evidence shows that individuals progressively decline in function until death, with periods of fluctuations between high and low function. Before more advanced analytic techniques were available, the longitudinal course of functional decline was mainly modeled as the mean or average population change, with a presumption of a linear trajectory of change. Although physical function generally declines in individuals over time, evidence suggests heterogeneity in this trajectory. Glaser and Strauss, in their widely cited papers “A Time for Dying” & “Awareness

of Dying, " indicated that in a given population, four different trajectories of function exist among dying persons(Glaser & Strauss, 2005; Strauss, 1968), each determined by the individual's disease or health condition.

Other researchers have explored the heterogeneity of functional trajectories among different older adult populations to glean insight that could be used to characterize disease progression and change in health status over time. Morgan *et al.* showed two distinct trajectories of functional decline among palliative care clients over the last four months of their life(D. D. Morgan et al., 2019), while Lunney *et al.*(Lunney et al., 2003) further elaborated on different trajectories of functional decline at the end of life in the general population, reporting differences in the terminal trajectories of functional decline in nursing homes by underlying disease conditions. The above studies have limitations that make their findings inadequate for person-centered planning in nursing homes. They all focused on trajectories at the end of life and, therefore, were not positioned to support improvement in function or quality of life at the time of placement in care homes. In addition, with only one exception, these studies were not conducted on nursing home residents. Lawrence *et al.*(Lawrence et al., 2017) attempted to bridge this gap by implementing trajectory prediction for nursing home residents during placement. It showed the usefulness of functional status trajectory for advanced care planning (ACP) among Australian nursing home residents. Anderson *et al.* (Anderson et al., 1998) used one- and two-state models to show dynamic transitions in active status among older adults, indicating that transitions are mostly to three states, namely "decline," "stable," and

"improve" over time. Li *et al.*(Li & Li, 2005) showed that the trajectory of ADL disability (functional decline) is dynamic with "temporal variations" in the pattern of change over time. The studies mentioned above mainly utilized methods identifying the average linear longitudinal trajectory of functional decline.

Modeling functional decline as a mean population parameter may be inadequate, especially for care planning. Such modeling assumes trajectory homogeneity in functional decline and oversimplifies the complex relationships within and between individuals(Nguefack et al., 2020). Newer trajectory modeling techniques address the inadequacy by describing distinct sub-groups within any heterogeneous population where the mean parameter does not adequately represent the variable of interest.

The World Health Organization (WHO) framework for healthy aging provides conceptual support for a heterogenous trajectory in the longitudinal trajectory of physical function. The framework hypothesizes the existence of three trajectories of change in physical capacity over time in the second half of life(World Health Organization (WHO), 2015), similar to functional decline sub-groups.

1.3.2. Transition Between ADL Functional Levels and Related Terminal Outcomes

Limited evidence exists about the dynamic transitions between ADL statuses in LTC settings. Lagergren(Lagergren, 1994) showed that ADL transitions among nursing home residents are active. Therefore, studies that account for these

multidirectional changes would better represent the actual changes that occur among this population group. Hirdes *et al.*(2019) investigated the transitions between states of health instability and good or adverse outcomes that occur within the first 90 days of nursing home admission, showing that they are affected by various resident-level factors. However, the study did not focus on transitions in ADL states. Instead, it examined the CHESS scale for health instability. Others have studied the transition to better or worse ADL performance among nursing home residents using survival analysis methods and showed that each transition is affected by resident factors. However, the applied survival analysis method did not accommodate the simultaneous multidirectional transitions between ADL states.

1.3.3. ADL Changes in Times of Unprecedented Health Crisis

The COVID-19 pandemic caught many off-guard, wreaking havoc across most countries, disproportionately affecting residents of long-term care (LTC) facilities with excess mortality (Akhtar-Danesh et al., 2022; Betini et al., 2021; McGrail, 2022; Morciano et al., 2021) and other adverse consequences. Despite an overwhelming volume of literature, gaps in knowledge of the impact of the pandemic in LTC settings remain. Statistical methods used to generate evidence of the pandemic's effect in the setting have yielded aggregate results. Also, most studies utilized only the pandemic cohort of residents to analyze the pandemic's impact. Using only one cohort is likely to have produced biased estimates as most of the impact of the pandemic is additional rather than new effects on residents.

Therefore, it is essential to address these shortcomings so the effect of the pandemic can be understood, and future similar events can be adequately planned for.

1.4. How Were the Gaps Addressed, and What Did this Dissertation Add?

This dissertation sought to address the gaps highlighted in previous sections using five interconnected studies that incrementally build on each other. The **goal** was "*to understand the changes in the performance of activities of daily living in long-term care settings through analyzing the trajectories, transition patterns, predictors, and associated health outcomes*."

1.5. Description of Concept

It is necessary to add two critical descriptions that would help readers of this work understand the fundamental concept and the context within which the concept was used. Next, I will briefly describe the idea of "functional decline" used in this dissertation and how they are generally measured. However, it is essential to note that this term is operationalized differently in each study but uses the same general principle described here.

This dissertation uses several keywords to refer to the phenomenon of ADL changes. Transition, impairment, and limitation refer to one form of ADL change or another. However, one of the terms, "**functional decline,**" deserves special mention because of its place as the central piece of the dissertation.

One major challenge with discussing or characterizing functional decline is the wide range of definitions associated with the condition in published literature. Researchers have used different terms and phrases interchangeably for their description (Hoogerduijn et al., 2007), and there is almost no consensus. Nagi put forward the "disablement model," in which functional decline [though NOT explicitly stated] connotes a condition between limitation at the person level (functional limitation) and restriction at the societal level (disability)(Nagi, 1965b). Nagi's model identifies functional decline as a phase in the "disease" to "disability" continuum.

The WHO International Classification of Functioning – "ICF" similarly describes a condition, "functional limitation," in which there is difficulty with person-level activity. The WHO ICF allows for characterizing the inability to "function" generally in society as a "disability," delineating it from the personal level limitation referred to as functional decline in Nagi's model. WHO's "biopsychosocial"(World Health Organization (WHO), 202 C.E.) conceptual definition of functional decline was further supported by the work of Verbrugge & Jette, who argued that disability is both physical and social but maintained that functional decline represents a social rather than physical disability. Disability is, therefore, used somehow in this construct as an umbrella term to cover both activity (person-level) and participation (societal-level) limitations. Perhaps the most telling contribution to defining the concept of function and functional decline comes from the work of Katz, a geriatrician and health researcher(Katz et al., 2014; Katz & Akpom, 1976). Katz & Akpom described functional decline as the change in a sociobiological measure consisting of

six items: bathing, dressing, toileting, incontinence, feeding, and transfer(Katz & Akpom, 1976). These items are called the index of independence in activities of daily living (ADL) or the Katz index(Katz & Akpom, 1976).

Other authors have used functional decline to describe untoward transitions in ADL performance (Branch et al., 1984; Fried et al., 2004; Gill et al., 2002, 2003). While studying community-dwelling older adults who were part of the US longitudinal study of aging (LSOA), Mor *et al.* defined functional decline as being unable to carry at least a 25 lbs. weight, walk a quarter mile, climb ten steps, or do heavy housework without help and difficulty(Mor et al., 1989). Fried *et al.* characterized functional decline as physical disability, stating that there is a difference between physical disability (or functional limitation) and social disability as described by Nagi, Verbrugge & Jette, and WHO(Nagi, 1965a; Verbrugge & Jette, 1994; World Health Organization (WHO), 202 C.E.). While Fried *et al.* categorized limitation in ADL as a physical disability(Fried et al., 2004), Verbrugge & Jette argue that it is a social disability.

Although less theoretically dogmatic than the disablement model definitions, several other terms have equally been used in the literature to describe a functional decline 68. Terms such as ADL impairment(Bellelli et al., 2012; Nagamatsu et al., 2003; Oida et al., 2003), ADL disability(Seeman et al., 1996; Vermeulen et al., 2011), "functional impairment," and "disability," among others, appear in applicable decline literature. Their definitions have been anything but set, with the terms often used interchangeably. For this dissertation work, functional decline describes,

"geriatric condition in which an individual loses the ability to carry out basic activities of daily living (ADL), because of changes in their physical, cognitive or psychosocial capabilities"(Fried et al., 2004; R. Hébert, 1997)**.**

It is a dynamic, potentially reversible condition(Fortinsky et al., 1999), sometimes acute, but often insidious in onset(Colón-Emeric et al., 2013; R. Hébert, 1997), making its diagnosis difficult, especially in a home setting(Lawrence et al., 2017). Because of this dynamic, reversible nature of functional decline, the concept of "*transitions in functional status"* and "*functional trajectory*"(C. C.-H. Chen et al., 2008) will commonly be referred to in this work, emphasizing the potential bidirectional nature of change in functional status.

1.6. Measurement of Functional Decline

Several tools for measuring functional decline exist with wide variability in operational definitions(Buurman et al., 2011). Some tools are based on measuring ADL or IADL performance or as a composite of the two, while others are based on other activity score composite. Functional decline is determined to be present when there is a unit(s) change in the score of the respective measure used. A recent survey of over 170 randomly selected geriatricians in Canada reported that over 90% of them would consider a 1-point [or more] drop in the 7-item ADL scale or a 2-point drop in a 14-item ADL scale as a functional decline(Abdulaziz et al., 2016).

Several composite scores of ADL, IADL, or both available as scales are used to track functional decline and have been validated. Examples include the interRAI ADL long, short, and hierarchical forms(Fedecostante et al., 2021; Morris et al., 1999, 2013b), the Barthel index(Functional Evaluation: The Barthel Index: A Simple Index of Independence Useful in Scoring Improvement in the Rehabilitation of the Chronically Ill., 1965), the Functional independence measure (FIM)(Keith et al., 1987), the Katz ADL index, and Lawton IADL tools. These scales can be obtained as single-domain self-reported measures or from multi-domain assessment instruments. A review by Landi *et al.* showed the validity of the interRAI measures against other measures considered the gold standard at the time(Landi et al., 2000).

ADL-based instruments include Katz ADL, interRAI ADL Hierarchy, ADL scales, and Barthel Index. IADL-based instruments include the Lawton IADL scale, while the Old American Resources and System (OARS) scale combines ADL and IADL measures. Other instruments, such as the WHO Disability Assessment Tool (WHODAS), are also available and have been used for studies in low-income settings. The choice of instrument will usually depend on the purpose of the assessment and the setting where it is performed. For example, the FIM instrument is widely used in rehabilitation settings to track changes in physical function.

For this study, the interRAI ADL Hierarchy Scale was the base variable from which functional decline was calculated.

1.7. Specific Objectives:

Five specific objectives were set to achieve the stated purpose of this dissertation. These objectives translate into five research questions, answered by this dissertation's five studies. The objectives are presented as studies in the following paragraphs.

1.7.1. Study 1:

This dissertation began by examining existing literature to understand statistical approaches to how longitudinal changes in ADL function are modeled and analyzed for older adult populations.

1.7.1.1. Methods & framework: The study employed a *scoping review* method using the *Arksey and O'Malley framework* to explore and synthesize existing literature information for approaches to examine longitudinal trajectories of change in physical function. It summarizes evidence of how physical function trajectories have been modeled over the past 20 years, showing the most frequently applied methods and their outputs. This study presents an easy-to-use, concise summary of the existing functional change modeling approach, highlighting the benefits of each technique and the situations where they would most likely be more appropriate. It contributes to our understanding of how physical function trajectory modeling evolved over the years and highlights current gaps in research. This study provided information that was used to choose the most appropriate functional decline trajectory modeling technique.

1.7.1.2. Primary research question: The study answered the following fundamental question.

- What statistical methods have been used to examine the trajectory of functional decline in older adult populations?

1.7.2. Study 2:

The second study in the series examined the population-level impact of a widespread health crisis on ADL changes within LTC settings.

1.7.2.1. Methods: This study generated evidence by using *generalized estimating equations* ***(GEE)*** to quantify the marginal effect of the COVID-19 pandemic on ADL performance in LTC settings in Canada.

1.7.2.2. Primary research question:

- Compared to the pre-pandemic period, did functional decline accelerate during the first wave of the COVID-19 pandemic (March to June 2020) for persons in long-term care facilities (LTC) in Canada?

This chapter provides an aggregate-level comparative analysis of functional decline between the pandemic and pre-pandemic periods. Its contribution to literature is the first to quantify the actual "***additional***" functional decline attributable to the pandemic, differentiating this effect from the deterioration commonly occurring among residents in the setting.

Findings from this study have already been published in the Journal of the American Medical Directors Association with the title, "Functional Decline in Long-

Term Care Homes in the First Wave of the COVID-19 Pandemic: A Population-based Longitudinal Study in Five Canadian Provinces",

https://doi.org/10.1016/j.jamda.2023.09.007

1.7.3. Study 3:

The third examines the longitudinal trajectories of ADL function that LTC home residents take after placement. This study brings a breadth (longitudinal) perspective to the ADL changes as opposed to the depth perspective discussed in a subsequent study.

1.7.3.1. Methods: Study 3 analyzes three-year longitudinal trajectories of functional decline in LTC settings using the Group-Based Trajectory Modeling (GBTM) technique, a latent class growth analysis. GBTM was identified through the scoping review in Study 1 as the better choice for answering the research question addressed in this chapter.

***Hypotheses**:*

H_1: Over time, the functional decline of LTC home residents will follow at least three distinct trajectories that approximate the WHO's hypothesized trajectories of physical functioning.

H_2: Future health-related outcomes, such as mortality and resource utilization, will be related to and can be predicted by the identified trajectory subgroups.

1.7.3.2. Primary research questions:

- What are the typical trajectories of functional change among LTC residents in Canada?
- What baseline patient-level characteristics of LTC residents' factors determine membership in trajectory groups?
- Does functional decline trajectory group membership predict future health outcomes for LTC residents?

A conceptual framework for functional decline trajectory modeling

The WHO framework for healthy aging(World Health Organization (WHO), 2015) and the work by Glaser & Strauss(Glaser & Strauss, 2005; Strauss, 1968) on the trajectory of dying provide a starting conceptual basis for modeling the trajectory of functional decline as a heterogeneous attribute rather than a single population mean parameter. WHO defines healthy aging as developing and maintaining "functional ability" that promotes well-being as we age(World Health Organization (WHO), 2015). Functional ability in this framework represents the interaction between a person's composite of physical and mental capacities [Intrinsic Capacity] and the individual's environment the individual lives in(Beard et al., 2019; Cesari et al., 2018; World Health Organization (WHO), 2015). The outputs of this interaction are the individual's activities, such as taking a shower, dressing up, and going to the toilet, reflecting the person's functional ability level.

1.7.4. Study 4:

In study 3, this dissertation presented a longitudinal perspective of changes in ADL function within LTC settings by modeling the three-year progressive

trajectory of functional decline. This approach, however, has limitations in that it does not account for the multidirectional dynamic transitions that simultaneously occur among residents at all points in time. This study expanded the knowledge about the longitudinal trajectory of functional changes by further describing the concurrent dynamic ADL transitions, including improvement, worsening, and stability of function, linking these to terminal health outcomes.

1.7.4.1. Methods:

This study bridges the shortcomings of longitudinal modeling using multistate Markov transition analysis to capture the complex multidirectional transition between different ADL functional levels (including improvement, decline, and remaining unchanged) and transition out of the setting observed during each assessment. This study's novel contribution expands our knowledge about the transient and terminal transitions that occur concurrently between ADL functional levels and other health outcomes in LTC settings.

1.7.4.2. Primary research questions:

- What are the characteristics of the multidirectional dynamic transitions in ADL function that occur among residents, and how do they relate to terminal health outcomes?

1.7.5. Study 5:

In the fifth study of this dissertation, the impact of COVID-19 on the LTC setting was further explored beyond marginal effects.

1.7.5.1. Methods: Multistate Markov transition analysis was used to produce evidence of the transitions between ADL functional levels and out of the LTC setting during the COVID-19 pandemic compared to similar transitions in the pre-pandemic period. It provides a granular, multidirectional analysis of our previous chapter on Functional Decline in Long-Term Care Homes in the First Wave of the COVID-19 Pandemic. The study, therefore, improves existing knowledge by providing a more granular analysis of the complex effect of the COVID-19 pandemic on the physical function of LTC home residents.

1.7.5.2. Primary research questions:

- What was the impact of the COVID-19 pandemic on the multidirectional dynamic transitions in ADL function that occur among residents, and how did they relate to terminal health outcomes?

1.8. In Summary

Through evidence generated from this series of studies, this dissertation expands existing knowledge regarding changes in the performance of daily living activities in an LTC setting. These studies, taken together, provide both analytic depth and breadth to scientific evidence about functional changes in LTC settings. They add a nuanced understanding of the complex multidirectional transitions between ADL performance levels and transitions out of the setting. By examining aggregated and disaggregated measures of functional status, the dissertation provides various perspectives with evidence that would allow care providers, health

administrators, and policymakers to make better decisions about care planning and service provision in LTC. Further, by generating evidence of ADL and other health outcome changes during the COVID-19 pandemic, the dissertation contributes knowledge that helps to plan future pandemics or similar widespread health crises. The following five chapters lay out each of these studies in detail.

Chapter 2:

Study 1: Trajectories of Change in the Physical Function of Older Adults: A Scoping Review of Modeling Techniques and Reported Patterns

2.1. Introduction

Functional decline is a pervasive health condition and one of the "geriatric giants" affecting the quality of life of older adults(World Health Organization (WHO), 2015). It is a reduction in the ability to perform instrumental or basic activities of daily living (IADL or ADL) such as meal preparation, managing medication, bathing, dressing, toileting, mobility, or eating, usually due to a decrement in physical, cognitive, and or psychosocial capacities. Up to 60%(Fedecostante et al., 2016, 2021; Hoogerduijn et al., 2014; Jerez-Roig, De Brito MacEdo Ferreira, et al., 2017) of older adults in nursing homes require some form of assistance in performing ADLs, and in more advanced cases, affected individuals lose functional autonomy(Covinsky et al., 1997; Fortinsky et al., 1999; Hoogerduijn et al., 2010). Consequences associated with functional decline include repeated hospitalizations for community-dwelling persons and admission to long-term care(Hirdes, Poss, et al., 2008). It is also strongly associated with higher nursing resource utilization(B. E. Fries et al., 1994; L. A. Turcotte et al., 2019; B. C. Williams, Fries, Foley, Schneider, Gavazzi, et al., 1994) and higher mortality(Covinsky et al., 1998; Covinsky, Palmer, et al., 2003; Hirdes et al., 2003, 2014; N. Williams et al., 2022; Yeh et al., 2014), yet the trajectory of change

in function remains less well understood, especially among long-term care (LTC) home residents.

Annually, about 12% of community-dwelling older adults in Canada(R. Hébert, 1997) and one in seven in the United States (US)(Colón-Emeric et al., 2013) experience functional decline. The condition is even more prevalent among hospitalized older adults(Hoogerduijn et al., 2014; J. P. de A. Tavares et al., 2021) and those receiving institutionalized care(Fedecostante et al., 2016, 2021). As the global population ages (World Health Organization (WHO), 2015), it is estimated that the number of individuals who will live with a disability due to functional decline will equally increase(Olshansky et al., 1991). Understanding the trajectory of functional decline could aid proactive management of the condition and substantially reduce the individual, family, and societal burden often associated with the condition.

Current approaches to managing functional decline are primarily restorative, including providing physical and occupational therapy. Others, however, are preventative, focused on avoiding or at least delaying the onset of limitations. These include screening individuals at their point of contact with the health system to detect the immediate risk of functional decline, followed by initiating appropriate intervention (De Vos et al., 2012; Gill et al., 2002; Hoogerduijn et al., 2007, 2010; Inouye et al., 2000a; Sager et al., 1996). This approach is practical for identifying the immediate risk(Gill et al., 2002; Inouye et al., 2000b; Sutton et al., 2008), but there is concern that it only identifies people after they have advanced, limiting their chance of succeeding with intervention(Beaton et al., 2015; Deckx et al., 2015). Deckx

et al. suggested that available geriatric assessment tools may only be practical in predicting short-term outcomes like functional decline for older adults(Deckx et al., 2015). They showed that such tools had low predictive value after one year of follow-up among cancer and non-cancer patients. The systematic review by Sutton, Grimmer-Somers, & Jefferies concluded that no "gold standard" tool for identifying older adults at risk of functional decline in the emergency department exists after examining five risk assessment tools(Sutton et al., 2008). Tools to accurately identify individuals at risk of functional decline are critical. Still, more importantly, tools that could predict a longer-term trajectory with more distal outcomes could further enhance the management of functional decline.

According to the World Health Organization's (WHO) "World Report on Ageing"(World Health Organization (WHO), 2015), individuals follow distinct trajectories of "physical function" during the second half of life, dictated mainly by the sum of individual physical, psychological, and mental capacities, or *intrinsic capacity* they possess(World Health Organization (WHO), 2015). By suggesting these *hypothetical trajectories of physical capacity*(World Health Organization (WHO), 2015), the report infers that it is possible to approximate a multi-year longitudinal trajectory of physical function for individuals and that such trajectories can be related to person-level factors. The ability to obtain and use such longitudinal trajectory information could be transformative in managing functional decline. Individuals at risk for harmful decline could be identified earlier, and remedial action could be taken before intractable losses of function. From such information, prognostic indices could

be developed to facilitate care planning for older adults requiring long-term care(Sands et al., 2008). However, the "How-to" of this idea is lacking.

Tools for forecasting a multi-year longitudinal course of functional decline that can overcome challenges with current approaches would enhance care planning and management of the condition. Interest in developing such tools is not new, as researchers have long utilized different modeling techniques to study the longitudinal course of functional decline. Growth Mixture Models (GMM), Latent Group, or Cluster analysis have been used to show hierarchical and distinct functional trajectory sub-groups within populations over time(Bimou et al., 2021; Brown et al., 2019; C. C.-H. Chen et al., 2008). Bimou *et al.* utilized group-based trajectory modeling techniques, a form of Latent Group analysis, to assess the longitudinal course of physical function in community-dwelling older adults(Bimou et al., 2021). Bollano *et al.* used the Hidden Mixture Transition Distribution (HMTD) model to evaluate the heterogeneity of disability trajectories in Later Life.

There is a need for a comprehensive understanding of the strengths and limitations of different methods of modeling the trajectory of functional decline. A clear description of the various functional decline trajectory modeling approaches, their outputs, and how they can be applied to answer different research questions would be of immense value. Having such information readily available will facilitate learning, even for experienced researchers. It will expand knowledge about applying various modeling techniques to answer questions related to physical function trajectories. Summarizing the body of evidence would be a valuable resource for

health program managers seeking to understand the patterns of functional decline in their care settings. It would also foster research interest in this area by providing a new focus on the most promising methods, their outputs, current gaps, and unanswered questions.

Despite the documented growth in literature on functional decline trajectory modeling and the patterns they elicit, we have found no study that summarized these methods and their findings. Our preliminary search of Cochrane Review, PubMed, and Google Scholar databases found no systematic or scoping reviews on physical function trajectory modeling methods and patterns.

This scoping review is therefore conducted to address the following key objectives: 1) to understand the range of statistical methods used to model the trajectory of functional decline in older adult populations; 2) to describe the patterns of functional decline trajectory in older adult populations that are obtained using existing methods; and 3) to explore how functional decline trajectory patterns compare across settings, populations, and clinical subgroups.

2.2. Methods

The Arksey and O'Malley framework was adopted for this scoping review, limiting the process to the first five recommended steps. The research question was initially identified and refined through an iterative procedure as stipulated by the framework.

2.2.1. Search Strategy

Relevant literature was searched for and retrieved across several electronic databases, including PubMed, Embase, OVID, Cochrane, and Cumulated Index to Nursing and Allied Health Literature (CINAHL), as well as ProQuest Dissertations (for grey literature, mainly looking at master's level and Ph.D. dissertations). The reference list of included articles was also manually searched for further materials for completeness. We chose four key constructs: `Functional decline,' 'Activities of daily living,' 'Trajectory,' and 'Older adults,' which were then searched using combinations that included synonyms according to the database searched (**See Supplementary Figure A.1 for search strategies**). All searches were limited to materials available in the English language, published or produced between January 2000 and December 2022. The identified abstracts were imported into COVIDENCE desktop software for review.

2.2.2. Selecting Relevant Studies

Articles retrieved from the literature search were selected through a two-stage process that first involved screening all titles and abstracts through which eligible articles were identified for full-text retrieval. Next, the retrieved full-text articles were screened for eligibility and selected if they met the set inclusion criteria. An article was chosen if the primary intervention involved older adult populations and the measures of physical function included ADL, IADL, or both, published between 2000 and 2022. Setting the year cut-off at 2022 was used to keep the review's focus on more current methods of modeling functional decline. Two reviewers conducted

abstract and full-text screening, and consensus resolved disagreement. The entire article identification and selection process is depicted in the PRISMA flow diagram below, **Figure 2.1**.

2.2.3. Extracting Data

Data was extracted from the included articles to answer the three research questions pursued in this study using an adaptation of the extraction template in the COVIDENCE software. Only one author completed the extraction. Qualitative and quantitative details were extracted from the articles, as Levac et al.(Levac et al., 2010) recommended.

2.2.4. Synthesizing the Information

Using the qualitative and quantitative information extracted from the selected articles, a descriptive, numerical, and narrative analysis of the extent and nature of the current literature on functional decline trajectory modeling was conducted. A thematic narrative synthesis of the gleaned information was then performed and presented in line with our research questions.

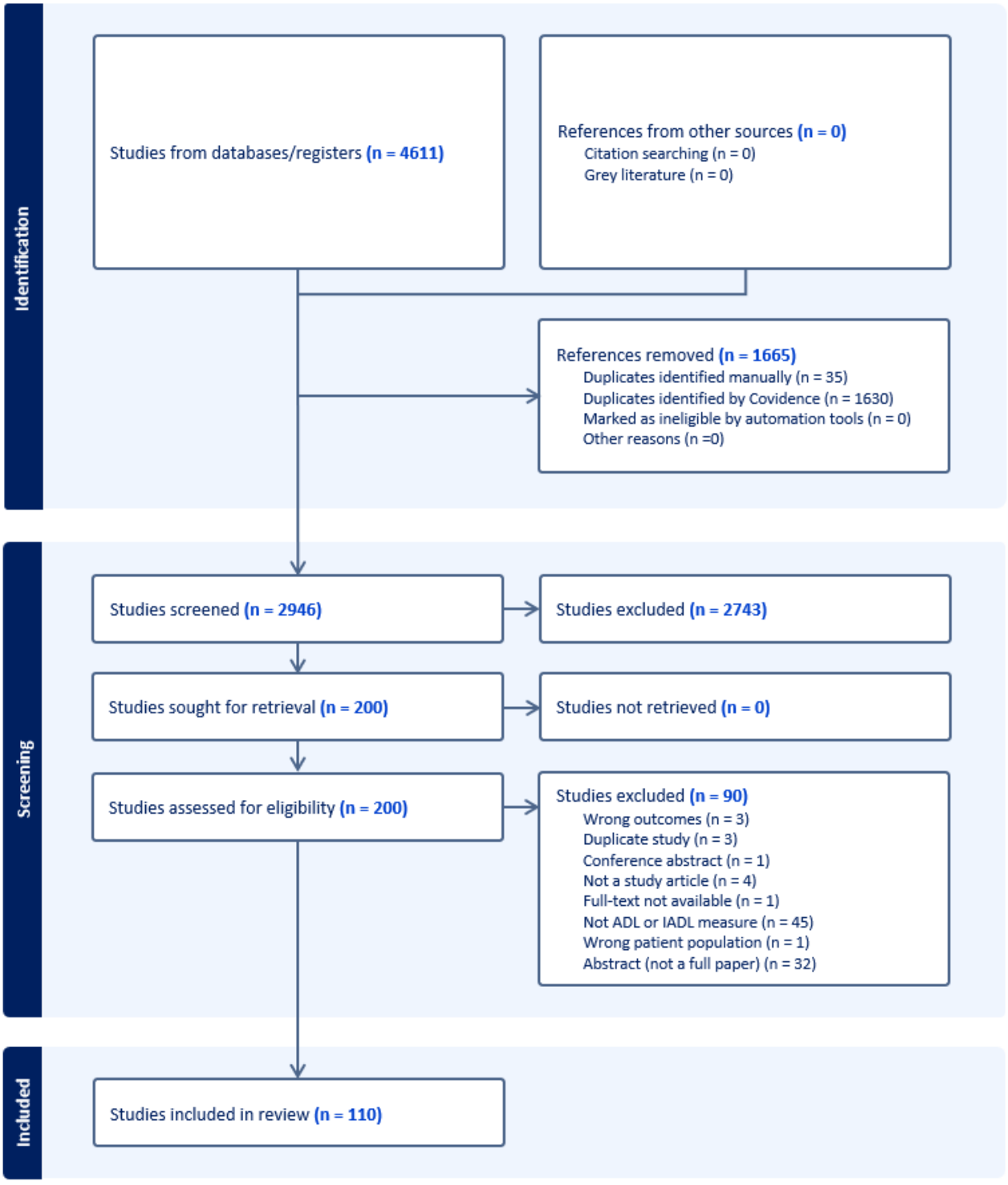


Figure 2.1: PRISMA Flow Diagram.

2.3. Results

2.3.1. Characteristics of Selected Studies

Number of articles

We reviewed the full-text articles of one hundred and ten (110) studies that met the study inclusion criteria (**See Supplementary Table A.1 for the complete list of included articles and their characteristics**). Over the 20 years covered by this review, there was a progressive growth in the number of studies modeling functional decline trajectory. Specifically, the number of published articles on functional decline that met our inclusion criteria has increased every five years since 2000 and almost tripled between 2015 and 2019 compared to the previous five years, **Figure 2.2**.

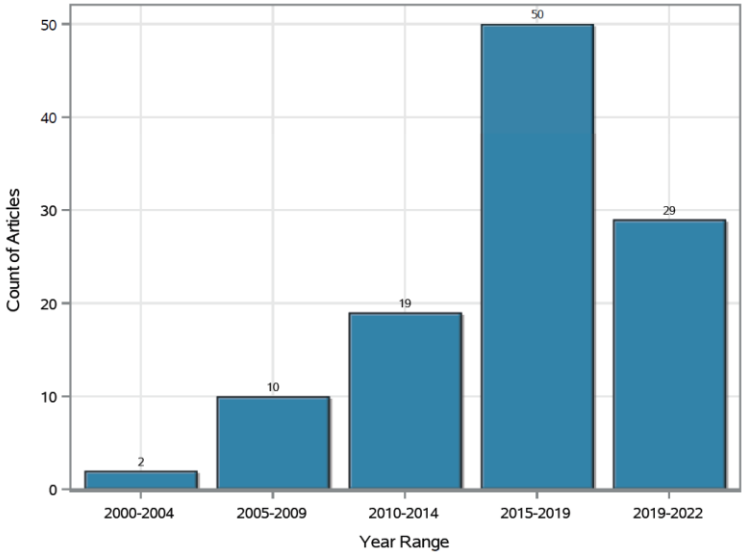


Figure 2.2: Distribution Of Five-Year Trends In Frequency Of Using Different Trajectory Methods 2000 – 2022, n = 110.

Study Country and Settings

Nearly half (45%) of the studies included in this review were conducted in the United States (US). Further to this, only eight countries combined, the US (49), Taiwan (11), Netherlands (9), China (7), Japan (5), France (5), Australia (3), Sweden (3) accounted for about 85% of included articles, **Figure 2.3a**. Only one article was from a study conducted in Sub-Saharan Africa, Nigeria.

Of the 110 studies included in this review, 91 (82.7%) were conducted on community-dwelling older adult populations. Twelve studies (10.9%) were conducted among hospitalized older adults, while only seven (6.4%) were conducted among nursing home populations, **Figure 2.3b**.

a. b.

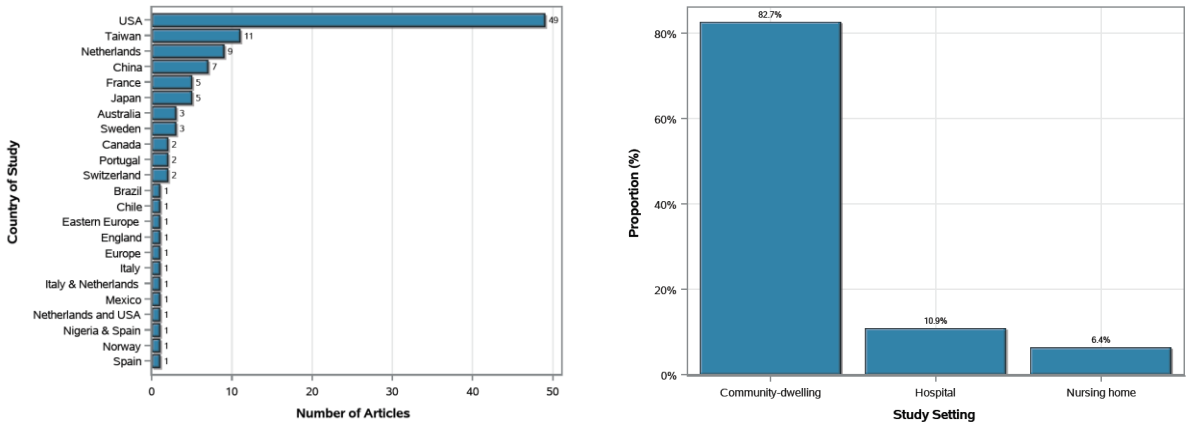


Figure 2.3: Distribution of Articles by the a) Country and b) Setting of Study 2000 – 2022, n = 110.

2.3.2. Outcome Measures and Instrument

We restricted this review to studies where IADL and, or ADL were the physical function measures used, aware that other measures are also currently used to assess the physical function of older adults. In 50.9% of the included studies, physical function was assessed using only ADL measures, while only 10.9% used IADL items to assess physical function.

The Katz index (original and modified versions) was our review's most commonly cited measurement instrument to assess functional decline. Other instruments often used in the reviewed studies include the Barthel index, interRAI ADL long form and interRAI ADL Hierarchy, Functional Independent Measure (FIM), Functional Assessment Questionnaire (FAQ), Lawton Scale, Functional Autonomy Measurement System (SMAF), as well as the Short Form Health Survey (SF-36).

2.3.3. What are the Existing Techniques for Modeling the Trajectory of Functional Decline?

The first objective of this scoping review was to map the range of statistical methods used to model the trajectory of functional decline in older adult populations. Various modeling techniques were used to determine the trajectory of functional decline, and they fall into two categories. These are i) techniques that modeled the trajectory of functional decline as a single mean parameter and ii) those that modeled functional decline as multiple distinct trajectories. Eleven different modeling techniques were identified to have been used at least once to investigate functional decline trajectory within the study period.

2.3.3.1 Single (Mean) Trajectory Modeling Techniques.

Among studies that modeled functional decline trajectory as a single trajectory, the "Hierarchical linear or Multilevel modeling (MM)" method was the most commonly used. Thirty-three (33) studies (or 30% of all studies) used the MM trajectory modeling method, 24 of which were linear mixed methods (Banaszak-Holl et al., 2011; J.-H. H. Chen et al., 2007; C.-J. J. Chiu et al., 2021; C.-J. Chiu & Wray, 2011; Cloutier et al., 2021; Diaz-Venegas & Wong, 2016; Edjolo et al., 2016; Gildengers et al., 2013; Hadidi et al., 2013; Hayward & Krause, 2013; Heshmatollah et al., 2021; Kruse et al., 2013; Lawrence et al., 2017; Li & Li, 2005; Liang et al., 2003, 2010; Mueller & Bartlett, 2019; Shrira & Litwin, 2014; Sun et al., 2009; Thomas et al., 2017; Vetrano et al., 2018, 2021; D. Wang et al., 2018), while the other nine studies applied generalized linear mixed method(Botoseneanu et al., 2016; Y. Han et al., 2021; Mueller-Schotte et al., 2019; Pérès et al., 2008; Sprung et al., 2021; Stolz et al., 2021; Whitson et al., 2011; Wu et al., 2018; Yang et al., 2021) to investigate functional decline trajectory.

For some of the included studies, functional decline trajectory was modeled by plotting the ***Mean score*** of the IADL or ADL measure obtained at each successive assessment point (Hsiao et al., 2013; H.-T. Huang et al., 2013; L.-W. Huang et al., 2022; Kempen et al., 2006; Lunney et al., 2003; Nikolova et al., 2009; J. Tavares, Grácio, Nunes, et al., 2018). For others(D'Onofrio et al., 2018; Medina Mirapeix et al., 2020; Menezes et al., 2021; Rodrigues et al., 2020; Wakefield & Holman, 2007), the ***Mean difference*** in the physical function measure between consecutive assessments

arithmetically calculated was used to derive trajectory pattern. In the latter types of studies, functional decline trajectories were described using narratives rather than plots.

The *Mean score* method generates trajectory groups by plotting mean ADL or IADL scores of multiple assessments for different baseline categories of persons. Categories of older adults according to factors such as disease status, cognitive function, and clinical conditions were studied using this method. This approach makes the *Mean score* technique a single trajectory modeling technique similar to other mean parameter techniques mentioned above.

Other modeling techniques in this review include linear regression analysis(Boissoneault et al., 2021; Vaughan et al., 2016), generalized estimation equation(Dhamoon et al., 2012, 2017, 2018), sequence analysis(Madero-Cabib et al., 2022), hidden mixture transition distribution (HMTD) model(Bolano et al., 2019), **Figure 2.3a.** These techniques also produced a single functional decline trajectory pattern.

2.3.3.2 Multiple Trajectories Modeling Techniques.

The second approach to modeling trajectories of functional decline involves identifying latent unobserved subgroups within studied populations. Among the 110 included studies, 37 (33.6%) modeled functional decline trajectory using "**Latent Class Growth Analysis (LCGA)**" techniques that assumed the existence of latent unobserved distinct subgroups in their studied populations. Of these 37 studies,

29(Aarden et al., 2017; Bimou et al., 2021; Brown et al., 2019; Buurman et al., 2016; C. C.-H. Chen et al., 2008; Dodge et al., 2006; Ferrante et al., 2015; Ferraro et al., 2021; Gardeniers et al., 2022; Gill et al., 2015; Gill, Murphy, et al., 2013; Gill et al., 2010; Guion et al., 2021; Howrey et al., 2016; H.-C. Hsu, 2013; Iwasaki & Yoshihara, 2021; Kuo et al., 2017; Liao & Chang, 2020; Lu et al., 2018; MacNeil Vroomen et al., 2018; Martin et al., 2017; Murayama et al., 2020; Pan et al., 2021; Presley et al., 2019; Stabenau et al., 2018; Taniguchi et al., 2019; Wei et al., 2018; Westrick et al., 2022; Zimmer et al., 2012) explicitly mentioned using "***Group-based trajectory modeling,***" a form of finite mixture modeling, to obtain their functional decline trajectories. Eight other studies stated that LCGA was the technique used. Thirteen studies(Edjolo et al., 2020; Gill, Gahbauer, et al., 2013; Haaksma et al., 2019; L. Han et al., 2013; Hochstetler et al., 2016; X. Huang et al., 2022; Norton et al., 2013; J. Saito et al., 2019; Soh et al., 2021; Verlinden et al., 2016; Villeneuve et al., 2019; Y. Wang et al., 2019; Xiao et al., 2021) applied the "**Growth Mixture Modeling**" technique, a latent class analysis, to identify subgroups of individuals with distinct FD trajectories.

When LCGA was applied, studies also chose between modeling the outcomes as Censored normal(Bimou et al., 2021; Buurman et al., 2016; Dodge et al., 2006; Gardeniers et al., 2022; Guion et al., 2021; Jonkman et al., 2018; Kuo et al., 2017; Lu et al., 2018; Zimmer et al., 2012), Poisson(Brown et al., 2019; Ferrante et al., 2015; Ferraro et al., 2021; Gill et al., 2010; Gill, Murphy, et al., 2013; Howrey et al., 2016; H.-C. Hsu, 2013; MacNeil Vroomen et al., 2018; Mutambudzi et al., 2019; Pan et al.,

2021; Presley et al., 2019; Stabenau et al., 2018; Wei et al., 2018; Westrick et al., 2022; Wu et al., 2018) and logit distributions(Liao & Chang, 2020; Martin et al., 2017; Y. Wang et al., 2019). Three studies modeled functional decline as a logit outcome.

Further, six of the included studies utilized a different form of latent trajectory modeling known as "**Latent Growth Curve Analysis (LGCA)**" to obtain the trajectory of change in ADL, IADL, or both over time in studied populations. This technique is a form of structural equation modeling that looks at how a variable changes over time but differs from the two latent trajectories modeling above, which examines how individuals change over time.

For a sizable number of the mentioned techniques, there was a progressive growth in the number of studies applying them to model the trajectory of functional decline over the period covered by this review. An increase in the frequency of use was most prominent for LCGA studies. The number of studies applying the GMM technique doubled between 2010/2014 and 2015/2019 and only increased by one for studies using the Multilevel modeling technique. In comparison, studies that employed LCGA quadrupled during the same period, **Figure 2.4b**.

a. b.

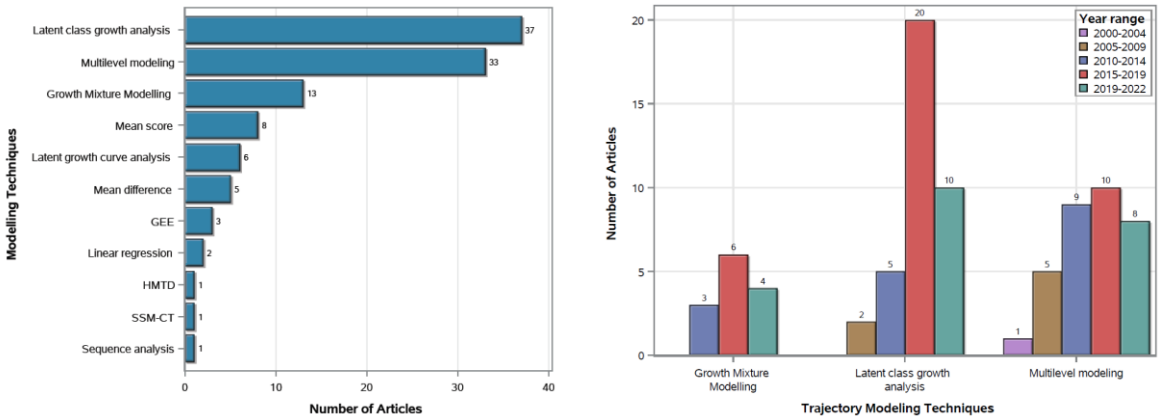


Figure 2.4: Distribution Of Studies by a) Modeling Techniques only and b) Modeling Techniques per 5-Year Period 2000 – 2022, n = 110.

2.3.4. Characteristics of Studies by Modeling Techniques

The methodological and population characteristics of studies applying the different modeling were further examined to identify distinct patterns of change. Besides studies using the Mean difference techniques, which had an average participant follow-up time of less than one year, studies using other techniques had follow-up time above five years (Sequence analysis-15 years, GMM-11 years, GEE-10 years, LCGA-9 years, LGCA-9 years, MM-8 years, Mean score-5 years).

2.3.4.1 Trajectory Patterns

Diverse types of trajectory patterns were **reported** by the studies included in this review, depending on the technique used.

Single Trajectory

Four modeling techniques, namely Multilevel Modeling **(MM)**, Latent Growth Curve Analysis **(LGCA)**, Generalized Estimating Equation **(GEE),** and SSM-CT, were used by researchers to produce a single mean functional decline trajectory for

the studied populations. Studies that utilized the mean trajectory technique focused on determining the functional decline trajectory of a pre-specified and delineated group of older adults, and such a group is assumed to have similar trajectory attributes. For instance, Stolz *et al.* (Stolz et al., 2021) and Chiu *et al.* (C.-J. J. Chiu et al., 2021) obtained the mean trajectory of functional decline in the last years of life for different conditions leading to death, while Hadidi *et al.* (Hadidi et al., 2013); Dhamoon *et al.* (Dhamoon et al., 2012, 2017); Hashmatollah *et al.* (Heshmatollah et al., 2021), all utilized single trajectory parameter modeling to study the trajectory of functional decline among stroke survivors. These studies prespecified and assumed that "people with the same causes of death" and stroke survivors are homogenous in terms of their functional trajectory. Other prespecified groups studied with the single trajectory parameter modeling technique identified in our review include people diagnosed with conditions like dementia or cognitive impairment, Diabetes, or stroke.

Another trajectory modeling technique, the *Mean score,* produced both single and multiple trajectories as its output, depending on the research inquiry. Studies with populations predefined clinically or by other characteristics yielded functional trajectory numbers equivalent to the predefined categories of the traits. For example, Lunney *et al.* used the *Mean score* method to examine the functional decline trajectory of four mortality groups: sudden death, cancer death, organ failure, and frailty deaths(Lunney et al., 2003). This method produced four trajectories, effectively one trajectory for each mortality group. On the other hand, Hsiao *et al.*, Nikolova *et al.*, Huang *et al.*; & Ailshire *et al.* used the *Mean score* of the ADL measure to obtain a

single trajectory for their studied populations(Ailshire et al., 2015; Hsiao et al., 2013; L.-W. Huang et al., 2022; Nikolova et al., 2009). Furthermore, when the *Mean score* method was used for trajectory modeling, researchers often sought to compare the functional decline trajectory of the predefined groups. Statistical methods such as ANOVA(H.-T. Huang et al., 2013; Nikolova et al., 2009) and Student's T-test(J. Tavares, Grácio, & Nunes, 2018) were then used to compare the trajectory groups.

Multiple Trajectories

Other studies in this review applied techniques that produced multiple rather than single functional decline trajectory subgroups. The LCGA, GMM, Mean score, Mean difference, and HMTD techniques yielded multiple trajectory subgroups as their modeling output but differed in how they were identified and interpreted.

When the *mean difference method was used, trajectory groups were generated by manually calculating the difference in ADL or IADL scores* between successive assessments. Individuals were then classified together if they had similar patterns of difference between the first and last assessments. Because it uses a manual calculation of the difference in score, with a high number of combinations of changes, using the *mean difference in trajectory modeling often produces* high numbers of trajectory subgroups. Of the five studies that utilized the *mean difference, two yielded six trajectory subgroups*(Medina Mirapeix et al., 2020; Vaughan et al., 2016)*, and* another two had five subgroups (Rodrigues et al., 2020; Wakefield & Holman, 2007), with one producing only two trajectory subgroups(D'Onofrio et al., 2018). All five

studies were conducted among hospitalized older adults with three assessments or less.

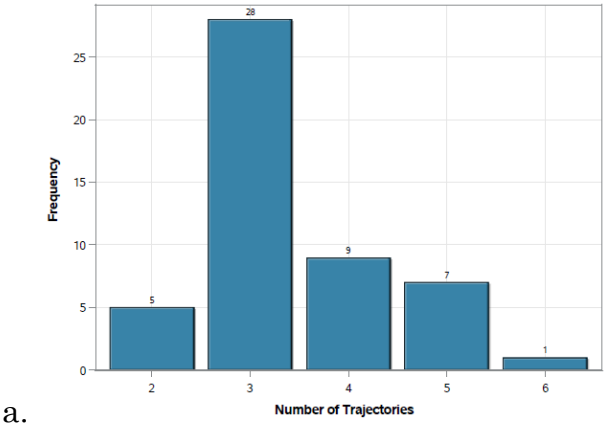
In contrast to the *Mean difference* and *Mean score* methods, LCGA and GMM methods produce trajectory subgroups through statistical modeling. Among the fifty studies that applied LCGA and GMM techniques, 28 (50%) reported three trajectory subgroups as the best-fitting pattern for their studied population, making three subgroups the most commonly observed trajectory pattern, **Figure 2.5a.** The other **s**tudies produced trajectory patterns that differed from the three-subgroup trajectory as their best-fitting pattern. Nine (18%), seven (14%), and five (10%) studies produced four-, five-, and 2-subgroups trajectory patterns, with one study obtaining a six-subgroup trajectory pattern in our reviewed articles, **Figure 2.5a**.

2.3.5. Comparison of Trajectory Patterns

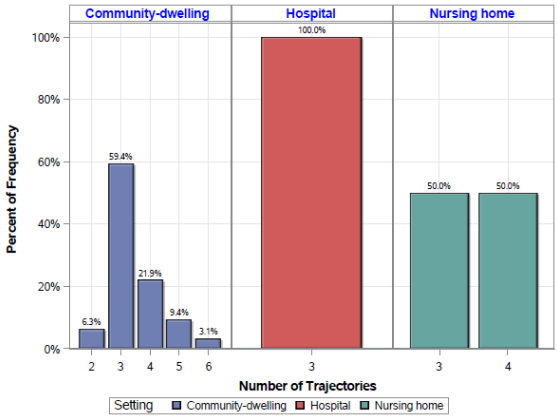
The relationships between the number of trajectory subgroups obtained using each method and the studied population's characteristics were examined to understand better the mixture of patterns reported by the reviewed studies. First, we analyzed the obtained trajectory outputs by the population type studied or the study setting for any discernible pattern. Studies conducted among community-dwelling older adults produced the highest range in the number of trajectory subgroups obtained. Between two and six trajectory subgroups were obtained from the reviewed studies conducted among community-dwelling populations, **Figure 2.5b**. In contrast, studies conducted among hospitalized populations produced only a three-subgroup

trajectory pattern. Likewise, studies conducted among nursing home populations obtained only three- and four-subgroup trajectory patterns.

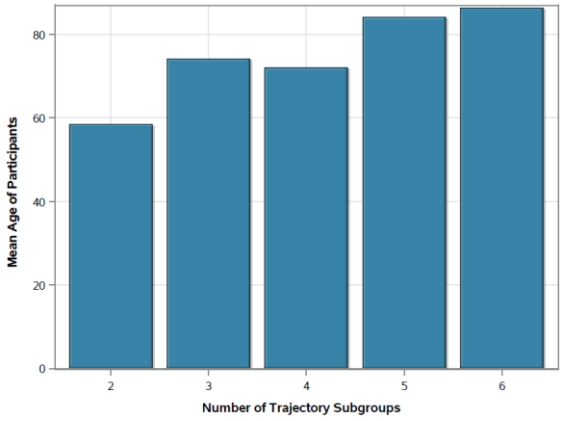
Further, we examined only studies that produced multiple trajectory subgroups (**Figure 2.5c**).



a.



b.



c.

Figure 2.5: Distribution of Studies by a) Number of Trajectories b) Number of Trajectories by Settings c) Mean Age of Participants by The Number of Trajectories

We also examined the membership of each trajectory subgroup by study setting. Among studies conducted among community-dwelling populations, 54.6% of study participants followed the trajectory subgroup commonly described as having no disability (**Figure 2.6**). Studies conducted among hospitalized and nursing home

populations reported that, on average, 49.2% and 24.3% of the study participants followed this trajectory pathway. Conversely, studies conducted among the nursing home population reported that, on average, more participants follow the severe disability trajectory (38.4%) compared to the community-dwelling (16.7%) and hospitalized populations (10.7%), **Figure** 2.6.

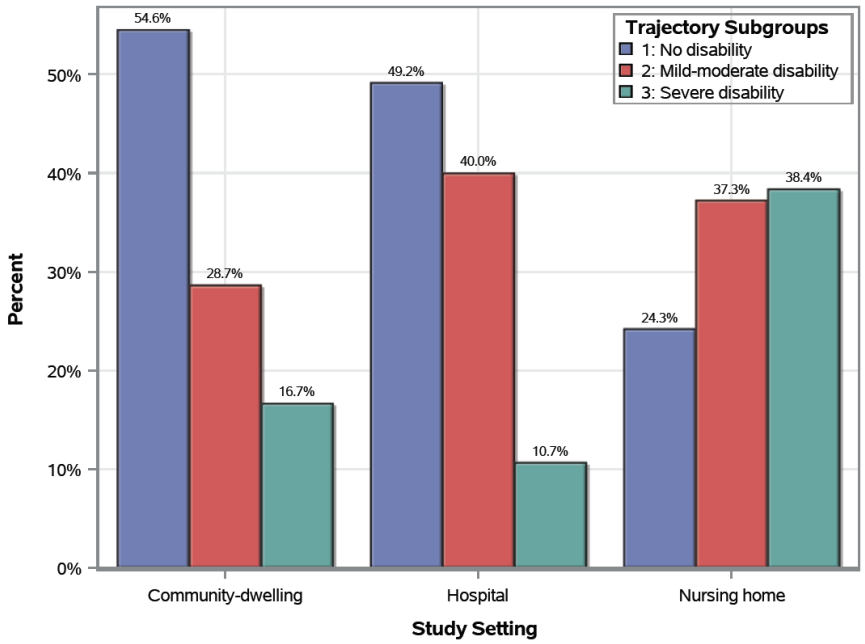


Figure 2.6: Percentage of Individuals in Specific Trajectory Subgroups by Setting.

2.3.6. Trajectory Nomenclature

One of the challenges encountered in studying functional decline is the wide range of definitions applied to the concept in existing literature and how it is measured. We found that a wide range of names are used to describe the different trajectory subgroups, even when such subgroups have similar shapes.

For the ***stable trajectory*** subgroup type, names that were used include "no disability, "independent," "stable," and "high-stable." For the next trajectory group in

the level of decline, names such as “mild disability,” “somewhat poorer function,” and “moderate disability” were used. To illustrate this challenge, we generated word clouds for our review's first three trajectory subgroups. The word clouds show the most common and frequently used names for each similar trajectory group in the reviewed articles, **Figure 2.7.**

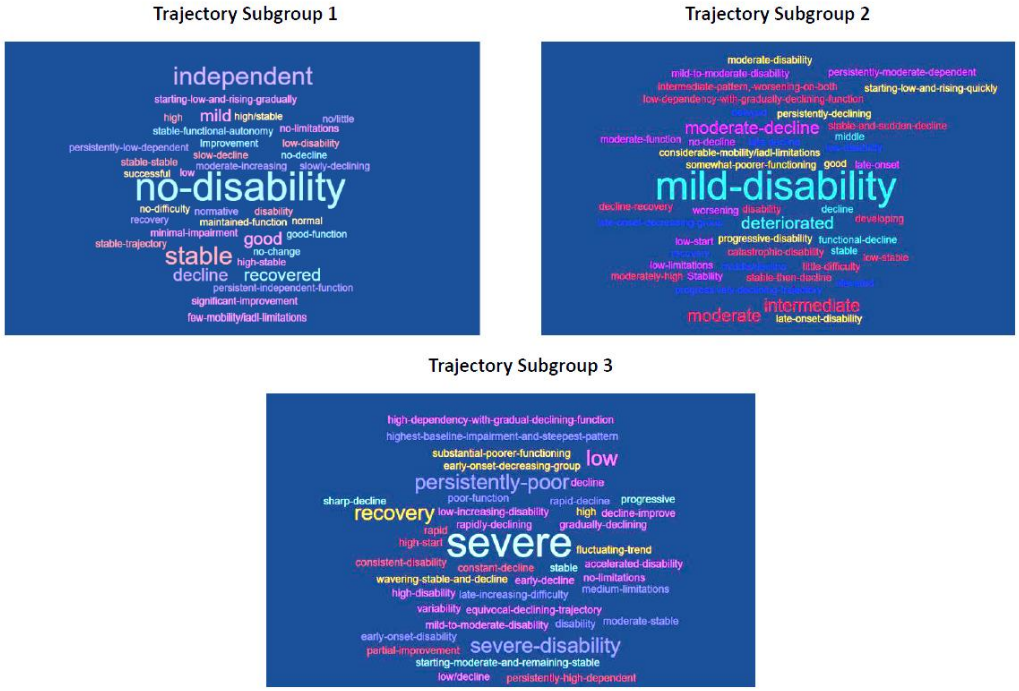


Figure 2.7: Word Cloud Showing Different Nomenclature for Similar Trajectory Groups

2.4. Discussion

We synthesized information from the existing literature on how functional decline trajectories are modeled and patterns obtained using the various models. Our

synthesis showed that different modeling techniques are used to investigate the trajectory of functional decline for older adult populations, producing single and multiple trajectory subgroup patterns. For the period covered by this review, the most utilized technique was the latent class growth analysis, which identifies distinct homogenous trajectory subgroups of studied populations.

This review showed increased utilization of LCGA compared to other methods in modeling functional decline trajectory over the past decade (**Figure 2.2b**). This could suggest a rising interest in understanding how subgroups within a population differ in health trajectories. It may also indicate a shift in assumptions and an evolving understanding of the trajectory of health for older adult populations from a homogenous to a more heterogenous one(H. C. Hsu & Jones, 2012; World Health Organization (WHO), 2015), with researchers increasingly attempting to identify and characterize subgroups within each population.

However, increasing LCGA utilization could have resulted from modern software availability for such analysis. Loughran *et al.* (Loughran & Nagin, 2006) referred to the increasing availability of 'canned" software applications (SAS Proc Traj, STATA, MPLUS) for trajectory model programming as having further boosted the utilization of LCGA technique(Arrandale et al., 2006; B. L. Jones & Nagin, 2013, 2016; Jung & Wickrama, 2008; Nielsen et al., 2014). Through the work done by Nagin and Jones(B. L. Jones et al., 2001; D. S. Nagin et al., 2005; Nutr & Nagin, 2014), the use of LCGA has been popularized in recent years(Loughran & Nagin, 2006). However, this method is not without its limitations. The loss of information that

results from averaging unique trajectories as individuals may have both positive and negative changes, which may cancel or mask each other out, calls for caution when using this technique for trajectory modeling(Columbia University Mailman School of Public Health, 2022).

Despite the growing use of the LCGA method, the choice of modeling technique is often tied to the research questions asked. Studies that obtained a single functional trajectory most likely investigated the difference in trajectory patterns between groups predefined by clinical or other characteristics that were assumed to be of similar trajectory. On the other hand, studies that utilized techniques to produce multiple trajectories often explored population groups to identify the underlying sub-population functional trajectories.

There are other potential challenges to be aware of when using the available techniques. For instance, using just the difference in mean ADL or IADL score between successive assessments to define functional decline trajectory may be feasible where only two or three assessments are conducted. With more assessment points, modeling functional trajectory with Mean difference or Mean score becomes implausible. The number of combinations of patterns that would arise due to multiple changes at each point would make it challenging to construct a trajectory pattern by simply calculating the mean difference between each point. For instance, Menezes *et al. and Medina-Mirapeix et al. mapped six different combinations* of functional decline trajectories from three assessments using this approach(Medina Mirapeix et al., 2020; Menezes et al., 2021). This challenge makes using the mean difference

between assessment points to derive a functional decline trajectory less attractive when longitudinal forecasting with more than three assessment time points is considered. Also, for non-normally distributed variables like ADL score, non-parametric methods are better suited for their analyses.

Our review also showed variations in the patterns and characteristics of trajectory subgroups between study settings. The observation of more trajectory subgroup patterns among community-dwelling older adults compared to other settings likely reflects the higher heterogeneity in functional capacity(World Health Organization (WHO), 2015) of older adults in this setting compared to different settings. The finding that more community-dwelling older adults follow the stable – no disability trajectory than the nursing home population and that, conversely, more nursing home population followed the severe disability trajectory than older adults in other settings was also not surprising. Losing functional autonomy is often the reason older adults are admitted to nursing homes, and the prevalence of functional decline in this setting is, therefore, higher than in other settings(Covinsky, Palmer, et al., 2003; Fortinsky et al., 1999; R. N. Jones et al., 2010a; Palese et al., 2016).

The wide variation in patterns obtained when using LCGA may also have resulted from differences in how the trajectory modeling techniques were applied and interpreted. Although some studies found four trajectory subgroups as their best-fitting model, a closer look at these trajectory outputs showed that they may not have been the best fit for the populations studied. For example, Murayama *et al.*(Murayama et al., 2020) reported that four trajectory sub-groups were found

among older Japanese adults using group-based trajectory modeling. However, the percentage of the total population in one of the groups (4.2%) falls below the minimum recommended (5%)(Nguefack et al., 2020) when using the GBTM method. The paper also failed to report on the posterior probability of group membership, which would have shown how well the number of trajectories fit the data.

We also observed that ADL trajectory decline was more frequently modeled than IADL decline. The higher investigation of ADL compared to the IADL decline observed in this review could be explained by the difference in how the two measures assess physical function. IADL tends not to be tracked in hospital or nursing home settings because people do not perform IADLs there. While ADL is critical in determining daily self-care functioning necessary for survival, IADL assesses the ability to complete complex tasks of daily living, which are useful but not critical for independent survival, given that others can perform them for the residents. Also, ADL may be more sensitive to changes in basic physical function, while IADL is more sensitive to complex cognitive and executive functions. Studies on basic physical function, the focus of retrieved articles, would measure ADLs. For this reason, future studies should include both measures when evaluating the physical function of older adults. The interRAI functional hierarchy scale is an excellent example of a tool consisting of ADL and IADL items(Morris et al., 2013b), which can serve this purpose.

Our review revealed a limited amount of research on functional decline trajectory being conducted with nursing home populations. This little research may be due to the assumption that people admitted to nursing homes are nearing the end

of life, and, as such, not a lot can be done about their functional trajectory. However, the loss of functional autonomy is not a uniform or irreversible process that might be amenable to intervention in some cases(Bolano et al., 2019). Therefore, assessing the trajectory of the functional decline of the nursing home population could help them develop tools to predict how a resident will progress within weeks of admission and in the coming months and years(Banaszak-Holl et al., 2011).

This review also shows that the functional trajectory of older adult populations in low- and middle-income countries, specifically sub-Saharan African (SSA) countries, needs more attention. Only one study(Ojagbemi et al., 2021) out of the 110 included in the review, was conducted among the older adult population in SSA despite the region being projected to experience the fastest rate of rise in more aging adult population than other regions over the coming decades(United Nations, Department of Economic and Social Affairs, 2015; United Nations Department of Economic and Social Affairs Population Division, 2019). With the health systems in this region not necessarily ready to deal with the long-term care that may be required for functionally impaired populations(World Health Organization (WHO), 2015), it is vital to study the region's trajectory pattern to identify potential intervention points to be prioritized. Challenges with data availability and lack of necessary skills to model longitudinal trajectory could prevent this. However, the information provided in this review would be helpful for researchers in the region hoping to understand the "how to" of functional decline trajectory modeling.

2.5. Recommendations

More studies of the nursing home population are needed, given that the current body of evidence is skewed toward hospital and community-dwelling populations. Not enough is known about the functional decline trajectory in LMIC, especially in Sub-Saharan Africa (SSA). Therefore, opportunities to study older adults in this region should be explored.

2.6. Limitations

Our review was limited to studies that used ADL and IADL measures to assess the physical function of their target population. This has the potential to introduce selection bias and reduce the generalizability of our findings since other measures of physical function like Timed Up and Go (TUG), 6-Minue Walk Test, Grip strength, and Short Physical Performance Battery (SPPB) were excluded. Because IADL and ADL are the most commonly used measures of physical function, we are confident that the review is applicable in the study settings noted here.

2.7. Conclusion

This scoping review has compiled a comprehensive summary of the state of knowledge regarding how functional decline trajectory is modeled by researchers, elucidating the multiple methods, their associated trajectory outputs, and the nuances surrounding their use. The review further allowed us to understand how the

utilization of available techniques has evolved and to identify the pitfalls associated with the different methods.

The review's findings highlight the growing interest among researchers to explore and understand how clusters of individuals differ in their functional decline trajectory. This interest is evident by the faster growth in utilizing latent class growth analysis and growth mixture modeling techniques, yielding distinct subgroup trajectories of studied populations.

Despite a wide array of techniques being available for trajectory modeling, this review also revealed a wide gap in the existing literature regarding population groups studied, with nursing home residents receiving very minimal attention despite being the population most likely to suffer the adverse consequences of functional decline. An equally important gap this review highlights is the absence of functional decline trajectory modeling in LMIC, especially SSA. However, the region is expected to witness the fastest increase in the older adult population over the coming decades.

In summary, modeling the trajectory of functional decline of older adults involves making decisions on the most suitable method from a wide range of techniques currently available in the literature. The findings of this review would provide comprehensive but concise information to researchers, clinicians, and policymakers about the various trajectory modeling options available and the patterns they generate.

Chapter 3:

Study 2: Functional decline in long-term care homes in the first wave of the COVID-19 pandemic: A population-based longitudinal study in Five Canadian provinces

3.1. Introduction

Residents of long-term care (LTC) facilities were disproportionately affected by the COVID-19 pandemic, experiencing adverse outcomes, including excess deaths. Mortality in LTC facilities accounted for over 80% of all COVID-19 deaths occurring in Canada as of May 25, 2020(Canadian Institute for Health Information, 2020), and harm from the virus itself was associated with respiratory, neurological, digestive, and other symptoms(CDC, 2021; Martini, 2021). Other adverse consequences resulting from pandemic measures, such as restriction of visits from family members or other visitors(Canadian Institute for Health Information, 2021b), designed to contain the spread of the virus, were reported to include functional decline, depression, mood changes, and loneliness (Burki, 2020; Canadian Institute for Health Information, 2021a; Rochon et al., 2022; Schoofs et al., 2022; Stall et al., 2021).

Functional decline is a common change that occurs in residents of long-term care facilities(Hirdes et al., 2011b; R. N. Jones et al., 2010b). It is defined as the inability to perform one or more activities of daily living due to a decrement in physical, mental, or cognitive capacity (Abdulaziz et al., 2016). Some have suggested that COVID-19 infection further impairs the physical function of older persons infected, reducing their ability to perform usual activities of daily living, with an

increase in functional decline rates(Cortés Zamora et al., 2022; de Oliveira Almeida et al., 2022; Hosoda & Hamada, 2021; Pérez-Rodríguez et al., 2021; Prampart et al., 2022; Trevissón-Redondo et al., 2021). Functional loss is a major concern among older adults because it can dramatically increase their need for support to meet basic tasks of daily living, thereby increasing resource intensity(B. E. Fries et al., 1994; L. A. Turcotte et al., 2019). It is also associated with higher rates of adverse health outcomes and mortality(Covinsky, Palmer, et al., 2003; Fortinsky et al., 1999; Roberts et al., 2021).

There are some potential mechanisms for how the pandemic may have affected changes in function over time, including reduced access to rehabilitative services, restrictions on movement within facilities for infection control leading to sedentary behavior, and cognitive changes associated with delirium from a variety of possible causes (e.g., stress, infection). However, for any such assertions to be substantiated, it is essential first to establish the extent to which rates of functional decline differed during the pandemic compared with prior experience. The proportion of residents who would usually experience a decline in physical function in LTC homes varies depending on the measure used, the period covered, and the country(Fedecostante et al., 2021; Palese et al., 2016). Some studies reported that up to 47% of residents experienced a functional decline during the pandemic(Cortés Zamora et al., 2022; Pérez-Rodríguez et al., 2021), but they do not state whether these rates *differ* from the pre-pandemic period.

We investigated whether exposure to the first wave of the COVID-19 pandemic (March to June 2020) was associated with further functional decline among persons in LTC facilities in Canada using pre-pandemic and pandemic comparison groups to account for the usual change in function in our study population.

3.2. Methods

3.2.1. Study Design

We conducted a population-based longitudinal study of persons receiving care in LTC homes in Canada before and during the COVID-19 pandemic.

Ethics approval for this study was provided by the University of Waterloo's Office of Research Ethics (**#30173**).

3.2.2. Data Sources

This study used data from the Canadian Institute for Health Information's Continuing Care Reporting System (CCRS). CCRS contains person-level data collected using the routinely administrated interRAI Minimum Data Set 2.0 (MDS 2.0) comprehensive health assessment. The interRAI MDS 2.0 collects standardized information about an individual's health status, functioning, and care needs based on a broad range of clinical domains (e.g., cognitive, behavioral, social support, frailty, and physical function). Trained assessors complete these assessments within 14 days of admission to LTC homes. They are repeated every 90 days after that or sooner in the case of a significant change in health status. The reliability and validity of the

assessment items, outcome measures, and summary scales are well established(Hirdes et al., 2013b; Morris et al., 1997; Poss, Jutan, et al., 2008). Information from these assessments is used for care planning(Morris, J.N., Belleville-Taylor, P., Berg, K., Björkgren, M., Frijters, D., Fries, B.E., Frise Smith, T., Gilgen, R., Gray, L., Hawes, C., Henrard, J.C., Hirdes, J.P., Ljunggren, G., Nonemaker, S., Rabinowitz, T., Finne-Soveri, H., Steel, R.K., Zimmerman, 2008; Morris et al., 2010), as well as program and system-level quality performance assessment(B. E. Fries et al., 1994; Hirdes et al., 2011b; L. A. Turcotte et al., 2019)

3.2.3. Study Participants

The study participants included LTC residents from British Columbia, Alberta, Manitoba (note: the Manitoba sample includes Winnipeg Regional Health Authority), Ontario, Newfoundland, and Labrador. The participants consisted of two groups selected based on exposure to the COVID-19 pandemic. Pre-pandemic residents were included if they were already receiving care or admitted into an LTC home between January 1st and March 31st, 2019. This group's index (Time 1) assessment was conducted with the MDS 2.0 instrument between January 1st and March 31st, 2019, and the follow-up (Time 2) assessment between April 1 and June 30, 2019. Participants in the pandemic group were selected if they were already receiving care or admitted into an LTC home between January 1st and March 31st, 2020. The pandemic group's index assessment was conducted between January 1 and March 31, 2020, and the follow-up assessment was between April 1 and June 30, 2020. Residents were excluded from the study if they were discharged, transferred to

other care settings, or died before their time two assessment. We excluded residents who were comatose at baseline or follow-up to maintain the validity of our study since their level of physical function performance cannot be credibly determined. Based on the MDS assessment item related to end-stage disease, we also excluded persons with less than six months to live at baseline.

3.2.4. Outcome of Interest

The study's primary outcome of interest was a functional decline between the index and follow-up MDS 2.0 assessments. We defined functional decline as a one or more-point worsening in the interRAI ADL Hierarchy scale. The interRAI ADL Hierarchy scale is a 7-level ordinal measure of functional performance based on a person's ability to complete early (personal hygiene), middle (toileting and locomotion), and late-loss (eating) ADLs(Carpenter et al., 2006; Morris et al., 1999). The ADL Hierarchy scale is particularly useful in situations where a system-induced change in ADL is being determined(Morris et al., 1999), such as the COVID-19 pandemic. One-point change in a 7-item Older Americans' Resource and Services (OARS) ADL scale [range 0 - 14] was considered to be clinically significant by geriatricians surveyed in Canada(Abdulaziz et al., 2016), while a study by Suijker *et al.* reported a 0.47 points difference on the KATZ ADL scale [range 0 – 6] to be a "minimally important change"(Suijker et al., 2017). A one-point change in the interRAI ADL hierarchy scale is equivalent to a 2.6-point mean change in interRAI short form [range 0 -14], similar to the OARS ADL scale. Therefore, we infer that a

1-point decline in the interRAI ADL hierarchy represents a clinically significant change.

We also considered changes in specific ADLs that were components of this scale to examine what areas of function were affected. Persons with an ADL Hierarchy Scale score of 6 (maximum) at baseline were excluded as no further decline on this measure is possible.

3.2.5. Independent Variable Selection

We selected independent variables based on previous literature showing their associations with functional decline among institutionalized persons(Fedecostante et al., 2021; Jerez-Roig, De Brito MacEdo Ferreira, et al., 2017). We included socio-demographic variables like age, sex, and the Revised Index of Social Engagement score, clinical variables like Cognitive Performance Scale (CPS)(Morris et al., 1994), ADL Hierarchy scale (described above), Changes in Health, End Stage Disease and Signs and Symptoms (CHESS) scale(Hirdes et al., 2003), acute frailty index(Hubbard et al., 2015). Other variables such as urinary and bowel incontinence status, perceived rehabilitation potential, visual and hearing impairment, a previous visit to the hospital or emergency room in the past 90 days, and number of medications used were also included in the original model, **Supplementary Table B.1.** We also utilized the resource utilization group (RUG) variable for stratification analysis(B. E. Fries et al., 1994). A full list of the RUG categories and description of their classification criteria is included in **Supplementary Table B.2**.

3.2.6. Statistical Analysis

We performed descriptive analysis using frequency distributions, percentages, chi-square test of association, and their p values to show the baseline characteristics of the COVID-19 and the pre-COVID-19 groups. We conducted cross-tabulations between each categorical variable and a variable representing the groups. We used the Wilcoxon rank sum test to examine the association between two-category independent variables and ordinal categorical dependent variables.

We fit a generalized estimating equation (GEE) regression model to compare the adjusted odds of functional decline among the COVID-19 pandemic-exposed cohort relative to the unexposed cohort using PROC GENMOD in SAS. To account for the repeated measure among residents in each group and the overlap between periods, we specified the "REPEATED" statement in the model using residents as subjects. To control against the likely clustering of effect at the facility level, we further nested residents within facilities using the REPEATED statement, specifying the subjects as residents by facilities. We included the interaction term between the treatment group variable (pandemic vs. pre-pandemic) and the pre-post variable (Time 1 vs. Time 2) to obtain the additional odds of functional decline during the pandemic. By including the known factors in the model, we controlled for differences in the baseline characteristics between cohorts, including factors associated with functional decline. In addition, we had stratified analyses by province, facility-type, and geographic setting since one might expect regional or facility-level differences in outcomes in addition to person-level covariates.

The STROBE(Von Elm et al., 2007) and RECORD(Benchimol et al., 2015) guidelines for reporting observational studies and routinely collected data were adhered to in preparing this manuscript. All statistical analysis was performed using SAS v9.4 (SAS Institute, Inc., Cary, NC).

3.3. Results

3.3.1. Participants' Characteristics

A total of 1,173 and 1,167 LTC homes in the pre-pandemic and pandemic periods, respectively, were included in the analytic sample. Of these, 876 were in urban areas during both periods, and the rest were in rural areas (**Supplementary Table B.3**). Our initial sample consisted of 129,752 pre-pandemic and 129,293 pandemic period residents assessed for study eligibility. The final analytic sample consisted of 199,598 (95,674 pandemic and 103,924 pre-pandemic) LTC residents with room for further functional decline. There was overlap between the study groups as 65,086 residents in LTC homes pre-pandemic remained in the homes during the pandemic. The mean age of all residents was 83.3 years, 67.4% (n = 157,265) of whom were females. A comparison of baseline characteristics between pre-pandemic and pandemic groups is presented in **Table 3.1.**

3.3.2. Frequency and Unadjusted Odds of Functional Decline

In the bivariate analysis using cross-tabulation, the overall frequency of 90-day functional decline was slightly higher among residents during the 1st wave of the COVID-19 pandemic compared to the pre-COVID-19 period (23.3% vs. 22.3%; p <

0.0001). Using the GEE model, the unadjusted odds of functional decline were also slightly higher during the pandemic, OR 1.05 (95% CI 1.03 – 1.08). Before and during the pandemic, the frequency of functional decline after 90 days was greater among residents with lower (better) baseline ADL Hierarchy scores. The incidence of functional decline then reduced progressively as baseline ADL Hierarchy scores increased (worsened) (**Figure 3.1**).

Table 3.1: Baseline Characteristics Comparison of the Overall and Two Study Cohorts, 2019 – 2020, N = 199,598.

		Total n = 199 598 (%)	**Pre-COVID** n = 103 924 (%)	**COVID** n = 95 674 (%)	**P values**
Variable	**Category**				
Age group	<65	18 345 (9.2)	9 513 (9.1)	8 832 (9.2)	0.22*
	65-74	28 210 (14.1)	14 497 (14.0)	13 713 (14.3)	
	75-84	62 775 (31.5)	32 797 (31.6)	29 978 (31.3)	
	85+	90 268 (45.2)	47 117 (45.3)	43 151 (45.1)	
Sex	F	133 835 (67.0)	69 801 (67.2)	64 034 (66.9)	0.26†
	M	65 763 (33.0)	34 123 (32.8)	31 640 (33.1)	
ADL Hierarchy Scale	0	7 771 (3.9)	4 198 (4.0)	3 573 (3.7)	< 0.0001*
	1-2	33 525 (16.8)	17 636 (17.0)	15 889 (16.6)	
	3-4	113 257 (56.7)	58 720 (56.5)	54 537 (57.0)	
	5	45 045 (22.6)	23 370 (22.5)	21 675 (22.7)	
CPS Scale	0	18 695 (9.4)	9 765 (9.4)	8 930 (9.3)	0.18*
	1-2	57 053 (28.6)	29 704 (28.6)	27 349 (28.6)	
	3-4	95 161 (47.7)	49 357 (47.5)	45 804 (47.9)	
	5-6	28 689 (14.3)	15 098 (14.5)	13 591 (14.2)	
CHESS Scale	0	98 212 (49.2)	51 090 (49.2)	47 122 (49.3)	0.02*
	1-2	94 525 (47.4)	49 173 (47.3)	45 352 (47.4)	
	3+	6 861 (3.4)	3 661 (3.5)	3 200 (3.3)	
DRS	0	91 548 (45.9)	47 190 (45.4)	44 358 (46.4)	
	1-2	56 346 (28.2)	29 505 (28.4)	26 841 (28.1)	0.03
	3+	51 704 (25.9)	27 229 (26.2)	24 475 (25.5)	

Frailty index	0.01-0.20	14 308 (7.2)	7 584 (7.3)	6 724 (7.0)	<0.0001*
	0.21-0.30	33 151 (16.6)	17 162 (16.5)	15 989 (16.7)	
	0.31-0.40	67 742 (33.9)	34 889 (33.6)	32 853 (34.3)	
	>0.40	84 397 (42.3)	44 289 (42.6)	40 108 (41.9)	
BMI Category	Underweight	14 797 (7.4)	7 723 (7.4)	7 074 (7.4)	0.59*
	Normal	76 014 (38.1)	39 639 (38.1)	36 375 (38.0)	
	Overweight	59 097 (29.6)	30 730 (29.6)	28 367 (29.7)	
	Obese	49 690 (24.9)	25 832 (24.9)	23 858 (24.9)	
Hearing	Adequate	125 261 (63.1)	65 096 (63.0)	60 165 (63.2)	0.03*
	Mini Difficulty	49 040 (24.7)	25 446 (24.6)	23 594 (24.8)	
	Special Situation Only	21 336 (10.8)	11 294 (10.9)	10 042 (10.6)	
	Highly Impaired	2 778 (1.4)	1 461 (1.4)	1 317 (1.4)	
Vision	Adequate	115 804 (58.4)	59 944 (58.0)	55 860 (58.7)	0.002*
	Impaired	55 744 (28.1)	29 284 (28.4)	26 460 (27.8)	
	Moderately impaired	13 592 (6.8)	7 194 (7.0)	6 398 (6.7)	
	Highly impaired	10 412 (5.3)	5 393 (5.2)	5 019 (5.3)	
	Severely impaired	2 853 (1.4)	1 381 (1.4)	1 381 (1.5)	
Rehabilitation potential	Yes	28 028 (14.0)	14 739 (14.2)	13 289 (13.9)	0.06†
	No	171 570 (86.0)	89 185 (85.8)	82 385 (86.1)	
Diabetes	Yes	52 560 (26.3)	27 263 (26.2)	25 297 (26.4)	0.29†
	No	147 038 (73.7)	76 661 (73.8)	70 377 (73.6)	
Parkinson's disease	Yes	11 928 (6.0)	6 236 (6.0)	5 692 (6.0)	0.62†
	No	189 495 (94.0)	97 065 (94.0)	89 430 (94.0)	

*** Kruskal-Wallis's test** **† Pearson's Chi-square test**

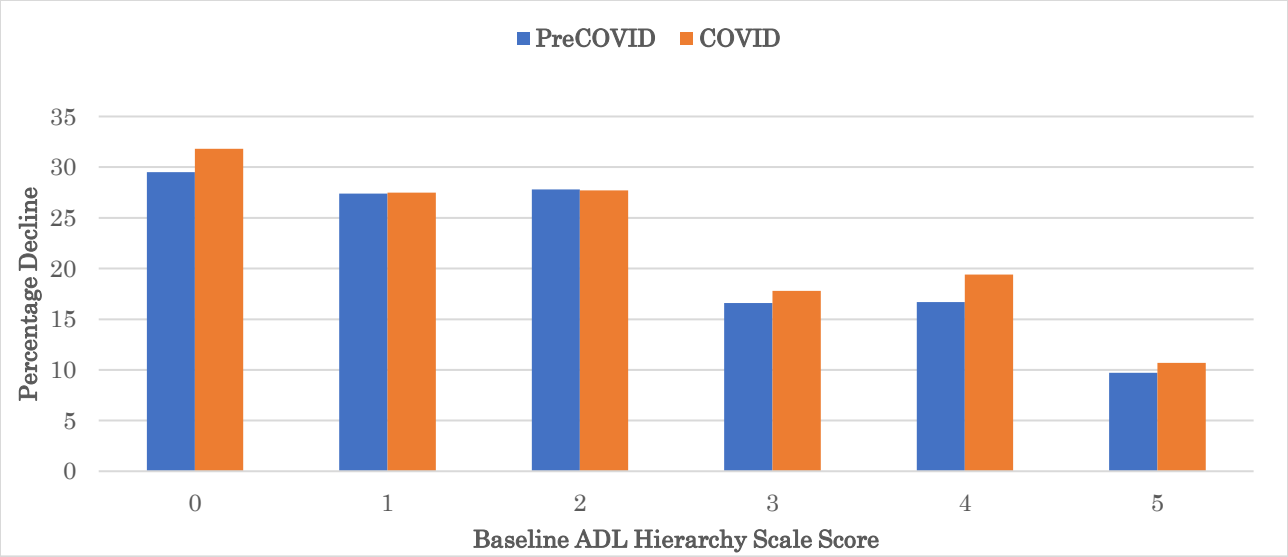


Figure 3.1: Percentage of Study Participants Who Experienced Functional Decline Between the Baseline ADL Hierarchy Scale Score Before and During the COVID-19 Pandemic.

We further analyzed functional decline to show residents whose ADL hierarchy score changed by 1, 2, or 3+ between baseline and follow-up. Pre-pandemic, the proportion of residents who declined by only 1 point had a curvilinear pattern, with maximum frequency at baseline ADL hierarchy score 2 (ADL score 0=13.2%, 1=17.0%, 2=20.5%, 3=11.2, 4=3.4, 5=9.5). In contrast, the proportion of residents who declined by two or 3+ points showed a linear trend, being maximum at the score of 0 and progressively reducing to 0 at baseline ADL hierarchy score of 5 (for 2 points decline: ADL hierarchy score 0=9.2%, 1=7.5%, 2=4.4%, 3=4.5, 4=2.2, 5=0.0%), (for 3+ points decline: ADL score 0=7.1%, 1=2.9%, 2=2.8%, 3=0.7, 4=0.0, 5=0.0%). The patterns of decline across baseline ADL hierarchy scores were similar during the pandemic, **Supplementary Table B.4**.

When comparing the frequency of functional decline among residents between the pandemic and pre-pandemic periods in specific components of the ADL Hierarchy Scale, we observed significant differences only in the locomotion (16.8% vs. 15.4%; p < 0.0001) and eating (17.6% vs. 15.9%; p < 0.0001) items.

3.3.3. Association Between Pandemic Period and Functional Decline

After adjusting for factors associated with functional decline at baseline, the odds of experiencing 90-day functional decline were 17% (OR 1.17; 95% CI 1.15 - 1.20) greater during the 1st wave of the pandemic period compared to the similar period before the pandemic (**Table 3.2**).

Table 3.2: Adjusted Odds of Functional Decline Among LTC Residents During the COVID-19 Period Vs. Pre-COVID Period, 2019 – 2020, n = 199,598.

Variable	Category	Parameter estimate	SE	Adjusted OR (95% CI)	P value
Cohort	Pre-COVID-19		ref		< 0.0001
	COVID-19	0.16	0.01	1.17 (1.15 – 1.20)	
Age group	<65		ref		<0.0001
	65 - 74	0.10	0.03	1.11 (1.05 – 1.17)	
	75 - 84	0.22	0.02	1.25 (1.19 – 1.31)	
	85+	0.30	0.03	1.34 (1.28 – 1.41)	
Sex	Female		ref		0.005
	Male	-0.04	0.01	0.96 (0.94 – 0.99)	
Frailty index	0.01 - 0.2		ref		<0.0001
	0.21 - 0.30	0.40	0.03	1.49 (1.41 – 1.58)	
	0.31 - 0.40	0.86	0.03	2.37 (2.22 – 2.52)	
	>0.40	1.15	0.04	3.17 (2.95 – 3.40)	
Depression Rating Scale (DRS)	0		Ref		<0.0001
	1-2	-0.11	0.02	0.89 (0.87 – 0.92)	
	3+	-0.16	0.02	0.85 (0.82 – 0.88)	
ADL Hierarchy	0		ref		<0.0001
	1-2	-0.62	0.03	0.54 (0.50 – 0.57)	
	3-4	-1.8	0.03	0.17 (0.15 – 0.18)	
	5-6	-2.8	0.04	0.06 (0.05 – 0.18)	

CPS	0			ref	<0.0001
	1-2	0.02	0.02	1.02 (0.97 – 1.07)	
	3-4	0.00	0.03	1.00 (0.95 – 1.06)	
	5-6	0.29	0.03	1.34 (1.26 – 1.43)	
Rehab potential	No			ref	<0.0001
	Yes	-0.12	0.02	0.89 (0.86 – 0.92)	
Social engagement		-0.08	0.00	0.92 (0.91 – 0.93)	<0.0001
Vision	Adequate			ref	<0.0001
	Impaired	0.03	0.01	1.03 (1.00 – 1.06)	
	Moderately impaired	0.06	0.02	1.06 (1.01 – 1.12)	
	Highly impaired	0.24	0.03	1.27 (1.21 – 1.34)	
	Severely impaired	0.37	0.05	1.44 (1.31 – 1.59)	
Hearing	Adequate			ref	0.0009
	Mini Difficulty	-0.02	0.02	0.98 (0.95 – 1.01)	
	Special Situation	-0.08	0.02	0.92 (0.89 – 0.96)	
	Highly Impaired	-0.11	0.05	0.90 (0.81 – 1.00)	
Making self understood	Understood			ref	<0.0001
	Usually	0.05	0.02	1.05 (1.02 – 1.08)	
	Sometimes	0.19	0.02	1.21 (1.16 – 1.26)	
	Rarely/Never	0.64	0.03	1.90 (1.78 – 2.03)	
Health Conditions					
ALS	Yes	0.65	0.16	1.92 (1.40 – 2.63)	<0.0001
Alzheimer	Yes	0.07	0.02	1.07 (1.03 – 1.11)	<0.0001
Parkinson	Yes	0.17	0.03	1.18 (1.12 – 1.24)	<0.0001
Quadriplegia	Yes	0.79	0.12	2.19 (1.73 – 2.78)	<0.0001
Anxiety disorder	Yes	-0.07	0.01	0.93 (0.90 – 0.97)	<0.0001
Arthritis	Yes	0.13	0.04	1.14 (1.05 – 1.25)	0.003
Unsteady gait	Yes	-0.15	0.01	0.86 (0.84 – 0.88)	<0.0001

When comparing within provincial strata, residents were more likely to experience functional decline during the pandemic period in British Columbia (OR 1.17; 95% CI 1.11 - 1.23) and Ontario (OR 1.25; 95% CI 1.21 - 1.29) but not in other provinces. In addition, the odds of functional decline were greater during the pandemic period in medium (OR 1.10; 95% CI 1.06 - 1.17) and large-sized LTC facilities (OR 1.20; 95% CI 1.17 - 1.24). We also observed a significant increase in the

odds of functional decline among facilities located in urban areas (OR 1.20; 95% CI 1.17 – 1.23) compared to those in rural areas (OR 1.06; 95% CI 1.00 - 1.13) (**Figure 3.2**). Stratifying by the RUG category classification, clinically complex residents (OR 1.19; 95% CI 1.13 – 1.26), as well as those who required *Specialized care* (OR 1.22; 95 CI 1.12 – 1.32) at baseline, had greater odds of functional decline during the first wave of the pandemic. The odds of functional decline by all the RUG categories and by the neighborhood income quintile of LTC home location are shown in Figure 2. Lastly, residents with the greatest need for assistance with basic ADLs at baseline were most likely to experience additional functional decline during the pandemic compared to the pre-pandemic period (**Figure 3.2**). This result is consistent with the finding on change in eating status, which is a late loss of ADL.

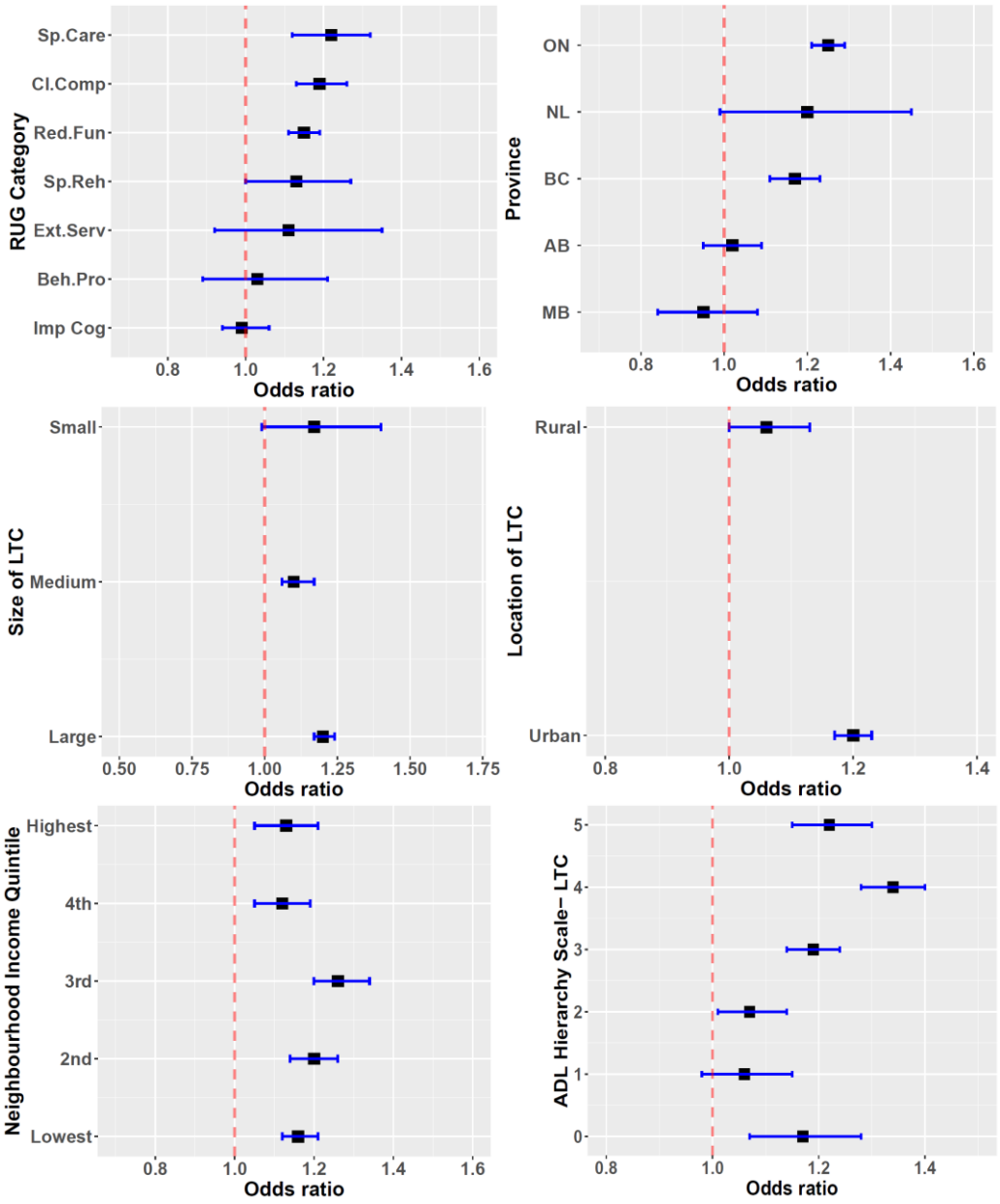


Figure 3.2: Adjusted Odds of Functional Decline Among LTC Residents During the COVID-19 vs. Pre-COVID Period, Stratified by Location, Province, Size, Neighborhood Income Quintile of LTC Home, RUG Category, and ADL Hierarchy Scale, Forest Plot.

3.4. Discussion

Using a large population-based longitudinal study of persons within five provinces in Canada, we found that LTC residents in the study population were more likely to experience functional decline during the first wave of the COVID-19 pandemic than in the year before the pandemic. Our finding of significantly higher odds of experiencing functional decline among LTC residents during the COVID-19 pandemic was consistent with other reports. Still, the degree of change that we found was less pronounced than has been suggested by others. Prior studies have reported functional decline among nursing home residents (Cortés Zamora et al., 2022; Pérez-Rodríguez et al., 2021) and older adults hospitalized due to COVID-19 infection(Larsson et al., 2021; Pérez-Rodríguez et al., 2021; Pizarro-Pennarolli et al., 2021; Walle-Hansen et al., 2021) without baseline comparison groups.

The failure to account for patterns of pre-pandemic change can lead to an exaggerated perception of the effect size of the pandemic on physical function. Using pre-pandemic and pandemic comparison groups enabled us to confidently make inferences about the effect of the pandemic-driven and sector-wide measures on rates of functional decline among LTC residents. McArthur et al., using a similar study design, recently showed reduced performance in instrumental activities of daily living (IADL) among home care recipients in Canada(McArthur et al., 2022). Also, by using routinely collected, high-quality, comprehensive health assessment data, we were able to measure individual-level changes in functional performance over time before and during the COVID-19 pandemic.

In addition to showing a small additional, significant effect of the COVID-19 pandemic on functional decline among LTC residents (**Table 3.2**), our analysis showed that the pandemic had a significantly greater effect for residents requiring the most assistance with performing their basic ADLs (ADL Hierarchy 3, 4 & 5) at baseline, but not for residents requiring little to no help with basic ADLs (**Figure 3.2**). This differential effect shows that the pandemic and associated control measures may harm the most vulnerable residents more. Our finding bolsters this conclusion that residents with deficits in mid- and late-loss ADLs (locomotion and eating) at baseline were more likely to experience additional functional decline during the pandemic. In contrast, those with a deficit only in the early loss ADLs (personal hygiene) were less affected.

The potential role played by pandemic measures adopted across Canada and globally in the occurrence of the observed differential physical function effects deserves further scrutiny(Heckman et al., 2020). Most Canadian provinces implemented public health measures during the initial wave of the COVID-19 pandemic to reduce the risk of exposure and spread among institutionalized older adults, but only two (Ontario and BC) showed evidence of functional decline in this period. That suggests that the restriction on external visitors was unlikely to be a predominant cause of functional decline. However, the extent and timing of the imposition of restrictions differed by province. Ontario and BC were often the first to initiate public health measures, while Alberta, Manitoba, and Saskatchewan were often the last (Cyr et al., 2021). Still, it is difficult to directly connect this difference

and the differential pandemic effect on functional decline. In addition to restricting external visits to LTC homes, the provinces adopted COVID-19 measures such as limiting access to informal caregivers and limiting transfers from LTC homes to hospitals for usual acute or chronic disease exacerbation.

The additional decline in physical function experienced by LTC home residents during the pandemic may have resulted from service disruptions during the pandemic. This includes those imposed by staffing challenges due to COVID-19 infection among staff, which may have brought about changes in the quality of care, likely creating collateral morbidity consequences(Stall et al., 2021).

Hospital transfers from LTC facilities to acute care hospitals were among the care services compromised during the first wave of the pandemic, leading to reductions in care for residents with other pre-existing chronic conditions. Relative to the pre-pandemic period (2019), hospital transfers from LTC homes in Canada decreased on average by up to 58% between March 2020 and June 2021 for many chronic conditions such as COPD (58%), Pneumonia (52%), Heart failure (41%), UTI (27%), delirium (23%)(Canadian Institute for Health Information, 2021a). Decompensation from lack of medical care for these conditions could have contributed to LTC residents' higher functional decline. However, the extent of functional decline as a result of the reduced transfers for chronic care may have been contained by avoidance of often unnecessary hospitalizations, sparing frail LTC residents from iatrogenic consequences commonly associated with hospital care(Kajdacsy-Balla Amaral et al., 2022).

The additional functional decline experienced by LTC residents during the pandemic may also have occurred through two pathways, both related to the pandemic. First, we found a further significant decline only in locomotion and eating ADLs during the first wave of the pandemic. While the additional loss in locomotion ADL function may be explained by the isolation and restriction of residents' movement within LTC homes during this period, the loss in eating ADL function cannot be explained only by reduced locomotion resulting from restricted movement during the pandemic. This additional loss in the eating ADL function may have been the result of worsening health conditions due to service disruptions, reducing the quality of care to residents living with chronic conditions, especially where there is acute exacerbation. Evidence shows that reduced appetite is strongly associated with worsening chronic conditions such as heart failure(Andreae et al., 2021; Pilgrim et al., 2015; Zukeran et al., 2022). The higher loss in eating ADL we found in this analysis could also be related to possible increases in depression and mood change reportedly experienced by nursing home residents during this period(Coe Pharmd et al., 2022; Dahab et al., 2021a). Depression and mood changes affect appetite, especially among older adults(Pilgrim et al., 2015). Furthermore, both reduced locomotion and eating function are causally associated with sarcopenia and could lead to deconditioning, a physiological change that may cause functional decline(Graf, 2006). Future planning and measures for controlling similar disease outbreaks would benefit from considering these pathways highlighted by our study.

Future studies should explore whether functional decline was significantly higher among COVID-19 survivors after accounting for the effect of other pandemic measures using pre-and-post cohorts' analysis.

3.5. Limitations

One limitation of our study was our inability to identify people in the cohort that COVID-19 had infected because that information is not included in the study dataset. Therefore, we could not adjust for COVID-19 infection as a risk factor for functional decline and could not stratify functional decline by infection status. Secondly, residents who were infected and died before the follow-up were not included in our analytic sample and may impact the effect size. Third, given that pandemic restrictions were in place over a more extended period than the first wave, future research should examine whether functional declines occurred in later waves of the pandemic. Other factors that may have affected functional decline during COVID-19 are staffing challenges, absenteeism, burnout, etc. However, data on these challenges was not available to us and was accounted for in the effects reported. Considering the significant effect these "structural and systems" factors have on functional decline, it is essential that in Canada and other places not already doing so, data about these factors are routinely collected and documented using assessment instruments. We would also highlight that not all provinces and territories in Canada were represented in the study population, so this may not be fully representative of all Canadians in LTC homes.

3.6. Conclusion and Implications

LTC residents in Canada experienced some additional functional decline during the first wave of the COVID-19 pandemic compared with changes before the pandemic. This finding provides valuable insight and other information to health administrators and policy makers seeking to understand how the COVID-19 pandemic and associated public health measures affected LTC residents' health outcomes. The findings will also be helpful for clinicians seeking to understand the pattern of ADL decline during the pandemic, which could be integrated into the planning of restitutive measures for those affected by the current pandemic, as well as for planning preventive measures for future occurrences.

Conflict of interest disclosure: The authors have no conflicts of interest or financial conflicts to declare related to the components of this research or the manuscript's content.

Chapter 4:

Study 3: Understanding the Trajectory Patterns of Functional Decline in Long-Term Care Settings: A Retrospective Cohort Study of Canadian Nursing Home Residents.

3.2. Introduction

The decline in the ability to perform activities of daily living (ADL) or "*functional decline"* is widespread in aging populations, especially long-term care (LTC) residents, partly because the loss of physical function is one of several reasons older adults receive institutionalized care(Covinsky, Palmer, et al., 2003; Fortinsky et al., 1999; Sager & Rudberg, 1998; Yeh et al., 2014). Evidence shows that ADL decline could sometimes be delayed, prevented, or even improved with interventions (Gill et al., 2002; Martínez-Velilla et al., 2019; Morris et al., 2019; Oida et al., 2003). This suggests that the physical function of some LTC residents can be further enhanced by accurately forecasting their expected future ADL decline trajectory as a guide for early intervention. However, the ability to predict ADL trajectories of change in the LTC setting is currently lacking, as existing tools are only designed to identify immediate risk(De Saint-Hubert et al., 2010; Deckx et al., 2015; Sutton et al., 2008). Besides improving or maintaining physical function, developing the capability to predict future trajectories of ADL change and its associated factors will strengthen patient-level care planning, improve resource allocation to the facilities, and substantially reduce healthcare costs.

Functional decline represents an adverse change in physical function caused by several factors, including cognitive impairment, lack of physical activity, poor nutrition, and other medical conditions. A significant proportion of residents are admitted following acute health events such as stroke(Cowman et al., 2010; Harrison et al., 2022; P. H. Lee et al., 2021), and within the setting, some experience decline associated with acute health changes such as respiratory tract infection, stroke, and falls, among others. These types of functional decline may be reversible with appropriate and timely interventions(Cho & Lee, 2012; Clery et al., 2021; Harrison et al., 2022). Functional decline is also associated with longer-term persistent changes such as the aging process(Joaquin & Gollapudi, 2001), the concurrent presence of multiple chronic conditions (multimorbidity), and the depletion of physiologic reserve (frailty)(Boyer et al., 2022; Tchalla et al., 2022). It is a condition that affects primarily older adults. Fong *et al.* showed an increasing cumulative incidence of functional decline with age among older adults in the US(Fong, 2019). Functional decline commonly occurs with other geriatric syndromes like delirium, incontinence, and cognitive impairment with which it shares common risk factors(Inouye et al., 2000a; Surkan & Gibson, 2018); however, there may also be circular patterns of causality between these syndromes. These will require a nuanced understanding and approach for optimal care.

Limitations in ADL performance are the primary determinant of resource utilization in LTC settings(Björkgren et al., 1999; Carpenter et al., 1997; B. E. Fries et al., 1994; B. E. Fries & Cooney, 1985; Ikegami et al., 1994; Turcotte et al., 2019; B.

C. Williams, Fries, Foley, Schneider, Gavazzi, et al., 1994). Similar results have been reported for home care settings(Björkgren et al., 2000; Poss, Hirdes, et al., 2008). It imposes an additional burden on the general health system, patients, and their families. In addition, ADL decline is a major component in the *Changes in Health and End-stage Signs and Symptoms* (CHESS) scale(Hirdes et al., 2003), which predicts the risk of 1-yr mortality among persons in LTC, home care, complex continuing care hospitals, and palliative care(Hirdes et al., 2014; Williams et al., 2022).

For LTC residents, functional decline does not necessarily involve permanent, unidirectional change with no possibility of recovery. Some residents have been shown to improve in function(Hirdes et al., 2019; McArthur et al., 2017), and for others, a decline could be delayed or prevented with appropriate lifestyle modifications, medical treatment, rehabilitation, or social support(Banaszak-Holl et al., 2011; Valenzuela et al., 2023; Walk et al., 1999). Improvement in physical function may be possible among some LTC residents. For example, improvement may occur where functional decline results from acute health problems or problems related to neglect (e.g., malnutrition)(Boaz, 1994). Although most individuals "*progressively*" decline in function until their death, with periods of fluctuations between high and low function(Lunney et al., 2003; Strauss, 1968; Wolinsky et al., 1993), individuals will follow different trajectories, with some showing functional improvement or remaining relatively stable over time(Hébert, 1997; Lowsky et al., 2014; Lunney et al., 2002, 2003). Jerez-Roig *et al.* showed that only about 44% of residents followed up in a study of nursing homes in Brazil maintained their physical

function after 24 months, but more importantly, the study showed that this trajectory pattern was not the same for all study participants(Jerez-Roig, De Brito MacEdo Ferreira, et al., 2017). It may also be that trajectories will change over time as admission criteria for long-term care placement change to reduce premature institutionalization.

Despite these expectations, trajectories of change in function have not been well studied among LTC residents, compared to community-dwelling and hospitalized older adults, based on literature evidence(Palese et al., 2016; Sands et al., 2008). Our recent (**see chapter 2**) scoping literature review showed that only 6.4% out of 110 eligible studies looked at trajectory patterns in LTC, compared to 82.7% focused on community-dwelling and 10.9% on hospitalized older adults. Much of the literature on ADL decline in LTC settings has focused on its terminal trajectory towards the end of life(Chen et al., 2007; Covinsky, et al., 2003; Guion et al., 2021; Morgan et al., 2019). While these studies help understand clinical management towards the end of life, they do not deal with LTC residents who have the potential to improve their function. A few studies have attempted to resolve this gap by considering ADL decline among LTC residents not only towards the end of life but also from the time of admission. Lawrence, Robinson & Aagar(Lawrence et al., 2017) studied how identifying diagnostic groups and their function trajectory can be used for advanced care planning in Australia (Lawrence et al., 2017). Hirdes *et al.*(Hirdes et al., 2011b) showed that nursing home residents' health needs can be better served using person-level evidence.

Advances in trajectory modeling allow clinical researchers to explore the "developmental" trajectory of clinical outcomes(Nguefack et al., 2020). As techniques and methods for trajectory modeling continue to evolve, interest in predicting the course of functional decline for older adults, especially that of identifying distinct sub-groups within populations, has grown. Before the availability of more advanced analytic techniques, such as latent class growth analysis, the longitudinal course of functional decline was mainly modeled using the mean or average population change. The previous modeling approach presumed that the decline in physical function trajectory for any given population could be represented by a single mean parameter around which every individual wavers. A major flaw with this method is that a single parameter masks essential information that may be embedded within the data because of the heterogeneous nature of older adult populations. Moreover, patterns of change are not necessarily normally distributed. Although physical function broadly and generally declines over time, the trajectory of health status is rarely linear, and evidence suggests that there are sub-trajectory patterns within each population of older adults(World Health Organization (WHO), 2015).

The WHO framework for healthy aging provides conceptual support for the idea of sub-trajectory patterns of health change(World Health Organization (WHO), 2015). The framework hypothesizes the existence of three trajectories of change in physical capacity over time in the second half of life(World Health Organization (WHO), 2015), similar to functional decline sub-groups. Before the development of the WHO framework, Glaser and Strauss, in their widely cited papers "A Time for

Dying" & "Awareness of Dying", had suggested the existence of different trajectories of physical function in a given population, theorizing that four different trajectories exist among dying persons(Glaser & Strauss, 2005; Strauss, 1968), each determined by the individual's prevalent disease or health condition. Evidence of functional sub-trajectories in older adults has also grown in the literature. Bimou *et* al. (Bimou et al., 2021), Gill *et al.* (Gill et al., 2010), and Saito *et* al. (J. Saito et al., 2019) provided evidence of distinct functional decline trajectory subgroups among community-dwelling older adults.

Identifying subgroup trajectories of functional decline for older adult populations is necessary since interventions required to improve physical function will likely differ for different trajectory subgroups(Lawrence et al., 2017). For example, people with Alzheimer's disease may experience a consistent pattern of decline. In contrast, those with stroke may improve in some cases or maintain a persistent level of function after an initial decline. Mapping the trajectory of ADL decline over time and identifying factors associated with each trajectory group membership will aid decision-making and enhance the design of targeted interventions. Further, understanding the trajectory of functional decline offers other opportunities and benefits.

First, it will allow for early identification of functional limitations and associated potential health challenges. Healthcare professionals could use such knowledge to implement interventions to prevent, delay, or mitigate the effects of the decline. Second, by understanding an individual's expected trajectory of functional

decline, healthcare providers can develop personalized treatment plans tailored to the individual's specific needs and anticipated progression. This approach allows targeted interventions and therapies to maintain functional abilities for as long as possible. Third, knowledge of the trajectory of functional decline could mitigate caregiver distress by enabling them to anticipate health trajectories, helping them to plan and adapt their caregiving strategies, seek necessary support networks, and make informed decisions about their loved one's well-being. It will equally help the affected persons themselves to adjust their expectations and be emotionally and psychologically prepared for the health trajectory ahead of them. This can, therefore, support an evidence-informed approach to person-level advance care planning.

Knowing the trajectory of functional change can also inform research efforts to develop new treatments, interventions, and technologies to slow down, reverse, or adapt to the decline. This knowledge provides a foundation for studying the underlying mechanisms of functional decline, identifying risk factors, and exploring potential strategies for intervention. However, as noted in the next section, current approaches to identifying ADL trajectories of change are inadequate to support long-term planning.

4.1.1. Risk of Functional Decline: Current Identification Approach

Researchers, care providers, and health administrators have long been interested in identifying the trajectory or at least the risk of functional decline, aware

that the hospitalization of older adults for acute care predisposes them to functional decline(Graf, 2006; Inouye et al., 2000b; Lafont et al., 2011; Sourdet et al., 2015).

Risk Assessment Tools

Several tools are currently used to identify older adults at risk of developing functional decline following acute health events. These are commonly available in hospitals and emergency rooms. Systematic reviews by Wang *et al.* (M.-C. ; Wang et al., 2022), Hoogerduijn *et al.* (Hoogerduijn et al., 2007), and Sutton *et al.* (Sutton et al., 2008) identified several instruments frequently used to predict functional decline in hospitalized older adults, including; Identification of Seniors at Risk (ISAR) for emergency department(Mccusker et al., 1999) and hospitalized patients(Hoogerduijn et al., 2012), Hospital Admission Risk Profile (HARP) tool(Sager et al., 1996), Triage Risk Screening Tool (TRST), Variables Indicative of Placement Risk (VIP)(Vandewoude et al., 2008), Care Complexity Prediction Instrument (COMPRI), and Score Hospitalier d'Evaluation du Risque de Perte d' Autonomie (SHERPA)(Cornette et al., 2006). Others include the interRAI Emergency Department Screener(Mowbray, Heckman, Hirdes, Costa, Beauchet, Eagles, et al., 2023), ED Vulnerability Screeners(Mowbray, Heckman, Hirdes, Costa, Beauchet, Archambault, et al., 2023)

These tools have been utilized to identify hospitalized older adults at higher risk of functional decline and provide mitigating intervention. For instance, the Prevention and Reactivation Care Program (PReCaP) program screened hospitalized patients with the ISAR-HP tool to identify those who were provided prevention

intervention(De Vos et al., 2012). The tools were developed for acute hospitals, so their validity in nursing home residents is unclear. Studies have also shown that some of these tools lack accuracy and precision when predicting long-term outcomes(Beaton et al., 2015; Deckx et al., 2015). Moreover, while some showed good promise, no gold standard currently exists(Braes et al., 2009; Deschodt et al., 2011; Sutton et al., 2008). In addition, these risk assessment tools are inaccurate in predicting the long-term risk of ADL decline(Beaton et al., 2015; Deckx et al., 2015), making them less functional in forecasting long-term future decline.

4.1.2. Research Purpose

With this study, I aim to investigate and describe the trajectory patterns of functional change for LTC residents in Canada, determining how individual-level factors influence these patterns and how the trajectory patterns relate to future health outcomes. Beyond understanding and describing the trajectory patterns and their associated factors, I am interested in utilizing this research information to develop decision support tools that would enhance patient-level care planning and overall management for LTC residents.

4.1.3. Research Questions

- What are the common trajectories of functional change among LTC residents in Canada?
- What baseline patient-level characteristics of LTC residents' factors determine membership in trajectory groups?

- Does functional decline trajectory group membership predict future health outcomes for LTC residents?

4.2. Method

4.2.1. Study Design and Population

This study is a retrospective longitudinal analysis of residents admitted into LTC facilities in the Canadian provinces of Alberta, British Columbia, Manitoba, Newfoundland & Labrador, and Ontario between January 1st, 2015, and December 31st, 2021. The analyses included each resident's repeated longitudinal assessments from entry into an LTC facility up to 36 months.

Eligibility: A participant was considered eligible and selected if they: a) are 60 years or older on admission, b) have received at least three quarterly or significant changes in health status assessments beginning with admission, c) are not comatose. Comatose patients are excluded since they are small in number and are unlikely to have diverse trajectories of change(McArthur et al., 2019). Individuals under 60 were also excluded, as this study focuses on the trajectory of decline among older people.

4.2.2. Study Samples

All residents who met the eligibility criteria above were analyzed as a unit representing the main study population. Further, the study sample was divided into three sub-analytic samples according to the baseline ADL hierarchy score of the residents. The first sub-analytic sample consists of residents with a baseline ADL hierarchy score of 0, meaning they had no ADL impairment on admission to LTC.

The second sub-analytic sample consists of residents with baseline ADL hierarchy scores from 1 to 2, while the third sub-analytic sample consists of residents with baseline ADL hierarchy scores ranging from 3 to 6.

4.2.3. Data Sources

The data analyzed for this study was obtained from the Canadian Institute for Health Information's Continuing Care Reporting System (CCRS). The CCRS contains patient-level data collected through multidimensional health assessments using the interRAI Minimum Data Set 2.0 (MDS 2.0). Full ethical approval for using this data was obtained through the University of Waterloo's Office of Research Ethics (ORE# 30173).

MDS 2.0 assessments are completed by trained assessors within 14 days of patients' admission to LTC settings and repeated every 90 days after that or sooner in the case of a significant change in health status. The reliability and validity of the MDS assessment items, outcome measures, and summary scales are well established (Hirdes et al., 2013a; Hirdes, Ljunggren, et al., 2008; Morris et al., 1994; Poss, Jutan, et al., 2008; L. Turcotte et al., 2022). The MDS is deployed within a software application, allowing for the generation of scales and Clinical Assessment Protocols (CAP), which facilitates care planning at the patient level and program and system-level quality performance assessment.

4.2.4. The Outcome of Interest - Operationalizing Functional Decline

There is currently no universal consensus on the operational definition of functional decline based on changes in ADL scores. Buurman *et* al. (Buurman et al.,

2011) showed the diversity and variability in operationalizing functional decline in research. Various researchers have used changes in ADL summary scores ranging from 1 or more points up to 5 or more points to define functional decline(Fedecostante et al., 2016; R. N. Jones et al., 2010c; Rosen et al., 1999). In the SHELTER study, Fedecostante *et al.* described functional decline as a 1-point or more increase in the interRAI ADL long form score(Fedecostante et al., 2021). Carpenter *et al.* concluded that a 1-point increase in ADL long form is clinically significant in a study looking at changes in ADL among nursing home residents(Carpenter et al., 2006). However, Tamura *et al.* operationalized functional decline as a 2 or more-point increase in the interRAI ADL long form score between two assessments(Tamura et al., 2009).

Similarly, a national survey of geriatricians to define functional Decline in Elderly People with minor injuries concluded that a 2-point change in a 14-item Older Americans' Resource and Services (OARS) ADL scale [range 0 - 14] was considered clinically significant. Further, Morris, Fries & Morris (1999)(Morris et al., 1999) concluded that both the interRAI ADL long form and the ADL Hierarchy scale can be applied to operationalize functional decline depending on the purpose of the research. In a recent paper, Fong & Youn (2023) showed that the ADL hierarchy scale maintained stability and consistency over time when used to assess functional decline(Fong & Youn, 2023).

For this study, functional decline was operationally defined as a 1 or more-point increase in the interRAI ADL Hierarchy scale between each assessment and that individual's admission or baseline value. The interRAI ADL Hierarchy scale is a

7-level ordinal measure of functional performance based on a person's ability to complete early (personal hygiene), middle (toileting and locomotion), and late-loss (eating) ADL(Morris et al., 1999). The ADL Hierarchy scale is particularly useful when assessing a system-induced change in ADL. One-point change in a 7-item Older Americans' Resource and Services (OARS) ADL scale [range 0 - 14] was considered to be clinically significant by geriatricians surveyed in Canada(Abdulaziz et al., 2016), while a study by Suijker et al. (Suijker et al., 2017) reported a 0.47 points difference on the KATZ ADL scale [range 0 – 6] to be a "minimally important change". A 1-point change in the interRAI ADL hierarchy scale is equivalent to a 2.6-point mean change in interRAI short form [range 0 -14], similar to the OARS ADL scale. Therefore, a 1-point decline in interRAI ADL hierarchy was deemed to represent a clinically significant change.

4.2.5. Independent Variables

Several independent variables were selected and used for the different phases of analysis performed for this study. These variables were chosen based on previous literature showing their associations with functional decline in institutionalized persons(Fedecostante et al., 2016, 2021; Palese et al., 2016). Socio-demographic variables such as age (categorized into <65, 65-74, 75-84, and 85+) and sex were included. Others include the index of Social Engagement score (SOCENG), clinical variables like Cognitive Performance Scale (CPS)(Morris et al., 1994), Changes in Health, End Stage Disease and Signs and Symptoms (CHESS) scale(Hirdes et al., 2003), acute frailty index(Hubbard et al., 2015) (categorized into 0.0-2.0, 2.1-3.0, 3.1-

4.0, 4.0+), perceived rehabilitation potential (resident and staff), visual and hearing impairments, number of medications used, chronic conditions such as diabetes, hypertension, congestive heart failure, Alzheimer's, Parkinson's, chronic obstructive airway disease, arthritis, falls, unsteady gait, hip fracture, schizophrenia, cancer, etc. A complete list of all included variables is attached in **Supplementary Table C.1.**

4.2.6. Statistical Analysis and Modeling

Analysis for this study was performed in two stages representing the three main research questions. In the first stage, group-based trajectory modeling was performed to identify trajectory subgroups. After that, multiple binary logistic regression was fitted to the GBTM model output to determine group membership predictors.

Broadly, descriptive analysis was used to summarize the characteristics of the main study participants, showing frequencies and percentages for categorical variables, as well as the mean and standard deviation for continuous variables. The Chi-square or Kruskal Wallis tests were used to check for significant association between two categorical variables depending on the number of categories in the variable and their nature.

4.2.6.1. Stage I. Trajectory Modeling

Trajectory modeling is commonly used in social sciences to study developmental trajectories of human behavior. The introduction of group-based trajectory modeling (GBTM)(B. L. Jones et al., 2001; B. L. Jones & Nagin, 2016; D. S. Nagin & Land, 1993; D. S. Nagin & Odgers, 2010; Nutr & Nagin, 2014) by Nagin and

Land(D. S. Nagin & Land, 1993) to model the controversial "career criminal" trajectory further promoted the application of this technique not only in social sciences, but other disciplines as well. Since then, the use of GBTM in clinical research has grown, with more clinical researchers embracing the technique(D. S. Nagin & Odgers, 2010; Nguefack et al., 2020). Bimou *et al.* (Bimou et al., 2021), Jonkman *et al.* (Jonkman et al., 2018), and Westrick *et* al. (Westrick et al., 2022) applied GBTM to reveal distinct subgroups of community-dwelling individuals following similar functional change trajectories. Bell *et al*. modeled the trajectory of functional limitation among Health and Retirement Study (HRS) study participants using GBTM, showing up to six different homogenous subgroups, Kuo *et al*. examined the trajectory of ADL changes in long-term care facilities in Taiwan showing three trajectory subgroups in their study cohort.(Kuo et al., 2017)

GBTM is a finite mixture model based on the assumption that populations comprise distinct subgroups containing individuals with similar developmental trajectories(Nguefack et al., 2020). It is a powerful analytical tool to predict the longitudinal trajectory of different subgroups within a given population(Nguefack et al., 2020).

In the first step of this analysis, GBTM was used to identify distinct trajectories of functional decline among LTC residents. The binary variable "functional decline" (1= Yes, 0=No) representing whether an individual declined in the ADL Hierarchy scale between an assessment and their baseline (admission) value was modeled as the outcome using the PROC TRAJ procedure in SAS(B. L. Jones &

Nagin, 2007). Since this outcome variable is binary, a **LOGIT** function was used to model the conditional distribution of the data(B. L. Jones et al., 2001). A logit distribution is appropriate for our binary outcome and assumes that a latent function y* allows us to state that y = 1 if y* > 0 and that y = 0 if y* $\leq$ 0(Sweeten, 2014). By using a logit function, this modeling approach avoids problems calculating mean scores in functional decline.

i. Model Selection

- Steps recommended by Nagin(D. Nagin, 2015) and restated by Arrandale *et al.*(Arrandale et al., 2006) were followed to select the model that more precisely identifies the trajectory subgroups.
- Step 1: Using existing domain knowledge about the decline in physical function, the WHO hypothetical trajectory of physical capacity, and literature evidence, 3 to 4 distinct subgroups were estimated a priori to be ideal for fitting the data.
- Step 2: Starting with 1 group and increasing stepwise to 5 groups, a quadratic order function model was fitted to the data to obtain a trajectory pattern. Where necessary, linear, cubic, quintic, or zero-order functions were also fitted to the data iteratively based on the outcome of each stepwise model fitting process. Bayesian Information Criterion (BIC) was used to select the best-fitting model, and new models were iteratively fitted until the best model was found. A model with lower BIC was considered better than the previous model (unless domain knowledge supports otherwise)(D. Nagin, 2015).

When using BIC, the best model is usually selected via two methods: a) change in BIC value between two models and b) Jeffery's evidence scale. For this study, the former was used.

A change in BIC value between an alternative (increasingly complex) model and a null (less complex) model was used to evaluate the evidence against the null model(Arrandale et al., 2006; B. L. Jones et al., 2001). The formula below (Arrandale et al., 2006) shows how this is calculated.

$$\Delta BIC = BIC_{complex} - BIC_{null}$$

When a more complex model (one with more groups or higher order terms, such as quadratic vs. linear or cubic vs. quadratic terms) is fitted, and the calculated ΔBIC obtained was greater than 2, the more complex model was selected. However, where the observed ΔBIC after fitting a more complex model is less than 2, the less complex was chosen as the better-fitting model. The obtained ΔBIC is multiplied by 2 to give the equivalent of the "**logged Bayes factor**"(Arrandale et al., 2006; D. Nagin, 2015). **Table 4.1** shows the complete interpretation of logged Bayes factor values and the level of evidence against the null model.

Table 4.1: Interpretation of The Logged Bayes Factor (2*ΔBIC) for Model Selection

2*ΔBIC	**Evidence Against null model**
0 to 2	Not worth mentioning
2 to 6	Positive
6 to 10	Strong
>10	Very strong

In addition to using the logged Bayes factor to determine best-fitting models, each trajectory subgroup must have a group membership probability of at least 0.5 and a mean group membership posterior probability of 0.7 for the model to be valid. A more complex model that fits better based on BIC changes but fails to meet the above two criteria is rejected in favor of the null model.

ii. Handling Attrition

Residents who died or were transferred out of the LTC setting before completing 36 months were considered censored or truncated, reflecting a form of attrition. Attrition in the study due to death or discharge before 36 months was accounted for by including a **DROPOUT** module in the PROC TRAJ model. Jones and Nagin showed that the PROC TRAJ application can handle incomplete data due to attrition using the DROPOUT module(B. L. Jones & Nagin, 2016) with recent extensions. Haviland, Jones, and Nagin demonstrated that adding the dropout module to the model helped to produce unbiased estimates of the model parameters, including trajectory shape and size(Haviland et al., 2011). By including the dropout module, the model estimates the future trajectory of each resident using either the last assessment value, the assessment value before the last, or two assessments before the last. For this study, the assessment before the last provided the best consistent estimate and was chosen for all models.

iii. Group Assignment

The GBTM model performs maximum likelihood estimation to obtain parameters of given models and uses this to predict the probability that a resident will belong to each trajectory subgroup. Outputs of the model estimates include the probability that an individual belongs to one of the trajectory groups identified by the model. An Individual is then assigned to the group where they have the highest probability of belonging (Maximum Posterior Probability Assignment Rule)(D. S. Nagin & Odgers, 2010), with 100% being the maximum and 0 the minimum. The software automatically handles this process, and the final result that shows the group assignments is provided as one of the outputs of the SAS PROC TRAJ modeling.

iv. Model Evaluation

Nagin recommended that trajectory model diagnostics(D. Nagin, 2015) be performed to ensure the adequacy of a chosen model. The following two diagnostic tests were performed.

I. **Average Posterior Probability (APP)**: For each fitted model, the average posterior probability (APP) of the group memberships was calculated, and a model was only accepted if the APP was 70% or higher for all the groups. This measure indicates how well the group is identified(Sweeten, 2014), with 100% showing that every individual had a 100% probability of being in the group.

II. **Odds of Correct Classification (OCC)**: Another diagnostic test recommended by Nagin is the OCC, which measures the odds that a group is correctly classified. It is obtained using the following formula:

$$OCC_j = \frac{APP_1 \,/\, 1 - APP_j}{\pi_j / 1 - \pi_j}$$

Where:

$$\text{APP} = \text{Group} - \text{specific average posterior classification}$$

$$\text{OCC} = \text{Odds of correct classification}$$

$$\pi = \text{estimated group} - \text{specific population size}$$

OCC greater than 5.0 for all obtained groups in a given model shows the fitted model has high assignment accuracy.

Model Fitting Steps.

- **Model 1**: First, a base model with no covariates was implemented to obtain the unadjusted trajectory pattern and distribution.
- **Model 2**: To account for the known strong effect of cognitive function on the trajectory of functional decline, the cognitive performance scale (CPS) was added as a time-varying covariate to the base model. With recent advances in the SAS PROC TRAJ software, time-varying and time-invariant covariates can be added to the models to account for their effect on obtained trajectory groups201 concurrently. For this study, the model with the CPS covariate is therefore considered the final model for all further analyses and discussions.

4.2.6.2. Stage II. Binary Logistic Regression

The purpose of the first phase of this study was to identify the trajectory subgroups and assign residents to the groups where they are most fitted. Once this

was done, the next phase of the study was to identify resident-level characteristics that predict or determine membership of the different trajectory subgroups.

In the second stage, binary logistic regression was performed to determine the independent predictors of membership of the trajectory groups obtained in phase one using the PROC TRAJ output containing the assigned groups. New binary variables were created for each trajectory subgroup obtained through GBTM to perform the binary regression. The regression analysis generated an adjusted odds ratio and 95% confidence intervals for the effect of predictors on trajectory group membership. Multiple binary logistic regression was preferred to a single multinomial regression because the interest is in obtaining the odds of belonging to one trajectory subgroup compared to belonging to others.

Further, using multiple binary logistic regression produced adjusted odds that were easy to interpret for the different trajectory groups since there were only two outcomes compared to multiple outcomes in a multinomial logistic regression. This approach helped to identify predictors with the highest effects for the different subgroups. Predictors and their effect sizes were determined and subsequently assigned to the groups where they had maximum effect sizes.

4.2.6.3. Sub-analysis

Sub-analysis was conducted on samples created according to residents' admission ADL hierarchy scale. Sub-samples created include residents with ADL Hierarchy = 0 (no impairment), residents with ADL Hierarchy 1-2 (mild impairment), and residents with ADL Hierarchy 3-6 (moderate/severe impairment).

4.3. Results

4.3.1. Overall Characteristics of the Primary Study Sample

The initial study data consisted of 286,124 unique LTC residents. From this sample, 204,036 met the study eligibility criteria and were selected as the primary study sample. The mean admission age of the primary study group was 83.7 (SD= 8.6), and 63.3% were female. 71.3% had ADL Hierarchy score ≥ 3, 76.6% had impairment in all ADL Hierarchy items (personal hygiene, toileting, locomotion, or eating), and most (95.8%) had impairment in at least one item. **Table 4.2** displays the admission characteristics of all residents and the sub-populations.

Further breakdown showed a hierarchical loss in ADL, typical of the LTC population. On admission, 96.6% of the residents had impairment in personal hygiene, representing early ADL loss, 89.4% and 93.4% in locomotion and toileting ADL items, respectively, which means mid-loss ADLs, and 82.8% in eating ADL items, a late-loss ADL. By the first 90-day follow-up assessment, 19.5% of residents had declined further in physical function relative to their admission functional level. At the time of their last recorded assessment, up to 54.9% of residents had declined in physical function relative to their admission level. As shown in the next section, the proportion of residents who declined within the first 90 days of admission and then by their last observation differed substantially between the identified trajectory subgroups.

Table 4.2. Admission Characteristics of All Residents and by their Admission ADL Hierarchy Scale Categories 2015 – 2021, n = 204,036.

	ADL Hierarchy 0-6 n = 204,036	**ADL Hierarchy 0** n = 8,405	**ADL Hierarchy 1-2** n = 50,263	**ADL Hierarchy 3-6** n = 145,368
Variable	% (n)	% (n)	% (n)	% (n)
Age group				
<65	3.0 (6,163)	4.8 (368)	3.0 (1.501)	3.0 (4.294)
65-74	12.7 (25,9462)	16.8 (1,408)	12.8 (6,407)	12.5 (18,131)
75-84	32.0 (65,373)	33.6 (2,826)	33.1 (16,618)	31.6 (45,929)
85+	52.2 (106,554)	45.3 (3,803)	51.2 (25,737)	53.0 (77,014)
Sex				
F	63.3 (129,043)	59.2 (4,974)	63.7 (32,009)	63.3 (92,060)
M	36.7 (74,993)	40.8 (3,431)	36.3 (18,254)	36.7 (53,308)
CPS Scale				
0	9.5 (12,112)	23.0 (1.930)	10.7 (5,382)	8.3 (12,112)
1-2	34.6 (70,580)	52.7 (4.350)	42.7 (21,449)	30.8 (44,781)
3-4	45.5 (92,754)	23.4 (1,968)	42.4 (21,300)	47.8 (69,486)
5-6	10.4 (21,278)	1.9 (157)	4.2 (2,132)	13.1 (18,989)
CHESS Scale				
0	52.9 (107,995)	73.9 (6,214)	64.2 (32,254)	47.8 (69,527)
1-2	43.4 (88,570)	25.3 (2,129)	34.0 (17,079)	47.7 (69,362)
3+	3.7 (7,471)	0.7 (62)	1.8 (930)	4.5 (6,479)
Depression Rating Scale (DRS)				
0	51.9 (105,831)	64.7 (5,434)	56.1 (28,177)	49.7 (72,220)
1-2	28.3 (57,692)	22.6 (1,901)	25.9 (13,023)	29.4 (42,768)
3+	19.8 (40,513)	12.7 (1,070)	22.4 (9,063)	20.9 (30,380)
Frailty index				
0.01-0.20	5.6 (11,463)	59.3 (4,989)	11.4 (5,729)	0.5 (745)
0.21-0.30	15.7 (32,111)	33.9 (2,849)	36.6 (18,401)	7.5 (10,861)
0.31-0.40	32.2 (65,643)	6.5 (544)	37.9 (18,593)	32.0 (46,506)
>0.40	46.5 (94,819)	0.3 (23)	15.0 (7,540)	60.0 (87,256)
BMI Category				
Underweight	10.0 (20,489)	8.2 (688)	8.5 (4,265)	10.7 (15,536)
Normal	44.0 (89,698)	43.3 (3,642)	45.3 (3,642)	43.6 (63,310)
Overweight	27.3 (55,599)	29.5 (2,479)	28.7 (14,438)	26.6 (38,682)
Obese	18.7 (38,250)	19.0 (1,596)	17.5 (8,814)	19.2 (27,840)
Hearing				
Adequate	59.1 (120,627)	70.3 (5,910)	62.5 (31,405)	57.3 (83,312)
Mini Difficulty	26.0 (53,133)	20.7 (1,738)	24.9 (12,503)	26.8 (38,892)
Special Situation	13.1 (26,688)	7.5 (635)	11.1 (5,572)	14.1 (20,481)
Highly Impaired	1.8 (3,588)	1.5 (122)	1.6 (783)	1.9 (2,683)
Vision				
Adequate	58.5 (119,438)	73.7 (6,197)	65.0 (32,691)	55.4 (80,550)
Impaired	29.1 (59,419)	20.6 (1,732)	26.7 (13,400)	30.5 (44,287)
Moderately impaired	6.9 (13,975)	4.0 (337)	5.3 (2,669)	7.6 (10,969)
Highly impaired	4.1 (8,257)	1.3 (107)	2.2 (1,084)	4.9 (7,066)
Severely impaired	1.4 (2,947)	0.4 (32)	0.8 (419)	1.7 (2,496)
Rehabilitation potential	19.1 (39,031)	23.6 (1,955)	25.2 (12,656)	16.8 (24,420)
Health Condition & Diagnosis				
Diabetes	25.3 (51,523)	23.2 (1,951)	23.6 (11,857)	25.9 (37,715)
Parkinson's	6.6 (13,417)	3.1 (261)	4.1 (2,059)	4.1 (2,059)
Unsteady gait	37.7 (76,990)	21.9 (1,840)	34.8 (17,472)	39.7 (57,678)

Fall past 30 days	22.4 (45,666)	9.7 (812)	15.2 (7,656)	25.6 (37,198)
Stroke	18.0 (36,648)	11.9 (999)	13.4 (6,711)	19.9 (28,938)
Hemiplegia/Hemi paresis	3.5 (7,166)	0.6 (50)	0.9 (469)	4.6 (6,647)
Arthritis	37.3 (76,167)	30.5 (2,567)	34.8 (17,502)	38.6 (56,098)
Alzheimer's disease	14.0 (28,534)	11.7 (983)	15.3 (7,695)	13.7 (19,856)
Hypertension	62.7 (128,009)	57.1 (4,797)	60.0 (30,169)	64.0 (93,043)
Heart failure	13.0 (19,541)	12.1 (1,017)	11.8 (5,921)	13.4 (19,541)
Cancer	9.9 (20,168)	9.5 (794)	9.4 (4.724)	10.1 (14,650)
Renal failure	10.7 (21,814)	9.2 (777)	9.9 (4,981)	11.1 (16,056)
ADL Hierarchy Items				
Personal Hygiene	96.6 (197,186)	0.0 (0)	90.0 (17,507)	99.8 (179,679)
Locomotion	84.9 (173,256)	0.0 (0)	42.9 (8,349)	91.6 (164,907)
Toileting	93.4 (191,666)	0.0 (0)	68.5 (13,320)	99.0 (178,346)
Eating	82.8 (168,900)	0.0 (0)	54.7 (10,628)	87.9 (158,272)

4.3.2. Identification of Functional Decline Trajectory Subgroups

Using GBTM, four distinct trajectory subgroups were identified as best fitting for this cohort of LTC residents **(Figure 4.1**). These subgroups were named according to the shape of their trajectory as follows.

The first subgroup was named "**catastrophic decline**" (**Group 1**: *n*= 48,441, 22.7%) due to the "steep" shape and short timeframe of their decline trajectory. Residents in this group declined precipitously immediately upon admission to LTC homes and remained at this lowest functional level until their last assessment (**Figure 4.1**). In the first 90 days of admission, 63.8% of residents who follow this trajectory experienced a functional decline. At their last recorded observation, 98.5% had reported a decline in physical function relative to their admission functional level. On admission, 43% of residents who follow this trajectory have an ADL Hierarchy Scale of 0, and only 18% had an ADL Hierarchy Scale of 3+ (**Figure 4.2**).

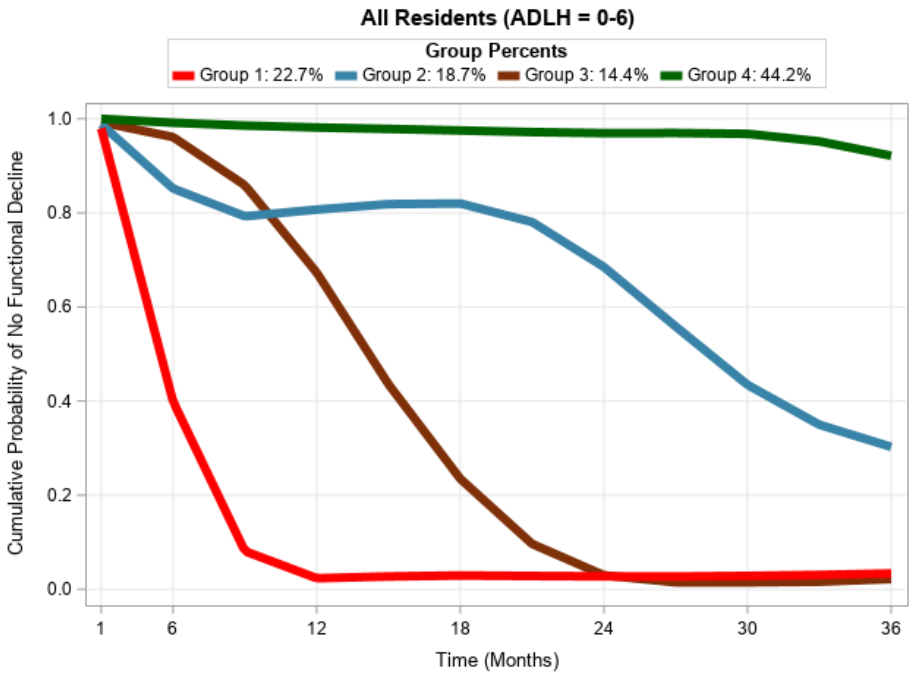


Figure 4.1: Best Fitting Functional Decline Trajectory Pattern Identified by the GBTM Technique 2015 – 2021, n = 204,036.

Next is the "**rapid decline with some recovery**" (**Group 2**: *n*= 27,620, 18.7%) subgroup. Residents in this group experienced an immediate decline in physical function upon admission. However, they differ from the former group in that they regain some function soon afterward (**Figure 4.1**). Within the first 90 days of admission, 25.2% of residents in this group declined in physical function. In contrast to the catastrophic decline group, only 62.3% (vs. 98.5%) reported functional decline relative to the admission functional level in their last recorded assessment.

A third group of residents followed a "**progressive decline**" trajectory (Group 3: n= 30,287, 14.4%). Residents in this subgroup followed a slower but persistently declining functional trajectory upon admission until their last observation (**Figure**

4.1). In contrast to residents who followed a catastrophic decline trajectory, only 4.8% of residents in this group declined in physical function within their first 90 days of admission. However, similar to the catastrophic decline group (98.5%), by their last recorded assessment, 99.1% of residents in this group declined in function relative to their admission functional level. On admission, 17% of residents who followed this trajectory had ADL Hierarchy Scale 3+, and 21% had no ADL impairment (**Figure 4.2**).

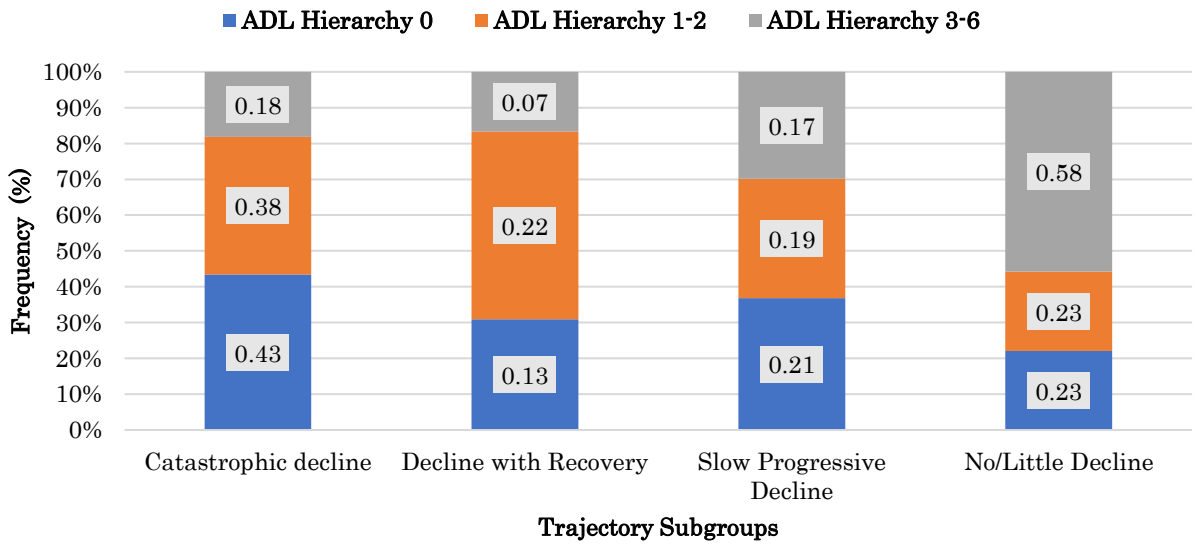


Figure 4.2. Distribution of Admission ADL Hierarchy Scale within Each Functional Decline Trajectory Groups 2015 – 2021, n = 204,036.

The fourth subgroup, "**No/Minimal decline**" (**Group 4:** *n*=97,688, 47.9%), comprises residents with little or no decline following admission into LTC homes. Residents in this group remained at or near their admission functional level for the study (Figure 1). In contrast to the other groups, only 0.54% of residents in this group experienced functional decline within 90 days of admission. By their last recorded

assessment, only 17.5% declined further in function relative to admission. Compared to the catastrophic (18%) and slow progressive (17%) decline groups, 58% of residents in this group had ADL Hierarchy Scale 3+ impairment on admission (**Figure 4.2**).

To identify the best fitting model, the logged Bayes factor was calculated for each successive model in the buildup as recommended by Nagin, and the stepwise changes in BIC resulting in the selection of this model are shown in **Table 4.3**.

Table 4.3. Stepwise Change In BIC for Different Complex Models Leading to the Best-Fitting Model Selection.

Number of trajectory groups	Polynomial order	BIC for Null model	BIC for Complex model	2* ΔBIC
1	2	1,394,045	-	
2	2 2	1,394,045	1,094,707	299,338
3	2 2 2	1,094,707	1,044,963	49,744
4	2 2 2 2	1,044,963	1,035,096	9,867
4	3 3 3 3	1,035,096	1,029,070	6,026
4	4 4 4 4	1,029,070	1,007,533	21,537
5	5 5 5 5		Did not converge	
4	5 4 5 5	1,007,533	1,006,825	708

Although a five-group model with quadratic order polynomial function had the lowest BIC, a priori domain knowledge suggested that five-group trajectories are uncommon for this population setting. Also, a review of the trajectory graph in a 5-subgroup model showed that two identified subgroups have almost identical trajectories but are only separated by time. The decision was then to continue with four subgroup trajectory models.

A model adequacy check was performed once the best-fitting model was identified using the logged Bayes factor. The check showed that 1) the APP of all

group assignments was above 0.7, and 2) the OCC was above 5.0 for all groups (**Table 4.4**).

Table 4.4: Diagnostic Tests Scores for Trajectory Groups Showing APP and OCC.

Category of residents	Metric	Catastrophic decline	Progressive decline	Rapid decline with recovery	No/Minimal decline
ADL Hierarchy 0-6	APP	0.91	0.87	0.81	0.88
	Group Probability	0.23	0.19	0.14	0.44
	OCC	33.85	28.53	26.19	9.33

4.3.3. Admission Profiles of Residents by Trajectory Subgroups

The association between residents' admission characteristics and the trajectory subgroups was further examined using cross tabulation. Residents who follow a No/Minimal decline trajectory were more likely to have a loss in the 4 ADL hierarchy items compared to those who follow any other trajectory (20.7%, 12.6%, 13.4%, and 53.4% for Groups 1, 2, 3 & 4 respectively, p-value < 0.0001), **Figure 4.3** displays the percentage distribution of the count of ADL item loss by trajectory groups.

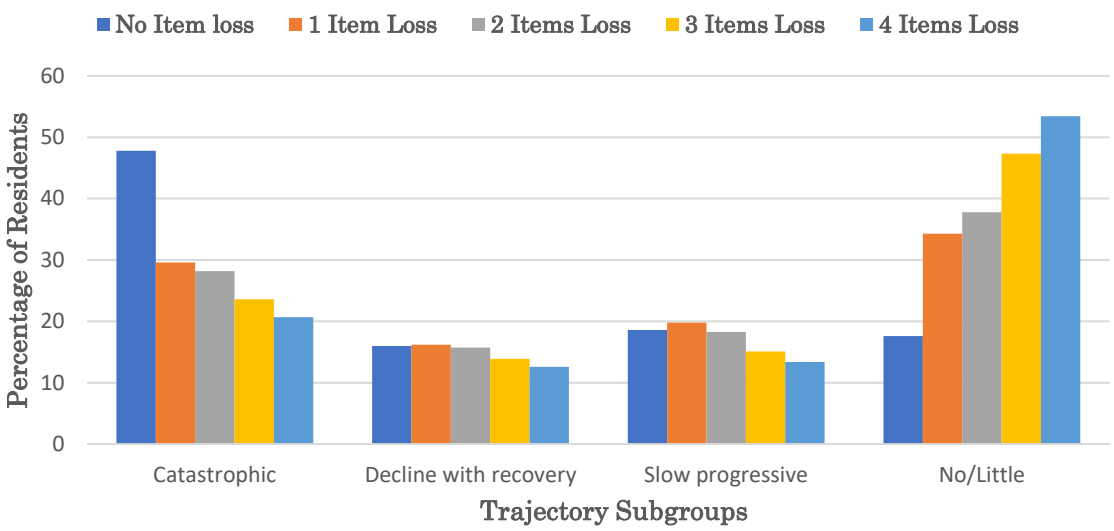


Figure 4.3: Percentage Distribution of Count of ADL Item Loss by Trajectory Group.

Conversely, residents who developed a catastrophic decline in physical function soon after admission were more likely to have no ADL impairments on admission (47.8%, 16.0%, 18.6% & 17.6% for groups 1, 2, 3 & 4, respectively, p-value <0.0001). Further, residents with no ADL impairment in any ADL item on admission were more likely to recover in function following a rapid decline than those with impairment in all 4 ADL items (16.0% vs.12.6%, p-value < 0.0001).

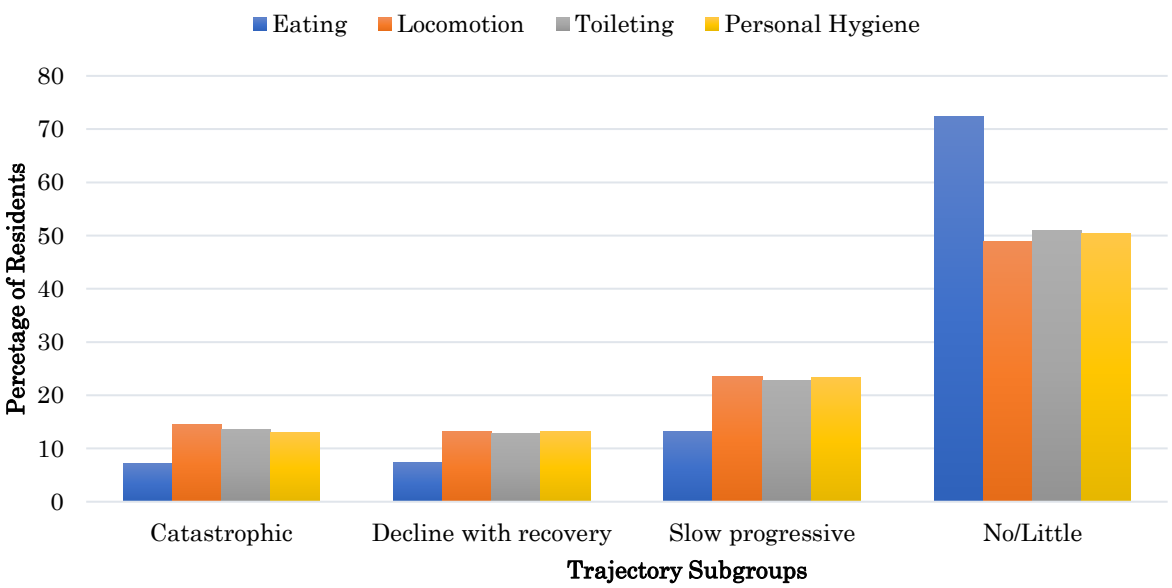


Figure 4.4. Distribution of ADL item loss by trajectory subgroups 2015 – 2020, n = 204,036.

Figure 4.4 describes the ADL item loss distribution of the primary study participants by the trajectory subgroups. Residents who follow the no/minimal decline trajectory have a higher percentage of late-loss ADL (eating) impairment than early (personal hygiene) and mid-loss ADL (locomotion & toileting) impairment. Residents who follow other trajectories have less late-loss ADL than early or mid-loss ADL impairment.

4.3.4. Sub-analysis

Sub-samples of residents created according to their admission ADL hierarchy scale were further analyzed. Trajectory modeling was performed using the sub-samples to examine how the admission ADL hierarchy scale influences functional decline trajectory pattern and shape.

First, a sub-sample of residents with no ADL impairment on admission was modeled. The best fitting GBTM model identified four distinct trajectory subgroups for this group with trajectory shapes and patterns that closely resembled those obtained for all residents. However, membership distribution to each subgroup differed substantially between the overall group and this subsample. A higher proportion of residents with no ADL impairment on admission experienced a catastrophic decline compared to the overall group (43.4% vs.22.7%). Conversely, a lower proportion of residents with no ADL impairment on admission followed a no/minimal decline trajectory compared to the overall group (22.6% vs.44.2%), **Figure 4.5.** Diagnostic tests using APP and OCC were also performed to check for model accuracy, and the results are displayed in Table **4.6**.

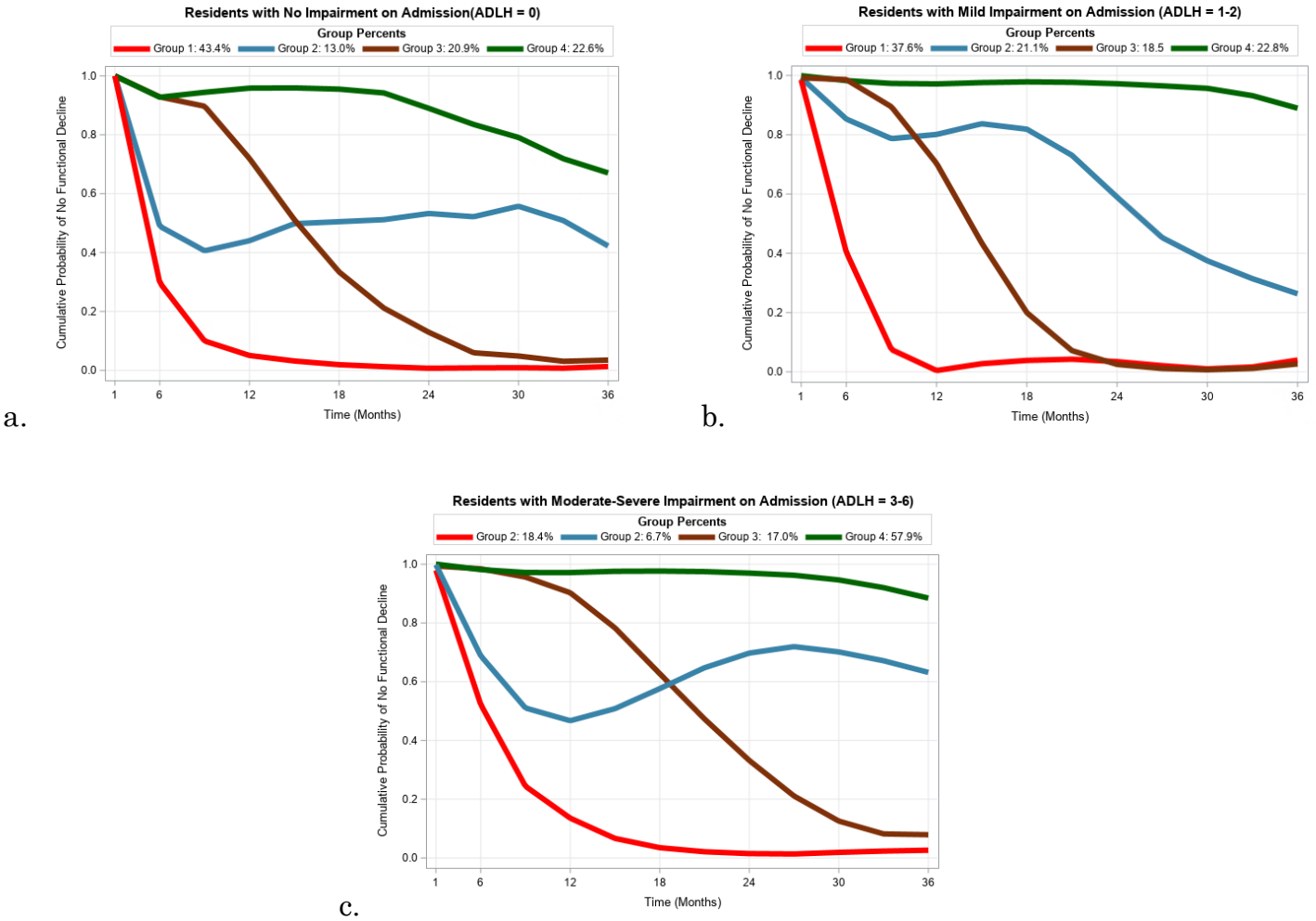


Figure 4.5: Best Fitting Functional Decline Trajectory Pattern Identified by the GBTM technique for a) No ADL Impairment b) ADL Hierarchy Scale 1-2, and c) ADL Hierarchy Scale 3-6.

Table 4.6. Diagnostic Tests Scores for Trajectory Groups Showing APP and OCC for Sub-Analytic Samples.

ADL Hierarchy Scale	**Metric**	Catastrophic decline	Progressive decline	Rapid decline with recovery	No/Minimal decline
0	APP	0.9	0.82	0.85	0.86
	Group Probability	0.43	0.13	0.21	0.23
	OCC	**11.93**	**30.49**	**21.32**	**20.57**
1-2	APP	0.92	0.85	0.83	0.83
	Group Probability	0.38	0.22	0.19	0.23
	OCC	**18.76**	**20.09**	**20.81**	**16.35**
3-6	APP	0.92	0.79	0.86	0.89
	Group Probability	0.18	0.07	0.17	0.58
	OCC	**52.39**	**49.98**	**29.99**	**5.86**

Four trajectories of functional decline were also identified for ADL Hierarchy Scale 1-2 residents, as shown in **Figure 4b**. In this group of residents, 21.1% followed the rapid decline with a recovery trajectory. Further, only 37.6% of residents in this sub-sample followed a catastrophic decline trajectory compared to 43.4% among residents with no ADL impairment on admission (**Figure 4.5**).

Last, four distinct sub-group trajectories were identified as the best-fitting model for the sub-sample of residents with moderate to severe ADL impairment (ADL Hierarchy Scale 3-6) (**Figure 4.5c**). The trajectory sub-groups are the catastrophic decline, slow progressive decline, stable then decline, and the No/minimal decline groups. Therefore, residents with moderate/severe impairments did not follow the rapid decline with recovery trajectory. Continuing with the trend observed in the two previous sub-samples, the distribution of residents to each distinct trajectory sub-group differed between this sub-sample and the overall group. For example, only

12.9% of residents in this sub-category followed a catastrophic decline trajectory, compared to 22.7% and 43.4% who did in the overall and ADLH 0 groups, respectively.

4.3.5. Predictors of Trajectory Group Membership (Primary Study Sample)

Four binary logistic regressions were fitted to the Proc Traj output data containing the predicted and assigned trajectory groups. Each logistic regression modeled a trajectory subgroup as a binary dependent variable.

4.3.5.1. Bivariate Analysis

Ignoring the effect of other variables, increasing age positively predicted a catastrophic functional decline trajectory in this study. Compared to residents who are less than 65 years of age, those who are older were more likely to follow a catastrophic decline trajectory, 65-74 years (OR 1.22 95% CI 1.11-1.30), 75-84 (OR 1.32 95% CI 1.24-1.41), 85+ (OR 1.29 95% CI 1.21-1.37).

Compared to no ADL impairment, higher (worse) ADL hierarchy function on admission strongly predicted membership of the no or little decline trajectory, ADLH 1-2 (OR 1.37 95% CI 1.29-1.46), ADLH 3-4 (OR 4.12 95% CI 3.89-4.37), ADLH 5-6 (OR 28.40 95% CI 26.68-30.22), while higher score on CPS strongly predicted a slow progressive decline trajectory, CPS 1-2 vs. 0 (OR 1.39 95% CI 1.20-1.46), CPS 3-4 vs. 0 (OR 1.48 95% CI 1.42-1.56), CPS 5-6 vs. 0 (OR 1.17 95% CI 1.10 – 1.24). **Table 7** displays the unadjusted odds of trajectory group membership for select summary scales.

Table 4.7: Unadjusted Odds of Membership by Functional Decline Trajectory Group 2015 – 2021, n = 204,036.

		Catastrophic decline **(n= 48,441)**	*Rapid decline with recovery* **(n= 27,620)**	*Slow progressive decline* **(n= 30,287)**	*No/Minimal decline.* **(n= 97,688)**
Variable	**Category**	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age group	<65			Ref	
	65-74	1.23 (1.15-1.32)	0.94 (0.87-1.02)	1.24 (1.14-1.35)	0.81 (0.77-0.86)
	75-84	1.33 (1.24-1.42)	0.95 (0.88-1.02)	1.36 (1.29-1.48)	0.73 (0.69-0.77)
	85+	1.29 (1.21-1.38)	0.88 (0.82-0.95)	1.32 (1.22-1.42)	0.79 (0.75-0.83)
Sex	F			Ref	
	M	1.05 (1.03-1.08)	0.94 (0.92-0.97)	0.97 (0.95-1.00)	1.00 (0.98-1.02)
ADL Hierarchy Scale	0			Ref	
	1-2	0.77 (0.74-0.81)	0.95 (0.89-1.01)	1.14 (1.07-1.21)	1.37 (1.29-1.46)
	3-4	0.30 (0.28-0.31)	0.99 (0.93-1.05)	0.84 (0.79-0.89)	4.12 (3.89-4.37)
	5-6	0.05 (0.05-0.05)	0.30 (0.28-0.32)	0.20 (0.19-0.22)	28.40 (26.68-30.22)
CPS Scale	0			Ref	
	1-2	0.88 (0.85-0.91)	0.92 (0.88-0.96)	1.39 (1.20-1.46)	0.99 (0.96-1.02)
	3-4	0.93 (0.90-0.96)	0.84 (0.80-0.87)	1.48 (1.42-1.56)	0.96 (0.93-0.99)
	5-6	0.83 (0.79-0.82)	0.68 (0.64-0.72)	1.17 (1.10-1.24)	1.28 (1.23-1.33)
CHESS Scale	0			Ref	
	1-2	0.91 (0.89-0.93)	0.87 (0.85-0.90)	0.83 (0.80-0.85)	1.26 (1.24-1.28)
	3+	0.77 (0.73-0.82)	0.80 (0.74-0.86)	0.66 (0.62-0.72)	1.61 (1.54-1.69)
Depression Rating Scale (DRS)	0			Ref	
	1-2	1.02 (0.99-1.04)	0.96 (0.93-0.99)	1.04 (1.01-1.07)	0.99 (0.97-1.01)
	3+	1.08 (1.05-1.11)	0.94 (0.90-0.97)	1.07 (1.03-1.10)	0.94 (0.92-0.97)
Rehab Potential	Yes	1.13 (1.10-1.15)	1.08 (1.05-1.12)	1.06 (1.03-1.09)	0.86 (0.84-0.88)
ADL Items Count	0			Ref	
	1	0.46 (0.43-0.49)	1.02 (0.94-1.10)	1.08 (1.01-1.16)	2.44 (2.28-2.61)
	2	0.43 (0.41-0.45)	0.98 (0.91-1.05)	0.98 (0.92-1.04)	2.84 (2.67-3.02)
	3	0.34 (0.32-0.36)	0.85 (0.80-0.91)	0.78 (0,73-0.83)	4.19 (3.95-4.45)
	4	0.29 (0.27-0.30)	0.76 (0.71-0.80)	0.67 (0.64-0.71)	5.34 (5.05-5.66)
Morbidity Count	0			Ref	
	1-2	1.05 (1.01-1.09)	0.94 (0.90-0.98)	1.16 (1.11-1.21)	0.93 (0.90-0.95)
	3+	0.98 (0.93-1.02)	0.85 (0.80-0.89)	1.04 (0.98-1.10)	1.08 (1.04-1.12)

4.3.5.2. Multivariable Analysis

Multivariable binary logistic regressions were fitted to the trajectory outputs, and independent variables associated with functional decline were included (see independent variables in the methods section). Four binary variables were created to represent the different trajectory subgroups. The binary variable "CTD" was created with "1" representing all residents that belonged to the catastrophic decline subgroup and "0" representing residents who followed any other trajectory. Likewise, binary variables "RDR", "SPD", and "NLD" were created to represent only residents that followed each subgroup trajectory. The results of each binary logistic regression analysis are presented as follows.

Catastrophic Decline

Resident's ADL Hierarchy Scale on admission was the strongest independent predictor of trajectory group membership across the four regression models. Residents without impairment on admission were most likely to follow a catastrophic decline trajectory compared to those with any form of impairment, ADLH 1-2 (OR 0.80 95% CI 0.76 – 0.85), ADLH 3-4 (OR 0.22 95% CI 0.21 – 0.23), ADLH 5-6 (OR 0.033 95% CI 0.031 – 0.035). Likewise, residents admitted with neurodegenerative conditions such as Amyotrophic Lateral Sclerosis (ALS) (OR 2.23 95% CI 1.73 – 2.88), Huntington's Chorea (OR 1.52 95% CI 1.09 – 2.12), and Parkinson's disease (1.28 95% CI 1.23 – 1.34) were also more likely to follow this trajectory. **Table 4.8** displays the predictors of trajectory group membership.

Rapid Decline with Recovery

Like those that follow a catastrophic decline trajectory, residents who follow this trajectory are also more likely to be admitted without ADL impairment, ADLH 1-2 (OR 0.93 95% CI 0.86 – 1.00), ADLH 3-4 (OR 1.01 95% CI 0.95 – 1.08), ADLH 5-6 (OR 0.31 95% CI 0.29 – 0.33), having severe visual impairment (OR 1.14 95% CI 1.02 – 1.27), schizophrenia (OR 1.18 95% CI 1.08 – 1.30). Unlike those who follow catastrophic decline, residents who follow this trajectory are likely to be younger than 85 years (Age 85+ OR 0.91 95% CI 0.85 – 0.99). Unlike the catastrophic decline group, female residents were more likely to follow this trajectory (OR 0.91 95% CI 0.89-0.99). (**Table 4.8**).

Slow Progressive Decline

Cognitive impairment was the strongest predictor of membership of this trajectory group, CPS 1-2 vs. 0 (OR 1.28 95% CI 1.22 – 1.35), CPS 3-4 vs. 0 (OR 1.37 95% CI 1.30 – 1.45), CPS 5-6 vs. 0 (OR 1.40 95% CI 1.31 – 1.50). Also, having a diagnosis of Alzheimer's disease (OR 1.23 95% CI 1.18 – 1.28) or other dementia (OR 1.14 95% CI 1.11 – 1.18) also predicted a higher likelihood of following this trajectory (**Table 4.8**).

No/Minimal Decline.

Compared to residents without ADL impairment, those with ADL Hierarchy Scale 5-6 on admission are 40 times more likely to follow a No/minimal decline trajectory (OR 40.23 95% CI 37.62 – 43.02). Further, residents diagnosed with schizophrenia (OR 1.45 95% CI 1.34 – 1.56), hip fracture (OR 1.17 95% CI 1.12 – 1.22),

manic depressive disorder (OR 1.11 95% CI 1.02 – 1.20), anxiety disorder (OR 1.13 95% CI 1.10 – 1.17), hemiplegia/hemiparesis (OR 1.08 95% CI 1.02 – 1.14) were also more likely to follow this trajectory (**Table 4.8**). Last, male residents were more likely to follow this trajectory than females.

Table 4.8: Adjusted Odds of Membership by Functional Decline Trajectory Group 2015 – 2021, n = 204,036.

		Catastrophic decline (n= 48,441)	*Rapid decline with recovery* (n= 27,620)	*Slow progressive decline* (n= 30,287)	***No/Minimal** decline.* (n= 97,688)
Variable	**Category**	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Demography					
Age group			<65		
	65-74	1.21 (1.13-1.31)	0.95 (0.88-1.03)	1.14 (1.04-1.24)	0.83 (0.78-0.89)
	75-84	1.28 (1.19-1.37)	0.98 (0.91-1.06)	1.16 (1.06-1.26)	0.78 (0.73-0.83)
	85+	1.33 (1.24-1.43)	0.91 (0.85-0.99)	1.15 (1.06-1.25)	0.80 (0.75-0.85)
Sex	F				
	M	*	0.91 (0.89-0.94)	0.97 (0.94-1.00)	1.08 (1.06-1.10)
Clinical Summary Scale					
ADL Hierarchy Scale	0				
	1-2	0.80 (0.76-0.85)	0.93 (0.86-1.00)	1.07 (1.00-1.13)	1.36 (1.27-1.45)
	3-4	0.22 (0.21-0.23)	1.01 (0.95-1.08)	0.79 (0.74-0.84)	5.37 (5.05-5.71)
	5-6	0.033 (0.03-0.04)	0.31 (0.29-0.33)	0.20 (0.19-0.22)	40.23 (37.62-43.02)
CPS Scale	0				
	1-2	0.82 (0.79-0.85)	0.92 (0.86-1.00)	1.28 (1.22-1.35)	1.09 (1.05-1.13)
	3-4	0.95 (0.91-0.99)	0.88 (0.84-0.92)	1.37 (1.30-1.45)	0.96 (0.93-1.00)
	5-6	1.28 (1.21-1.35)	0.87 (0.82-0.93)	1.40 (1.31-1.50)	0.79 (0.75-0.83)
CHESS Scale	0				
	1-2	1.10 (1.08-1.13)	0.94 (0.91-0.97)	0.94 (0.91-0.96)	0.9 (0.97-1.02)
	3+	1.05 (0.98-1.12)	0.93 (0.86-1.00)	0.85 (0.78-0.91)	1.10 (1.05-1.17)
Depression Rating Scale (DRS)	0				
	1-2	1.02 (0.99-1.050	0.97 (0.95-1.00)	1.04 (1.01-1.07)	0.97 (0.95-1.00)
	3+	1.04 (1.01-1.07)	0.95 (0.92-0.99)	1.06 (1.02-1.09)	0.95 (0.93-0.98)
Clinical items					
BMI Category	Normal				
	Underweigh t	1.02 (0.98-1.06)	0.91 (0.87-0.96)	0.91 (0.87-0.95)	1.10 (1.06-1.14)
	Overweight	1.04 (1.01-1.07)	1.01 (0.98-1.04)	1.04 (1.01-1.07)	0.94 (0.92-0.96)
	Obese	1.14 (1.11-1.18)	1.02 (0.98-1.05)	1.00 (0.96-1.033)	0.89 (0.96-0.91)
Hearing	Adequate				
	Mini Difficulty	0.97 (0.95-1.00)	0.99 (0.96-1.02)	0.98 (0.95-1.01)	1.05 (1.02-1.07)
	Special Situation	0.95 (0.92-0.99)	0.95 (0.91-0.99)	0.96 (0.92-1.00)	1.10 (1.07-1.13)

	Highly Impaired	0.90 (0.83-0.99)	1.12 (1.01-1.23)	0.88 (0.79-0.97)	1.10 (1.02-1.19)
Vision	Adequate				
	Impaired	1.06 (1.04-1,09)	0.98 (0.96-1.01)	*	0.95 (0.93-0.97)
	Moderately impaired	1.10 (1.06-1.16)	1.05 (0.99-1/11)	*	0.90 (0.86-0.94)
	Highly impaired	1.28 (1.21-1.36)	1.04 (1.02-1.27)	*	0.81 (0.77-0.86)
	Severely impaired	1.38 (1.25-1.52)	1.14 (1.02-1.27)	*	0.77 (0.71-0.84)
Rehab Potential	Yes	0.93 (0.90-0.96)	*	0.97 (0.94-1.00)	1.10 (1.07-1.12)
Unsteady gait	Yes	1.05 (1.03-1.08)	0.96 (0.94-0.99)	*	0.97 (0.95-0.99)
Fall past 30 days	Yes	1.22 (1.19-1.25)	0.92 (0.89-0.95)	0.96 (0.93-0.99)	1.52 (1.45-1.60)
Hip fracture	Yes	0.90 (0.85-0.95)	*	0.83 (0.78-0.88)	1.17 (1.12-1.22)
Health conditions					
Diabetes	Yes	1.03 (1.01-1.06)	*	*	
Congestive heart failure	Yes	*	0.92 (0.88-0.96)	0.94 (0.90-0.98)	1.06 (1.03-1.10)
Osteoporosis	Yes	*	*	1.04 (1.00-1.07)	
ALS	Yes	2.23 (1.73-2.88)	0.50 (0.34-0.75)	1.44 (1.01-1.96)	0.57 (0.45-0.73)
Alzheimer's	Yes	1.09 (1.06-1.13)	*	1.23 (1.18-1.28)	0.80 (0.78-0.83)
Stroke	Yes	1.02 (0.99-1.05)	*	*	
Dementia	Yes	1.04 (1.01-1.07)	*	1.14 (1.11-1.18)	0.91 (0.89-0.93)
Hemiplegia/Hemiparesis	Yes	*	*	0.76 (0.70-0.83)	1.08 (1.02-1.14)
Huntington's Chorea	Yes	1.52 (1.09-2.12)	*	1.47 (1.02-2.11)	0.56 (0.41-0.77)
MS	Yes	*	*	0.74 (0.61-0.89)	*
Parkinson's	Yes	1.28 (1.23-1.34)	*	1.17 (1.12-1.24)	0.74 (0.71-0.77)
TIA	Yes	1.08 (1.02-1.14)	1.07 (1.01-1.13)	*	0.89 (0.85-0.93)
TBI	Yes	0.89 (0.79-0.99)	*	*	1.17 (1.06-1.30)
Anxiety disorder	Yes	0.90 (0.87-0.94)	*	0.96 (0.92-0.99)	1.13 (1.10-1.17)
Manic depressive disorder	Yes	0.91 (0.84-0.99)	*	0.89 (0.80-0.99)	1.11 (1.02-1.20)
Schizophrenia	Yes	0.61 (0.56-0.67)	1.18 (1.08-1.30)	0.85 (0.77-0.94)	1.45 (1.34-1.56)
Emphysema	Yes	0.92 (0.90-0.95)	0.93 (0.89-0.96)	*	1.13 (1.09-1.16)
Cancer	Yes	1.07 (1.04-1.11)	0.92 (0.88-0.96)	*	*
Liver disease	Yes	*	0.89 (0.78-1.00)	*	1.21 (1.10-1.32)
Renal failure	Yes	*	0.91 (0.87-0.95)	0.93 (0.90-0.96)	

* No significant association found; TIA = Transient Ischemic Attack; TBI = Traumatic Brain Injury; ALS – Amyotrophic Lateral Sclerosis; MS = Multiple Sclerosis

4.3.6. Profile of Residents Who Follow Different Functional Decline Trajectories.

Using information from the multivariable analysis, a broad profile of residents was created, as shown in **Figure 4.6**

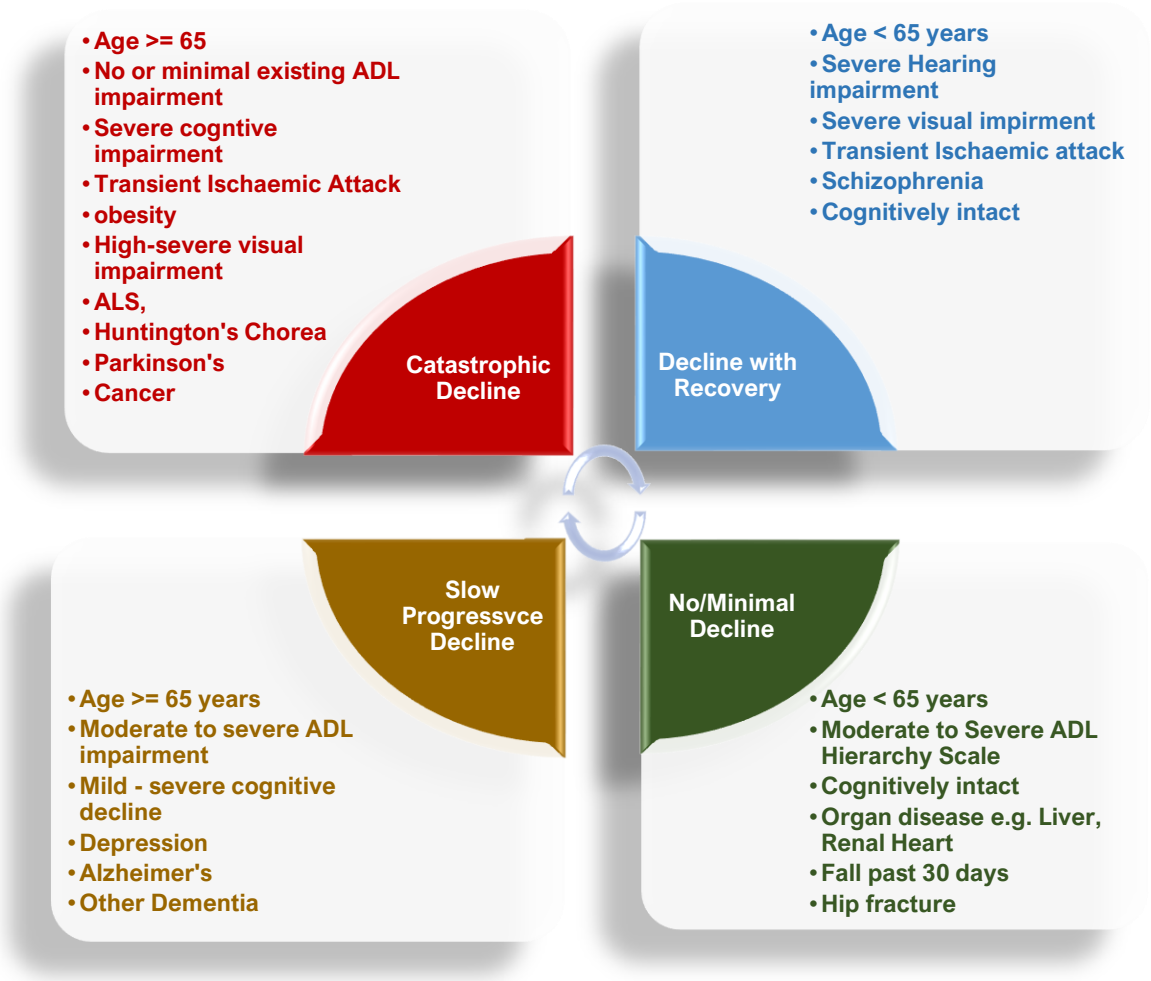


Figure 4.6: Predicted Membership Profile for the Different Functional Decline Trajectories 2015 = 2021, n = 204,036.

4.3.7. Prognostic Value of Trajectory Groups:
Do they predict future outcomes?

4.3.6.1. Resource Utilization

Trend plots of the mean case-mix index (CMI) for residents using modeling outputs showed distinctive resource consumption patterns by the trajectory groups over time. As shown in **Figure 4.7**, despite entering LTC care settings with the lowest mean CMI, residents who followed a catastrophic decline trajectory soon escalated to

the highest mean CMI compared to other residents. This escalation in resource utilization occurred rapidly within the first six months of admission. Likewise, residents who followed a slow progressive decline trajectory also escalated in their resource utilization; however, unlike residents who experienced a catastrophic decline, their resource utilization increased much slower, taking almost two years to reach peak recorded levels.

Residents who entered the setting with very high ADL experienced little or no ADL decline and had stable CMI trends, meaning their resource utilization demand did not change much over time. On the other hand, residents who recovered in function after an initial rapid decline maintained stable low CMI throughout the study (**Figure 4.7**).

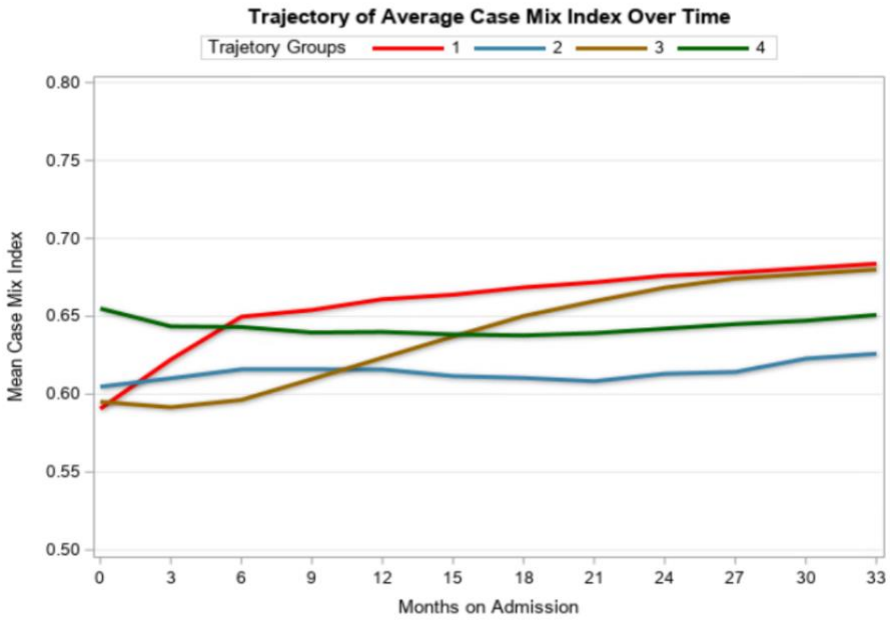


Figure 4.7: Three-Year Trend in Residents' Average CMI by Functional Decline Trajectory Groups 2015 – 2021, n = 204,036.

4.3.6.2. Mortality

Further to its value in predicting resource demand over time, the identified trajectory groups predicted subsequent mortality over the next five-year period. **Figure 4.8**, Kaplan Meier plot showed that residents who experienced a catastrophic decline in ADL function had a consistently higher probability of 5-year mortality compared to residents who followed other trajectory paths. Conversely, residents who declined and recovered in function had consistently lower risk of 5-year mortality versus other residents. The risk of mortality eventually begins to even up among all residents.

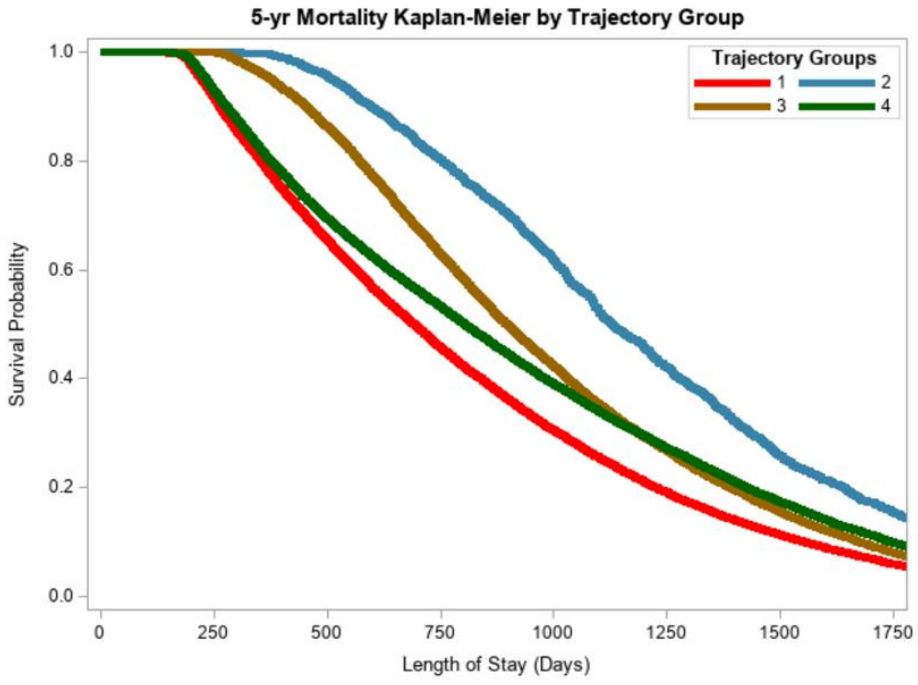


Figure 4.8. Five-year Mortality Kaplan Meier Estimate by Functional Decline Trajectory Group 2015 – 2021, n = 204,036.

4.4. Discussion

This study aimed to describe the trajectory patterns of functional decline for residents in LTC settings. A secondary aim was to determine the patient-level factors that predict membership of identified functional decline trajectory groups and how each trajectory group membership relates to future health outcomes. The results show that residents in LTC settings broadly follow four distinct functional decline trajectories upon entry into the setting. These were named according to their shapes "catastrophic decline", rapid decline with recovery", "slow progressive decline", and "no/minimal decline". Admission ADL hierarchy score was the strongest, albeit not the only, determinant of which trajectory a resident will follow.

Further, the admission ADL hierarchy score determined the proportional distribution of residents into different trajectory groups but did not influence the overall group trajectory shape. It is important to emphasize that the trajectories we have shown with this study are not fixed and immutable. Instead, they are amenable to life events, including interventions(Nutr & Nagin, 2014).

To the best of my knowledge, this is the first study to characterize the patterns of functional decline trajectory for nursing home residents across Canada. Overall, the result of this study is consistent with prior studies on the trajectories of functional decline among older adults in nursing homes, showing four distinct trajectory groups. A study by Guion, De Souto Barreto & Rolland identified four distinct functional decline trajectories among nursing home residents in South-Western France(Guion et al., 2021). Yoon *et al.* (Kassebaum et al., 2016) studied the longitudinal effects of

the Green House nursing home model on activities of daily living over time in the US and found four distinct trajectories of change in ADL function. Four trajectories of functional independence have also been found among community-dwelling older adults in many other countries using GBTM(Bimou et al., 2021; Brown et al., 2019). Other studies have identified different numbers of physical function trajectories among nursing home residents. This finding may be because prior studies have focused on the last years of life, while this study tracked residents on admission. The trajectory of function towards the end of life(Glaser & Strauss, 2005; Lunney et al., 2002, 2003; Strauss, 1968) is likely different compared to other times.

Residents' admission ADL scores significantly determined how they progressed in physical function. Residents with better ADL performance on admission were likelier to decline in function than those with worse ADL scores. This could be due to the ceiling effect(Banaszak-Holl et al., 2011; Rodríguez López et al., 2014; Seematter-Bagnoud et al., 2013), where those with worse (higher) ADL scores have little or no room for further decline. To be precise, more residents with lower (better) ADL scores on admission followed a catastrophic decline trajectory, and conversely, more residents with higher (worse) ADL followed the no/minimal decline trajectory. Residents with admission ADL scores 3-6 were 40 times more likely to remain unchanged in physical function trajectory within LTC homes than residents with no ADL impairment. Trajectory membership was also affected by other patient-level factors.

The observed pattern of group membership showed that residents entering LTC homes with neurodegenerative conditions such as Parkinson's disease, ALS, and Huntington's Chorea were most vulnerable to and likely to experience a catastrophic decline in ADL performance irrespective of their ADL score on admission (Table 8). The effect of neurodegenerative conditions such as Parkinson's disease on functional decline is well established(Jankovic & Kapadia, 2001; Mollà-Casanova et al., 2022; Stella et al., 2008; Tan et al., 2018), with suggestions that it affects both motor and cognitive function.

Except for those with severe cognitive decline, residents with poor cognitive function did not follow the catastrophic decline trajectory. Instead, they followed a slow progressive functional decline trajectory. Those diagnosed with Alzheimer's disease or other dementias, those with CPS of 1 or more, were more likely to follow a slow progressive decline in ADL function. The separation between the decline trajectory associated with neurological conditions and cognitive impairment is informative. Although previous studies show that cognitive impairment is associated with worse functional ability for residents in nursing homes(Chen et al., 2007), this study showed that on admission, residents with intact cognitive function, as well as those with severe cognitive impairment, were more likely to experience catastrophic functional decline than those with cognitive impairment. McConnel *et al.* (McConnell et al., 2002) concluded that cognitive impairment did not affect the rate of ADL decline among LTC residents in their study, but only the magnitude of the decline. The results of this study contrast this finding as different categories of cognitive

impairment affected rates of functional decline. The reason for such contrast might be due to the methods that were used to assess the relationships between the variables. McConnel et al.(McConnell et al., 2002) used a mixed-method longitudinal analysis to determine the effect level in their study. There is, therefore, an assumption of a mean population effect parameter around which the individuals vary. This study assumed that LTC populations are heterogeneous and utilized GBTM to derive different parameter estimates for trajectory groups.

Overall, the majority of residents followed the no/minimal decline trajectory. This finding agrees with other studies showing that nursing home residents were more likely to remain at their initial ADL level than to change (**See chapter on Multistate transition**).

Whether LTC residents recover in physical function is an ongoing debate that presently has no consensus. Results of our study suggest that some, albeit a tiny number of residents, make some degree of recovery of their baseline or admission functional level. Figures 4.1 and 4.5a show that 18.7% and 13.0% of all residents and those without ADL impairment followed a trajectory of initial rapid decline, with subsequent incomplete recovery, before finally declining in function again. Further analysis will show that residents were more likely to recover ADL function if they were not frail, not cognitively impaired, not older than 65 years, and if they were females. The lower (better) the average baseline ADL score of the residents, the higher the number of persons likely to recover in function.

Recovery of function is vital for LTC residents as it could facilitate their return to the community. For residents whose goal is not to return to the community, restoring function would enhance their quality of life as they could participate in social or other activities. Residents who recover in function would likely demand and use health resources less (including nursing care), freeing such resources for other residents. Therefore, identifying residents with this recovery potential should be a fundamental care quality pursuit for facility administrators. Our analysis showed few positive markers of potential to recover in function on admission. Cognitively intact residents, those who had severe visual and hearing impairment, transient ischemic attack, and those diagnosed with Schizophrenia were all likely to recover in physical function. Except for cognition, a commonality between the other attributes is that they are treatable or modifiable, suggesting that residents who are identified early could be supported to improve in function.

Clinicians can utilize the trajectory groups' information to set treatment goals or expectations for residents with certain health conditions. Knowing which trajectory residents with particular health conditions will follow could guide clinicians on what care planning would be most appropriate for such individuals and the timing of any functional improvement intervention. Functional improvement intervention will likely differ for different trajectory groups, and so will the intended outcomes. For clients at risk of catastrophic decline, early intervention would be appropriate to delay or prevent such a decline. For clients who follow a no/minimal decline trajectory, care planning will monitor them to ensure new ADL declines do

not decline. It is, however, important to highlight that among the residents that follow the no/minimal decline trajectory, most have very severe ADL impairment, and no declines would not necessarily be expected. For such residents, treatment goals and, therefore, care planning will be different.

Clinicians can also utilize such information for patient education, informing clients of the likely course of their health and what possible action would be helpful. Informed residents are more likely to be engaged with their management plan, which could optimize health outcomes.

The findings of this study could be used to enhance the current need-based resource allocation in the LTC setting. Relevant jurisdictions usually fund LTC homes with consideration of their bed sizes as well as residents' acuity based on the case-mix value at the beginning of the funding cycle. However, as shown in **Figure 4.7**, the CMI value at the start of a cycle hardly remains constant over the funding period (usually one year). Instead, the trajectory modeling showed that within six months of admission, residents' functional status changes dramatically, resulting in shifts in the intensity of resource requirements needed between trajectory groups. Such a switch in resource requirement must be accommodated during initial resource allocation.

The findings of this study provide one objective way of identifying the different trajectories of function among LTC residents and subsequently showing how resource requirements vary between the trajectory groups over time. More significantly, the trajectory method provides additional information that shows at what points

residents are likely to change in the function and, by extension, when their resource requirements would likely change. This information would help forecast management time and staffing needs of LTC homes.

4.5. Future Work

For evidence generated from this study to be useful for clinical purposes, further work will be required to create a decision support tool that could be used by clinicians or residents themselves. Future work on developing a functional decline trajectory classification algorithm would be helpful. This is an area of research interest for me, and I intend to pursue the development of predictive algorithms from the trajectory groups and their associated predictors in the next phase of my research work. Such an algorithm will serve many purposes. Most importantly, it would be helpful to classify residents into trajectory groups at admission, assisting care providers with their care planning.

While this study examined the trajectory of functional decline over 36 months, Exploring the trajectory over a more extended period may be helpful. It is unknown what advantage such long-term prediction will have over a shorter one, as health changes occur more frequently among the LTC population. Also, the median length of the stay in the setting, which is 2-3 years on average, might make this unnecessary. However, some residents who stay longer in the setting may benefit from information regarding the long-term (>36 months) trajectory of function.

4.6. Recommendations

By identifying subgroups of residents of LTC homes who experience functional decline differently, this study confirms the heterogeneity of the adult population in this setting. Personalized care will, therefore, be enhanced if such information is used to identify clusters of individuals to be provided differentially targeted interventions. For this to be successful, information about the specific ADL changes that occur within each trajectory group will be required. The trajectory modeling output does not answer this question. Studies examining health changes within each trajectory group would be necessary and could provide a better understanding of individual care needs, facilitating personalized care.

4.7. Limitations

As a condition for the GBTM analytic technique, a resident must have at least three consecutive assessments to be eligible for inclusion in the analytical sample. Short-stay residents with less than three assessments were excluded from the analysis, which could introduce bias into the sample. It will not be appropriate to generalize the findings to all LTC residents. However, because this study focused on the longitudinal changes in ADL, it is reasonable to assume that the findings would not be biased for the target resident types.

One attribute of the GBTM method used in the study is that the subgroup identified using this technique does not represent fixed, immutable properties of such residents. This calls for caution in interpreting the result as the groups represent a

latent average trajectory within which residents have many functional decline paths. Obtaining these distinct groups, however, adds lots of value to residents' management. It further drills down what is known at the population level closer to the individual level, allowing for personalized care planning.

4.8. Conclusion

The provision of personalized care is critical for managing older adults, especially those in LTC settings. Such management strategy relies on the availability of precise person-level information for optimized care planning. Results obtained from this study confirm that personalized care is indeed required in the LTC setting. The information generated from the results shows who among residents would be most at risk for different levels of functional decline, further showing at what points changes in function would likely occur.

This information would be helpful for clinicians seeking to predict or forecast the potential trajectory of residents' functional levels based on their admission profile. This information in a ready-to-use format will empower care providers to make informed decisions about when and what intervention to provide to specific residents.

The insights generated from this study also provided evidence that could be used to optimize resource allocation to LTC facilities. Evidence for resource allocation that is not solely based on the initial acuity or case-mix properties of residents but on

the longitudinal shifts in acuity would be helpful for policymakers and health administrators alike. More work would be required to transform this evidence into decision-making tools.

Chapter 5:

Study 4: Pattern of Changes in Activities of Daily Living Function and Related Terminal Outcomes In Long-term Care Facilities: A Multistate Transition Markov Model of Population-Based Longitudinal Data In Canada.

5.1. Introduction

Nursing home residents are typically placed with impairment in the performance of activities of daily living (ADL)(Fong et al., 2012; Gaugler et al., 2007; Jette et al., 1992; Qureshi et al., 2020), and over time, could worsen, remain the same, or in some cases, improve, depending on several factors(Fedecostante et al., 2016, 2021; Jerez-Roig, De Brito MacEdo Ferreira, et al., 2017; Palese et al., 2016). Transitions between different ADL functional states are multidirectional and dynamic, presenting challenges for ongoing care planning and may lead to unwanted consequences when the direction of change is adverse. Understanding these dynamic transitions and the associated factors is essential for care planning and delivery in this setting(Banerjee & Sadana, 2021; Lagergren, 1994). Achieving optimal care delivery for this continually evolving population group requires that up-to-date research evidence on ADL and associated terminal transitions is consistently available.

Limitations in ADL are usually associated with higher healthcare costs(B. C. Williams, Fries, Foley, Schneider, & Gavazzi, 1994a). Therefore, transitions from better to worse states would most likely exacerbate the cost of caring for residents

in LTC homes. Dai et al.(Dai et al., 2017) showed that transitions to more severe ADL states are associated with significantly higher average annual care costs and that those who transition from severe to moderate ADL states cost substantially less to care for (-US$6,045) compared to persons who remain in severe states of ADL impairment. Understanding transitions between functional levels is essential for effective care planning and policy decision-making. It could improve our understanding of residents' trajectories of change, provide helpful information that would enhance care planning for older adults(Raîche et al., 2012), and reduce care costs associated with preventable functional decline.

Utilizing data to improve the quality of care in institutional settings is one of the ways to mitigate against the rising nursing home population(Hirdes et al., 2011a). Lagergren(Lagergren, 1994) had earlier pointed out that data analysis that captures health changes in nursing homes as dynamic exchanges rather than a one-dimensional process can improve care planning for residents in the setting. With huge investments and efforts made in data collection across many countries, good quality population-level data that can be utilized to improve our understanding of ADL transitions among LTC residents are now available.

In addition to its cost implication, ADL function changes are a powerful quality-of-care indicator in nursing homes, explaining why it is a major component of most quality-of-life care measures for this population group(B. C. Williams, Fries, Foley, Schneider, Gavazzi, et al., 1994). These include case-mix systems, especially the resource utilization group (RUG) categorization(Carpenter et al., 1997; B. E.

Fries et al., 1994; Hirdes et al., 2010), changes in health, and end-stage signs and symptoms (CHESS)(Hirdes et al., 2003). An in-depth understanding of the ADL transitions in LTC settings will, therefore, be valuable, not only for cost purposes but also for measuring and monitoring the quality of care for residents.

Few studies have examined the dynamic transitions between ADL statuses in LTC settings over time. Hirdes *et al.*(Hirdes et al., 2019) investigated the transitions between states of health instability and good or adverse outcomes that occur within the first 90 days of nursing home admission, showing that they are affected by various resident-level factors. However, the study did not focus on transitions in ADL states; instead, it examined a different health measure, CHESS(Hirdes et al., 2003). Burge, van Gunten & Berchtold studied the transition to better or worse ADL performance among nursing home residents using the survival analysis method and showed that each transition is affected by resident factors(Bürge et al., 2013). They modeled each ADL change event (worsening and improvement) separately and did not accommodate the simultaneous multidirectional transitions between ADL states. Lagergren(Lagergren, 1994) showed that ADL transitions are dynamic among nursing home residents, so studies that accommodate these multidirectional changes would more appropriately represent the actual changes that occur among this population group. Evidence of this multidirectional transition in ADL function is scanty.

In chapter four of this thesis, I examined and showed that the longitudinal transition of functional decline follows four subgroups' trajectories in nursing home

settings. The study addressed an essential question regarding the heterogeneity of longitudinal ADL changes in nursing homes that was previously unknown for the Canadian population. However, one question not addressed by the study is "***what the dynamic transitions in physical function that occur among residents are***". The modeling method utilized for this study, ***latent class group analysis***, cannot address the dynamic nature of transitions that occur even within distinct trajectory subgroups, as alluded to by Lagergren(Lagergren, 1994).

Therefore, This study focused on expanding the existing knowledge about the longitudinal trajectory of functional changes by describing the concurrent dynamic ADL and terminal transitions, including improvement, worsening, and stability of function. The study examined what factors are associated with each component of these dynamic transitions and how the transitions affect future health-related outcomes in the setting.

5.2. Methods

5.2.1. Study Design

This was a retrospective longitudinal study of residents receiving care in LTC homes within three Canadian provinces, Alberta, British Columbia, and Ontario, between January 2010 and December 2020.

The University of Waterloo's Office of Research Ethics (#30173) provided ethics approval for the study.

5.2.2. Data Sources

A linked dataset provided by the Canadian Institute of Health Information (CIHI) that includes data from the Continuing Care Reporting System (CCRS) was used for this analysis. Data from the Discharge Abstract Dataset (DAD) that captures administrative, clinical, and demographic information on hospital discharges (including deaths, sign-outs, and transfers), the National Ambulatory Care Reporting System (NACRS) that collects demographic, administrative, clinical, and service-specific data for ED, day surgery and other ambulatory care visits are included in the linked dataset. The CCRS houses resident-level administrative data collected in LTC facilities using interRAI's multidomain assessment instrument, MDS 2.0. Trained assessors usually complete the MDS 2.0 assessments within two weeks of the resident's admission. Assessments are then repeated every 90 days or sooner if a resident's health status changes. The validity and reliability of the interRAI assessment instrument items have been extensively examined and reported(Carpenter, 2006; Hermans et al., 2016; Hirdes et al., 2013a; Morris et al., 1997, 2013a; Penny et al., 2016; Poss, Jutan, et al., 2008; Tsuchiya-Ito et al., 2022; Wellens et al., 2013; Yoon & Kim, 2017).

5.3.3. Study Cohort

To be eligible for inclusion in the study, a resident must be 65 years or older, not comatose, and must have two completed or one assessment with discharge information. Residents with only one assessment and no discharge information are deemed to have been on admission for less than 90 days. They would not have any

information to determine their next transition state. These types of residents were excluded from the analysis.

All residents who met the above inclusion criteria and whose first assessment was within the study period were selected and included in the analysis. From this, pairs of transition were created for each resident such that the initial assessment represents the originating state of the first pair and the second assessment the next state of the first pair. Likewise, the second pair has 2nd assessment as originating, and the 3rd assessment is the terminal state. This process is continued until the resident enters an absorbing state or the end of the data series has been reached. The transition matrix was derived, and a Markov model was fitted using these pairs of transitions.

5.3.4. Outcomes of Interest

This study's primary outcome of interest was the change in ADL function. ADL function was measured using the interRAI ADL Hierarchy scale, which is a 7-level ordinal measure of functional performance based on a person's ability to complete early (personal hygiene), middle (toileting and locomotion), and late-loss (eating) ADLs(Carpenter et al., 2006; Morris et al., 1999). For the study, ADL function was categorized into three mutually exclusive levels based on the ADL hierarchy score as **ADL 0 [**No existing impairment**]**, **ADL 1-2 [**Mild impairment**]**, and **ADL 3+ [**Moderate to severe impairment**]**. Change in ADL function here means moving from one level of the ADL categories to another in any direction.

The secondary outcome of interest in this study is the eventual terminal outcome for residents who transition out of the LTC setting. For those residents, several outcomes are possible as the terminal event following admission. For this study, we classified these terminal events into four distinct categories. **Death** [residents who died within the nursing home or are known to have died following hospital or ER admission], **Home** [residents discharged back home], **Hospital** [residents discharged to hospital for acute care with an immediate return not expected but who are not known to have died in the hospital], **Other** [residents discharge to other destinations such as Assisted Living, Board care, and others].

5.3.5. Independent Variables

Resident-level factors previously reported in the literature as having associations with ADL decline among nursing home residents were included in our analysis as independent variables(Egbujie et al., 2023; Fedecostante et al., 2016, 2021). These included socio-demographic variables like sex, age group, marital status, and the Index of Social Engagement (ISE) score(Gilbart & Hirdes, 2000). Clinical conditions like pneumonia, urinary tract infection (UTI), congestive heart failure (CHF), Parkinson's, Alzheimer's, renal failure, cancer, and stroke have all been associated with functional decline and were included in this analysis. Summary scales like Cognitive Performance Scale (CPS)(Morris et al., 1994), ADL Hierarchy Scale (Morris et al., 1999), Changes in Health, End Stage Disease, and Signs and Symptoms (CHESS) scale(Hirdes et al., 2003), and ADL clinical assessment protocol (CAP ADL) were also included as independent variables.

Further, variables such as perceived rehabilitation potential and number of medications used were also included. A complete list of all independent variables included in the analysis is available in **Supplementary File D.1.**

Additionally, system-level factors known or expected to affect ADL decline were also included in the analysis as independent variables. To examine the difference between residents according to where their LTC home is located, the province of LTC home was also included as an independent variable. Further, the location of the LTC home within the province (rural or urban) was included, as well as the size of the facility(Baldwin et al., 2017; Wilkinson et al., 2019).

5.3.6. Statistical Analysis

Descriptive statistics of the baseline characteristics of study participants were presented using frequencies and percentages for categorical variables and mean and standard deviations for continuous variables. Associations between two categorical variables were tested using the Chi-square test. In contrast, the Wilcoxon rank sum test was used to test the association between categorical independent variables and ordinal categorical dependent variables (ADL levels).

5.3.6.1. Transition Probabilities Estimation

The cumulative probabilities of transitions from one state to the next for successive assessment periods were obtained using **SAS MACRO** to build a "*transition matrix*"(Wicklin, 2016a, 2016b, 2023). First, the **PROC FREQ** procedure generated the actual frequencies (and percentages) of transition from one state to another for each successive assessment(Wicklin, 2023). Using the generated

frequency table(Wicklin, 2023), a transition matrix (**Supplementary Figure D.1**) representing the average probability of a resident transitioning from one state to another per unit of time was estimated with the **SAS PROC IML procedur**e(Basawa, 2014; Wicklin, 2023). This average probability was used to estimate the probability of future transitions at different time points.

The transition matrix in our model comprises seven (7) states, three transient and four **absorbing (**represented below**).** The state space diagram below shows all possible transitions between the states (**Figure 5.1**). The transition matrix was, therefore, a 7x7 matrix (**Supplementary Figure D.1)**; the probability of transitioning from an absorbing state to any other state is 0, while the probability of transition to itself is equal to 1.

State 1: ADL 0
State 2: ADL 1-2
State 3: ADL 3+
} Transient states

State 4: Home
State 5: Hospital
State 6: Death
State 7: Other
} Absorbing states

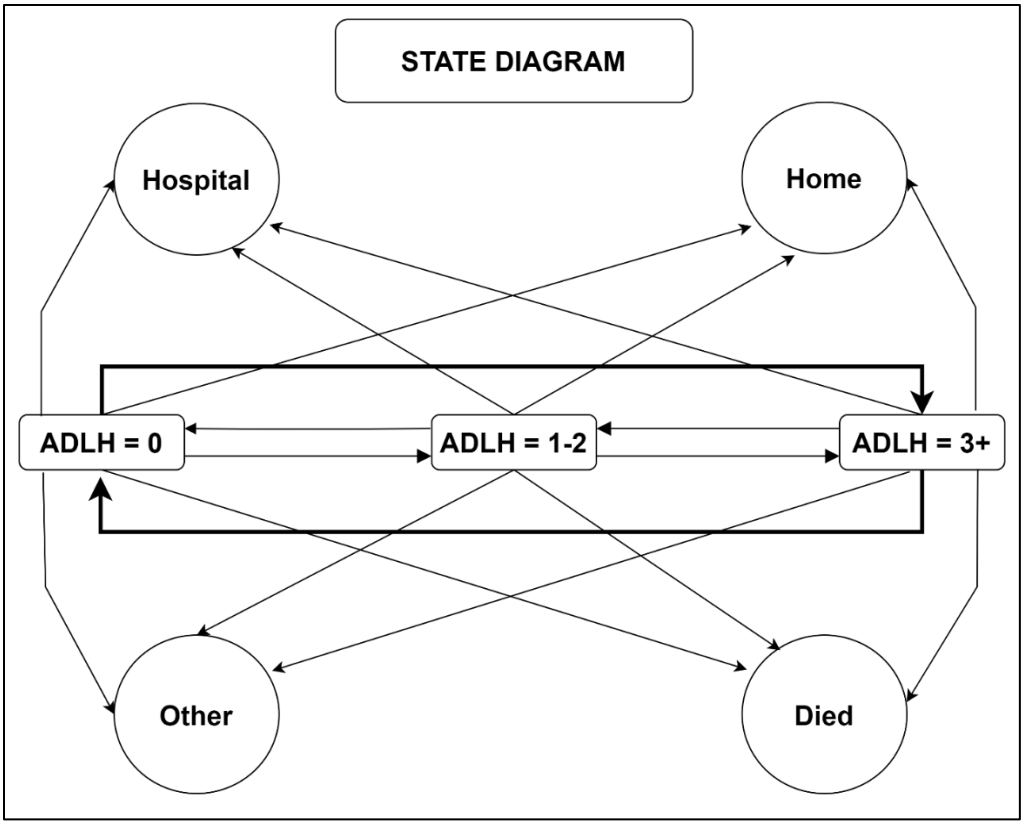


Figure 5.1: State-Space Diagram for Transition Between ADL States and Terminal States in LTC Setting.

5.3.6.2. Multi-state Markov Model

A 7-state Markov-chain multistate transition model was fitted to the data using a series of multinomial logistic regression to obtain the independent effect of different variables on the transition rates. In choosing a Markov process, we assumed from domain knowledge that future transition in ADL only depends on the present ADL state and not the historical values. Variables with a significance value of 0.05 or less were retained in the final model. All effects were presented in the tables for the adjusted odds ratio. This approach has been used in previous studies

of ADL and frailty(Larsen et al., 2020) transitions in home care(Cook et al., 2013) and transitions in health instability(Adekpedjou et al., 2022; Hébert et al., 2019; Hirdes et al., 2019) in LTC homes.

5.4. Results

5.4.1. Baseline Characteristics

A total of 334,676 unique residents aged 65 years and above in LTC homes within Canada consisting of residents in Ontario (227,461 [68.0%]), British Columbia (56,639 [16.9%]), and Alberta (50,576 [15.1%]) were included in the analysis. The residents transitioned a combined total of 1,680,660 times between the various ADL states and terminal states used for this modeling. More than 90% had some form of cognitive impairment, 62.6% had Alzheimer's disease or other dementia, 75.9% were 80 years or older, and 63.2% were females.

Table 1 displays the admission characteristics of all included residents. On admission, 72.9% (244,042) of the residents had moderate/severe impairment in ADL, **State 3**), 23.3% (77,810) had mild impairment **State 2**), while only 3.8% (12,824) had no ADL impairment, **State 1**. Twenty percent (20%) of the residents or their direct care staff believed they could improve their admission ADL function.

There was a statistically significant difference between residents according to ADL status on admission with a p-value < 0.05. Overall, residents with moderate/severe impairment were older, more cognitively impaired, and had higher

health instability (Table 1). Also, all disease and health conditions were higher among residents with moderate/severe impairment, and they had less self-perceived potential to improve physical function (**Table 5.1**). Residents differed in all measured variables according to their baseline ADL hierarchy scale category. Still, the difference was markedly different for summary variables such as CPS, CHESS, ISE, and DRS, showing consistently that worse ADL function was associated with worse clinical summary scales (**Table 5.1**).

Table 5.1. Baseline Characteristics Comparison of All Residents on Admission and Between ADL Hierarchy Categories 2010 – 2020, n = 334,678.

	All residents	Not impaired	Mildly Impaired	Moderate/ Severely Impaired	P-value
Sex					
Female	63.1 (211329)	62.1 (7967)	64.8 (50398)	62.7 (152964)	< 0.0001
Male	36.9 (123347)	37.8 (4857)	35.2 (27412)	37.3 (91078)	
Age group					
65 - 74	11.5 (38599)	15.2 (1949)	11.6 (8992)	11.3 (27658)	< 0.0001
75 - 84	33.5 (112109)	36.4 (4673)	35.0 (27254)	32.9 (80182)	
85 - 94	47.0 (157147)	43.4 (5563)	46.9 (36496)	47.2 (115088)	
95+	8.0 (26821)	5.0 (639)	6.5 (5068)	8.7 (21114)	
Married	22.2 (74442)	18.5 (2369)	19.2 (14949)	23.4 (57124)	<0.0001
CHESS					
0	63.4 (212024)	78.6 (10079)	71.5 (55631)	60.0 (146314)	< 0.0001
1 - 2	33.3 (111508)	20.9 (2675)	27.0 (21044)	36.0 (87789)	
3+	3.3 (11144)	0.5 (70)	1.5 (1135)	4.0 (9939)	
Cognitive Performance Scale (CPS)					
0	9.6 (32006)	27.1 (3474)	11.0 (8554)	8.2 (19978)	< 0.0001
1 - 2	34.5 (115378)	51.2 (6571)	43.8 (34075)	30.6 (74732)	
3 - 4	44.7 (149758)	20.3 (2605)	41.5 (32304)	47.1 (114849)	
5 - 6	11.2 (37534)	1.4 (174)	3.7 (2877)	14.1 (34483)	
Depression Rating Scale (DRS)					
0	46.5 (155468)	63.7 (8169)	51.6 (40126)	43.9 (107173)	< 0.0001
1 - 2	30.5 (102018)	23.4 (2996)	28.0 (21794)	31.7 (77228)	
3+	23.0 (77190)	12.9 (1659)	20.4 (15890)	24.4 (59641)	
Pain Scale					
0	59.1 (197960)	64.2 (8230)	64.7 (50306)	57.1 (139424)	< 0.0001
1-2	38.9 (130023)	33.9 (4348)	34.0 (26471)	40.7 (99204)	
3+	2.0 (6693)	1.9 (246)	1.3 (1033)	2.2 (5414)	
Social Engagement Score (ISE)					

0	8.1 (27188)	3.1 (395)	4.1 (3183)	9.7 (23610)	< 0.0001
1-2	34.7 (116260)	21.3 (2730)	27.8 (21602)	37.7 (91928)	
3-4	39.8 (133022)	42.2 (5410)	43.6 (33901)	38.4 (93711)	
5-6	17.4 (58206)	33.5 (4289)	24.6 (19124)	14.3 (34793)	
Hearing					
Adequate	57.1 (190863)	69.1 (8863)	61.1 (47517)	55.1 (134483)	< 0.0001
Minimal difficulty	26.7 (89297)	21.4 (2741)	25.5 (19817)	27.4 (66739)	
Special Situation	14.4 (48253)	8.3 (1067)	11.9 (9290)	15.5 (37896)	
Highly Impaired	1.8 (6170)	1.2 (149)	1.5 (1165)	2.0 (4856)	
Vision					
Adequate	56.7 (189786)	73.1 (9376)	64.4 (50133)	53.4 (130277)	< 0.0001
Impaired	29.5 (98808)	20.7 (2652)	26.8 (20837)	30.9 (75319)	
Moderately Impaired	7.6 (25291)	4.2 (544)	5.6 (4352)	8.4 (20395)	
Highly Impaired	4.6 (15207)	1.5 (187)	2.3 (1757)	5.4 (13263)	
Severely Impaired	1.6 (5491)	0.5 (61)	0.9 (710)	1.9 (4720)	
Meds Changed last 90 days.					
No	37.4 (124990)	41.7 (5346)	40.3 (31359)	36.2 (88285)	< 0.0001
Yes	39.6 (132657)	32.1 (4116)	35.3 (27438)	41.4 (101103)	
Unknown	23.0 (77029)	26.2 (3362)	24.4 (19013)	22.4 (54654)	
Physician Visit					
0	30.6 (102446)	18.7 (2399)	24.2 (18798)	33.3 (81249)	< 0.0001
1	20.4 (68237)	33.7 (4315)	25.3 (19694)	18.1 (44228)	
2+	49.0 (163993)	47.6 (6110)	50.5 (39318)	48.6 (118565)	
Province					
Alberta	15.1 (50574)	8.5 (1093)	12.2 (9499)	16.4 (39982)	< 0.0001
British Columbia	16.9 (56634)	36.8 (4715)	25.0 (19474)	13.3 (32445)	
Ontario	68.0 (227468)	54.7 (7016)	62.8 (48837)	70.3 (171615)	
Facility Location					
Rural	14.0 (46874)	21.3 (2727)	16.9 (13151)	12.7 (30996)	< 0.0001
Urban	85.6 (334676)	78.7 (10097)	83.1 (64659)	87.3 (213046)	
Facility Size					
Large	82.5 (275934)	76.1 (9741)	79.9 (62111)	83.7 (204082)	< 0.0001
Medium	16.0 (53500)	20.8 (2669)	18.3 (14235)	15.0 (36596)	
Small	1.5 (4871)	3.1 (396)	1.8 (1366)	1.3 (3109)	
Health Diagnoses					
Alzheimer's/Other Dementia	62.6 (209463)	54.1 (6938)	66.1 (51458)	61.9 (151067)	< 0.0001
Heart Failure	15.4 (51639)	13.9 (1789)	13.4 (10439)	16.1 (39411)	< 0.0001
Cancer	10.9 (36467)	10.5 (1347)	10.1 (7872)	11.2 (27248)	< 0.0001
Renal Failure	11.7 (39211)	10.1 (1296)	10.5 (8148)	12.2 (29767)	< 0.0001
Pneumonia	1.8 (6134)	0.8 (105)	1.0 (758)	2.2 (5271)	< 0.0001
UTI	7.7 (25658)	3.4 (434)	5.0 (3927)	8.7 (21297)	< 0.0001
COPD	16.6 (55553)	18.5 (2376)	17.1 (13343)	16.3 (39834)	< 0.0001
Parkinson	6.7 (22384)	3.1 (398)	4.0 (3093)	7.7 (18893)	< 0.0001
Hemi/Paraplegia	3.9 (12241)	0.7 (91)	1.0 (760)	5.0 (12241)	< 0.0001
Schizophrenia	1.4 (4672)	2.3 (296)	1.7 (1298)	1.3 (3074)	< 0.0001
Stroke	19.2 (64075)	12.9 (1648)	14.0 (10867)	21.1 (51560)	< 0.0001
Clinical condition					
Rehab potential	20.5 (68587)	21.8 (2801)	26.9 (20899)	18.4 (44887)	< 0.0001
Fall last 30 days	22.3 (74684)	8.9 (1147)	15.1 (11788)	25.3 (61749)	< 0.0001
Hip Fracture last 180 days	3.5 (11796)	1.2 (159)	1.7 (1309)	4.2 (10328)	< 0.0001
Unsteady Gait	40.2 (134435)	25.8 (3311)	39.6 (30843)	41.1 (100281)	< 0.0001

5.4.2. Transition Patterns and Probabilities

Several patterns were found in examining resident changes between ADL (transient) and absorbing states during admission. These are presented in the following paragraphs.

5.4.2.1. Transient ADL Changes within 90 days

In the first 90 days of admission, most residents remained unchanged in their ADL state. Residents admitted with moderate-to-severe impairment had a 0.79 probability of staying in the same state after 90 days, while those entering with mild or without impairment had 0.59 and 0.55 probabilities of remaining in the same ADL state, respectively.

Despite the high probability of remaining unchanged in ADL status during the first 90 days of admission, many residents experienced noticeable changes in ADL function during this period. Residents had about 0.25 probability of declining from having no impairment to becoming mildly impaired and about 0.27 probability of further declining from being mildly impaired to becoming moderately/severely impaired during these initial 90 days. In addition, a subgroup of residents with no existing ADL impairment on admission had a 0.11 probability of becoming moderately/severely impaired during these first 90 days, representing a form of catastrophic decline.

During these initial 90 days, transitions were not always adverse. Some residents improved to better ADL functional states. Residents with mild impairment at the start had a 0.06 probability of returning to a no ADL impairment

state. Those with moderate/severe impairment on admission had a 0.06 probability of improving to a mild impairment state and a 0.05 probability of complete return to no ADL impairment state within 90 days of admission.

5.4.2.2. Transitions Between ADL States Over Time

Over time, the instantaneous transition rates from one ADL state to another moved back and forth between periods of high and low intensities. However, the probability of ADL decline accelerated over time while improvement decelerated. For residents admitted with no existing impairment, the probability of remaining without impairment reduced to 0.15 by 12 months (vs. 0.59 in the first 90 days). However, the probability accelerated to 0.37 by 24 months before dropping to merely 0.003 by the end of 5 years, showing rapid acceleration over time. Residents consistently moved into and exited from different ADL states. For those with initial mild impairment, the probability of remaining unchanged in ADL status reduced to 0.20 by 12 months (vs. 0.63 in the first 90 days), 0.08 by 24 months, and 0.001 at the end of 5 years.

For residents admitted with mild ADL impairment, the probability of declining further to a moderate/severe ADL impairment state over time was 0.44 by 12 months and 0.06 by the end of 5 years, with a quadratic shape (**Supplementary Figure D.2**). Since ADL status is transient, residents enter and exit the different ADL states over time, and the probability of transitioning and remaining in any of the states from another ADL state increases initially and then reduces depending on the assessment's timing. Assessments conducted within the first 12 months

showed that the probability of transitioning to the different ADL states increased, but beginning from the second year, as more residents transitioned out of the ADL states to the four other absorbing states, the probability of being in that state started to reduce (**Supplementary Figure D.2**).

Among residents admitted with moderate/severe impairment, over time, the probability of improving to no ADL impairment at 12 months, two years, and five years was 0.008, 0.007, and 0.002, while the probability of improving to a mild impairment state was 0.05, 0.04 and 0.008 respectively.

5.4.2.3. Transitions to Absorbing States.

Residents who were discharged back a) to their homes, b) to other care settings for continuing care, c) or to a hospital with no expectation of immediate return, d) or those who died were considered to have transitioned to terminal states, which are known as **absorbing states**.

i. Probability of Hospital Admission

The probability of hospital admission was high in the first 90 days of admission for all residents, although differentially higher for those with moderate/severe impairment (~ 0.04) than those with mild impairment (~ 0.02). It was the lowest for those admitted with no impairment (~ 0.02). The point prevalence of hospital discharge subsequently slowed until the end of the first year and then increased again by the beginning of the second year, staying high until after the third year (**Figure 5.2b**).

Cumulatively, by the end of 12 months, the probability of hospital admission increased to 0.09 for residents admitted with moderate-to-severe ADL impairment, 0.07 for those admitted with mild impairment, and 0.06 for those with no existing impairment. These probabilities rise by the end of five years to 0.18, 0.19, and 0.19, respectively. There was a slight reversal in magnitudes after about 30 months (**Supplementary Figure D.2**).

ii. Probability of Mortality

In the first 90 days of admission, the probability of mortality for residents with no ADL impairment was 0.02, 0.03 for those with mild ADL impairment, and 0.09 for those with moderate/severe impairment. By the end of the first year of admission, the probability of mortality was 0.01, 0.02, and 0.06 for the ADL states, respectively, showing a slowdown similar to hospital admission.

The trend in probability of mortality was similar to the trend observed for hospital admission, being highest for those with moderate/severe impairment at all points (**Figure 5.2a**). Trend analysis showed that the point mortality probability reduced slightly in the first 12 months for all resident types. It then increased from the second year and finally began to drop after the end of the third year (**Figure 5.2a**). This curvilinear shape in the historical transition rates to mortality was similar for all residents, irrespective of their admission ADLH score.

Although cumulative probabilities were initially significantly different for the different ADL states, the final probability of dying in the LTC home did not differ substantially between residents, irrespective of their admission ADL status. By the

end of 5 years, the cumulative probability of mortality was 0.63, 0.66, and 0.72 for residents with no, mild, and moderate/severe impairments, respectively. The probability of mortality plateaued at 0.70, 0.71, and 0.76 for residents who were not impaired, mildly, or moderately/severely impaired, respectively, on admission. **Figure 5.3a** shows a trend in the distribution of cumulative mortality probability by the 3 ADL states over time.

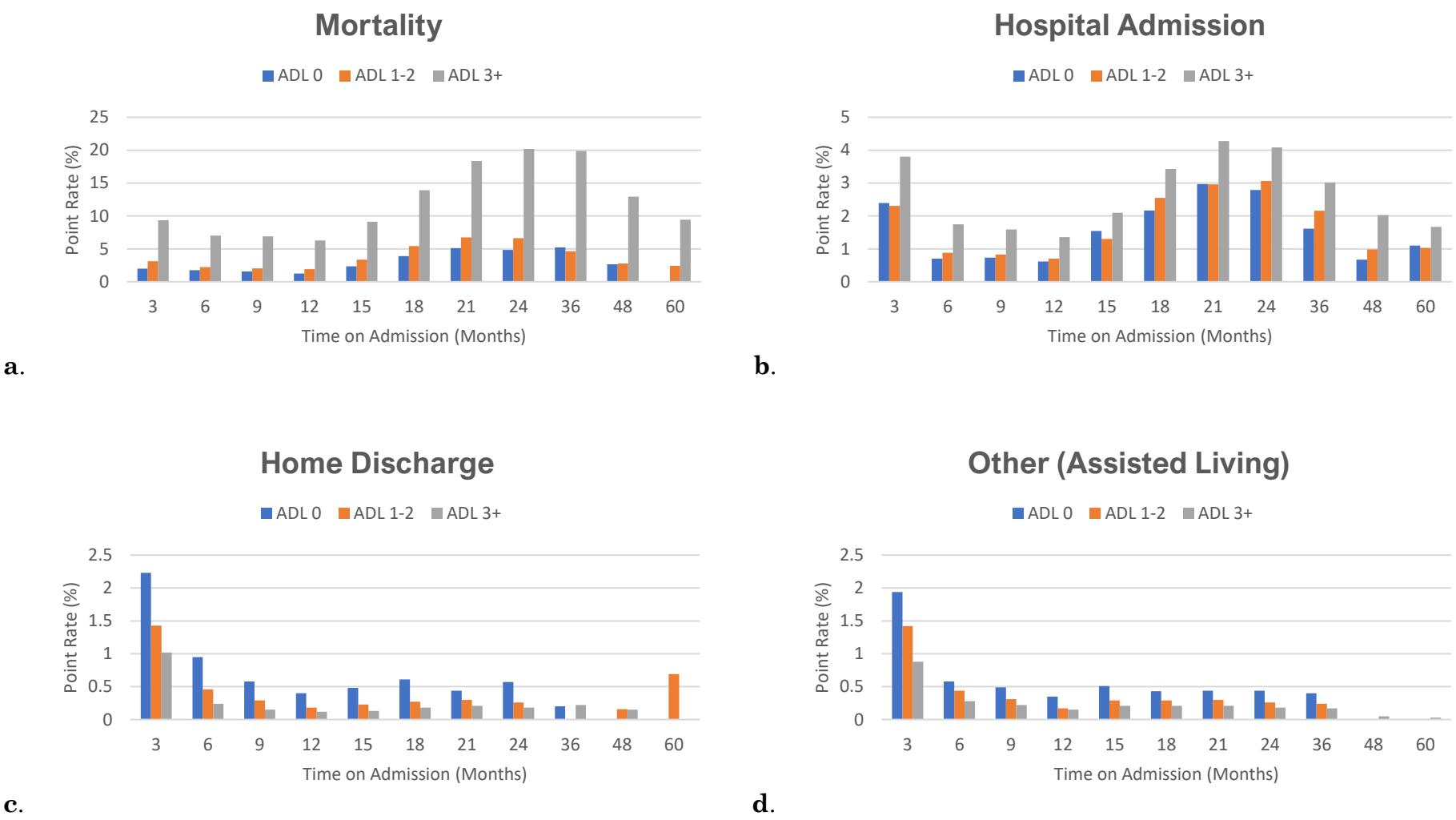


Figure 5.2: Trend in Point Rates of Transition to Absorbing States a) Mortality, b) Hospital, c) Home and d) Other.

[The y-axes were rescaled to highlight the trend difference between ADL groups]

iii. Probability of Home Discharge

The cumulative probability of home discharge was only 0.02 for those admitted with moderate-to-severe impairments in this cohort. For residents admitted with no or mild ADL impairments, the probability was 0.05 and 0.04, respectively.

In contrast to hospital and mortality transitions, the final cumulative probability of home discharge differed between residents based on their ADL status on admission. Residents without existing ADL impairment on admission had 2.5 times greater odds of being discharged home eventually than residents who were severely impaired on admission (**Figure 5.3c**). On admission, the all-time probability of home discharge plateaued at 0.05, 0.04, and 0.02 for residents who were not impaired, mildly, or moderately/severely impaired, respectively.

iv. Probability of Discharge to Other Settings

Discharge to other settings followed similar trends to home discharge. Residents were more likely to be discharged to the other setting if admitted without existing ADL impairment (**Figure 5.3d**).

5.4.3. Sojourn Time

Residents who started with no ADL impairment spent an estimated average of 8.1 months in a state of no impairment and then 6.6 months living with mild impairment. Such residents eventually declined to moderate-to-severe impairment and spent 14.7 months living in this state. For residents starting with mild ADL impairment, they spent on average a total of 10.2 months being mildly impaired,

15.6 months in a moderate-to-severe impairment state, and only 1.2 months without impairment. Among residents admitted in a moderate-to-severe impairment state, they spent an average of 19.5 months overall in this state, about 1.8 months in a mild impairment state, and less than one month without impairment before transitioning to an absorbing state.

Overall, residents entering LTC homes without any existing impairment spent an average of 29.4 months (2.5 years) in various ADL functional states before transitioning to one of the terminal states. Residents admitted with mild impairment spent an average of 27 months (2.3 years) in between the transient ADL states, while those admitted with moderate-to-severe ADL impairment spent an average of 21 months (1.8 years) in the various transient ADL states before moving to one of the terminal states.

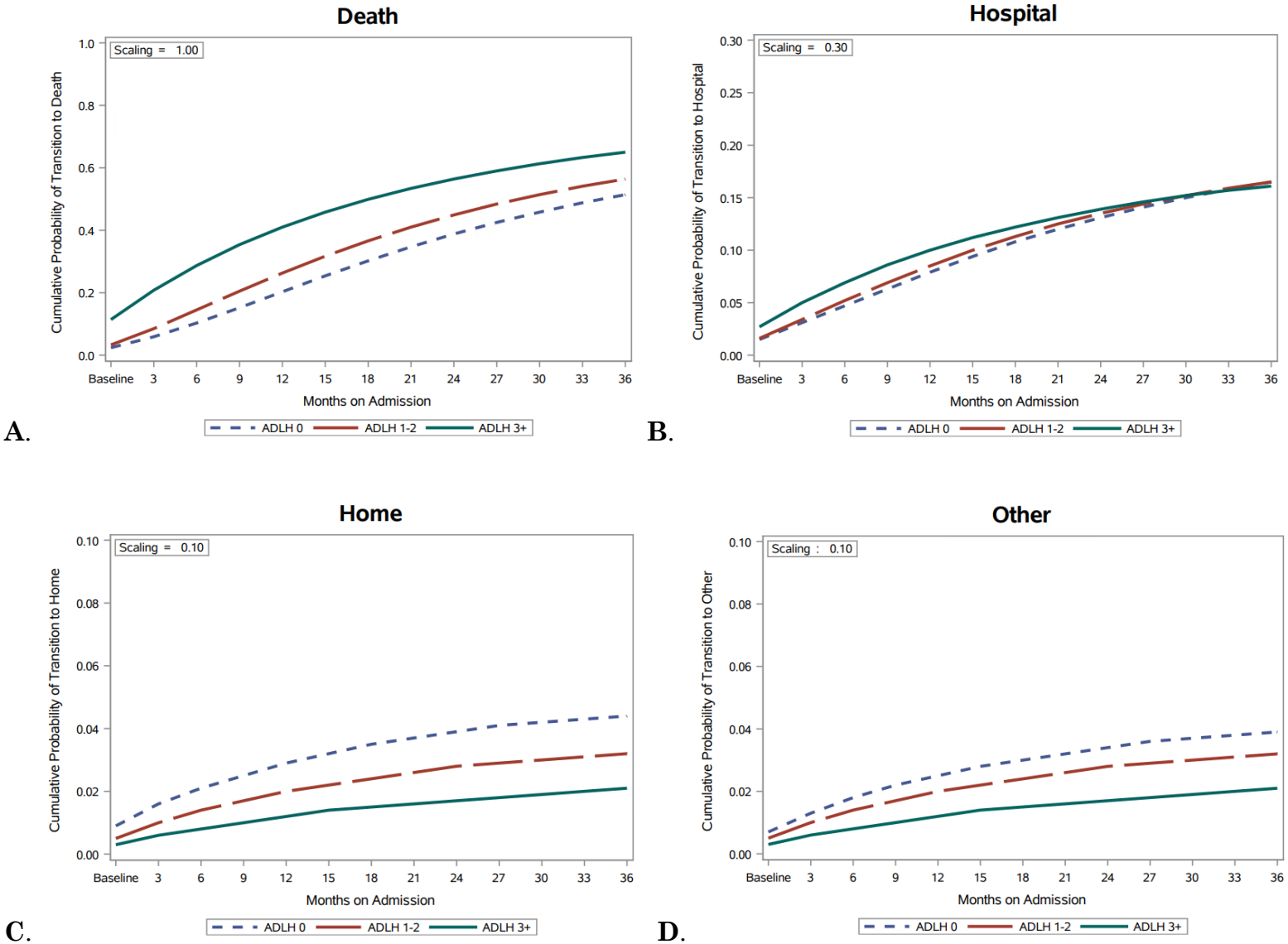


Figure 5.3: Cumulative Probability of Transition from Three ADL States to Four Absorbing States 2010 = 2020, n = 334,678. [*The y-axis for b, c, and d were rescaled to highlight the trajectories of different ADL groups*]

5.4.4. Independent Predictors of Transition to Transient and Absorbing States.

The adjusted odds of transitioning from one transient ADL to another transient or absorbing states, compared to remaining in the initial state, was generated using multiple multinomial logistic regression.

5.4.4.1. Adjusted Odds of ADL Decline

The strongest predictors of decline in ADL function to mild impairment for residents with no existing impairment (ADL state 1) were a) CPS Scale 5-6 (OR 2.68 95% CI 2.02-3.57), b) CPS Scale 3-4 (OR 1.82 95% CI 1.67-1.97), c) being in an LTC home in AB vs. ON (OR 1.55 95% CI 1.40-1.72), d) CPS Scale 1-2 (OR 1.28 95% CI 1.20-1.37), e) Alzheimer's disease and other Dementia (OR 1.16 95% CI 1.09-1.22), Age 85-84 years (1.15 (1.00-1.33). Other predictors of decline are shown in **Figure 5.4, Supplementary Table D.2a.**

5.4.4.2. Adjusted Odds of ADL Improvement

Based on the magnitude of adjusted odds ratios, the strongest independent predictors of improving from mild ADL impairment to no impairment were a) Index of Social Engagement (ISE) 5-6 (OR 1.42 95% CI 1.21-1.66), b) being in an urban LTC home (OR 1.36 95% CI 1.28-1.44), c) ISE 3-4 (OR 1.29 95% CI 1.10-1.51), d) CHESS 3+(OR 1.25 95% CI 1.02-1.53), e) when recent change to the resident's medication is unknown (OR 1.19 95% CI 1.11-1.28), and f) being in an LTC home in BC vs. ON (OR 1.16 95% CI 1.11-1.24). A list of other positive predictors of ADL

improvement from state two is provided in **Figure 5.5, Supplementary Table D.2b.**

For residents with moderate-to-severe impairment, the strongest independent predictors of returning to no impairment status were a) triggering the ADL CAP to facilitate improvement (OR 2.43 95% CI 1.71-3.47), b) ISE 5-6 (OR 2.38 95% CI 1.82-3.11), c) being in an LTC home in BC vs. ON (OR 2.26 95% CI 2.00-2.55), d) triggering the ADL CAP to prevent decline (OR 2.03 95% CI 1.41-2.90), ISE 5-6 (OR 1.86 95% CI 1.43-2.41). Other predictors include receiving physical therapy, having a medication change status that is unknown, and having a positive belief in rehab potential. CHESS Score of 3+, **Figure 5.6**, **Supplementary Table D.2c.** The independent predictors of residents improving from moderate to severe to mild impairment were similar to those mentioned above.

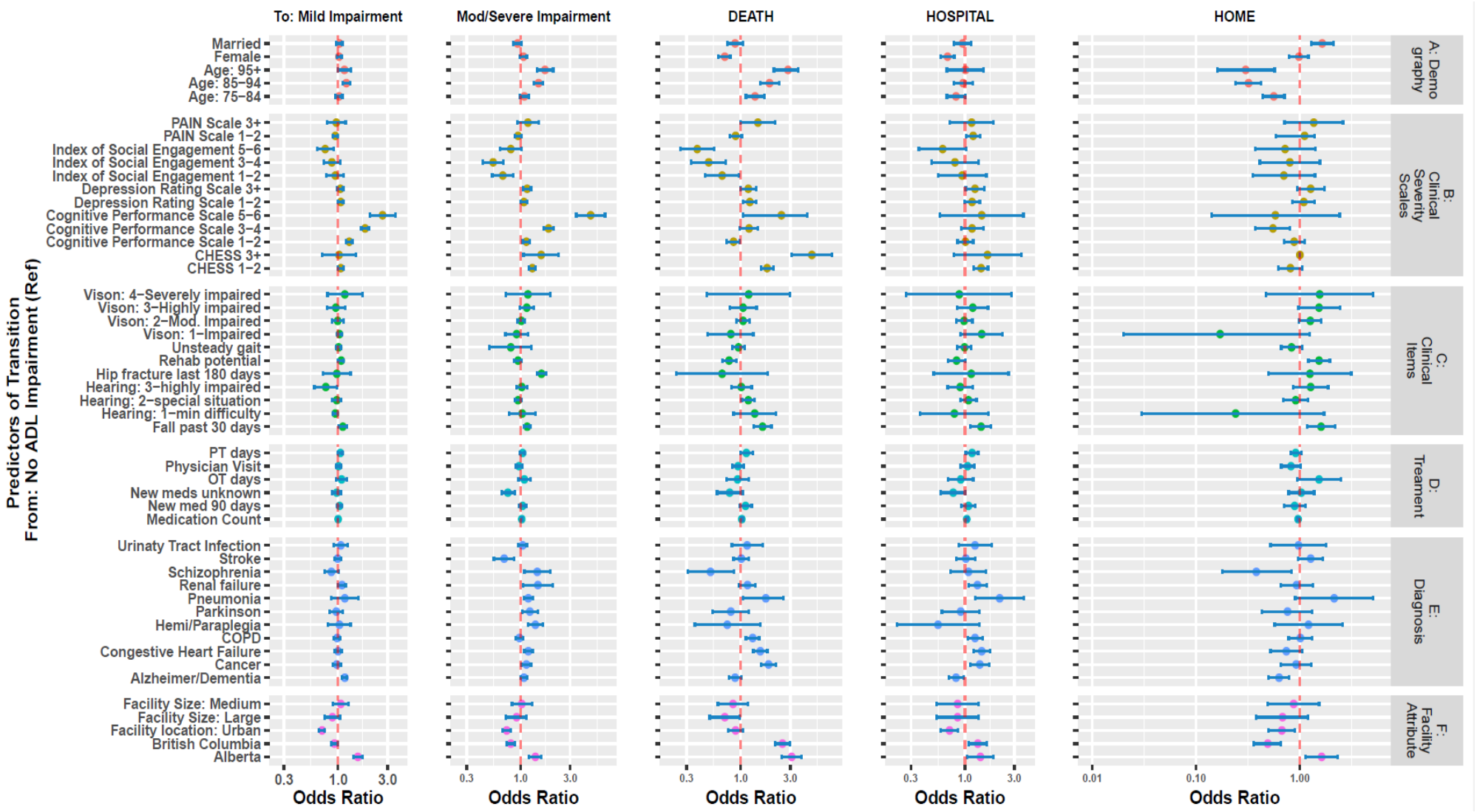


Figure 5.4: Adjusted Odds of Transitioning from No ADL Impairment State to Different ADL and Terminal States, Forest Plot 2010 = 2020, n = 334,678. (X-Axis Is Log_{10} Scaled).

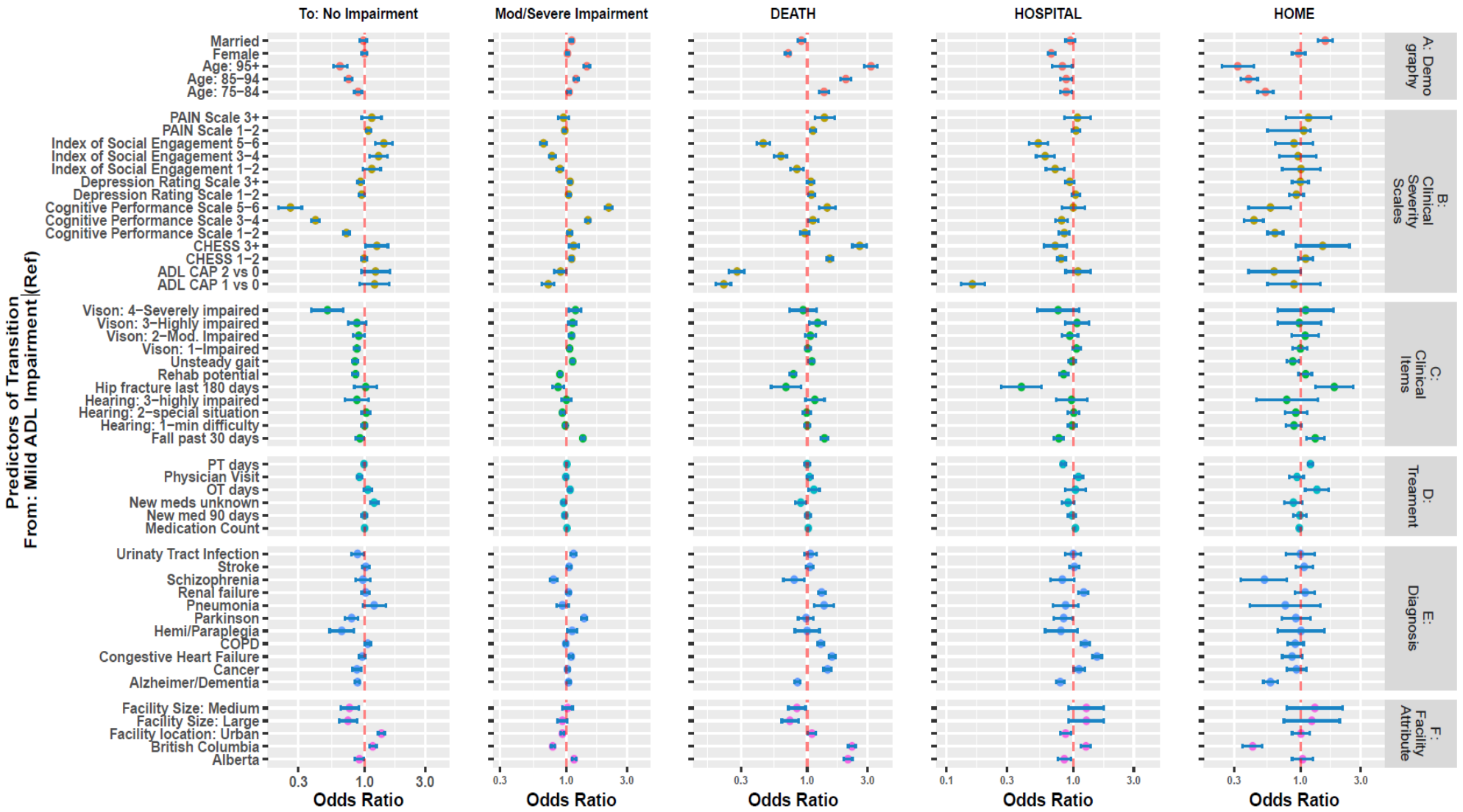


Figure 5.5: Adjusted Odds of Transitioning from Mild ADL Impairment State to Different ADL and Terminal States, Forest Plot 2010 - 2020, n = 334,678 (X-Axis Is Log_{10} Scaled).

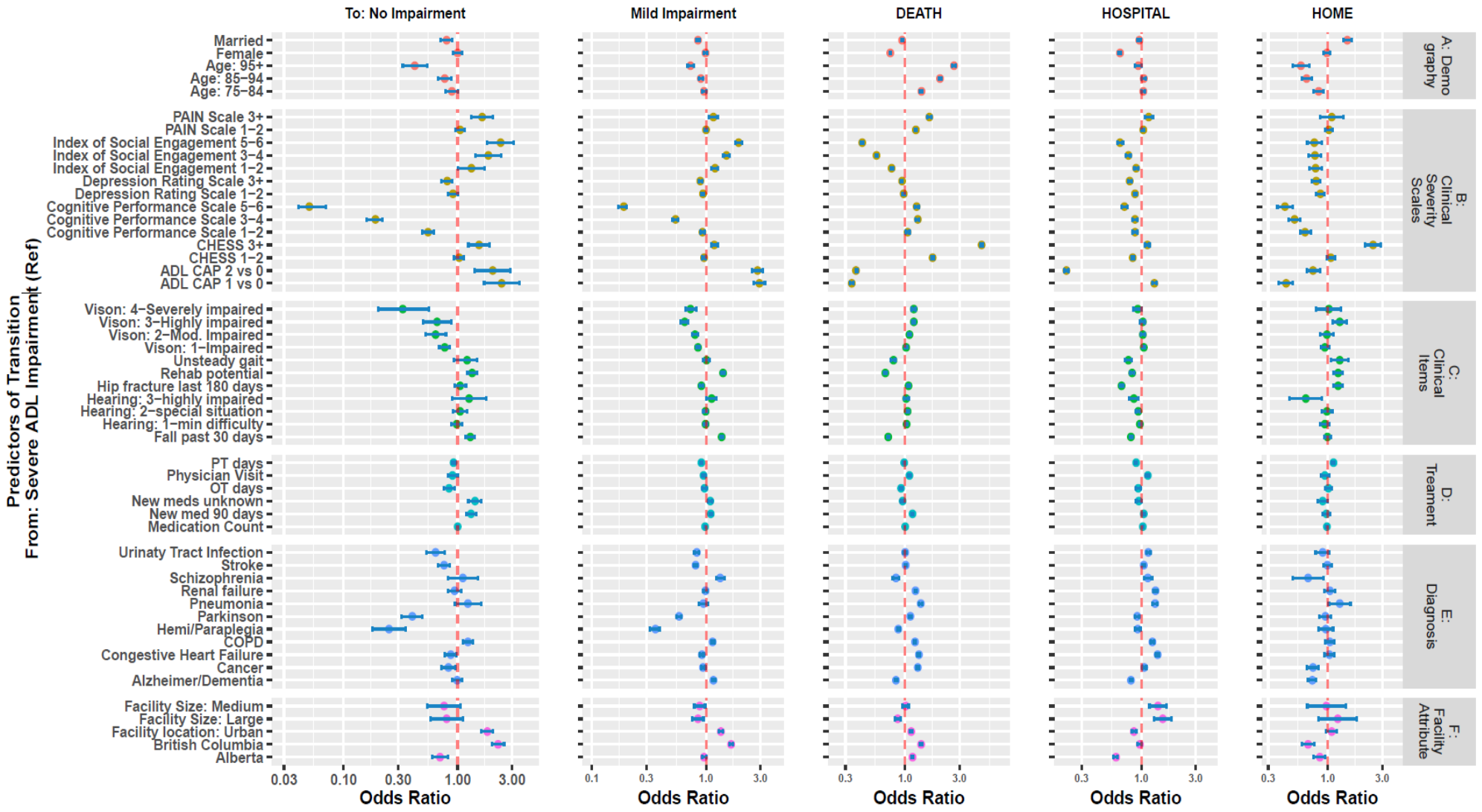


Figure 5.6: Adjusted Odds of Transitioning from Moderate/Severe ADL Impairment State to Different ADL and Terminal States, Forest Plot 2010 - 2020, n = 334,678 (X-Axis is Log_{10} Scaled).

Catastrophic Decline

Residents who transition from no impairment to moderate to severe impairment within a short period can be said to experience a catastrophic decline. The strongest independent predictors of such decline were a) CPS Scale 5-6 (OR 4.71 95% CI 3.42-6.48), b) CPS Scale 3-4 (OR 1.85 95% CI 1.67-2.06), c) Age 95+ years (OR 1.71 95% CI 1.44-2.05), d) Fall in the past 30 days (OR 1.58 95% CI 1.43-1.76), e) CHESS Scale 3+ (OR1.57 95% CI 1.06-2.32), f) pneumonia (OR 1.46 95% CI 1.05-2.03). Other predictors include Parkinson's disease, depression, CHESS scale, and being in an LTC home in AB vs. ON. Being socially engaged (ISE 3 or more), schizophrenic, and having a medication change during the last 90 days (unknown status) were strongly protective against such catastrophic decline, **Forest Plot 5.1, Supplementary Table D.2a**.

Further, declining to state 3 for residents in state two was strongly predicted by a) CPS Scale 5-6 (OR 2.16 95% CI 2.01-2.31), b) CPS Scale 3-4 (OR 1.48 95% CI 1.42-1.54), c) Age group 95+ (OR 1.45 95% CI 1.37-1.53), Parkinson's (OR 1.38 95% CI 1.31-1.46), **Forest Plot 5.2, Supplementary Table D.2b.**

5.4.4.3. Adjusted Odds of Mortality

Irrespective of a resident's ADL functional level, the CHESS scale was the strongest predictor of mortality (OR 4.83 95% CI 3.10-7.55) for those without ADL impairment, (OR 2.60 95% CI 2.27-2.96) for residents with mild impairment, and (OR 4.68 95% CI 4.57-4.80) for those with moderate-to-severe impairment. Age was a strong independent predictor of mortality, with OR 2.85 95% CI 2.08-3.59, OR

3.19 95% 2.83-3.60) & OR 2.68 (2.59-2.77) for residents in ADL states 1, 2, and 3, respectively. Other strong independent predictors of mortality include the CPS scale, being in an LTC home in BC or AB vs. ON, heart failure, cancer, and recent falls.

5.4.4.4. Adjusted Odds of Home Discharge

Among clients without ADL impairment, the strongest positive predictors of eventual home discharge were a) being married (OR 1.64 95% CI 1.29-2.10), b) being in Alberta, c) falls in the past 30 days, c) having a positive self or direct care staff belief in rehabilitation potential (OR 1.53 95% CI 1.21-1.94). For these types of clients, the strongest negative predictor was age and cognitive impairment. Similarly, being married and having a fall in the past 30 days were strongly predictive of home discharge for residents who are mildly or moderately/severely impaired. The strongest negative predictor of home discharge for residents with severe ADL decline was severe cognitive impairment (OR 0.42 95% CI 0.36-0.49).

5.4.4.5. Adjusted Odds of Hospital Discharge

The strongest predictor of hospital admission among residents with no existing ADL impairment was the diagnosis of pneumonia (OR 2.16 95% CI 1.26-3.68). For residents who are mildly and moderate/severely impaired, the strongest clinical predictor of hospital admission was congestive heart failure [CHF] (OR 1.54 95% CI 1.42-1.68) and (OR 1.54 95% CI 1.29-1.83), respectively. Other strong

positive predictors of hospital transition were cancer, chronic obstructive pulmonary disease [COPD], renal failure, and CHESS score.

5.5. Discussion

This study examined the pattern of transitions between ADL functional levels, their terminal transitions among LTC residents and the role played by individual and system-level factors on the rates of the transitions. Findings showed that residents transition between ADL functions that include deterioration, improvement, or remained unchanged over time. ADL "*stability*"(staying the same) between successive assessments was the most common pattern observed, while *improvement* was the least. Also, when residents transitioned out of this setting, it was most frequently as a result of mortality and least because they were discharged home. Categories of factors predicted rates of the transitions, but overall, demographic [**residents' age**] and the Clinical Severity Scales [**CHESS, ADL CAP, CPS, ISE**] were the strongest consistent predictors of odds for the different transitions.

Unsurprisingly, residents' cognitive ability, measured by the CPS scale, had the strongest overall effect on the pattern of ADL transitions, exacerbating decline and simultaneously hindering functional recovery. The association between cognition and physical function in institutional settings is well documented(Carpenter et al., 2006; Jerez-Roig, De Brito MacEdo Ferreira, et al., 2017; Loomer et al., 2019; McConnell et al., 2002). On the other hand, residents'

overall health instability, measured by the CHESS scale, and advancing age were the two strongest predictors of negative terminal transition, specifically to mortality state, irrespective of functional level. Further to this, residents with organ or system-wide failure, such as those with cancer and renal failure, were more prone to hospitalization as the terminal transition. A diagnosis of CHF was strongly associated with higher rates of terminal hospital admission and mortality at every ADL functional level. Heart failure poses a threat to the health of residents in nursing homes and ranks among the highest causes of morbidity and mortality in the setting(Heckman et al., 2018, 2019b; Hirdes et al., 2019).

Residents in this study, more so, those with moderate-to-severe impairment, most commonly remained unchanged in their ADL function between successive 90-day assessments. Trajectory studies show that most residents in nursing homes follow a stable/no change trajectory while the rest will decline gradually or, in some cases, very rapidly. Studies have suggested and shown that ADL changes, especially decline, were usually worse for individuals that are mildly impaired or without impairment(Egbujie et al., 2023). This is attributed to a ceiling effect, with those who are highly impaired not having any more room to decline.(Banaszak-Holl et al., 2011) Over 70 percent of residents in this analysis were already living with moderate-to-severe ADL impairment, which suggests that a ceiling effect may explain why they had a very high average probability (0.82) of remaining unchanged between assessments.

A high proportion of residents, especially those without existing ADL impairment, experienced ADL decline between successive 90-day assessments, with a few more experiencing a very rapid decline (from ADL 0 to 3+) within the first 90 days of admission. Such a decline could be problematic on many fronts. It could fast-track the transition to mortality, ADL dependency being a strong predictor of mortality(Vossius et al., 2018; Yeh et al., 2014). It could also escalate the cost of providing care if such residents remain in the new, worse state for an extended period of time(B. C. Williams, Fries, Foley, Schneider, & Gavazzi, 1994b). Equally related to this, such residents would likely consume more nursing resources. Identifying residents who are prone to such adverse events and intervening early could be one way to mitigate the challenge. Residents' characteristics predictive of very rapid decline include any form of cognitive impairment, Parkinson's disease, age 75 years and above, pneumonia, depression, and hemi-or paraplegia. On the other hand, higher levels of social engagement were the only protective characteristics. Some of these factors are not modifiable; however, social engagement can be supported with adequate staff support and an emphasis on providing residents access to meaningful activities of interest.

Awareness of the different ADL transitions and the average duration of stay in each state before exiting LTC homes could provide helpful information for forecasting resource demand and will enhance care planning. Residents without ADL impairment initially spent an average of 2.5 years in care before exiting the setting; about 50% (14.7 months) of this time was spent in the worst dependency

state (ADL 3+). In comparison, residents who started in the worst ADL state spent about 90% of their entire admission in this state, with cost implications that LTC administrators and policymakers should consider.

Typically, few residents placed in LTC homes eventually return to their homes in the community. Findings from this study affirmed this and showed that home discharge, if it happened, was most likely to occur within the first 12 months of admission and afterward remained low (**Figure 5.2c**). Home discharge from this setting was facilitated by residents' characteristics such as being married before placement, having a positive self or care staff's perception of rehabilitation potential, and receiving some physical or occupational therapy (PT/OT). It is worth mentioning that PT/OT only enhanced home discharge among residents who were mildly impaired but not those who were moderate/severely impaired or those without impairment. This may suggest that providing PT/OT to those not requiring it may not offer additional benefits. Individuals who were married before nursing home placement stayed less time in the setting than their unmarried counterparts before home transition(Kelly et al., 2010). Home transition among this cohort of residents was hindered by cognitive impairment, depression, and advanced age.

Identifying residents with the enabling profile for early home transition intervention could yield positive outcomes. For instance, the results showed that residents with mild ADL impairment who received physical or occupational therapy (PT/OT) recovered some physical function and were more likely to be discharged home (**Figures 5.4, 5.5, and 5.6**). In comparison, residents with moderate to severe

ADL impairment, as well as those with no impairment, did not show any benefit from the administration of PT/OT. Therefore, the timing of such interventions is critical if the benefit is to be derived by residents. Residents with positive self- or direct care staff perception of rehabilitation potential will also benefit from home discharge interventions. They are more likely to improve ADL function, be discharged home, and have higher odds of avoiding hospitalization or death.

Compared to home discharge, placement in LTC homes more commonly ended in mortality, irrespective of residents' initial ADL status(Hirdes et al., 2019). In the first 90 days of admission, mortality was about three and five times more likely for residents with moderate to severe impairment compared to those who are mildly or not impaired at all, respectively. Differential mortality rates between residents soon after placement may be because residents arrive in different health states more often due to very late placement. This, in turn, may be policy or practice related. For example, it may reflect efforts to keep older people at home with home care for more extended periods such that they are admitted to LTC with more severe impairments than was typical historically. The changing profile of nursing home residents with increasing age and worse ADL function on admission is reported elsewhere. Even before a person is placed in an LTC home, an ADL improvement intervention institution may be supportive. Exercise and other related interventions have been shown to improve ADL function and delay LTC placement among community-dwelling older adults (Gill et al., 2002). On the other hand,

targeted therapies early after admission to LTC may support a return to the community for some residents.

Even where home discharge is not considered feasible, efforts toward improving residents' quality of life need to be sustained or enhanced. This study showed that sensory impairment affects ADL transitions in LTC homes. Recognizing that moderate/severely impaired residents are less likely to improve in function if they are visually impaired, additional attention should be paid to residents who have this form of sensory impairment. Over 40 percent of residents in the study had some form of visual impairment, with more than 7 percent of those who are moderate/severely impaired also being highly severely visually impaired. These residents are at the most risk for mortality and are not likely to improve in physical function. Knowing that vision loss is common among nursing home residents(Guthrie et al., 2022; Owsley et al., 2007; Swanson et al., 2009) and is associated with poor ADL performance(Marx et al., 1992; Swanson et al., 2009), and care plans should address the unique needs of residents with vision or hearing loss. Also, since some adverse effects of vision loss could be remedied with intervention(De Winter et al., 2004), LTC homes should ensure the provision of vision care where needed and provide environmental supports to compensate for non-modifiable vision loss (e.g., ensuring appropriate lighting and contrasts in facility design).

Further, residents in institutional care are known to benefit from medication review(Gaubert-Dahan et al., 2019; Liou et al., 2021). In this study, those who

received a new medication in the last 90 days were more likely to improve their ADL function, especially if already moderately/severely impaired. When the status of drugs changed in the previous 90 days is unknown (***a unique interRAI variable***) compared to when it is known not to have changed, residents showed even better benefits. For such residents, the risk of death and hospital was lower for those with any form of ADL impairment, and the odds of improving were favorable. This medication change variable was also associated with better health performance in a separate study (Egbujie et al., 2022).

Social interventions should also be considered when planning care for LTC residents. Social participation had a strong positive effect on residents' ADL and terminal transitions. A higher social engagement index was protective against decline for those without existing impairment and had an even much stronger effect for those who are moderately/severely impaired, for whom it substantially enhanced recovery in ADL function as well protected against both mortality and hospitalization. This aligns with a study of Japanese long-term care residents, which found that social participation reduces care costs(M. Saito et al., 2019). Other studies have similarly shown beneficial effects associated with social engagement for nursing home residents(Bethell et al., 2021; Pastor-Barriuso et al., 2020).

System-level challenges that predispose to adverse ADL transitions should also receive additional attention. This study affirms previous studies(Egbujie et al., 2023; Matthews et al., 2016), finding that facility size was associated with residents'

outcomes in LTC settings before and during the COVID-19 pandemic, showing that these effects transcend the pandemic period.

ADL transitions varied between provinces included in our analysis, supporting the notion that system-level challenges may equally play a role in transition patterns. Irrespective of the ADLH state on admission, residents within LTC homes in British Columbia and Alberta had higher odds of mortality and hospitalization (BC only) compared to their counterparts in Ontario. Residents in both Alberta and BC were also significantly less likely to be discharged home compared to similar residents in Ontario. Since the known individual-level factors were adjusted for in our analytic models, it is safe to assume that the difference in the odds of transition observed in this study was not resident-related but system-associated.

5.6. Strengths and Limitations

Among the strengths of this study is the utilization of a large population-based longitudinal dataset for the secondary analysis, which removes sampling/selection bias, allowing the findings to be generalizable to the LTC populations in the provinces included in the analysis. Very few studies have examined ADL transition with a similar large dataset. The large sample size also gives confidence that the effect sizes obtained most likely reflect the actual population estimate as shown by the narrow confidence interval for the adjusted odds ratio associated with most of the independent variables.

The transition probabilities over time presented in this study represent an estimated average probability from all possible transitions made by residents in the analysis. There is, therefore, the possibility that some transitions may deviate slightly from this average. However, a review of existing literature shows that the values obtained using this method were reasonably accurate with what has been reported in other studies that examined transitions at different time points.

5.7. Recommendations

The study confirms that improvement in ADL function is possible among LTC home residents. Therefore, it gives impetus to the urge to do more to support ADL improvement intervention in the setting. It is important to note that ADL improvement is not necessarily meant to improve the life span of the residents. It should aim to improve the quality of life for residents in a way that will allow them to be active for as long as possible.

Secondly, social engagement improvement interventions/activities should be prioritized and promoted in this setting since, as the results showed, there were very few modifiable attributes of residents that could be the target of non-medical interventions. Interventions that enhance residents' ability to stay interested and engaged with others would substantially improve their quality of life, allowing some to improve their physical function and possibly be discharged back home.

5.8. Conclusion

Evidence from this study suggests there should not always be ***one way*** out for individuals placed in LTC facilities. The dynamic multidirectional transitions in the setting allow a small but significant percentage of residents to regain enough physical function to function independently once more, even for a short while. LTC home administrators should be encouraged to invest in identifying such residents and providing them with the proper intervention to facilitate improvement while preventing further decline. Information from this study can guide care providers who must navigate challenging multidirectional transitions among LTC residents to make care planning decisions. This study breaks these complex transitions into interrelated components that are easy to understand and use for care planning. Information about potential enablers of positive transitions would be helpful for care administrators and family members of residents alike.

A few findings from the study should be of interest to policymakers. First, the timing of LTC placement may be associated with the cost of care provision for government and individuals. As shown by the sojourn time analysis, individuals who arrive at LTC facilities with advanced ADL impairment will most likely remain in that state for the duration of their stay, which will invariably lead to a higher cost of caring for such a person. Programs targeting individuals waiting for LTC placement to improve their ADL function could help reduce the cost of caring for such people when they eventually enter the setting.

Second, most identified resident-level characteristics associated with ADL transitions in LTC are non-modifiable, except for a few. Policy recommendations that increase the capacity of LTC facilities to target these few modifiable attributes should be pursued. Social engagement and self-perceived potential for rehabilitation are the few modifiable attributes or mutable intervention points that can be subject to policy recommendations with more evidence.

Overall, the transition between ADL states among LTC residents is multidirectional and is affected by the initial status on admission and the resident's overall health status. Most residents will spend the most extended time in the ADL state of their admission. Admission in a poor ADL state does not bode well for the resident or the health system. Any effort to improve ADL function before placement may enhance quality of life and reduce cost and resource utilization.

Chapter 6

Study 4: Changes in Functional Levels and Terminal Transitions in Long-Term Care Homes During COVID-19 Pandemic: A Multistate Transition Markov Model of Population-Based Longitudinal Data In Canada.

6.1. Introduction

The COVID-19 pandemic disproportionately impacted long-term care (LTC) homes, causing excess mortality among residents(Akhtar-Danesh et al., 2022; Ballin et al., 2021; Betini et al., 2021; McGrail, 2022; Morciano et al., 2021), as well as other consequences(Canadian Institute for Health Information, 2021b; Dahab et al., 2021b; Pérez-Rodríguez et al., 2021; Trevissón-Redondo et al., 2021; L. A. Turcotte et al., 2023). Other consequences of the pandemic include changes in residents' ability to perform usual basic activities of daily living (ADL) (Egbujie et al., 2023; Pérez-Rodríguez et al., 2021; Trevissón-Redondo et al., 2021). Existing studies have characterized the pandemic's aggregate level one directional worsening effect on ADL function(Egbujie et al., 2023; Pérez-Rodríguez et al., 2021; Roberts et al., 2021; Trevissón-Redondo et al., 2021). Composite details of *who* among LTC residents experienced *what* quantity of change relative to their starting ADL functional level is therefore unknown. Information on the pandemic's effect on the usual multidirectional ADL transitions residents typically experience, which could be to improve, decline, or remain unchanged, is equally lacking. With the knowledge that LTC residents are a heterogenous group comprising individuals at different

functional levels(Morris et al., 1999, 2013a), granular analysis about the "who", "by how much," and "why" will provide better information that would improve our understanding of COVID-19's effect at the individual level.

Despite overwhelming literature on COVID-19's impact on nursing home residents, much remains unknown. For example, granular information of who among LTC residents had higher odds of functional decline and the magnitude of such decline is unknown. Current studies of the COVID-19 effect in this setting mostly quantified functional decline as an aggregate effect. Transitions in ADL function are usually hierarchically related to the baseline ADL function (**See Chapter 5**). Therefore, changes during the COVID-19 pandemic would follow the same trend. This knowledge gap about the pandemic's effect also extends to details of functional changes among residents during the different pandemic waves. The COVID-19 pandemic epidemiology changed during waves (Ascencio-Montiel et al., 2022; Ioannidis et al., 2021; Otshudiema et al., 2022); therefore, it is also likely that its effect on residents differed during the waves as well(Harvey et al., 2023).

The impact should be analyzed and contextualized according to the different waves to obtain better information on the pandemic's effect on LTC homes. Another reason a differential and contextualized analysis is essential is because pandemic mitigation measures that affected care home residents(Egbujie et al., 2023) also fluctuated between tightening and loosening of restrictions during the different waves, likely with varying effects on residents. Therefore, an in-depth examination

of functional changes during the pandemic contextualized to the different waves is needed.

Further, existing analyses of risk factors associated with excess COVID-19 mortality in care homes have not accounted for the pre-pandemic association between these factors and mortality in the setting. This also extends to the association between functional changes and mortality during this period. A study of LTC residents in Ontario, Canada(D. S. Lee et al., 2021) and US care home residents(Panagiotou et al., 2021) reported that those with worse ADL function, higher health instability (CHESS), more advanced in age, and higher cognitive impairment experienced higher mortality during the pandemic(Dyer et al., 2022; D. S. Lee et al., 2021). A study investigating changes in COVID-19-related mortality utilizing a large nationwide population-based dataset in England reported higher mortality among individuals with a wide range of comorbidities(Nab et al., 2023). However, these factors are usually associated with higher mortality in LTC settings without the pandemic. Therefore, whether the reported values represent additional effects during the pandemic, or a combination of pre-pandemic and pandemic effects is unclear. This question could be addressed by studies that utilize pre-pandemic and pandemic cohorts of residents to estimate the additional effect attributable to the pandemic(Egbujie et al., 2023).

Additionally, no study was found to have explored the dual position of functional change as an outcome and a predictor of adverse consequences such as mortality and hospitalization during the pandemic. In existing studies of COVID-19

impact, mortality was consistently modeled as the outcome with functional level as a predictor. Mortality and functional decline are interlinked and are both consequences of the COVID-19 pandemic. Therefore, an analytic approach accommodating this peculiar dual position of functional change would augment our knowledge of COVID-19 's impact on LTC homes. Integrating changes in ADL function with other outcomes during the pandemic, such as mortality, hospitalization, or home discharge, would better represent the pandemic's impact on LTC homes. Accommodating the multidirectional functional changes into the analysis of COVID-19 impact and linking them with transitions to other terminal health outcomes would also enhance existing knowledge. It would assist care providers in developing person-centered functional maintenance or improvement interventions in future events of a similar nature.

Therefore, the purpose of this study was to provide a granular description of the multidirectional transitions between ADL functional levels and transitions to four terminal health outcomes during both waves of COVID-19 relative to the pre-COVID era. This study bridges existing methodological and knowledge gaps by providing evidence of the effect of COVID-19 on functional levels and simultaneously modeling how they are associated with terminal transitions. Using pre-pandemic and wave 1 and 2 cohorts of residents would enable us to estimate the actual pandemic effect in the setting.

6.2. Methods

6.2.1. Study Design

We conducted a retrospective longitudinal analysis of residents receiving care in LTC homes within three Canadian provinces of Alberta, British Columbia, and Ontario between January 2010 and December 2020, from which two groups were created. The first group was the pre-COVID cohort, consisting of residents who received care between January 2010 and February 2020. The second group was those who received care between March 2020 and December 2020, called the COVID cohort. The COVID cohort was further subclassified into Wave 1 if they received an assessment between March 2020 and August 2020 and Wave 2 if they had an assessment between September 2020 and December 2020.

The University of Waterloo's Office of Research Ethics (#30173) provided ethics approval for the study.

6.2.2. Data Sources

A linked dataset provided by the Canadian Institute of Health Information (CIHI) that includes data from the Continuing Care Reporting System (CCRS) was used for this analysis. Data from the Discharge Abstract Dataset (DAD) that captures administrative, clinical, and demographic information on hospital discharges (including deaths, sign-outs, and transfers), the National Ambulatory Care Reporting System (NACRS) that collects demographic, administrative, clinical, and service-specific data for ED, day surgery and other ambulatory care visits are included in the linked dataset. The CCRS houses resident-level administrative data collected in LTC

facilities using interRAI's multidomain assessment instrument, MDS 2.0. Trained assessors usually complete the MDS 2.0 assessments within two weeks of the resident's admission. Assessments are then repeated every 90 days or sooner if a resident's health status changes. The validity and reliability of the interRAI assessment instrument items have been extensively examined and reported(Carpenter, 2006; Hermans et al., 2016; Hirdes et al., 2013a; Morris et al., 1997, 2013a; Penny et al., 2016; Poss, Jutan, et al., 2008; Tsuchiya-Ito et al., 2022; Wellens et al., 2013; Yoon & Kim, 2017).

6.2.3. Study Cohort

To be eligible for inclusion in the study, a resident must be 65 years or older, not comatose, and must have two completed or one assessment with discharge information. Residents with only one assessment and no discharge information are deemed to have been on admission for less than 90 days. They would not have any information to determine their next transition state. These types of residents were excluded from the analysis.

All residents who met the above inclusion criteria and whose first assessment was within the study period were selected and included in the analysis. From this, pairs of transition were created for each resident such that the first assessment represents the originating state of the first pair and the second assessment was the next state of the first pair. Likewise, the second pair has a 2nd assessment as originating and the 3rd assessment as the terminal state. This is continued until the resident enters an absorbing state or the end of the data series has been reached. The

transition matrix was derived, and a Markov model was fitted using these pairs of transitions.

6.2.4. Outcomes of Interest

This study's primary outcome of interest was the change in ADL function. ADL function was measured using the interRAI ADL Hierarchy scale, which is a 7-level ordinal measure of functional performance based on a person's ability to complete early (personal hygiene), middle (toileting and locomotion), and late-loss (eating) ADLs(Carpenter et al., 2006; Morris et al., 1999). For the study, ADL function was categorized into three mutually exclusive levels based on the ADL hierarchy score as **ADL 0 [**No existing impairment**]**, **ADL 1-2 [**Mild impairment**]**, and **ADL 3+ [**Moderate to severe impairment**]**. Change in ADL function here means moving from one level of the ADL categories to another in any direction.

The secondary outcome of interest in this study is the eventual terminal outcome for residents who transition out of the LTC setting. For those residents, several outcomes are possible as the terminal event following admission. For this study, we classified these terminal events into four distinct categories. **Death** [residents who died within the nursing home or are known to have died following hospital or ER admission], **Home** [residents discharged back home], **Hospital** [residents discharged to hospital for acute care with an immediate return not expected but who are not known to have died in the hospital], **Other** [residents discharge to other destinations such as Assisted Living, Board care, and others].

6.2.5. Independent Variables

The main independent variable investigated by this study was the assessment period. The assessment period was designed as a nominal variable consisting of three categories, classified according to when the assessment was conducted. Assessments conducted between January 2010 and February 29, 2020, were classified as "Pre-COVID", those conducted between March 1, 2020, and August 31, 2020, as "COVID Wave 1", while those conducted between September 1, 2020, and December 31, 2020, were categorized into "COVID Wave 2".

To reduce the confounding effects from other covariates associated with functional decline and the period, resident-level factors previously reported in the literature as having associations with ADL decline among nursing home residents were included in our analysis as covariates(Egbujie et al., 2023; Fedecostante et al., 2016, 2021). These included socio-demographic variables like sex, age group, marital status, and the Index of Social Engagement (ISE) score(Gilbart & Hirdes, 2000). Clinical conditions like pneumonia, urinary tract infection (UTI), congestive heart failure (CHF), Parkinson's, Alzheimer's, renal failure, cancer, and stroke have all been associated with functional decline and were included in this analysis. Summary scales like the Cognitive Performance Scale (CPS)(Morris et al., 1994), ADL Hierarchy scale(Morris et al., 1999), Changes in Health, End Stage Disease and Signs and Symptoms (CHESS) scale(Hirdes et al., 2003), and ADL clinical assessment protocol (CAP ADL) were also included as independent variables. Further, variables such as perceived rehabilitation potential and number of medications used were also

included. A complete list of all independent variables included in the analysis is available in **Supplementary File E.1**.

Additionally, system-level factors known or expected to affect ADL decline were also included in the analysis as independent variables. To examine the difference between residents according to where their LTC home is located, the province of LTC home was also included as an independent variable. Further, the location of the LTC home within the province (rural or urban) was included, as well as the size of the facility(Baldwin et al., 2017; Wilkinson et al., 2019).

6.2.6. Statistical Analysis

Descriptive statistics of the baseline characteristics of study participants were presented using frequencies and percentages for categorical variables and mean and standard deviations for continuous variables. Associations between two categorical variables were tested using the Chi-square test. In contrast, the Wilcoxon rank sum test was used to test the association between categorical independent variables and ordinal categorical dependent variables (ADL levels).

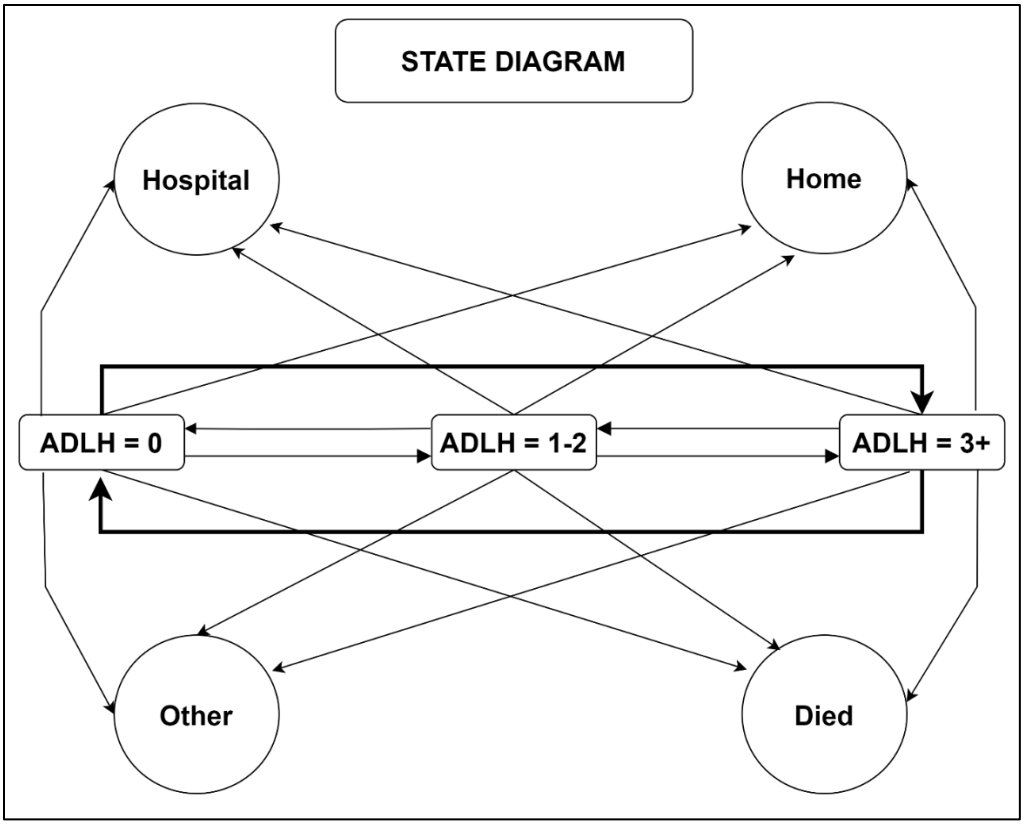


Figure 6.1: State-Space Diagram for Transition Between ADL States and to Terminal States in LTC Setting Pre-COVID and During COVID-19 2010 - 2020, n = 410,991.

Multi-state Markov Model

A 7-state Markov-chain multistate transition model was fitted to the data using a series of multinomial logistic regression to obtain the independent effect of different variables on the transition rates. In choosing a Markov process, we assumed from domain knowledge that future transition in ADL only depends on the present ADL state and not the historical values. Variables with a significance value of 0.05 or less were retained in the final model. All effects were presented in the tables for the adjusted odds ratio. This approach has been used in previous studies of ADL and

frailty(Larsen et al., 2020) transitions in home care(Cook et al., 2013) and transitions in health instability (Adekpedjou et al., 2022; P. C. Hébert et al., 2019; Hirdes et al., 2019) in LTC homes.

6.3. Results

6.3.1. Baseline Characteristics

Table 6.1 shows the baseline profile of residents receiving care in LTC homes before the pandemic and at the start of each COVID-19 wave. A total of 334,676 unique residents aged 65 years and above who met the eligibility criteria were included in the analysis. The final sample consisted of 314,051 residents admitted into LTC homes before the pandemic and 59,113 and 37,827 residents at the start of waves 1 and 2 of the COVID-19 pandemic, respectively.

Residents' baseline profiles differed between the three periods. There were more residents with moderate/severe ADL impairment and health instability at the start of each wave of the pandemic compared to the pre-pandemic period. Residents were also more cognitively impaired and more depressed during the pandemic as well. Fewer residents or their direct care staff reported that they perceived themselves as having the potential to improve physical functioning during both waves of the pandemic (**Table 6.1**).

Physician visits were also significantly less, especially for residents with moderate/severe impairment during the pandemic compared to the pre-pandemic period.

Table 6.1. Baseline Characteristics Comparison of All Residents on Admission and by the Study Periods (Pre-COVID-19, COVID-19 Wave 1 and COVID-19 Wave 2) 2010 – 2020, n = 410,991

	All residents n= 410,991	**Pre-COVID n= 314,051**	**COVID Wave 1 n= 59,113**	**COVID Wave 2 n= 37,827**	**P-value**
Sex					
Female	63.1	63.4	65.1	63.7	< 0.0001
Male	36.9	36.6	34.9	36.3	
Age group					
65 - 74	12.0	11.4	13.8	14.0	< 0.0001
75 - 84	33.6	33.6	34.1	33.5	
85 - 94	46.5	47.1	44.4	44.4	
95+	7.9	7.9	7.7	8.1	
Married	22.9	22.0	25.6	26.1	< 0.0001
ADL Hierarchy Scale					
0	3.7	4.0	2.7	2.8	< 0.0001
1-2	21.8	24.0	14.5	14.8	
3+	74.5	72.0	82.8	82.4	
CHESS					
0	62.1	63.0	59.4	58.6	< 0.0001
1 - 2	34.0	33.6	35.2	35.2	
3+	3.9	3.4	5.4	6.2	
Cognitive Performance Scale (CPS)					
0	9.0	9.7	7.0	6.9	< 0.0001
1 - 2	33.0	34.9	26.7	27.3	
3 - 4	45.5	44.5	48.6	48.9	
5 - 6	12.5	10.9	17.7	16.9	
Depression Rating Scale (DRS)					
0	45.9	46.3	45.1	44.1	< 0.0001
1 - 2	30.2	30.5	29.2	29.4	
3+	23.9	23.2	25.7	26.5	
Pain Scale					
0	61.2	58.9	69.9	67.5	< 0.0001
1-2	37.0	39.1	29.0	31.2	
3+	1.8	2.0	1.1	1.3	
Social Engagement Score (ISE)					
0	8.0	7.9	8.1	8.2	< 0.0001
1-2	34.4	34.4	33.8	35.1	
3-4	40.0	39.7	40.8	40.6	
5-6	17.6	17.9	17.2	16.1	
Physician Visit					
0	30.7	30.7	29.2	32.5	< 0.0001
1	23.3	19.7	36.8	32.0	
2+	46.0	49.6	33.9	35.5	
Health Diagnoses					
Alzheimer's/Other Dementia	62.6	62.6	61.4	60.2	< 0.0001
Heart Failure	14.9	15.4	13.2	13.7	< 0.0001
Cancer	10.7	10.8	10.2	10.7	< 0.0001
Renal Failure	11.7	11.5	12.0	12.8	< 0.0001
Pneumonia	1.9	1.9	1.9	2.0	0.23
UTI	7.3	7.9	5.3	5.7	< 0.0001

COPD	16.2	16.6	14.7	14.9	< 0.0001
Parkinson	6.7	6.7	6.7	6.5	0.43
Hemi/Paraplegia	4.0	3.8	4.7	4.4	< 0.0001
Schizophrenia	1.5	1.4	2.0	1.9	< 0.0001
Stroke	19.0	19.1	18.9	18.3	0.001
Clinical condition					
Rehab potential	17.8	21.1	7.2	6.8	< 0.0001
Fall last 30 days	22.0	22.5	20.1	21.1	< 0.0001
Hip Fracture last 180 days	3.2	3.6	1.8	2.2	< 0.0001
Unsteady Gait	39.2	40.7	33.8	34.5	< 0.0001

6.3.2. Time Spent in the Setting (Sojourn Time)

The average length of time residents spent in transient ADL states before transitioning to one of the four absorbing states (sojourn time) was compared across the three study periods.

Overall, during the first wave of the pandemic, the average time spent in the setting by residents who started without ADL impairment before transitioning out to one of the absorbing states was 22 months, compared to 29.7 months before the pandemic. Residents with mild impairment spent an average of 21 months compared to 27.6 months pre-pandemic, while those with moderate-to-severe ADL impairment spent 16 months versus 22.5 months before the pandemic.

In the second wave, sojourn time increased marginally for residents starting with no ADL impairment (22.2 months) but reduced for residents with mild (20 months) and moderate/severe impairment (14.7 months).

6.3.3. Transition Probabilities

Figure 6.2 shows the probability of transitioning to different absorbing states within 90 days when starting with different ADL functional impairment levels. Residents with moderate/severe ADL impairment consistently had a higher

probability of mortality at all times, but this was further exacerbated during both waves of the pandemic. Residents with no impairment had a higher probability of death during both waves of the pandemic relative to the pre-pandemic, but the probability was higher during the first wave. Home discharge was also higher for all resident types during the first wave of the pandemic but not during the second wave. It was, however, significantly higher for those without ADL impairment compared to other residents.

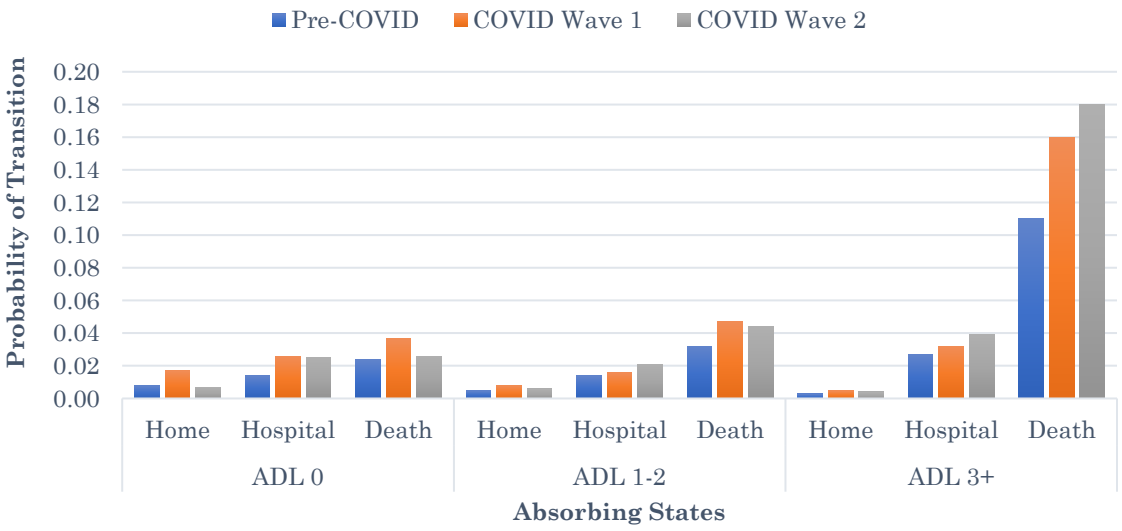


Figure 6.2: Distribution of Probability of Transitioning from ADL Functional Levels to Different Terminal States within 90 Days

6.3.4. Independent Predictors of Transition

6.3.4.1. The transition Between Transient ADL States

The odds of transitioning between the different ADL states during COVID-19 were compared to similar transitions before the pandemic, adjusting for variables

usually associated with such transitions (**Supplementary Files D.2a, D.2b, D.2c**). In general, the odds of additional functional decline were greater for residents with mild or no ADL impairment during both waves of COVID-19 but only greater for residents with mild or moderate/severe impairment during the second wave.

Table 2 shows the adjusted odds of ADL decline during each pandemic wave compared to the pre-pandemic periods by resident's starting ADL functional level. For residents with no existing ADL impairment, the odds of declining to mild impairment were not different between the two periods. However, for such residents, the odds of declining to moderate/severe impairment were 23% greater during the first wave of the pandemic compared to the Pre-COVID period (OR 1.23 95% CI 1.01-1.49) but not during the second wave (OR 1.25 95% CI 0.96-1.64).

For residents with mild ADL impairment, compared to the pre-pandemic period, they had slightly higher odds of additional functional decline during the first (OR 1.08 95% CI 1.01-1.15) and second (OR 1.12 95% CI 1.03-1.21) waves of the pandemic. Residents with mild impairment did not experience significant improvement in ADL function during both waves of the pandemic (**Table 6.2**), as was the pre-pandemic case.

Similar to those with mild impairment, residents with moderate/severe ADL impairment did not improve to no ADL impairment during both waves of the pandemic relative to the pre-pandemic period. However, they had slightly higher odds of improvement to mild ADL impairment during the second wave (OR 1.10 95% CI 1.02-1.19) than the pre-pandemic.

In addition to transitions between the ADL states, transitions out of the LTC homes were also examined by their baseline ADL function. **Table 6.2** also presents the adjusted odds of transitioning to the four absorbing states according to the residents' baseline ADL functional level. In general, it showed that, compared to the pre-pandemic period, residents had higher odds of mortality, hospital admission, and home discharge during the pandemic and that the pattern of decline differed by the initial ADL level and pandemic wave.

Relative to the pre-pandemic period, residents with no ADL impairment had the highest odds of mortality during the first wave (OR 1.97 95% CI 1.48-2.62) of the pandemic compared to those with mild impairment (OR 1.55 95% CI 1.48-2.62) or moderate/severe impairment (OR 1.67 95% CI 1.62-1.72), **Table 6.2**. In the second wave of the pandemic, the odds of mortality were similar relative to the pandemic period for residents with no existing impairment.

Among residents with mild impairment, mortality was substantially higher during both waves of the pandemic relative to pre-pandemic. However, it was lower during the second wave (OR 1.29 95% CI 1.10-1.52) than in the first wave (OR 1.55 95% CI 1.48-2.62). For residents with moderate/severe ADL impairment, mortality was also higher during both waves of the pandemic. Still, unlike residents with mild impairment, it was lower during the first wave (OR 1.67 95% CI 1.62-1.72) compared to the second wave (OR 1.74 95% CI 1.68-1.80), **Table 6.2**.

Table 6.2: Adjusted Odds of Transitioning from Different ADL Functional States to Other ADL and Terminal States 2010 – 2020, n = 410,991.

Period	ADL Hierarchy Scale	Transient ADL States			Home	Hospital	Death	Other
		0	1 - 2	3+				
Odds ratios (95% CI) with reference = PreCOVID period								
Wave 1	**0**	-	1.12 (0.96-1.30)	**1.23 (1.01-1.49)**	**2.38 (1.5-3.79)**	**2.74 (2.02-3.71)**	**1.97 (1.48-2.62)**	1.16 (0.62-2.16)
Wave 2		-	1.19 (0.97-1.46)	1.25 (0.96-1.64)	1.15 (0.5-2.63)	**2.38 (1.53-3.69)**	1.06 (0.64-1.76)	0.33 (0.17-1.70)
Odds ratios (95% CI) with reference = PreCOVID period								
Wave 1	**1 - 2**	1.01 (0.89-1.15)	-	**1.08 (1.01-1.15)**	**2.18 (1.69-2.82)**	**2.07 (1.79-2.40)**	**1.55 (1.39-1.74)**	**0.63 (0.42-0.94)**
Wave 2		0.94 (0.80-1.12)	-	**1.12 (1.03-1.21)**	1.17 (0.76-1.82)	**2.40 (2.00-2.89)**	**1.29 (1.10-1.52)**	**0.54 (0.31-0.93)**
Odds ratios (95% CI) with reference = PreCOVID period								
Wave 1	**3+**	1.13 (0.92-1.40)	0.95 (0.89-1.01)	-	**1.95 (1.71-2.23)**	**1.68 (1.60-1.77)**	**1.67 (1.62-1.72)**	0.91 (0.76-1.10)
Wave 2		1.28 (0.99-1.66)	**1.10 (1.02-1.19)**	-	**1.24 (1.01-1.52)**	**1.77 (1.66-1.89)**	**1.74 (1.68-1.80)**	0.86 (0.67-1.09)

6.4. Discussion

This study examined the pattern and odds of transitioning between different ADL functional levels during COVID-19 pandemic waves compared to the pre-pandemic period. It also looked at residents' patterns and odds of transitioning out of care homes (absorbing states) during the same periods and how these are affected by residents starting ADL functional level. The results showed that relative to the pre-pandemic period, residents without existing ADL impairment experienced worse ADL decline during the first wave of the pandemic but not during the second wave. The results also showed that all residents' odds of hospitalization, home discharge and mortality were significantly higher during the first wave. Hospitalization and mortality were substantially higher among residents with moderate/severe forms of ADL impairment during the second wave of the pandemic compared to the pre-pandemic periods, but not for residents with no existing ADL impairment.

Findings from this study highlight the complex nature of changes in function among LTC home residents. The broad transition pattern between ADL functional levels observed in this study is consistent with previous studies showing higher functional decline during the pandemic(Cortés Zamora et al., 2022; Egbujie et al., 2023; Pérez-Rodríguez et al., 2021). However, this study adds granular detail about which resident types were at higher risk and the magnitude of such risks. This study showed 23% and 8% higher odds of decline among residents with No and mild ADL impairments during the first wave, providing further information compared to our

previous finding of 17% aggregate odds of decline among LTC homes in Canada. This further highlights the strength of the analytic approach we have taken.

The study also found higher odds of mortality and hospitalization during the first wave of the COVID-19 pandemic among residents with no ADL impairment relative to the pre-pandemic period. This may seem to be in contrast with findings of higher mortality among residents with higher ADL functional scores in prior studies(D. S. Lee et al., 2021; Panagiotou et al., 2021). However, this is explained by the comparative nature of the study, whereby the odds presented were relative to the pre-pandemic period. Although residents with higher ADL impairment usually have higher odds of mortality compared to those with lower impairment, during the pandemic, mortality increased additionally for all resident types. Compared to their usual baseline, this jump in mortality ***relative to the usual*** was more pronounced for residents with no ADL impairment. This further underscores the strength of this study design and analytic approach, which allows the estimation of additional, rather than absolute, COVID-19 effects.

Further to the observed mortality during the first wave, the higher mortality observed during the second wave of the pandemic among residents with worse ADL function could be related to the effect of pandemic measures taken by provinces to mitigate the spread of the virus. There were reduced acute care hospital transfers for LTC residents suffering from other chronic disease conditions once the pandemic started (Betini et al., 2021). Our analysis also showed a substantial reduction in physician visits during both waves of the pandemic, especially for residents with

worse ADL function (**Table 6.1**). There was up to a 50% reduction in hospital transfers to receive acute care among LTC residents during the pandemic, especially for those with chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), pneumonia, and so on, which may have resulted in decompensation, especially among the very sick(Betini et al., 2021). Not receiving care for acute exacerbation of their ongoing chronic condition likely caused further deterioration in health for residents over time, resulting in a higher risk of mortality than would otherwise happen. In addition, COVID-19-related staff shortage contributed to reduced quality of care to residents who suffered further consequences as a result(Stall et al., 2021).

The findings also showed that home discharge from LTC settings increased significantly for all resident types during the first wave of the pandemic compared to the pre-pandemic periods. It, however, reduced to pre-pandemic rates during the second but remained slightly higher for residents with moderate/severe ADL impairment. As news of high mortality and poor care conditions in nursing homes spread during the pandemic, families that could afford it removed their loved ones from the setting. It is unknown whether such residents end up in private homes within the community, assisted living, or other LTC homes. An answer to this question could shed light on the possibility of managing individuals outside the LTC setting, especially if they do not require support to perform the usual activities of daily living.

Residents with no impairment had lower ADL declines and mortality during the second wave of the pandemic relative to the pre-pandemic period. A report in Canada suggested that although the number of deaths increased during the second wave of the pandemic, the percentage of residents infected who died reduced, possibly due to differences in the age and health status of residents that were infected during the different waves(Rochon et al., 2022). This difference in the age and health status of those infected with COVID-19 may also explain why mortality, hospitalization, and functional declines differed between residents by their functional level during the second wave.

The discharge of residents from the setting during the first wave also could have meant that only residents who must receive nursing care, indicating unstable health status, remained in the setting. The total number of residents in LTC homes and new admissions reduced for the 2020/21 period across most provinces in Canada, corresponding with the pandemic period(L. A. Turcotte et al., 2023). The result of the study confirms that residents with no impairment had the highest odds of being discharged home during the first wave of the pandemic. It was also possible that resident management and other support measures improved generally during the second wave of the pandemic as care providers and administrators learned more about the infection.

6.5. Strengths and Limitations

A major strength of this study is the utilization of a large population-based individual-level dataset to estimate the COVID-19 effect. Using such data removes the bias that would otherwise result from sample selection or an inadequately powered study with a small data size. Another strength of this study is that it provides granular details about COVID-19's effect on residents by their functional level. This includes information that could support person-level care planning. Using pre-pandemic and pandemic cohorts for this analysis also strengthens our confidence that the results represent actual pandemic effects.

6.6. Recommendations

Real-time data must be available to care providers and health administrators as quickly as possible during public health crises to support decisions about care and other related issues. Future pandemic measures should consider the potential effect of such measures on residents with existing health conditions that could be exacerbated.

6.7. Conclusion

This study further expands our understanding of COVID-19's effect on LTC settings by providing more granular details of the complex effect of the COVID-19 pandemic on the physical function of LTC home residents. Functionally intact

residents may not usually be at greater risk of adverse health outcomes. However, as shown by this analysis, a health crisis of an epidemic or pandemic could change this and expose them to even more harmful impacts. It is essential to anticipate and suspect that health impact might follow irregular patterns when seismic health events such as a pandemic occur. This study further highlights the complex transitions between ADL functional levels and terminal health outcomes during the COVID-19 pandemic, showing that aggregate analysis insufficiently represents these changes.

In times of widespread public health crisis, appropriate investigative methods should be employed when generating evidence to support decision-making. This could make a lot of difference in successfully containing or mitigating the effects of such a crisis. Clinicians and care administrators should also have access to such appropriate real-time evidence delivered as quickly as possible to enhance their management choices.

Future studies should utilize pre-pandemic and pandemic comparison cohorts to investigate mortality among COVID-19-infected persons by their baseline functional levels. Based on the highlighted home discharge pattern during the pandemic, future studies should also examine the impact of such home discharges during the pandemic. This information would be helpful for families and LTC home administrators to understand how the decision to discharge may have enhanced or worsened residents' conditions.

Chapter 7

General Discussion and Conclusion

7.1. Background

Functional decline predisposes LTC home residents to adverse clinical outcomes, such as pressure ulcers, depression, incontinence, and increased risk of mortality. It is often a forerunner to other harmful consequences, including hospital admission and mortality. The condition results from complex interactions between individual and system-level factors, some modifiable. Residents may decline further, improve, or remain the same over time. Those who improve in function are usually more likely to report better quality of life and overall health status and are also more likely to return to the community. If instituted early, targeted interventions and person-centered approaches to care could delay or prevent functional decline. Adverse outcomes could be avoided, and beneficial changes may be possible. This result may be achieved through a) understanding how residents transition between the different ADL levels over time, b) identifying positive predictors of operational improvement, and c) using this information to support person-centered care provision.

This dissertation aimed to explore and describe the patterns of transitions among LTC residents to produce actionable information that could be used to support targeted person-centered care planning. Findings across the five studies presented in this dissertation combine to provide broader practice, policy, and future research implications.

7.2. Summary of Findings from the Studies

The different studies included in this dissertation were sequentially organized such that each study incrementally builds on the findings from the preceding one.

In Chapter 2, evidence obtained from the first study, a scoping review, showed that modeling techniques that can identify subgroups within each population were preferred over those that rely on mean trajectory parameters for the studied population. The review showed that GBTM was increasingly the most commonly used modeling method researchers chose when investigating longitudinal trajectories of change in physical function. The review also showed a lack of studies examining the longitudinal trajectory of functional decline in LTC settings and low- and middle-income countries. This study, therefore, contributes to our understanding of how physical function trajectory modeling evolved over the past 20 years and what outputs they generate. It also highlighted gaps that currently exist in this research area.

Chapter 4 presented evidence obtained from the study of the longitudinal trajectory of physical function using GBTM, which showed that LTC residents cluster into four distinct trajectories of functional decline upon admission. These trajectory groups were named "catastrophic," rapid decline with some recovery," "slow progressive," and "no/minimal decline" according to the shape of the trajectory, and the membership of each group is determined by the resident's characteristics. Residents with neurodegenerative conditions such as Huntington's disease, Parkinson's, and ALS were more vulnerable to a catastrophic decline in function upon

placement in LTC homes. In contrast, those with cognitive impairment, such as those seen with Alzheimer's disease, have a slow progressive trajectory of functional decline. Others with transient acute health issues or modifiable conditions decline rapidly on placement but can recover some function with time. These include residents admitted with transient ischaemic attack, schizophrenia, and hearing and visual impairment, especially if they are cognitively intact. This study also showed that following a particular trajectory is strongly associated with outcomes like mortality and health resource utilization costs.

Study 2 of this dissertation, presented in Chapter 3, provided evidence of how an unprecedented health crisis in the COVID-19 pandemic affected the physical function of LTC residents relative to the pre-pandemic period. The study showed that functional decline accelerated among LTC residents during the pandemic but that, in contrast to previous studies, there was only an additional decline of about 17% during this time. The study showed that residents already severely impaired in physical functionality experienced a more substantial physical impairment during the pandemic. This additional decline may have been due to the pandemic measures instituted to slow down the spread of the disease, particularly restriction of movement, reduced hospital transfers, and limited human interactions. This study, therefore, contributes new knowledge of the actual changes in physical functionality associated with the COVID-19 pandemic.

The study on the longitudinal trajectory of physical function produced helpful evidence about the progression of functional decline among residents over time.

However, it did not give a detailed account of the multidirectional transition in ADL function that residents are known to experience. Study 4, presented in Chapter 5, bridged this knowledge gap by demonstrating the complex nature of multidirectional transitions. Most importantly, the study showed that some residents improve their ADL function upon placement in the setting and that about 20% transition to their homes in the community. Factors associated with these positive outcomes were higher social engagement, receiving physical or occupational therapy, and having a positive self or staff perception about the potential to improve physical function.

In study 5, the pattern of this multidirectional transition in ADL function was analyzed with evidence showing that the rates and direction of transitions between ADL functional levels and other outcomes, such as mortality, were substantially affected by COVID-19. The significance of this study is that it provided a granular analysis of who among the residents was affected by the pandemic and to what extent. For example, while the aggregate analysis in the second study showed a 17% additional decline in function during the pandemic, the fourth study went further to show that residents with no existing impairment had a higher rate of decline (23%) compared to those mild ADL impairments (12%) relative to the pre-pandemic. The study also highlighted the difference in COVID-19 consequences between waves, revealing higher comparable death rates in the first wave among residents with no ADL impairment relative to the pre-pandemic period.

7.3. Common Themes

Evidence from the different studies in this dissertation consistently showed that LTC home residents are functionally heterogeneous, comprising individuals at different ADL performance levels. This heterogeneity is equally reflected in the residents' ADL transition patterns or trajectories, suggesting a further emphasis on person-centered care in the setting.

Also, consistently shown across the studies was that residents with no existing ADL impairment were the most at risk for a catastrophic decline in function upon LTC home placement. This may have partly been due to methodological considerations such that those in mid-ranges of baseline loss had "less distance to fall". Both aggregate and granular analysis showed that functional decline was additionally higher for residents with no ADL impairment during the COVID-19 pandemic. The study on the longitudinal trajectories of functional decline also showed that residents without ADL impairment were the most likely to experience catastrophic decline on LTC placement. This cross-cutting finding is crucial because it shows the higher vulnerability of residents with good physical function to decline further. It also highlights the need for extra focus on this type of resident when interventions to prevent functional decline are planned in LTC.

Another common observation across all studies was that the typical transition pattern was for residents to remain unchanged in their ADL functional levels between assessments, irrespective of the starting value. In study 2, about 44% of analyzed residents followed the ***no/minimal*** change trajectory, which included

residents with different ADL scores. Likewise, in study 4, 59%, 63%, and 82% of residents with no, mild, and moderate/severe ADL impairment remained unchanged in ADL functional level between assessments.

Further, several individual-level factors were consistently shown across the different studies to be associated with ADL transition in a particular direction. For example, severe cognitive impairment, age above 85 years, and having a neurodegenerative condition like Parkinson's disease was consistently associated with catastrophic decline trajectory and transitioning from no impairment to moderate/severe ADL impairment.

7.4. Practical Implications

The findings of this dissertation have several implications for the care of residents in LTC settings.

7.4.1. Clinical Practice and Care Planning:

The trajectory modeling study provided a three-year forecast of functional decline that care providers can utilize to anticipate residents' ADL transitions long before they happen so that adequate preparation is made to accommodate the anticipated transitions. Outputs of the different studies could be converted into decision-support tools to predict residents' functional trajectories when placed in LTC homes. Such a tool would inform clinicians about when a resident will decline further and what clinical conditions will likely accelerate such decline. Care practitioners

equipped with such information would be better prepared to decide the best management approach for each resident, including the timing of interventions to prevent decline or improve function. Trajectory information would be beneficial in educating residents and their family members about the likely progression of their physical condition. This could enhance the participation of residents in their management plan, which increases the chance that such a plan would be successful.

Another helpful finding from this dissertation was that the provision of physical and occupational therapy (PT/OT) was not beneficial to residents who had no ADL impairment on admission, as their odds of home discharge, hospitalization, and death remained the same. For residents with mild ADL impairment and, to a smaller extent, those with moderate/severe impairment, the provision of PT/OT increased their odds of home discharge. It simultaneously reduced their odds of hospitalization or death. This implies that the timing of PT/OT is crucial if the benefit is to be derived by residents. Providing this service to some residents with no ADL impairment and no other indication for it would only waste resources while not adding any benefit. Also, waiting too late to institute such services will reduce the magnitude of benefit that would have been derived from it.

Evidence from the study of functional decline during the first wave of COVID-19 showed how important it is to maintain nutrition and physical activity during periods of heightened stress to avoid functional decline. This information would help care providers develop appropriate plans for residents in the future.

In previous studies(Gilbart & Hirdes, 2000; Kiely et al., 2000; Pastor-Barriuso et al., 2020), higher social engagement is reported to promote health and quality of life among LTC residents. From the findings of this dissertation, social engagement greatly facilitated improvement in ADL function and home discharge, as well as protection against hospitalization and mortality, especially for residents with some form of ADL impairment. Social engagement should be prioritized in the setting as a mitigating intervention, especially for those who have developed some form of ADL impairment.

7.4.2. Staff Management and Resource Allocation

LTC homes are resource-intensive settings mainly due to care demands resulting from the acuity levels of residents. Among the many challenges care home administrators face is managing staff time and availability so that the correct number of people are on-site to attend to the needs of residents. Evidence from the functional decline trajectory modeling study could support the forecast of residents' trajectory of changes over time, which would help estimate the required staff time at any given time. Estimating future resource requirements would significantly enhance care planning in the LTC setting and likely improve the quality of care.

7.5. Policy Implications

7.5.1. Future Public Health Mitigation Measures

Through examining the extent of functional decline during the first wave of COVID-19, this dissertation showed that pandemic mitigation measures, such as

limiting visitation to residents during the health crisis, may have led to increased functional loss. The same was also true for other measures such as reducing the number of transfers to acute care hospitals to manage acute-on-chronic conditions. Findings of this dissertation suggests that in future pandemics, service providers and policymakers should consider using approaches that protect residents against mortality risk without unduly constraining access to physical activity within facilities. Given the evidence that functional decline occurred during COVID-19, this suggests that any future pandemic strategy should include clinical interventions that reduce the risk of functional decline when public health measures are in place.

7.5.2. Resource Allocation

Funding is an important policy area for the provinces, and resource allocation is often informed by acuity levels and resource intensity of residents using the resource utilization group (RUG) case-mix classification system. Evidence from this dissertation suggests that baseline acuity level on admission based on ADL function may not be the best indicator of residents' resource demand over 12 months. Trend analysis of CMI for the relative resource demand over time by the different ADL trajectory subgroups showed that residents with no ADL impairment on admission started with the lowest CMI but soon switched with escalation into the worst CMI of all trajectory groups. Such residents were modeled in this dissertation to follow a catastrophic decline trajectory, which may explain the massive shift in their resource demand over time. Importantly, this change in resource demand level was estimated to occur quickly within the first six months of admission. Therefore, relying on the

admission or starting ADL levels for the 12-month estimate of resource requirement could produce inaccurate values. It is therefore useful to consider this likely switch in acuity (ADL) trajectory when determining funding allocation for LTC homes.

7.5.3. Prevention Program

Residents who were admitted with no ADL impairment were the most likely to experience a very rapid decline in function with subsequent worse outcomes. Such residents could benefit from functional decline prevention intervention commenced even before arrival at the LTC homes. This could include individuals still in hospitals as alternate levels of care (ALC) or those on LTC on the waitlist within the community. Developing intervention programs targeting this set of individuals could avert the risk of early rapid decline on placement, ultimately reducing the cost of caring for such residents and increasing their chance of beneficial outcomes such as home discharge.

7.6. Methodological Reflections

This dissertation emphasized applying the most appropriate methodologies to generate evidence supporting care planning for LTC residents. The justification for the different methods was based on research questions and assumptions about the distributional properties of ADL in the LTC population. The adopted conceptual frameworks also supported the methods.

Study 1 focused on determining the best methodological approach to modeling the trajectory of functional decline in LTC settings. Evidence synthesis, such as a systematic or scoping review, is usually recommended when an answer is sought on the status of literature about a topic area. The scoping review is preferred where the research question is broad, as it was in the first study of this dissertation.

Study two of the dissertation used the modeling technique suggested by the scoping review to answer the functional decline trajectory question. This method was fit for purpose given that the conceptual framework for the study supports the idea of trajectory subgroups within each population. However, answers provided by trajectory modeling left other transition questions unresolved.

This unresolved question required a different methodology to find the correct answers. This unresolved question is related to the multidirectional transition that longitudinal modeling failed to account for. With the assumption that future ADL states will depend on the current ADL status of residents, the Markov multistate transition model was applied to bridge the methodological and substantial knowledge gap left by the longitudinal trajectory modeling study.

Last, the two studies focused on functional decline during COVID-19 highlight the importance of the methodological approach taken for the dissertation. The methods chosen for the two studies complemented each other and provided information highlighting their strengths and weaknesses. Both aggregate and granular analyses of the COVID-19 effects on residents were conducted using the two studies. While the aggregate analysis enables the generation of evidence about the

marginal impact of the pandemic on the entirety of LTC settings, the granular analysis delved much deeper to produce nuanced estimates of who among the residents was more affected and what the associated factors were.

By using a combination of different methodological approaches, this dissertation was able to answer several questions that allowed an understanding of the longitudinal changes in the performance of activities of daily living in long-term care settings, including the trajectories, transition patterns, predictors, and associated health outcomes.

7.7. Overall Strengths

A major strength of this dissertation was that large population-based datasets were analyzed to generate evidence from the included studies. Utilizing extensive population-based data reduced the potential selection bias that would have occurred otherwise. It also increased the power of the studies, improving the precision of effects obtained from the studies.

Using pre-pandemic and pandemic cohorts of residents to examine the COVID-19 effect in the LTC setting was another area of strength for the dissertation that is important to mention. Up till the publication of the study of functional decline in the first wave of the pandemic, existing studies failed to compare pandemic period effects with an equivalent pre-pandemic effect when assessing the pandemic's impact in the setting. This failure resulted in the exaggeration of COVID-19's effect in LTC

settings. Utilizing the two cohorts of residents in the two COVID-19-related studies allowed us to obtain the additional functional decline residents experienced during the pandemic.

By providing evidence about both the unidirectional longitudinal trajectory of ADL function and the multidirectional transitions, this dissertation has a unique strength of forecasting not just the future risk of functional decline up to three years from the time of admission but also detailing the different changes in ADL that occur between 90-day assessments. Existing tools for predicting the risk of functional decline are not precise beyond one year. If validated, this unique strength offers an advantage over existing tools and would enable a much earlier institution of prevention intervention.

7.8. Limitations

Despite the many strengths of this dissertation, which makes the evidence it generated helpful for decision support in the LTC setting, there are limitations to be aware of. Our scoping review of existing literature restricted the search to articles published in English, which may have excluded articles published in other languages relevant to the research inquiry. The review was also limited to articles published between 2000 and 2022, excluding papers published before 2000. The search strategy was developed with guidance from a librarian and covered at least five indexed and grey literature databases. This search was, therefore, very robust and gave me confidence that the most relevant articles were retrieved for the study.

Another limitation of this dissertation was that functional decline trajectory was obtained for long-stay LTC residents with at least three assessments following admission. The analysis, therefore, excluded short-stay residents and residents with less than three assessments. For this reason, the dissertation does not have trajectory information for short-stay or convalescent residents, limiting the generalizability of the findings to only long-stay residents. Despite this, the study findings are valid for long-stay residents who were the intended target of the research inquiry.

It is equally important to state that the functional trajectory subgroups themselves do not represent fixed properties of residents but are latent classifications based on admission profiles. A resident's trajectory, therefore, can change, and not everyone who was predicted to follow a particular trajectory had a 100% probability of doing so. Some residents eventually follow a different trajectory from what was expected, and residents could switch trajectories with a change in health and other conditions. There is a need for caution in interpreting trajectory group membership and using it to educate residents.

7.9. Future Research

For the practical application of the findings of this dissertation, a decision support tool that could easily be understood and used by care providers and administrators in LTC settings would need to be developed. Future studies should explore the development of functional decline predictive tools relevant to the LTC settings. Such studies would be more useful if they developed tools that could predict

or forecast long-term trajectories of functional decline beyond 12 months, which is the precision limit of existing predictive tools.

Future research should also explore how ADL functional trajectories before admission to LTC homes are related to or affect the trajectories while on admission. Along the same line, it would also be helpful to explore the lifetime longitudinal trajectory of physical function starting from time in the community until placement in LTC settings. Data for this will encompass all data points from health events such as hospitalizations, emergency room visits, and post-acute care treatment. Such a study would require data linked across the different continuums of care for each individual, such as that provided through the interRAI suite of assessment instruments.

The dissertation evidence established a relationship between functional decline trajectory subgroups and resource utilization. Still, more importantly, it showed that the intensity of resource utilization switches between the trajectory within six months. It would be worthwhile to determine whether trajectory subgroups provide a better estimation of resource utilization among residents over a year compared to the RUG categorization used for resource allocation to LTC homes in most Canadian provinces.

7.10. Conclusion

As the Canadian aging population grows and the demand for long-term care rises, so do the complexities of residents in the setting, with a higher proportion now admitted with multiple chronic conditions as well as functional limitations. Credible and usable evidence is needed to make care-planning decisions in the setting, but as the COVID-19 crisis exposed, this evidence is not always available. Knowledge about the longitudinal trajectory of ADL changes and the multidirectional transition between ADL functional levels would substantially support a person-centered plan that improves care provision in the setting.

This dissertation contributes to bridging the identified knowledge gap in LTC settings by producing new, previously undocumented evidence about functional decline trajectories and the multidirectional transitions between ADL functional levels and their associated predictive factors. It improves our understanding of the residents most vulnerable to future functional decline and who will consume more resources while in the setting, further highlighting the potentially modifiable individual-level factors associated with adverse changes in ADL function. Several questions about the future trajectory, magnitude, and direction of change in ADL function among residents in the setting were also answered by this dissertation, generating information that could be developed into a decision-support tool.

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Appendix A: Supplementary Materials for Study 1

A.1. Search Strings For Different Databases

Search String: PubMed

Search: ((((("functional frailty"[Title/Abstract:~2] OR "physical frailty"[Title/Abstract:~2]) OR ("functional decline"[Title/Abstract:~2] OR "physical decline"[Title/Abstract:~2])) OR ("loss of function"[Title/Abstract:~2])) OR ("Activities of Daily Living"[Majr])) AND (((longitud*[Title/Abstract] OR trajector*[Title/Abstract])) OR ("Longitudinal Studies"[MAJR])) AND ((humans[Filter]) AND (2000:2022[pdat])) Filters: Humans, from 2002 – 2022

Search String: Medline OVID:

1 *Longitudinal Studies/

2 (function$ adj2 (declin$ or impair$ or "loss of" or disab$ or frailty)).ab,kf,ot,ti.

3 trajector$.ab,kf,ot,sy,ti.

4 (longitud$ adj2 (estimat$ or course or path)).ab,kf,ot,ti.

5 (physical adj2 (declin$ or impair$ or "loss of" or disab$ or frailty)).ab,kf,ot,ti.

6 "loss of independence".ab,kf,ot,ti.

7 *"Activities of Daily Living"/

8 2 or 5 or 6 or 7

9 1 or 3 or 4

10 8 and 9

11 10 and 2000:2022. (sa_year).

Search String: CINAHL

Expanders - Apply related words; Apply equivalent subjects.

Search modes - Boolean/Phrase

Limiters - Peer Reviewed

S1 longitudinal study

S2 function$ N2 (declin$ or impair$ or "loss of" or disab$ or frailty

S3 trajectory

S4 longitudinal N2 (estimat$ or course or path)

S5 physical N2 (declin$ or impair$ or "loss of" or disab$ or frailty)

S6 "loss of independence"

S7 activities of daily living

S8 human

S9 S1 OR S3 OR S4

S10 S2 OR S5

S11 S6 OR S7

S12 S9 AND S10 AND S11 AND S8 (57)

A.2. Complete List and Details of Included Articles

Title	Author(s)	Year	Country	Aim	Outcome measures	Modelling method	No. of trajectories	Setting
Hospitalized older adults: functional trajectory in a Portuguese hospital	de Almeida et al	2018	Portugal	To analyze the FT (Functional Trajectory) of HOA between baseline and 3-month follow-up.	Katz (0-6)	Mean score	4	Hospital
Predicting Trajectories of Functional Decline in 60- to 70-Year-Old People	Jonkman et al	2018	Italy & Netherlands	To identify and predict trajectories of functional decline over 9 years in males and females aged 60-70 years.	iADL & ADL	Latent class growth analysis	3	Community-dwelling
A pilot study of the trajectory of functional outcomes in stroke survivors: implications for home healthcare	Hadidi et al	2013	USA	To explore patterns of recovery in functional subcategories of FIM in a sample of stroke survivors' post-acute ischemic stroke	FIM	Multilevel modeling	1	Hospital
Trajectory of Functional Independent Measurements during First Five Years after Moderate and Severe Traumatic Brain Injury	Lu et al	2018	Norway	To classify and characterize patients with moderate-to-severe TBI based on their functional trajectories up to 5 years post-injury.	ADL	Latent class growth analysis	3	Hospital
Trajectories of ADL Disability Among Community-Dwelling Frail Older Persons	Li	2005	USA	To examine how activity of daily living (ADL) disability of community-living frail elders changes in a two-year period and how the pattern of change varies between those who subsequently died or were institutionalized and those who continued to live in the community	ADL	Multilevel modeling	1	Community-dwelling
Predictors of ADL disability trajectories among low-income frail elders in the community	Li	2005	USA	To examine the effects of psychosocial and health factors on the ADL disability trajectory of low-income frail elders living in the community.	ADL	Multilevel modeling	1	Community-dwelling

Trajectory of Functional Decline Before and After Ischemic Stroke	Dhamoon et al	2012	USA	To compare the long-term trajectory of functional status before and after ischemic stroke	Barthel Index	GEE	1	Community -dwelling
Longitudinal declines in instrumental activities of daily living in stable and progressive mild cognitive impairment	Hsiao et al	2015	USA	To examine longitudinal changes in FAQ scores among individuals meeting the criteria for MCI whose data are included in the Unified Data Set (UDS	IADL	Mean score	1	
Functional Independence in Late-Life: Maintaining Physical Functioning in Older Adulthood Predicts Daily Life Function after Age 80	Vaughan et al	2016	USA	To examine physical functioning (PF) trajectories (maintaining, slowly declining, and rapidly declining) spanning 15 years in older women aged 65-80 and protective factors that predicted better current levels and less decline in functional independence outcomes after age 80	IADL & ADL	Linear regression	3	Community -dwelling
Natural History of Decline in Instrumental Activities of Daily Living Performance over the 10 Years Preceding the Clinical Diagnosis of Dementia: A Prospective Population-Based Study	Karine Peres et al	2008	France	To examine the trajectory of restriction in four IADLs over the 10 years pre-ceding the clinical diagnosis of dementia in a French population-based study	IADL (Lawton scale)	Multilevel modeling	1	Community -dwelling
Three-year trajectories of disability and fatigue in systemic sclerosis: A cohort study	Willems et al	2017	Netherlan ds	To identify and characterize homogeneous sub-groups with distinct 3-year trajectories	ADL	Latent class growth analysis	2	Community -dwelling
Functional trajectories before and after a new cancer diagnosis among community-dwelling older adults	Presley et al	2019	USA	To characterize functional trajectories in the year before and after a new cancer diagnosis among older adults and to identify risk factors for worsening disability post-diagnosis	IADL, ADL & Mobility	Latent class growth analysis	3	Community -dwelling
Latent class analysis identifies functional decline with Amsterdam IADL in preclinical Alzheimer's disease	Villeneuv e et al	2019	Netherlan ds	To assess functional changes over three years in 289 elderly memory complainers from the Investigation of Alzheimer's Predictors in subjective memory complainer's cohort using the	IADL	Growth Mixture Modelling	5	Community -dwelling

				Amsterdam Instrumental-Activities-of-Daily-Living questionnaire (A-IADL-Q)				
Trajectories of decline on instrumental activities of daily living prior to dementia in persons with mild cognitive impairment	Cloutier et al	2021	Canada	To assess the trajectory of decline in IADL for MCI progressors and compare this trajectory with the one found in MCI non-progressors	IADL component of SMAF	Multilevel modeling	1	Community-dwelling
Late-life disability trajectories in Yoruba Nigerians and the Spanish population: a state space model in continuous time	Ojagbemi	2021	Nigeria & Spain	To compare the trajectory of activities of daily living (ADL) in a nationally representative sample of older Nigerians with their Spanish peers and identified factors to explain country-specific growth models	Barthel index	SSM-CT	1	Community-dwelling
Functional aging trajectories of older cancer survivors: a latent growth analysis of the US Health and Retirement Study	Westrck et al	2022	USA	To identify prototypical functional aging trajectories of US cancer survivors aged 50 and older, overall and stratified by sociodemographic and health-related characteristics	ADL	Latent class growth analysis	4	Community-dwelling
Patterns of Functional Decline at the End of Life	Lunney et al	2003	USA	To determine if functional decline differs among 4 types of illness trajectories: sudden death, cancer death, death from organ failure, and frailty	ADL	Mean score	4	Community-dwelling
Changes in functional status among older adults in Japan: successful and usual aging.	Liang	2003	Japan	To chart the trajectories of functional status in old age in Japan and to assess how self-rated health and cognitive functioning differentiate these trajectories and account for interpersonal differences	IADL & ADL	Multilevel modeling	1	Community-dwelling
Risk and Protective Factors of Different Functional Trajectories in Older Persons: Are These the Same?	Kempen et al	2006	Netherlands	We examined whether risk and protective factors of different functional trajectories were the same in 1,765 Dutch older persons	IADL & ADL	Mean score	3	Community-dwelling

Cognitive Domains and Trajectories of Functional Independence in Non-demented Elderly Persons	Dodge et al	2006	USA	To examine predictors of longitudinal trajectories in ability to perform Instrumental Activities of Daily Living (IADL) among non-demented elderly persons	OARS	Latent class growth analysis	3	Community -dwelling
Functional Trajectories Associated with Hospitalization in Older Adults	Wakefield and Holman	2007	USA	This study describes functional trajectories in hospitalized older adults and identifies risk factors associated with those trajectories	ADL	Mean difference	5	Hospital
Functional Trajectory6 Months Post Hospitalization Cohort Study of Older Hospitalized Patients in Taiwan	Chen et al	2008	Taiwan	To describe functional trajectory during and 6months posthospitalization and to ascertain the predictors that signal different classes of functional trajectory	ADL	Latent class growth analysis	3	Hospital
Trajectories of cognitive decline and functional status in the frail older adults	Nikolova, Demers & Beland	2009	Canada	To investigate the implications of different levels of cognitive decline on functional status in frail older adults	IADL (OARS) and Katz ADL	Mean score	1	Community -dwelling
Predictors of physical functioning trajectories among Chinese oldest old adults: rural and urban differences	Sun et al	2009	USA	To examine the differences between rural/urban older adults in their trajectories of activities of daily living (ADL) over a 4-year period	ADL	Multilevel modeling	1	Community -dwelling
Trajectories of mobility and IADL function in older patients diagnosed with major depression	Hybels et al	2010	USA	To explore the latent traits of trajectories of limitations in mobility and instrumental activities of daily living (IADL) tasks in a sample of older adults diagnosed with major depression.	IADL/mobility	Latent class growth analysis	3	Community -dwelling
Trajectories of disability in the last year of life	Gill et al	2010	USA		ADL	Latent class growth analysis	5	Community -dwelling
Trajectory of functional status among older Taiwanese: Gender and age variations.	Liang	2010	Taiwan	To examine gender and age variations in the trajectory of functional status among older adults in Taiwan	ADL	Multilevel modeling	1	Community -dwelling

Physical Disability Trajectories in Older Americans with and without Diabetes: The Role of Age, Gender, Race or ethnicity, and Education	Ching-Ju Chiu et al	2011	USA	To characterize age-related trajectories in physical disability for adults with and with-out diabetes in the United States and to investigate if those patterns differ by age, gender, race or ethnicity	IADL, ADL and mobility items	Multilevel modeling	1	Community -dwelling
Trajectories of Functional Change Among Long Stayers in Nursing Homes: Does Baseline Impairment Matter?	Banaszak -Holl et al	2011	USA	To examine the effects of baseline medical conditions and functional status on changes in physical impairment across residents' length of stay (LOS)	interRAI ADL Hierarchy	Multilevel modeling	1	Nursing home
Comorbid cognitive impairment and functional trajectories in low vision rehabilitation for macular disease	Whitson et al	2011	USA	To investigate whether baseline cognitive status predicts functional trajectories among older adults in low vision rehabilitation (LVR) for macular disease.	IADL	Multilevel modeling	1	Community -dwelling
Modeling disability trajectories and mortality of the oldest-old in China	Zimmer et al	2012	China	To jointly estimate disability and mortality trajectories over time based on data from the population aged80 and older in China, and explores relations of demographic, socioeconomic, and early-life characteristics to membership in gender-specific trajectory groups	ADL	Latent class growth analysis	3	Community -dwelling
Trajectories of disability in older adulthood and social support from a religious congregation: a growth curve analysis	Hayward and Krause	2013	USA	To examine the role of congregational support as a mechanism by which religious involvement may slow the decline of functional ability during late life	IADL & ADL	Multilevel modeling	1	Community -dwelling
Two-year course of cognitive function and instrumental activities of daily living in older adults with bipolar disorder: evidence for neuroprogression	Gildenger s et al	2013	USA	To characterize the 2-year course of cognitive function and IADLs in older adults with BD		Multilevel modeling	1	Community -dwelling
Effects of physical function trajectories on later long-term care utilization among the Taiwanese elderly	Hsu	2013	Taiwan	To examine the effects of trajectories of physical function on later long-term care utilization based on longitudinal panel data of older adults	IADL and ADL	Latent class growth analysis	4	Community -dwelling

Comparisons between older men and women in the trajectory and burden of disability over the course of nearly 14 years	Gill et al	2013	USA	To compare the trajectories and burden of disability over an extended period of time between older men and women	IADL, ADL and mobility	Growth Mixture Modelling	5	Community -dwelling
Dynamics of functional aging based on latent-class trajectories of activities of daily living	Han et al	2013	USA	To identify and characterize major patterns of functional aging based on activities of daily living (ADL)	iADL & ADL	Growth Mixture Modelling	5	Community -dwelling
Trajectories of functional limitation in early rheumatoid arthritis and their association with mortality	Norton et al	2013	England	To identify subgroups with distinct trajectories of functional (HAQ) progression over 10 years following diagnosis of RA and identify baseline characteristics associated with the trajectories and their prognostic value for mortality	HAQ score	Growth Mixture Modelling	4	Community -dwelling
The Course of Disability Before and After a Serious Fall Injury	Gill et al	2013	USA	To identify distinct sets of functional trajectories in the year immediately before and after a serious fall injury, to evaluate the relationship between the prefall and post fall trajectories, and to determine whether these results differed based on the type of injury	IADL, ADL & Mobility	Latent class growth analysis	5	Community -dwelling
Activity of daily living trajectories surrounding acute hospitalization of long-stay nursing home residents.	Kruse et al	2013	USA	To explore patterns of change in nursing home (NH) residents' activities of daily living (ADLs), particularly surrounding acute hospital stays	ADL	Multilevel modeling	1	Nursing home
The effect of lifetime cumulative adversity and depressive symptoms on functional status	Shrira & Litwin	2014	Europe	To examine whether lifetime cumulative adversity (LCA) and depressive symptoms moderate time-related trajectories of functional status	IADL & ADL	Multilevel modeling	1	Community -dwelling
Disability trajectories and associated disablement process factors among older adults in Taiwan	Yu et al	2015	Taiwan	To identify disability trajectories and examine whether the predisposing, intra-individual, and extra-individual factors in the disablement process predicted different disability trajectories among older adults in Taiwan.	IADL & ADL	Latent class growth analysis	3	Community -dwelling

Functional Trajectories Among Older Persons Before and After Critical Illness	Ferrante et al	2015	USA	To characterize functional trajectories in the year before and after ICU admission and to evaluate the associations among pre-ICU functional trajectories and post-ICU functional trajectories, short-term mortality, and long-term mortality.	IADL, ADL, Mobility	Latent class growth analysis	3	Community -dwelling
The role of intervening hospital admissions on trajectories of disability in the last year of life: prospective cohort study of older people	Gill et al	2015	USA	To evaluate the role of intervening hospital admissions on trajectories of disability in the last year of life	ADL	Latent class growth analysis	6	Community -dwelling
Trajectories of decline in cognition and daily functioning in preclinical dementia	Verlinde et al	2016	Netherlan ds	To investigate trajectories of cognition and daily functioning in preclinical dementia, during 18 years of follow-up	IADL & ADL	Growth Mixture Modelling	2	Community -dwelling
Stability and Change in Activities of Daily Living Among Older Mexican Americans	Howrey et al	2015	USA	To identify subgroups of trajectories in a sample from the Hispanic Established Populations for Epidemiologic Study of the Elderly, a population-based study of noninstitutionalized Mexican Americans aged 65 and older	Katz ADL	Latent class growth analysis	3	Community -dwelling
Trajectories of disability among older persons before and after a hospitalization leading to a skilled nursing facility admission	Buurman et al	2016	USA	To identify distinct sets of disability trajectories in the year before and after a Q-SNF admission	ADL & IADL & Mobility	Latent class growth analysis	3	Community -dwelling
Natural History of Dependency in the Elderly: A 24-Year Population-Based Study Using a Longitudinal Item Response Theory Model	Edjolo et al	2016	France	To describe the hierarchical structure of Instrumental Activities of Daily Living (IADL) and basic Activities of Daily Living (ADL) and trajectories of dependency before death in an elderly population using item response theory methodology.	IADL & Katz ADL	Multilevel modeling	1	Community -dwelling

Trajectories of Older Adults' Leisure Time Activity and Functional Disability: a 12-Year Follow-Up.	Ya-Mei Chen	2016	Taiwan	To explore how changes in leisure time activities interplayed with changes in functional disability among Taiwanese older adults.	IADL and ADL	Latent growth curve analysis	1	Community -dwelling
Determinants of rate of change in functional disability: An application of latent growth curve modeling	Chen	2015	Taiwan	To identify disablement factors, including predisposing, intra-individual, and extra-individual factors, which predict the rate of change in general functional disability (GFD) In older adults	IADL & ADL	Latent growth curve analysis	1	Community -dwelling
Trajectories of limitations in activities of daily living among older adults in Mexico, 2001-2012	Diaz-Venegas et al	2017	Mexico	To provide an overview of the progression of limitations in ADLs in the Mexican elderly population over time.	Modified Katz index	Multilevel modeling	1	Community -dwelling
Sex Differences in Concomitant Trajectories of Self-Reported Disability and Measured Physical Capacity in Older Adults	Botosenea nu	2016	USA	To measure sex differences in trajectory of self-reported functional status and measured physical capacity	ADL, IADL,	Multilevel modeling	1	Community -dwelling
Foundations of Activity of Daily Living Trajectories of Older Americans	Martin et al	2017	USA	To assesses the extent to which early phases of the disablement processes are associated with individual-level disability trajectories by age.	ADL	Latent class growth analysis	3	Community -dwelling
Activities of daily living trajectories among institutionalized older adults: A prospective study.	Kuo et al	2017	Taiwan	To examine activities of daily living trajectory groups among older residents in Taiwan, and to determine the relative risks of demographic characteristics and health status in explaining the trajectory group of activities of daily living	Barthel index	Latent class growth analysis	3	Nursing home
Longitudinal Trajectories of Informant-Reported Daily Functioning in Empirically Defined Subtypes of Mild Cognitive Impairment	Thomas et al	2017	USA	To investigate the functional change over time in these empirically derived MCI subgroups	ADL	Multilevel modeling	1	Community -dwelling

Disability Trajectories Before and After Stroke and Myocardial Infarction: The Cardiovascular Health Study	Dhamoon et al	2017	USA	To test whether the increase in long-term disability is steeper after than before the event for ischemic stroke but not myocardial infarction (MI)	IADL & ADL	GEE	1	Community -dwelling
Physical Functioning and Disability Trajectories by Age of Migration Among Mexican Elders in the United States	Garcia and Reyes	2016	USA	To address a gap in our understanding of the long-term consequences of nativity and age of migration for the health of the Mexican elderly population.	ADL	Latent growth curve analysis	1	Community -dwelling
Race Differences in ADL Disability Decline 1984-2004: Evidence from the National Long-Term Care Survey	Taylor, Lynch & Urena	2018	USA	To examine cohorts entering later life between 1984 and 1999, by race, to understand changing ADL disability	ADL	Latent class growth analysis	3	Community -dwelling
Functional trajectories of older patients admitted to an Acute Care Unit for Elders	D'Onofrio	2018	Switzerland	To describe the functional trajectories of older medical inpatients and to identify factors associated with overall and in-hospital functional decline	ADL and IADL	Mean difference	2	Hospital
Impact of the disability trajectory on the mortality risk of older adults in China	Wei, Li & Wang	2018	China	To compare the difference in the disability trajectory (DT) of survivor, decedent and dropped-out survey respondents and examined gender differences in DT	ADL	Latent class growth analysis	3	Community -dwelling
Functional Trajectories Before and After Major Surgery in Older Adults	Stabenau	2018	USA		IADL & ADL	Latent class growth analysis	4	Community -dwelling
Smoking Cessation and 16-year Trajectories of Functional Limitations Among Dutch Older Adults: Results from the Longitudinal Aging Study Amsterdam	Timmermans et al	2018	Netherlands	To examine whether smoking cessation in middle age and old age is associated with following a successful trajectory of functional limitations over time in Dutch older adults	IADL & ADL	Latent class growth analysis	4	Community -dwelling
Longitudinal Modeling of Functional Decline Associated with Pathologic Alzheimer's Disease in Older Persons without Cognitive Impairment.	Wang et al	2018	USA	To understand the magnitude of amyloid-related functional decline and to identify the functional domains sensitive to decline in a preclinical AD population	IADL & ADL	Multilevel modeling	1	Community -dwelling

Diabetes, Heart Disease, and Dementia: National Estimates of Functional Disability Trajectories	Vroomen et al	2018	USA	To quantify the associations between diabetes, heart disease, dementia, and their combinations with trajectories of functional disability accounting for attrition in a nationally representative sample of American community-dwelling older adults	ADL	Latent class growth analysis	3	Community -dwelling
Change in Activities of Daily Living in the Year Following a Stroke: A Latent Growth Curve Analysis.	Pai et al	2018	Taiwan	To test the trajectory of change across time in activities of daily living (ADLs) and to determine whether the National Institutes of Health Stroke Scale (NIHSS) score within 24 hours poststroke, gender, and age predict ADLs at 1, 3, 6, and 12 months poststroke	Barthel index	Latent growth curve analysis	1	Community -dwelling
Mediterranean diet and physical functioning trajectories in Eastern Europe: Findings from the HAPIEE study	Stefler et al	2018	Eastern Europe	To examine the association between overall diet quality and physical functioning in Eastern European populations	(PF-10) of the 36-item Short-Form Health Survey (SF-36)	Latent growth curve analysis	1	Community -dwelling
Trajectory of Disability in Older Adults with Newly Diagnosed Diabetes: Role of Elevated Depressive Symptoms	Wu et al	2018	USA	To examine whether the trajectory of disability differed between older adults with and without elevated depressive symptoms before and after the onset of diabetes mellitus (DM) over 10 years (2004 - 2014) and explored difficulties in basic and instrumental activities of daily living between the two groups	IADL & ADL	Multilevel modeling	1	Community -dwelling
U.S. Immigration Policy Regimes and Physical Disability Trajectories Among Mexico-U.S. Immigrants.	Mueller et al	2019	USA	To evaluate whether exposure to U.S. Immigration Policy Regimes (IPRs) corresponds with later-life disability disparities among Mexico-U.S. migrant women and men, and assess the degree to which observed differences may also	IADL & ADL	Multilevel modeling	1	Community -dwelling

				be associated with immigration policies and occupational composition				
Association of Trajectories of Higher-Level Functional Capacity with Mortality and Medical and Long-Term Care Costs Among Community-Dwelling Older Japanese	Taniguchi et al	2019	Japan	To identify aging trajectories in higher-level functional capacity of community-dwelling older Japanese, to determine whether these trajectories were associated with all-cause and cause-specific mortality, and to examine differences in medical and long-term care costs between aging trajectories of higher-level functional capacity	IADL	Latent class growth analysis	4	Community-dwelling
Early-Life Military Exposures and Functional Impairment Trajectories Among Older Male Veterans: The Buffering Effect of Psychological Resilience	Taylor et al	2019	USA	To examine the impact of early-life service-related exposures (SREs) on later-life functional impairment trajectories among older U.S. male veterans.	ADL	Latent growth curve analysis	1	Community-dwelling
Trajectories of Limitations in Instrumental Activities of Daily Living in Frail Older Adults with Vision, Hearing, or Dual Sensory Loss.	Mueller-Schotte et al	2019	Netherlands	To investigate the trajectories of decline in individual instrumental activities of daily living (IADL) with aging and the effect of hearing loss, vision loss, or dual sensory loss on these trajectories in community-living frail older persons.	IADL & ADL	Multilevel modeling	1	Community-dwelling
Association Between Baseline Glycemic Markers (HbA1c) and 8-Year Trajectories of Functional Disability.	Mutambudzi	2018	USA	To examine the association between HbA1c and functional disability trajectories in older adults aged 50 years and older.	Katz ADL	Latent class growth analysis	3	Community-dwelling
Predicting Cognitive and Functional Trajectories in People with Late-Onset Dementia: 2 Population-Based Studies	Haaksma et al	2019	Sweden	To explore the heterogeneity in dementia progression to detect disease, patient, and social context factors related to slow progression	Katz ADL	Growth Mixture Modelling	2	Community-dwelling

Cognitive and functional progression of dementia in two longitudinal studies	Wang et al	2019	Netherlands and USA	To perform a coordinated analysis of latent trajectories of cognitive and functional progression in dementia across two datasets	IADL	Growth Mixture Modelling	3	Community-dwelling
Trajectories of functional impairment in homeless older adults: Results from the HOPE HOME study	Brown et al	2019	USA	To identify trajectories of functional impairment in homeless adults aged 50 and older, and risk factors for differing trajectories	ADL	Latent class growth analysis	4	Community-dwelling
Functional trajectories of older acute medical inpatients	Rodrigues	2020	Portugal	To describe the changes in basic activities of daily living (BADL) function before and during hospital admission in older patients admitted to an acute medical unit and to assess the effect of age on loss of BADL function.	ADL	Mean difference	5	Hospital
Heterogeneous Long-Term Trajectories of Dependency in Older Adults: The PAQUID Cohort, a Population-Based Study over 22 years	Edjolo et al	2020	France	To describe the heterogeneity in trajectories of dependency preceding death in elders and to identify factors associated with this heterogeneity	IADL & ADL	Growth Mixture Modelling	5	Community-dwelling
Socioeconomic Differences in Trajectories of Functional Capacity Among Older Japanese: A 25-Year Longitudinal Study.	Murayama et al	2020	Japan	To identify distinct trajectories of functional capacity over a 25-year period and to explore socioeconomic differences in trajectory-group membership probabilities, using a national sample of older Japanese.	IADL & ADL	Latent class growth analysis	4	Community-dwelling
Age trajectories of disability in instrumental activities of daily living and disability-free life expectancy among middle-aged and older adults in Taiwan: an 11-year longitudinal study.	Liao and Chang	2020	Taiwan	To identify the age trajectories of disability in instrumental activities of daily life (IADLs) over 11 years and their correlates, and to estimate disability-free life expectancy for identified trajectory groups in middle-aged and older adults	IADL	Latent class growth analysis	2	Community-dwelling
Trajectories and Predictors of Functional Capacity Decline in Older Adults from a Brazilian Northeastern Hospital	Menezes	2021	Brazil	To evaluate functional changes from preadmission (baseline) until discharge of hospitalized older adults and identify predictors of loss in functional capacity	ADL	Mean difference	6	Hospital

Health Trajectories in Swedish Centenarians	Vertrano et al	2021	Sweden	To compare health trajectories of older adults becoming centenarians and their shorter-living counterparts in terms of chronic diseases, disability, and cognitive decline	Katz ADL	Multilevel modeling	1	Community -dwelling
Nursing Home Residents Functional Trajectories and Mortality After a Transfer to the Emergency Department	Guion et al	2021	France	To describe nursing home residents (NHRs) functional trajectories and mortality after a transfer to the emergency department (ED)	Katz ADL	Latent class growth analysis	4	Nursing home
Dentition status and 10-year higher-level functional capacity trajectories in older adults	Iwasaki & Yoshihara	2021	Japan	To identify distinct higher-level functional capacity trajectories in individuals aged 70-80 years, and examine whether dentition status at 70 years predicted the trajectory	IADL using TMIG-IC	Latent class growth analysis	3	Community -dwelling
Trajectories of Late-Life Disability Vary by the Condition Leading to Death	Stolz et al	2021	USA	To directly model the nonlinear shape of disability trajectories by the condition leading to death	IADL & ADL	Multilevel modeling	1	
Association Between Disability Trajectory and Health Care Service Utilization Among Older Adults in China	Xiao, Shi & fang	2021	China	To identify the heterogeneous disability trajectories among older Chinese adults and examine the association between disability trajectories and health care service utilization	IADL & ADL	Growth Mixture Modelling	3	
Patterns and predictive factors of loss of the independence trajectory among community-dwelling older adults	Bimou et al	2021	France	To investigate the patterns of independence loss in a representative sample of French community-dwelling adults aged 75 years using the SMAF tools	Functional Autonomy Measurement System (SMAF)	Latent class growth analysis	3	Community -dwelling
Trajectories of functional performance recovery after inpatient geriatric rehabilitation: an observational study	Soh et al	2021	Australia	To identify functional performance trajectories and the characteristics of people who receive inpatient geriatric rehabilitation after hospital admissions	IADL (Lawton and Brody) and Katz ADL	Growth Mixture Modelling	3	Hospital

Longitudinal trajectories of physical functioning among Chinese older adults: the role of depressive symptoms, cognitive functioning, and subjective memory	Yang et al	2021	China	To examine whether, and to what degree, the rate of change in physical functioning over time was associated with depressive symptoms, subjective memory and cognitive functioning	IADL & ADL	Multilevel modeling	1	Community -dwelling
Disability trajectories prior to death for ten leading causes of death among middle-aged and older adults in Taiwan	Ching-Ju Chiu	2021	Taiwan	To determine the different disability trajectories for the top ten leading causes of death in Taiwan.	Modified Katz ADL	Multilevel modeling	1	Community -dwelling
Joint trajectories of disability and related factors among older adults in China	Pan, Kelifa & Wang	2021	China	To identify disability trajectories and discover early disablement process factors associated with disability trajectories among older adults in China	IADL & ADL	Latent class growth analysis	3	Community -dwelling
Cognitive, physical and disability trajectories in community-dwelling elderly people	Ferraro et al	2021	Italy	To identify different aging trajectories and to investigate their influence on the cumulative incidence of dementia	ADL	Latent class growth analysis	3	Community -dwelling
Hierarchical structure in the activities of daily living and trajectories of disability prior to death in elderly Chinese individuals	Han et al	2021	China	To determine the hierarchical structure of the ability of Chinese elderly individuals to perform ADL and further describe the trajectories of disability prior to death	Katz scale	Multilevel modeling	1	Community -dwelling
Trajectories of stroke recovery of impairment, function, and quality of life in response to 12-month mobility and fitness intervention	Boissoneault 2021	2021	USA	To quantify treatment response to a neurorehabilitation mobility and fitness program	FIM	Linear regression	5	Community -dwelling
Long-term trajectories of decline in cognition and daily functioning before and after stroke	Heshmatollah et al	2021	Netherlands	To determine the long-term trajectories of cognition and daily functioning before and after stroke	IADL & ADL	Multilevel modeling	1	Community -dwelling
Malnutrition is associated with poor trajectories of activities of daily living in geriatric	Hettiarachchi et al	2021	Australia	To determine the association between (the risk of) malnutrition at admission and trajectories of Activities of Daily Living (ADL) and Instrumental ADL	IADL & ADL	Latent class growth analysis	3	Community -dwelling

rehabilitation inpatients: RESORT				(IADL) from pre-admission to post-discharge in geriatric rehabilitation inpatients				
Gait Speed and Instrumental Activities of Daily Living in Older Adults After Hospitalization: A Longitudinal Population-Based Study	Sprung et al	2021	USA	To determine the association between hospitalization of older adults and changes in long-term longitudinal trajectories of 2 measures of physical and functional status: gait speed (GS) and instrumental activities of daily living measured with Functional Activities Questionnaire (FAQ).	IADL	Multilevel modeling	1	Community -dwelling
Growth patterns of activity of daily living disability and associated factors among the Chinese elderly: A twelve-year longitudinal study	Huang, Zhang and Fang	2022	China	To identify potential distinct trajectories of ADL disability development and the influential factors of trajectory membership	Katz ADL	Growth Mixture Modelling	2	Community -dwelling
Three-year trajectories in functional limitations and cognitive decline among Dutch 75+ year olds, using nine-month intervals.	Gardeniers et al	2022	Netherlands	To identify three-year trajectories in cognitive and physical functioning among Dutch older adults, and the characteristics associated with these trajectories	ADL	Latent class growth analysis	5	Community -dwelling
Extending the Analysis of Functional Ability Trajectories to Unexplored National Contexts: The Case of Chile.	Madero-Cabib et al	2022	Chile	To examine functional ability trajectories in Chile	ADL	Sequence analysis	4	Community -dwelling
Patterns and Predictors of Functional Decline after Allogeneic Hematopoietic Cell Transplantation in Older Adults	Huang	2022	USA	To describe the longitudinal change in GA and quality of life (QoL) measures after alloHCT and to identify predictors of greater functional decline post-transplantation	IADL	Mean score	1	Community -dwelling
Patterns, Trajectories, and Predictors of Functional Decline after Hospitalization for Acute Exacerbations in Men with Moderate to Severe Chronic	MedinaMirapeix et al	2020	Spain	To determine the rate and time course of functional changes 3 months after hospital discharge for AE-COPD compared with baseline levels 2 weeks before admission, and to identify predictors of functional decline	ADL	Mean difference	6	Hospital

Obstructive Pulmonary Disease: A Longitudinal Study								
Subclinical brain infarcts are associated with functional decline trajectories	Dhamoon et al	2018	USA	To test associations between SBI and functional decline independently of intervening clinical vascular events and other vascular risk factors	Barthel index	GEE	1	Community -dwelling
Identification of the trajectory of functional decline for advance care planning in a nursing home population	Lawrence et al	2017	Australia	To identify diagnostic groups and the form of the trajectory of functional decline that has the potential to enhance advance care planning (ACP) in a nursing home (NH) population	ADL	Multilevel modeling	1	Nursing home
Terminal Trajectories of Functional Decline in the Long-Term Care Setting	Chen et al	2007	USA	To better understand the patterns of functional decline in LTC populations	ADL	Multilevel modeling	1	Nursing home
Trajectories of functional decline in older adults with neuropsychiatric and cardiovascular multimorbidity: A Swedish cohort study	Vertrano et al	2018	Sweden	To explore possible clinical pathways underlying functional heterogeneity in older adults by quantifying the impact of cardiovascular (CV) and neuropsychiatric (NP) chronic diseases and their co-occurrence on trajectories of functional decline	ADL & mobility	Multilevel modeling	1	Community -dwelling
Trajectories and predictors of functional decline of hospitalized older patients	Huang et al	2013	Taiwan	To delineate the trajectories of functional status over four time points and to examine predictors of functional decline (FD) in hospitalized older patients.	IADL & ADL	Mean score	3	
Empirically Defining Trajectories of Late-Life Cognitive and Functional Decline	Hochstetler	2016	USA	To define latent classes from participants in the Alzheimer's Disease Neuroimaging Initiative (ADNI) database who had similar growth patterns of both cognitive and functional change using Growth Mixture Modeling (GMM),	ADL	Growth Mixture Modelling	3	Community -dwelling
Exploring 2.5-Year Trajectories of Functional Decline in Older Adults by Applying a Growth Mixture Model and Frequency	Saito et al	2019	Japan	To explore the distinct trajectories of functional decline among older adults in Japan, and evaluate whether the frequency of outings, an important	ADL	Growth Mixture Modelling	3	Community -dwelling

of Outings as a Predictor: A 2010-2013 JAGES Longitudinal Study				indicator of social activity, predicts the identified trajectories				
Hip fractures in older patients: trajectories of disability after surgery	Aarden, JJ	2017	Netherlands	To identify distinct disability trajectories from admission to one-year post-discharge in acutely hospitalized older patients after hip fracture	modified Katz index score	Latent class growth analysis	3	
The Heterogeneity of Disability Trajectories in Later Life: Dynamics of Activities of Daily Living Performance Among Nursing Home Residents	Bolano *et al*	2019	Switzerland	This study investigated the variability in activities of daily living (ADL) trajectories among 6,155 nursing home residents using unique and rich observational data.	RAI-MDS ADL.	HMTD	4	Nursing home
Becoming Centenarians: Disease and Functioning Trajectories of Older U.S. Adults as They Survive to 100	Allshire *et al*	2015	USA	To examine disease and functioning trajectories of centenarians and their shorter-lived cohort counterparts.	Modified Katx index	Mean score	1	Community -dwelling

Appendix B: Supplementary Materials for Study 2

B.1. Complete list of Independent Variables Included in the Model

	Variable	Description	Range and Levels	Reference
1	ADL Hierarchy Scale	A measure of functional performance in 4 activities of daily living from early to late loss (hygiene, locomotion, toilet use, eating)	0 - 6 independent to dependent	Morris et al., 1999; Morris et al., 2013
2	Acute Frailty Index	Measures the proportion of assessed deficit present	0.0 – 1.0 robust to frail Collapsed into Frailty index categories: [0.0-0.2, 0.21-0.30, 0.31-0.40, >0.40]	Hubbard et al, 2015
3	Cognitive performance scale	Measures cognition	0 – 6 intact to severe impairment [Collapsed into **0, 1-2, 3+]**	Morris et al., 2016
4	Depression rating scale	Measures depression	0 – 6 No symptoms to severe symptoms [Collapsed into **0, 1-2, 3+]**	Burrows et al. 2000; InterRAI 2015

5	CHESS scale	Measures medical complexity and instability	0 – 5 most stable to most unstable [Collapsed into **0, 1-2, 3+]**	Hirdes et al., 2003; Hirdes et al., 2014
6	SOCENG Scale			
7	Resource Utilization Group (RUG) Categorization	Measures and classifies residents according to the level of care required	1 - Special Rehabilitation 2 - Extensive Services 3 - Special Care 4 - Clinically Complex 5 - Impaired Cognition 6 - Behavioural Problems 7 - Physical Functions Reduced	Fries et al, 1994
8	Visual impairment	Measure ability to see in adequate light (with glasses if used)	0 - 4 Adequate to severe visual impairment	MDS 2.0 Manual
9	Making self-understood	Measures the ability to express information content, however able	0 – 3 understood to rarely or never understood	MDS 2.0 Manual
10	Ability to understand others	Measures the ability to understand verbal information content, however able	0 – 3 understands to rarely or never understands	MDS 2.0 Manual
11	Rehabilitation potential	A composite score for where: Care Staff or resident believes self to be capable of increased independence in at least some ADLs. Measures ADL functional rehabilitation potential.	0,1 neither patient nor care staff believes to both believe the patient is capable of increased independence in at least one ADL	
12	Respite Care		Yes/No	MDS 2.0 Manual

13	Full bed rails		Yes/No	MDS 2.0 Manual
14	Fell in past 30 days		Yes/No	MDS 2.0 Manual
15	Hip fracture past 180 days		Yes/No	MDS 2.0 Manual
16	Hypertension		Yes/No	MDS 2.0 Manual
17	Osteoporosis		Yes/No	MDS 2.0 Manual
18	Alzheimer's		Yes/No	MDS 2.0 Manual
19	Parkinson's		Yes/No	MDS 2.0 Manual
20	Quadriplegia		Yes/No	MDS 2.0 Manual
21	Traumatic brain injury		Yes/No	MDS 2.0 Manual
22	Anxiety		Yes/No	MDS 2.0 Manual
23	Hypotension		Yes/No	MDS 2.0 Manual
24	Unsteady gait		Yes/No	MDS 2.0 Manual
25	Personal Hygiene*	Measures how patient moves to and from lying position, turns from side to side, and positions body while in bed	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
26	Eating*	Measures how resident moves between surfaces-to and from: bed, chair, wheelchair, standing position (Excluding to and from bath and toilet)	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
27	Walk in room*	Measures how resident walks between locations in own room	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
28	Toilet use*	Measures how resident uses the toilet room (or commode,	0 –4, 8	MDS 2.0 Manual

	bedpan, urinal); transfers on/off toilet, cleanses, changes pad, manages ostomy or catheter. Adjusts clothes	independent to total dependence, activity did not occur
*** Not in the final model, but sub-analyzed**		

B.2: Description of RUG category assignment criteria

RUG Category (RUG-III Plus)	Category assignment criteria
1 - Special Rehabilitation	150 or more minutes of therapy AND 1 or more therapies on 5 or more days OR 45 or more minutes of therapy AND 1 or more therapies on 3 or more days AND 2 or more nursing rehab techniques
2 - Extensive Services	High ADL Impairment score (7 to 18) AND tracheostomy care OR ventilator/respirator OR antibiotic-resistant infection OR Clostridium difficile infection
3 - Special Care	Tracheostomy care OR ventilator/respirator OR antibiotic-resistant infection OR Clostridium difficile infection OR High ADL Impairment score (7 to 18) AND any Special Care items
4 - Clinically Complex	Tracheostomy care OR ventilator/respirator OR antibiotic-resistant infection OR Clostridium difficile infection OR Any Special Care items OR Any Clinically Complex items
5 - Impaired Cognition	RUG_III_ADL score of 4 to 10 AND high Cognitive Performance Scale (CPS) score of 3 to 6
6 - Behavioural Problems	RUG_III_ADL score of 4 to 10 AND troubling behaviours
7 - Physical Functions Reduced	All assessments qualify

B.3: LTC homes distribution by province and location

Province	Location	Count of LTC homes (pre-COVID-2019)	Count of LTC homes (COVID-2020)
Alberta	Urban	104	106
	Rural	75	75
British Columbia	Urban	238	237
	Rural	58	54
Manitoba	Urban	39	38
	Rural	0	0
Newfoundland and Labrador	Urban	9	9
	Rural	26	26
Ontario	Urban	486	486
	Rural	138	136

B.4: Distribution of The Number of Point with Which ADL Declined pre-COVID vs. COVID by baseline ADL score 2019 - 2020.

	1 point		2 points		3+ points	
Baseline ADL Hierarchy Score	pre-COVID	COVID	pre-COVID	COVID	pre-COVID	COVID
0	13.2	14	9.2	10	7.1	7.8
1	17.0	15.9	7.5	7.2	2.9	4.3
2	20.5	19.2	4.4	3.8	2.8	4.7
3	11.2	10.8	4.5	5.8	0.7	1.0
4	14.2	16.9	2.2	2.4	0.0	0.0
5	9.5	10.4	0.0	0.0	0.0	0.0

Appendix C: Supplementary Materials for Study 3

C.1. Complete list of Independent Variables Included in the Model

	Variable	Description	Range and Levels	Reference
1	ADL Hierarchy Scale	A measure of functional performance in 4 activities of daily living from early to late loss (hygiene, locomotion, toilet use, eating)	0 - 6 independent to dependent	Morris et al., 1999; Morris et al., 2013
2	Acute Frailty Index	Measures the proportion of assessed deficit present	0.0 – 1.0 robust to frail Collapsed into Frailty index categories: [0.0-0.2, 0.21-0.30, 0.31-0.40, >0.40]	Hubbard et al, 2015
3	Cognitive performance scale	Measures cognition	0 – 6 intact to severe impairment [Collapsed into **0, 1-2, 3+]**	Morris et al., 2016
4	Depression rating scale	Measures depression	0 – 6 No symptoms to severe symptoms [Collapsed into **0, 1-2, 3+]**	Burrows et al. 2000; InterRAI 2015
5	CHESS scale	Measures medical complexity and instability	0 – 5 most stable to most unstable [Collapsed into **0, 1-2, 3+]**	Hirdes et al., 2003; Hirdes et al., 2014
6	SOCENG Scale			

7	Resource Utilization Group (RUG) Categorization	Measures and classifies residents according to the level of care required	1 - Special Rehabilitation 2 - Extensive Services 3 - Special Care 4 - Clinically Complex 5 - Impaired Cognition 6 - Behavioural Problems 7 - Physical Functions Reduced	Fries et al, 1994
8	Visual impairment	Measure ability to see in adequate light (with glasses if used)	0 - 4 Adequate to severe visual impairment	MDS 2.0 Manual
9	Making self-understood	Measures the ability to express information content, however able	0 – 3 understood to rarely or never understood	MDS 2.0 Manual
10	Ability to understand others	Measures the ability to understand verbal information content, however able	0 – 3 understands to rarely or never understands	MDS 2.0 Manual
11	Rehabilitation potential	A composite score for where: Care Staff or resident believes self to be capable of increased independence in at least some ADLs. Measures ADL functional rehabilitation potential.	0,1 neither patient nor care staff believes to both believe the patient is capable of increased independence in at least one ADL	
12	Respite Care		Yes/No	MDS 2.0 Manual
13	Full bed rails		Yes/No	MDS 2.0 Manual
14	Fell in past 30 days		Yes/No	MDS 2.0 Manual
15	Hip fracture past 180 days		Yes/No	MDS 2.0 Manual

16	Hypertension		Yes/No	MDS 2.0 Manual
17	Osteoporosis		Yes/No	MDS 2.0 Manual
18	Alzheimer's		Yes/No	MDS 2.0 Manual
19	Parkinson's		Yes/No	MDS 2.0 Manual
20	Quadriplegia		Yes/No	MDS 2.0 Manual
21	Traumatic brain injury		Yes/No	MDS 2.0 Manual
22	Anxiety		Yes/No	MDS 2.0 Manual
23	Hypotension		Yes/No	MDS 2.0 Manual
24	Unsteady gait		Yes/No	MDS 2.0 Manual
25	Personal Hygiene*	Measures how patient moves to and from lying position, turns from side to side, and positions body while in bed	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
26	Eating*	Measures how resident moves between surfaces-to and from: bed, chair, wheelchair, standing position (Excluding to and from bath and toilet)	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
27	Walk in room*	Measures how resident walks between locations in own room	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
28	Toilet use*	Measures how resident uses the toilet room (or commode, bedpan, urinal); transfers on/off toilet, cleanses, changes	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual

	pad, manages ostomy or catheter. Adjusts clothes
*** Not in the final model, but sub-analyzed**	

Appendix D: Supplementary Materials for Study 4

D.1. Complete list of Independent Variables Included in the Model

	Variable	Description	Range and Levels	Reference
1	ADL Hierarchy Scale	A measure of functional performance in 4 activities of daily living from early to late loss (hygiene, locomotion, toilet use, eating)	0 - 6 independent to dependent	Morris et al., 1999; Morris et al., 2013
2	Acute Frailty Index	Measures the proportion of assessed deficit present	0.0 – 1.0 robust to frail Collapsed into Frailty index categories: [0.0-0.2, 0.21-0.30, 0.31-0.40, >0.40]	Hubbard et al, 2015
3	Cognitive performance scale	Measures cognition	0 – 6 intact to severe impairment [Collapsed into **0, 1-2, 3+]**	Morris et al., 2016
4	Depression rating scale	Measures depression	0 – 6 No symptoms to severe symptoms [Collapsed into **0, 1-2, 3+]**	Burrows et al. 2000; InterRAI 2015
5	CHESS scale	Measures medical complexity and instability	0 – 5 most stable to most unstable [Collapsed into **0, 1-2, 3+]**	Hirdes et al., 2003; Hirdes et al., 2014
6	SOCENG Scale			

7	Resource Utilization Group (RUG) Categorization	Measures and classifies residents according to the level of care required	1 - Special Rehabilitation 2 - Extensive Services 3 - Special Care 4 - Clinically Complex 5 - Impaired Cognition 6 - Behavioral Problems 7 - Physical Functions Reduced	Fries et al, 1994
8	Visual impairment	Measure ability to see in adequate light (with glasses if used)	0 - 4 Adequate to severe visual impairment	MDS 2.0 Manual
9	Making self-understood	Measures the ability to express information content, however able	0 – 3 understood to rarely or never understood	MDS 2.0 Manual
10	Ability to understand others	Measures the ability to understand verbal information content, however able	0 – 3 understands to rarely or never understands	MDS 2.0 Manual
11	Rehabilitation potential	A composite score for where: Care Staff or resident believes self to be capable of increased independence in at least some ADLs. Measures ADL functional rehabilitation potential.	0,1 neither patient nor care staff believes to both believe the patient is capable of increased independence in at least one ADL	
12	Respite Care		Yes/No	MDS 2.0 Manual
13	Full bed rails		Yes/No	MDS 2.0 Manual
14	Fell in past 30 days		Yes/No	MDS 2.0 Manual
15	Hip fracture past 180 days		Yes/No	MDS 2.0 Manual

16	Hypertension		Yes/No	MDS 2.0 Manual
17	Osteoporosis		Yes/No	MDS 2.0 Manual
18	Alzheimer's		Yes/No	MDS 2.0 Manual
19	Parkinson's		Yes/No	MDS 2.0 Manual
20	Quadriplegia		Yes/No	MDS 2.0 Manual
21	Traumatic brain injury		Yes/No	MDS 2.0 Manual
22	Anxiety		Yes/No	MDS 2.0 Manual
23	Hypotension		Yes/No	MDS 2.0 Manual
24	Unsteady gait		Yes/No	MDS 2.0 Manual
25	Personal Hygiene*	Measures how patient moves to and from lying position, turns from side to side, and positions body while in bed	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
26	Eating*	Measures how resident moves between surfaces-to and from: bed, chair, wheelchair, standing position (Excluding to and from bath and toilet)	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
27	Walk in room*	Measures how resident walks between locations in own room	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual
28	Toilet use*	Measures how resident uses the toilet room (or commode, bedpan, urinal); transfers on/off toilet, cleanses, changes	0 –4, 8 independent to total dependence, activity did not occur	MDS 2.0 Manual

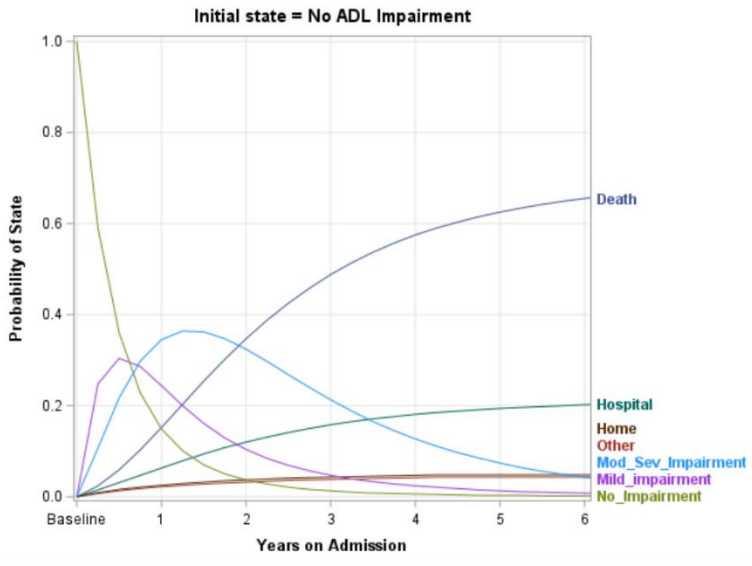
	pad, manages ostomy or catheter. Adjusts clothes
*** Not in the final model, but sub-analyzed**	

a. Transition matrix: successive 90-	**b. Average transition probabilities for days assessments:**
$P_{1\,1}$ $P_{1\,2}$ $P_{1\,3}$ $P_{1\,4}$ $P_{1\,5}$ $P_{1\,6}$ $P_{1\,7}$	$\mathbf{P_{0.590}}$ $P_{0.248}$ $P_{0.107}$ $P_{0.009}$ $P_{0.015}$ $P_{0.024}$ $P_{0.007}$
$P_{2\,1}$ $P_{2\,2}$ $P_{2\,3}$ $P_{2\,4}$ $P_{2\,5}$ $P_{2\,6}$ $P_{2\,7}$	$P_{0.050}$ $\mathbf{P_{0.623}}$ $P_{0.269}$ $P_{0.005}$ $P_{0.016}$ $P_{0.033}$ $P_{0.005}$
$P_{3\,1}$ $P_{3\,2}$ $P_{3\,3}$ $P_{3\,4}$ $P_{3\,5}$ $P_{3\,6}$ $P_{3\,7}$	$P_{0.002}$ $P_{0.032}$ $\mathbf{P_{0.816}}$ $P_{0.003}$ $P_{0.027}$ $P_{0.114}$ $P_{0.003}$
$P_{4\,1}$ $P_{4\,2}$ $P_{4\,3}$ $P_{4\,4}$ $P_{4\,5}$ $P_{4\,6}$ $P_{4\,7}$	$P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $\mathbf{P_{1.\,00}}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$
$P_{5\,1}$ $P_{5\,2}$ $P_{5\,3}$ $P_{5\,4}$ $P_{5\,5}$ $P_{5\,6}$ $P_{5\,7}$	$P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $\mathbf{P_{1.\,0}}$ $P_{0.\,00}$ $P_{0.\,00}$
$P_{6\,1}$ $P_{6\,2}$ $P_{6\,3}$ $P_{6\,4}$ $P_{6\,5}$ $P_{6\,6}$ $P_{6\,7}$	$P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $\mathbf{P_{1.\,00}}$ $P_{0.\,00}$
$P_{7\,1}$ $P_{7\,2}$ $P_{7\,3}$ $P_{7\,4}$ $P_{7\,5}$ $P_{7\,6}$ $P_{7\,7}$	$P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $P_{0.\,00}$ $\mathbf{P_{1.\,00}}$

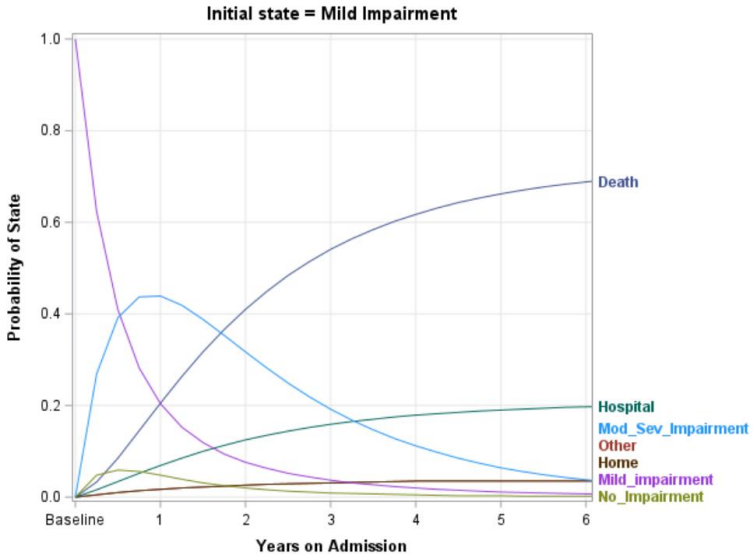
Key: 1= ADL 0; **2**= ADL 1-2; **3**= ADL 3+; **4**= Home; **5**= Hospital; **6**= Death; **7**= Others

D.1: Transition Matrix and The Probabilities For Different Transitions

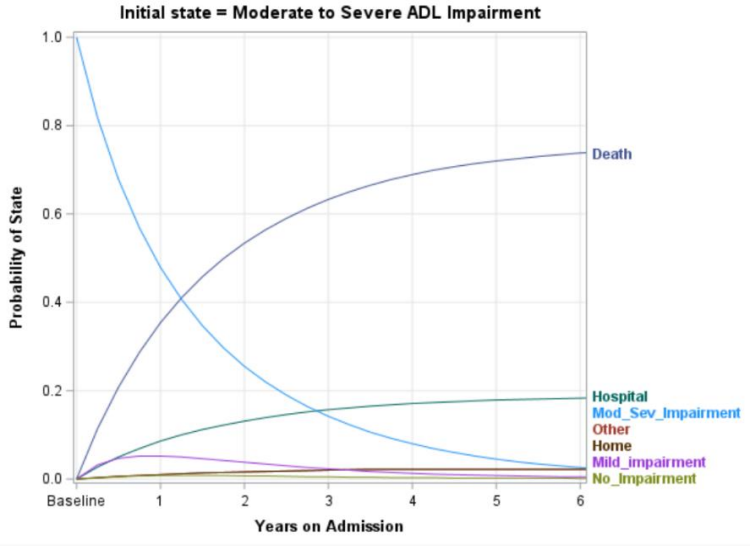
a.



b.



c



D.2: The probability of transition from different ADL states on admission to other ADL states or absorbing states showing changes over time.

D.2a: Adjusted odds of transition to other ADL and Absorbing states from No ADL impairment state

VARIABLE	TWO	THREE	DEATH	HOSPITAL	HOME
A. Demography					
Female	1.02 (0.97-1.08)	1.06 (0.98-1.14)	**0.70 (0.61-0.79)**	**0.68 (0.58-0.79)**	0.98 (0.79-1.21)
Age 75-84	1.02 (0.94-1.10)	1.08 (0.98-1.20)	**1.37 (1.12-1.68)**	0.82 (0.67-1.01)	**0.56 (0.44-0.71)**
Age 85-94	**1.20 (1.11-1.30)**	**1.48 (1.33-1.64)**	**1.89 (1.54-2.33)**	0.96 (0.78-1.19)	**0.32 (0.24-0.42)**
Age 95+	**1.15 (1.00-1.33)**	**1.71 (1.44-2.05)**	**2.85 (2.08-3.59)**	1.01 (0.67-1.51)	**0.30 (0.16-0.57)**
Married	**1.03 (0.96-1.10)**	0.93 (0.85-1.02)	0.88 (0.74-1.05)	0.95 (0.78-1.15)	**1.64 (1.29-2.10)**
B. Clinical Severity Scales					
CHESS 1-2 vs. 0	**1.06 (1.00-1.13)**	**1.29 (1.19-1.39)**	**1.79 (1.56-2.05)**	**1.43 (1.21-1.67)**	0.81 (0.62-1.06)
CHESS 3+ vs. 0	1.02 (0.70-1.49)	**1.57 (1.06-2.32)**	**4.84 (3.10-7.55)**	1.65 (0.78-3.49)	**1.00 (1.00-1.00)**
Cognitive Performance Scale 1-2 vs. 0	**1.28 (1.20-1.37)**	**1.13 (1.04-1.22)**	**0.85 (0.73-0.98)**	1.01 (0.85-1.20)	0.88 (0.70-1.11)
Cognitive Performance Scale 3-4 vs. 0	**1.82 (1.67-1.97)**	**1.85 (1.67-2.06)**	1.20 (0.98-1.46)	1.17 (0.92-1.5)	**0.55 (0.37-0.80)**
Cognitive Performance Scale 5-6 vs. 0	**2.68 (2.02-3.57)**	**4.71 (3.42-6.48)**	**2.46 (1.05-4.36)**	1.45 (0.57-3.66)	0.58 (0.14-2.42)
Depression Rating Scale 1-2 vs. 0	**1.06 (1.00-1.12)**	1.07 (0.99-1.15)	**1.22 (1.05-1.41)**	1.17 (0.99-1.39)	1.09 (0.85-1.39)
Depression Rating Scale 3 vs. 0	1.05 (0.97-1.12)	**1.15 (1.05-1.25)**	1.18 (0.99-1.41)	**1.25 (1.02-1.53)**	1.27 (0.95-1.72)
ISE 1-2 vs. 0	0.94 (0.77-1.13)	0.80 (0.63-1.01)	**0.66 (0.45-0.96)**	0.94 (0.55-1.61)	0.70 (0.35-1.40)
ISE 3-4 vs. 0	0.87 (0.73-1.05)	**0.67 (0.53-0.85)**	**0.49 (0.33-0.71)**	0.80 (0.48-1.36)	0.80 (0.41-1.56)
ISE 5-6 vs. 0	**0.75 (0.63-0.91)**	**0.54 (0.43-0.68)**	**0.38 (0.26-0.55)**	0.61 (0.36-1.03)	0.72 (0.37-1.41)
Pain Scale 1-2 vs. 0	0.94 (0.89-1.00)	0.94 (0.87-1.01)	0.89 (0.78-1.02)	**1.20 (1.03-1.40)**	1.11 (0.59-1.38)
Pain Scale 3+ vs. 0	0.96 (0.78-1.18)	1.17 (0.92-1.48)	1.46 (0.99-2.14)	1.16 (0.71-1.89)	1.36 (0.71-2.60)
C. Clinical Items					
Minimal Difficulty	0.94 (0.89-1.00)	0.94 (0.87-1.01)	**1.18 (1.02-1.36)**	1.08 (0.91-1.29)	0.91 (0.69-1.19)
Hears In Special Situations Only	0.97 (0.88-1.07)	1.02 (0.91-1.15)	1.01 (0.81-1.27)	0.90 (0.68-1.19)	1.27 (0.86-1.87)
Highly Impaired	0.76 (0.59-0.98)	1.03 (0.77-1.39)	1.36 (0.85-2.19)	0.79 (0.37-1.69)	0.24 (0.03-1.71)
Impaired	1.03 (0.97-1.09)	1.01 (0.93-1.09)	1.05 (0.90-1.22)	0.98 (0.82-1.18)	1.26 (0.98-1.61)
Moderately Impaired	0.99 (0.87-1.13)	1.14 (0.98-1.34)	1.05 (0.78-1.42)	1.19 (0.84-1.67)	1.53 (0.97-2.43)
Highly Impaired	0.95 (0.78-1.17)	0.91 (0.71-1.17)	0.80 (0.48-1.32)	1.45 (0.91-2.31)	0.17 (0.02-1.24)
Severely Impaired	1.16 (0.79-1.72)	1.17 (0.72-1.91)	1.19 (0.47-2.97)	0.88 (0.27-2.82)	1.55 (0.47-5.10)
Fall 30 Days	**1.11 (1.01-1.22)**	**1.58 (1.43-1.76)**	**1.62 (1.34-1.97)**	**1.43 (1.13-1.79)**	**1.60 (1.17-2.20)**

Hip Fracture 180 Days	0.97 (0.71-1.32)	0.80 (0.50-1.26)	0.66 (0.24-1.81)	1.15 (0.50-2.64)	1.25 (0.50-3.13)
Unsteady Gait	1.01 (0.96-1.07)	**1.15 (1.07-1.23)**	0.95 (0.83-1.09)	0.99 (0.84-1.15)	0.83 (0.66-1.05)
Rehab Potential	**1.07 (1.00-1.13)**	0.94 (0.86-1.02)	**0.77 (0.66-0.91)**	0.83 (0.69-1.01)	**1.53 (1.21-1.94)**
D. Diagnosis					
Alzheimer/Other Dementia	**1.16 (1.09-1.22)**	**1.07 (1.00-1.16)**	0.88 (0.77-1.01)	**0.82 (0.70-0.97)**	**0.63 (0.50-0.79)**
Cancer	0.98 (0.91-1.04)	0.97 (0.59-1.05)	**1.30 (1.12-1.50)**	**1.25 (1.06-1.48)**	1.01 (0.78-1.31)
COPD	1.00 (0.93-1.08)	1.18 (1.08-1.30)	**1.54 (1.32-1.80)**	**1.45 (1.21-1.74)**	0.74 (0.52-1.06)
Heart Failure	1.16 (0.86-1.56)	1.46 (1.05-2.03)	**1.74 (1.05-2.58)**	**2.16 (1.26-3.68)**	2.14 (0.90-5.11)
Hemi/Paraplegia	0.97 (0.89-1.06)	1.18 (1.07-1.31)	**1.85 (1.56-2.19)**	**1.39 (1.13-1.72)**	0.92 (0.65-1.29)
Parkinson	**1.09 (1.00-1.18)**	**1.13 (1.02-1.25)**	1.16 (0.96-1.39)	**1.32 (1.08-1.62)**	0.93 (0.65-1.34)
Pneumonia	0.96 (0.83-1.11)	1.38 (1.17-1.63)	0.80 (0.53-1.19)	0.91 (0.60-1.37)	0.76 (0.43-1.31)
Renal Failure	1.03 (0.80-1.32)	1.44 (1.08-1.92)	0.74 (0.36-1.53)	0.55 (0.22-1.37)	1.21 (0.57-2.59)
Schizophrenia	0.86 (0.74-1.01)	0.69 (0.55-0.86)	**0.51 (0.31-0.86)**	1.08 (0.73-1.60)	**0.38 (0.18-0.83)**
Stroke	0.99 (0.92-1.07)	1.04 (0.94-1.14)	1.01 (0.85-1.20)	1.02 (0.83-1.25)	1.27 (0.96-1.66)
Urinary Tract Infection	1.06 (0.91-1.23)	1.22 (1.03-1.46)	1.15 (0.82-1.62)	1.25 (0.87-1.81)	0.97 (0.52-1.79)
E. Treatment					
Med Count	1.00 (0.99-1.00)	1.02 (1.02-1.03)	**1.02 (1.01-1.04)**	**1.04 (1.03-1.06)**	**0.96 (0.94-0.98)**
New Med 90 Days vs. None	1.03 (0.97-1.08)	1.04 (0.97-1.12)	1.11 (0.97-1.27)	1.08 (0.92-1.26)	0.89 (0.70-1.13)
New Med 90 Days Unknown vs. None	0.97 (0.88-1.06)	0.75 (0.65-0.87)	0.78 (0.59-1.04)	0.77 (0.58-1.01)	1.03 (0.78-1.37)
Ot Days	1.08 (0.96-1.21)	1.08 (0.95-1.24)	0.93 (0.73-1.19)	0.91 (0.69-1.20)	1.53 (0.95-2.47)
Pt Days	**1.05 (1.00-1.10)**	1.04 (0.98-1.09)	1.13 (0.99-1.30)	**1.17 (1.02-1.34)**	0.91 (0.81-1.03)
Physician Visit	1.01 (0.96-1.06)	0.96 (0.90-1.03)	0.94 (0.83-1.07)	1.06 (0.91-1.24)	0.82 (0.66-1.02)
F. Facility Attribute					
Facility Location Urban	**0.70 (0.65-0.74)**	**0.73 (0.67-0.80)**	0.89 (0.75-1.05)	**0.71 (0.58-0.86)**	**0.67 (0.50-0.89)**
Facility Size L vs. S	0.88 (0.74-1.04)	0.91 (0.72-1.13)	**0.70 (0.50-0.98)**	0.85 (0.53-1.35)	0.68 (0.38-1.20)
Facility Size M vs. S	1.06 (0.89-1.26)	1.02 (0.82-1.29)	0.84 (0.60-1.17)	0.85 (0.53-1.36)	0.87 (0.49-1.53)
Alberta Vs. Ontario	**1.55 (1.40-1.72)**	**1.38 (1.20-1.57)**	**3.09 (2.48-3.85)**	**1.41 (1.05-1.89)**	**1.62 (1.14-2.31)**
British Columbia Vs. Ontario	**0.92 (0.86-0.99)**	**0.80 (0.73-0.87)**	**2.52 (2.13-2.97)**	**1.33 (1.09-1.62)**	**0.49 (0.36-0.65)**

D.2b: Adjusted odds of transition to other ADL and Absorbing states from mild ADL impairment state

VARIABLE	ONE	THREE	DEATH	HOSPITAL	HOME
A. Demography					
Female	1.00 (0.95-1.05)	**1.02 (1.00-1.05)**	**0.71 (0.67-0.74)**	**0.67 (0.63-0.72)**	0.97 (0.86-1.09)
Age 75-84	**0.89 (0.83-0.95)**	**1.05 (1.01-1.08)**	**1.36 (1.24-1.49)**	**0.88 (0.79-0.97)**	**0.53 (0.46-0.61)**
Age 85-94	**0.75 (0.70-0.80)**	**1.19 (1.15-1.24)**	**2.02 (1.84-2.21)**	**0.88 (0.79-0.97)**	**0.39 (0.34-0.46)**
Age 95+	**0.64 (0.57-0.73)**	**1.45 (1.37-1.53)**	**3.19 (2.83-3.60)**	**0.82 (0.68-0.98)**	**0.32 (0.24-0.43)**
Married	0.98 (0.92-1.04)	1.10 (1.07-1.13)	**0.90 (0.84-0.96)**	0.55 (0.87-1.04)	1.57 (1.38-1.79)
B. Clinical Severity Scales					
ADL CAP 1 (Prevent decline)	1.22 (0.94-1.59)	0.90 (0.80-1.00)	**0.28 (0.24-0.32)**	1.09 (0.87-1.38)	0.62 (0.39-1.01)
ADL CAP 2 (Facilitate improvement)	1.20 (0.92-1.56)	0.72 (0.64-0.80)	**0.22 (0.19-0.25)**	**0.16 (0.13-0.20)**	0.89 (0.55-1.44)
CHESS 1-2 vs. 0	0.99 (0.94-1.05)	1.10 (1.07-1.13)	**1.51 (1.43-1.59)**	**0.80 (0.75-0.87)**	1.10 (0.96-1.25)
CHESS 3+ vs. 0	**1.25 (1.02-1.53)**	**1.14 (1.05-1.25)**	**2.60 (2.27-2.96)**	**0.72 (0.59-0.89)**	1.50 (0.92-2.44)
Cognitive Performance Scale 1-2 vs. 0	**0.72 (0.68-0.76)**	**1.06 (1.02-1.11)**	0.96 (0.88-1.04)	**0.85 (0.77-0.93)**	**0.63 (0.55-0.73)**
Cognitive Performance Scale 3-4 vs. 0	**0.41 (0.38-0.44)**	**1.48 (1.42-1.54)**	**1.11 (1.02-1.22)**	**0.81 (0.72-0.90)**	0.43 (0.36-0.51)
Cognitive Performance Scale 5-6 vs. 0	**0.26 (0.21-0.32)**	**2.16 (2.01-2.31)**	**1.44 (1.24-1.67)**	1.00 (0.81-1.23)	**0.58 (0.39-0.84)**
Depression Rating Scale 1-2 vs. 0	0.95 (0.90-1.00)	**1.04 (1.01-1.07)**	**1.08 (1.02-1.15)**	1.07 (0.95-0.90)	1.00 (0.82-1.06)
Depression Rating Scale 3 vs. 0	0.93 (0.88-0.99)	**1.07 (1.04-1.10)**	**1.07 (1.00-1.14)**	1.10 (0.93-0.88)	0.99 (0.86-1.16)
ISE 1-2 vs. 0	1.14 (0.97-1.34)	**0.89 (0.84-0.94)**	**0.83 (0.74-0.94)**	**0.72 (0.61-0.85)**	1.01 (0.72-1.43)
ISE 3-4 vs. 0	**1.29 (1.10-1.51)**	**0.77 (0.73-0.82)**	**0.62 (0.55-0.69)**	**0.60 (0.51-0.71)**	0.96 (0.68-1.34)
ISE 5-6 vs. 0	**1.42 (1.21-1.66)**	**0.66 (0.62-0.70)**	**0.45 (0.40-0.51)**	**0.53 (0.45-0.63)**	0.89 (0.63-1.25)
Pain Scale 1-2 vs. 0	**1.07 (1.03-1.13)**	**0.97 (0.95-0.99)**	**1.11 (1.06-1.17)**	1.05 (0.98-1.13)	1.06 (0.55-1.20)
Pain Scale 3+ vs. 0	1.14 (0.95-1.36)	0.95 (0.86-1.05)	**1.37 (1.15-1.64)**	1.08 (0.85-1.38)	1.16 (0.77-1.74)
C. Clinical Items					
Hearing: Minimal difficulty	1.00 (0.95-1.05)	0.98 (0.96-1.01)	1.00 (0.95-1.06)	0.98 (0.91-1.06)	0.89 (0.77-1.02)
Hearing: In Special Situations Only	1.03 (0.95-1.11)	**0.93 (0.90-0.97)**	0.99 (0.92-1.07)	1.01 (0.90-1.12)	0.92 (0.76-1.13)
Hearing: Highly Impaired	0.87 (0.70-1.08)	1.00 (0.91-1.09)	1.15 (0.97-1.37)	0.97 (0.73-1.29)	0.78 (0.45-1.37)
Vision: Impaired	**0.87 (0.82-0.91)**	**1.06 (1.03-1.08)**	1.01 (0.96-1.07)	1.06 (0.99-1.15)	1.00 (0.87-1.13)
Vision: Moderately Impaired	0.90 (0.81-1.00)	**1.10 (1.05-1.15)**	1.06 (0.96-1.17)	0.94 (0.81-1.09)	1.09 (0.85-1.40)

Vision: Highly Impaired	0.87 (0.74-1.03)	**1.12 (1.04-1.20)**	**1.21 (1.04-1.40)**	1.07 (0.86-1.33)	0.98 (0.66-1.46)
Vision: Severely Impaired	**0.51 (0.38-0.68)**	**1.18 (1.05-1.31)**	0.93 (0.73-1.19)	0.76 (0.52-1.11)	1.10 (0.66-1.82)
Fall 30 days	**0.92 (0.85-0.99)**	**1.35 (1.31-1.39)**	**1.37 (1.28-1.47)**	**0.77 (0.70-0.84)**	**1.31 (1.11-1.54)**
Hip fracture 180 days	1.02 (0.83-1.25)	**0.86 (0.78-0.96)**	**0.68 (0.52-0.89)**	**0.39 (0.27-0.56)**	**1.85 (1.31-2.62)**
Unsteady Gait	**0.84 (0.80-0.88)**	**1.12 (1.09-1.14)**	**1.09 (1.03-1.14)**	0.98 (0.92-1.05)	**0.87 (0.78-0.98)**
Rehab potential	**0.85 (0.80-0.89)**	**0.89 (0.87-0.91)**	**0.78 (0.73-0.82)**	**0.84 (0.78-0.91)**	1.10 (0.97-1.23)
D. Diagnosis					
Alzheimer/Other Dementia	**0.88 (0.84-0.92)**	**1.04 (1.02-1.07)**	**0.84 (0.79-0.88)**	**0.79 (0.73-0.85)**	**0.58 (0.51-0.66)**
Cancer	**0.87 (0.80-0.94)**	1.02 (0.98-1.06)	**1.45 (1.35-1.55)**	**1.11 (1.01-1.23)**	0.93 (0.78-1.12)
COPD	**1.06 (1.00-1.12)**	0.99 (0.96-1.02)	**1.28 (1.21-1.36)**	**1.24 (1.15-1.35)**	0.91 (0.79-1.06)
Heart Failure	0.96 (0.90-1.02)	**1.09 (1.05-1.13)**	**1.57 (1.48-1.67)**	**1.54 (1.42-1.68)**	0.86 (0.72-1.03)
Hemi/Paraplegia	**0.66 (0.53-0.82)**	**1.11 (1.01-1.22)**	1.00 (0.80-1.25)	0.80 (0.60-1.08)	1.01 (0.66-1.54)
Parkinson	**0.79 (0.70-0.89)**	**1.38 (1.31-1.46)**	0.98 (0.85-1.12)	**0.84 (0.70-0.99)**	0.92 (0.71-1.20)
Pneumonia	1.19 (0.97-1.47)	0.93 (0.84-1.04)	**1.36 (1.14-1.63)**	0.87 (0.69-1.10)	0.76 (0.40-1.43)
Renal Failure	1.02 (0.95-1.09)	1.04 (1.00-1.07)	**1.30 (1.22-1.40)**	**1.21 (1.10-1.32)**	1.09 (0.91-1.30)
Schizophrenia	0.97 (0.85-1.11)	**0.79 (0.74-0.85)**	**0.79 (0.65-0.95)**	0.82 (0.66-1.02)	**0.52 (0.34-0.78)**
stroke	1.02 (0.96-1.09)	**1.05 (1.02-1.09)**	1.05 (0.98-1.12)	1.02 (0.93-1.11)	1.07 (0.92-1.25)
Urinary Tract Infection	**0.88 (0.79-0.99)**	**1.14 (1.08-1.20)**	1.06 (0.95-1.19)	1.00 (0.86-1.15)	1.00 (0.77-1.30)
E. Treatment					
Med count	**1.00 (1.00-1.01)**	**1.01 (1.01-1.02)**	**1.02 (1.02-1.03)**	**1.04 (1.03-1.04)**	0.98 (0.97-1.00)
New Med 90 days vs. None	1.00 (0.95-1.05)	**0.97 (0.95-0.99)**	1.01 (0.96-1.07)	0.98 (0.91-1.05)	0.99 (0.88-1.12)
New Med 90 days unknown vs. None	**1.19 (1.11-1.28)**	**0.95 (0.92-0.99)**	**0.89 (0.81-0.98)**	0.91 (0.81-1.02)	0.88 (0.75-1.03)
OT days	1.06 (0.99-1.14)	**1.07 (1.04-1.10)**	**1.13 (1.02-1.25)**	1.04 (0.86-1.25)	**1.35 (1.09-1.67)**
PT Days	0.99 (0.97-1.01)	**1.01 (1.00-1.02)**	1.00 (0.95-1.05)	**0.83 (0.80-0.87)**	**1.20 (1.15-1.25)**
Physician visit	**0.91 (0.87-0.96)**	0.99 (0.97-1.02)	1.04 (0.99-1.10)	**1.10 (1.02-1.19)**	0.94 (0.82-1.06)
F. Facility Attribute					
Facility Location Urban	**1.36 (1.28-1.44)**	**0.93 (0.90-0.96)**	**1.09 (1.01-1.17)**	**0.87 (0.79-0.96)**	1.01 (0.86-1.18)
Facility size L vs. S	**0.74 (0.63-0.87)**	0.93 (0.85-1.02)	**0.73 (0.63-0.86)**	1.27 (0.92-1.74)	1.23 (0.74-2.04)
Facility size M vs. S	**0.76 (0.65-0.90)**	1.02 (0.93-1.12)	**0.83 (0.71-0.97)**	1.27 (0.92-1.75)	1.30 (0.78-2.15)
Alberta vs. Ontario	**0.91 (0.84-0.98)**	**1.15 (1.11-1.19)**	**2.10 (1.94-2.27)**	**0.85 (0.76-0.96)**	1.04 (0.86-1.26)
British Columbia vs. Ontario	**1.16 (1.10-1.24)**	**0.78 (0.76-0.81)**	**2.26 (2.11-2.41)**	**1.26 (1.15-1.38)**	**0.42 (0.35-0.50)**

D.2c: Adjusted odds of transition to other ADL and Absorbing states from moderate/severely impaired ADL state

VARIABLE	ONE	TWO	DEATH	HOSPITAL	HOME
A. Demography					
Female	1.00 (0.91-1.10)	0.99 (0.96-1.02)	**0.74 (0.73-0.75)**	**0.65 (0.63-0.66)**	0.98 (0.91-1.05)
Age 75-84	0.89 (0.78-1.01)	0.96 (0.93-1.00)	**1.39 (1.35-1.42)**	**1.04 (1.00-1.08)**	**0.83 (0.75-0.91)**
Age 85-94	**0.77 (0.67-0.88)**	**0.90 (0.86-0.94)**	**2.02 (1.97-2.07)**	**1.05 (1.01-1.09)**	**0.65 (0.59-0.72)**
Age 95+	**0.42 (0.33-0.54)**	**0.73 (0.69-0.78)**	**2.68 (2.59-2.77)**	0.94 (0.88-1.00)	**0.58 (0.49-0.69)**
Married	**0.80 (0.71-0.90)**	**0.85 (0.83-0.88)**	**0.94 (0.93-0.96)**	**0.96 (0.93-0.98)**	**1.48 (1.37-1.61)**
B. Clinical Severity Scales					
ADL CAP 1 (Prevent decline)	**2.03 (1.41-2.90)**	**2.83 (2.53-3.16)**	**0.37 (0.37-0.38)**	**0.22 (0.21-0.23)**	**0.74 (0.65-0.85)**
ADL CAP 2 (Facilitate improvement)	**2.43 (1.71-3.47)**	**2.94 (2.63-3.28)**	**0.34 (0.33-0.35)**	**1.30 (1.25-1.36)**	**0.43 (0.37-0.49)**
CHESS 1-2 vs. 0	1.03 (0.93-1.13)	**0.96 (0.93-0.99)**	**1.74 (1.71-1.77)**	**0.84 (0.82-0.86)**	1.06 (0.98-1.15)
CHESS 3+ vs. 0	**1.54 (1.24-1.90)**	**1.18 (1.11-1.27)**	**4.68 (4.57-4.80)**	**1.13 (1.07-1.18)**	**2.49 (2.13-2.90)**
Cognitive Performance Scale 1-2 vs. 0	**0.55 (0.49-0.62)**	**0.93 (0.89-0.97)**	**1.05 (1.01-1.09)**	**0.88 (0.84-0.92)**	**0.63 (0.57-0.71)**
Cognitive Performance Scale 3-4 vs. 0	**0.19 (0.16-0.22)**	**0.54 (0.51-0.57)**	**1.29 (1.24-1.33)**	**0.88 (0.84-0.93)**	**0.51 (0.45-0.37)**
Cognitive Performance Scale 5-6 vs. 0	**0.05 (0.04-0.07)**	**0.19 (0.17-0.20)**	**1.26 (1.21-1.31)**	**0.71 (0.67-0.76)**	**0.42 (0.36-0.49)**
Depression Rating Scale 1-2 vs. 0	0.91 (0.82-1.01)	**0.94 (0.91-0.96)**	**0.97 (0.95-0.99)**	**0.88 (0.86-0.91)**	**0.86 (0.79-0.93)**
Depression Rating Scale 3 vs. 0	**0.81 (0.72-0.90)**	**0.89 (0.86-0.92)**	**0.94 (0.92-0.95)**	**0.79 (0.77-0.82)**	**0.79 (0.72-0.86)**
ISE 1-2 vs. 0	**1.32 (1.01-1.73)**	**1.20 (1.12-1.28)**	**0.76 (0.75-0.78)**	**0.90 (0.87-0.94)**	**0.78 (0.69-0.89)**
ISE 3-4 vs. 0	**1.86 (1.43-2.41)**	**1.51 (1.42-1.61)**	**0.56 (0.55-0.57)**	**0.77 (0.73-0.80)**	**0.77 (0.68-0.87)**
ISE 5-6 vs. 0	**2.38 (1.82-3.11)**	**1.93 (1.80-2.06)**	**0.42 (0.41-0.43)**	**0.65 (0.62-0.69)**	**0.76 (0.66-0.88)**
Pain Scale 1-2 vs. 0	1.05 (0.96-1.15)	1.00 (0.98-1.03)	**1.24 (1.22-1.26)**	**1.04 (1.01-1.06)**	1.02 (0.95-1.10)
Pain Scale 3+ vs. 0	**1.64 (1.32-2.04)**	**1.16 (1.06-1.26)**	**1.63 (1.56-1.70)**	**1.16 (1.07-1.26)**	1.08 (0.86-1.37)
C. Clinical Items					
Hearing: Minimal difficulty	0.98 (0.88-1.09)	0.99 (0.96-1.02)	**1.03 (1.01-1.04)**	0.97 (0.95-1.00)	0.94 (0.86-1.02)
Hearing: In Special Situations Only	1.05 (0.91-1.21)	0.99 (0.95-1.03)	**1.05 (1.03-1.07)**	**0.94 (0.90-0.97)**	0.98 (0.88-1.09)
Hearing: Highly Impaired	1.26 (0.89-1.79)	**1.12 (1.01-1.23)**	1.02 (0.98-1.07)	**0.86 (0.78-0.94)**	**0.64 (0.46-0.88)**
Vision: Impaired	**0.77 (0.69-0.85)**	**0.85 (0.83-0.88)**	**1.02 (1.00-1.04)**	**1.05 (1.02-1.08)**	0.94 (0.87-1.02)
Vision: Moderately Impaired	**0.64 (0.52-0.79)**	**0.80 (0.76-0.85)**	**1.09 (1.07-1.12)**	1.03 (0.99-1.08)	0.98 (0.86-1.12)
Vision: Highly Impaired	**0.66 (0.50-0.88)**	**0.65 (0.60-0.70)**	**1.19 (1.16-1.22)**	1.03 (0.98-1.08)	**1.27 (1.10-1.46)**
Vision: Severely Impaired	**0.33 (0.20-0.56)**	**0.73 (0.66-0.82)**	**1.19 (1.14-1.24)**	0.93 (0.85-1.01)	1.02 (0.79-1.30)
Fall 30 days	**1.29 (1.18-1.41)**	**1.37 (1.34-1.41)**	**0.71 (0.70-0.72)**	**0.81 (0.79-0.83)**	0.99 (0.93-1.07)
Hip fracture 180 days	1.05 (0.94-1.18)	**0.91 (0.88-0.94)**	**1.07 (1.05-1.09)**	**0.67 (0.65-0.69)**	**1.23 (1.12-1.34)**
Unsteady Gait	1.21 (0.93-1.49)	1.01 (0.94-1.08)	**0.79 (0.75-0.82)**	**0.77 (0.72-0.82)**	**1.27 (1.06-1.51)**
Rehab potential	**1.34 (1.22-1.48)**	**1.41 (1.37-1.45)**	**0.67 (0.66-0.69)**	**0.83 (0.20-0.86)**	**1.23 (1.13-1.34)**

D. Diagnosis					
Alzheimer/Other Dementia	0.99 (0.90-1.10)	**1.16 (1.13-1.20)**	**0.83 (0.82-0.85)**	**0.81 (0.79-0.83)**	**0.73 (0.67-0.79)**
Cancer	**0.83 (0.72-0.96)**	**0.94 (0.91-0.98)**	**1.29 (1.26-1.31)**	**1.06 (1.02-1.10)**	**0.74 (0.65-0.83)**
COPD	**1.23 (1.11-1.37)**	**1.14 (1.11-1.18)**	**1.22 (1.19-1.24)**	**1.25 (1.21-1.29)**	1.04 (0.95-1.14)
Heart Failure	**0.87 (0.77-0.97)**	**0.92 (0.88-0.95)**	**1.32 (1.29-1.34)**	**1.39 (1.35-1.43)**	1.03 (0.93-1.14)
Hemi/Paraplegia	**0.25 (0.18-0.35)**	**0.36 (0.32-0.39)**	**0.87 (0.85-0.90)**	**0.93 (0.88-0.98)**	0.96 (0.83-1.11)
Parkinson	**0.40 (0.32-0.49)**	**0.58 (0.55-0.61)**	**1.11 (1.08-1.14)**	**0.92 (0.88-0.96)**	0.95 (0.84-1.07)
Pneumonia	1.23 (0.95-1.60)	0.95 (0.87-1.04)	**1.37 (1.32-1.41)**	**1.32 (1.25-1.39)**	**1.27 (1.02-1.58)**
Renal Failure	0.94 (0.82-1.07)	0.99 (0.95-1.03)	**1.23 (1.21-1.26)**	**1.33 (1.28-1.37)**	1.04 (0.93-1.15)
Schizophrenia	1.11 (0.82-1.50)	**1.33 (1.23-1.45)**	**0.83 (0.78-0.88)**	**1.14 (1.05-1.24)**	**0.67 (0.49-0.92)**
stroke	**0.76 (0.67-0.85)**	**0.81 (0.79-0.84)**	**1.01 (1.00-1.03)**	**1.05 (1.02-1.08)**	0.99 (0.91-1.08)
Urinary Tract Infection	**0.64 (0.53-0.77)**	**0.83 (0.79-0.87)**	1.00 (0.97-1.02)	**1.15 (1.11-1.20)**	0.90 (0.78-1.02)
E. Treatment					
Med count	1.00 (0.99-1.01)	**0.98 (0.98-0.99)**	**1.00 (1.00-1.00)**	**1.03 (1.03-1.04)**	**0.98 (0.97-0.99)**
New Med 90 days vs. None	**1.31 (1.19-1.45)**	**1.10 (1.07-1.13)**	**1.16 (1.14-1.17)**	**1.05 (1.03-1.08)**	0.97 (0.90-1.04)
New Med 90 days unknown vs. None	**1.42 (1.24-1.62)**	**1.09 (1.04-1.13)**	**0.95 (0.92-0.98)**	0.95 (0.90-1.00)	0.90 (0.81-1.00)
OT days	**0.84 (0.76-0.94)**	0.97 (0.92-1.01)	**0.92 (0.90-0.94)**	**0.94 (0.89-0.99)**	1.01 (0.94-1.08)
PT Days	**0.92 (0.89-0.95)**	**0.91 (0.90-0.92)**	**0.98 (0.96-0.99)**	**0.90 (0.88-0.91)**	**1.12 (1.09-1.14)**
Physician visit	0.90 (0.82-1.00)	**0.95 (0.92-0.98)**	**1.09 (1.07-1.11)**	**1.14 (1.10-1.17)**	0.94 (0.87-1.03)
F. Facility Attribute					
Facility Location Urban	**1.82 (1.62-2.04)**	**1.35 (1.30-1.40)**	**1.13 (1.11-1.15)**	**0.86 (0.83-0.90)**	1.08 (0.96-1.20)
Facility size L vs. S	0.80 (0.58-1.12)	**0.85 (0.76-0.95)**	**0.86 (0.81-0.91)**	**1.54 (1.29-1.83)**	1.22 (0.83-1.80)
Facility size M vs. S	0.76 (0.54-1.06)	**0.88 (0.79-0.98)**	1.01 (0.95-1.07)	**1.40 (1.18-1.67)**	0.97 (0.66-1.44)
Alberta vs. Ontario	**0.70 (0.60-0.82)**	0.96 (0.93-1.00)	**1.16 (1.13-1.18)**	**0.60 (0.57-0.62)**	**0.85 (0.75-0.95)**
British Columbia vs. Ontario	**2.26 (2.00-2.55)**	**1.66 (1.60-1.72)**	**1.38 (1.35-1.41)**	0.97 (0.93-1.01)	**0.67 (0.59-0.76)**