8-15-2022 9:30 AM

The Investigation of Prosthetic Rehabilitation Outcomes Following a Lower Limb Amputation in the Oldest Old

Ashvene Sureshkumar, *The University of Western Ontario*

Supervisor: Hunter, Susan W., *The University of Western Ontario*
A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Health and Rehabilitation Sciences

Abstract

This thesis sought to investigate the changing characteristics of people with lower limb amputations (LLAs) who participate in prosthetic rehabilitation programs and evaluate an under-investigated subgroup; the oldest old (aged 80 years and older). Study 1 included 601 consecutive admissions to a Canadian prosthetic rehabilitation program from 2012 to 2019. Although participant's age did not increase at admission over time, individuals presented with a higher number of comorbidities each year. Participants were admitted from amputation surgery faster over time. Study 2 assessed functional prosthetic rehabilitation outcomes for the oldest old against participants aged 50 to 79 years old. Despite the oldest old having reduced balance confidence compared to all other age groups, they demonstrated similar potential for walking ability. These findings show that the participant profile is changing for individuals accepted for prosthetic rehabilitation, and advanced age alone should not be a disqualifying factor for admission to these programs.

Keywords: *lower limb amputation, prosthetic rehabilitation, aged 80 and over*

Lay Summary

More people are expected to have lower limb amputations at advanced ages due to population aging and an increase in conditions such as diabetes and peripheral vascular disease. People aged 80 years old and older (oldest old) are part of the fastest-growing age group in Canada, yet most of the current amputee literature fails to consider the oldest old as a separate group. Prosthetic rehabilitation programs allow people to become trained in walking with their prosthetic limb, which is the main contributing factor to quality of life in this population. While these programs aim to improve function, progress may be negatively affected by the multiple health issues present in advanced age groups. It is therefore important to understand the impact of advanced age on prosthetic rehabilitation outcomes to maximize gains related to walking and quality of life. The objective of Study 1 was to evaluate how the population has changed over time at admission to prosthetic rehabilitation programs. Study 1 found that while participants did not get older at admission to prosthetic rehabilitation over time, individuals had an increased number of health issues each year at admission. Further, the time period between amputation surgery and admission to the program became shorter each year. Study 2 compared functional outcomes (i.e., endurance) of the oldest old participants to younger groups aged 50 to 79 years old. The oldest old had similar potential for ability to walk with a prosthesis as individuals aged 60 and older but had lower confidence in performing activities without losing their balance. These studies provide novel insight into the changing needs of individuals with limb loss who participate in prosthetic rehabilitation and the oldest old group specifically. These projects give clinicians a better understanding of the relationship between age and prosthetic rehabilitation outcomes, which is important for service delivery.

.

Acknowledgements

I would like to express my deepest gratitude to my supervisor Dr. Susan Hunter. Thank you for your endless commitment to my learning and for providing the support and encouragement to realize my potential as a researcher. You have always invested in my growth and continuously challenged me to think critically. I would not have been able to accomplish what I have without your mentorship.

Thank you to all my peers in the Mobility in Aging Lab. To Humberto, for your guidance and positive energy. To Eddy and Tony, for your words of encouragement and advice. Thank you, Kristin, for you have been my ultimate big sister, taking me under your wing and teaching me all that you could.

I am grateful to Dr. Payne and Dr. Viana for their guidance, feedback, and wisdom. Thank you to the participants and the entire amputee rehabilitation team at Parkwood Institute. This work would not be possible without your support.

Thank you to my dear friends in Full House (Kayla, Grace, Matthew, Michael, Chloe, Lily, Litsa, Alex, and Isabella) for watching endless Cillian Murphy movies with me. Jalen, thank you for your compassion and friendship. Thank you to Megan, Jill, and Del for our roommate extravaganzas and Taylor Swift parties. Special thanks to my brilliant pianist Joshua for sending me beautiful instrumentals to listen to while writing this thesis. Your love and motivation have meant the world. I would like to thank my parents (Amma and Appa), brother (Thumbi), and sister (Ashvigaa) for their unconditional love and support as I pursue my dreams. I am forever indebted to the sacrifices you have made for me. Finally, thank you to my Bella.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

2MWT: 2-Minute Walk Test

6MWT: 6-Minute Walk Test

ABC: Activities-specific Balance Confidence scale

ANOVA: Analysis of Variance

BMI: Body Mass Index

CI: Confidence Interval

CLI: Critical Limb Ischemia

FCI: Functional Comorbidity Index

LLA: Lower Limb Amputation

L-Test: The L-Test of Functional Mobility

MCI: Mild Cognitive Impairment

MoCA: Montreal Cognitive Assessment Score

PVD: Peripheral Vascular Disease

PTSD: Post-Traumatic Stress Disorder

SCS: Socket Comfort Score

SD: Standard Deviation

TF: Transfemoral

TT: Transtibial

TUG: Timed Up and Go

CHAPTER 1:

1.1 Introduction

People acquire lower limb amputations (LLAs) primarily due to complications of chronic conditions such as diabetes and/or peripheral vascular disease (PVD).[1] The goal of an LLA is to address underlying tissue damage, provide a mechanism to maximize functional mobility to regain independence and improve quality of life.[2] Individuals with an LLA experience complex physical and psychological challenges that require support throughout recovery.[1,2] They may be referred and accepted to a prosthetic rehabilitation program depending on their post-amputation medical status and motivation for independently walking with a prosthesis.[3] Prosthetic rehabilitation programs provide education and training on prosthesis use, independent ambulation, and performance of activities of daily living.[3,4]

The number of LLAs performed is predicted to increase in part due to the rising rates of diabetes and PVD, which account for over 80% of all LLAs.[1] These conditions are especially prevalent in older age groups (65 years and older).[5] The fastest-growing age group globally are people aged 80 and over (the oldest old) due to the population aging phenomenon.[6] It is expected that this age group will comprise a higher percentage of the LLA population in the future as the population continues to increase in age while the rate of chronic conditions contributing to an LLA rise.[1,6,7] Prosthetic rehabilitation programs are most effective when the needs of people with LLAs are considered.[3] This requires an understanding of how the characteristics of people with an LLA are changing over time as it relates to important demographic factors such as age and types of comorbidities. Recent demographic changes have not been comprehensively assessed for the Canadian LLA population.

The oldest old group of people with LLAs experience a significant health burden as they often have multiple comorbidities across physical and psychological domains.[6,7] These present distinct challenges to the prosthetic rehabilitation process in terms of making functional mobility gains.[6,7] However, rehabilitation outcomes for the oldest old group specifically are largely unknown. Instead, current amputee literature has only investigated their outcomes while grouped with those aged 65 and older.[7,8] Older age groups experience health challenges at different levels, and this must be accounted for when evaluating the oldest old LLA group.[6] Our healthcare system will have challenges providing care for this population if their rehabilitation outcomes remain uncontextualized against other age groups.

The first objective of this research project was to evaluate the changing demographic characteristics of the LLA population at admission to a prosthetic rehabilitation program. The second objective was to investigate the prosthetic rehabilitation outcomes of the oldest old group of people with LLAs comparatively against younger groups.

1.2 Lower Limb Amputation

An LLA is an invasive procedure involving the surgical removal of a portion or multiple portions of the lower limb.[2] An LLA is often preceded by years of attempts to salvage the limb through extensive wound care, bypass surgery or stenting.[4,8] An amputation is typically performed as a life-saving procedure when the limb is presumed non-salvageable due to a disease process and/or traumatic injury.[9] Although it is an emotionally and physically demanding process, an LLA may be considered an opportunity for returning the person to a better health status and higher functional level.[2,9]

For the objectives of this paper, only major LLAs will be considered. A major LLA consists of the partial or complete surgical removal of the lower limb proximal to the ankle and includes both transtibial (TT) and transfemoral (TF) level amputations.[10] A TT amputation is performed below-the-knee by cutting through the tibia bone and smaller fibula bone, while a TF amputation occurs above-the-knee through the femur.[2,10] Necrotic tissue viability, wound severity, restoration of function and prosthetic options are important factors considered when determining the level of amputation.[2,4] A TF amputation is associated with increased morbidity and decreased rehabilitation potential.[2,11,12] This is in part due to the presence of a higher number of comorbidities in people with a TF level amputation.[13] Similarly, people with bilateral LLAs generally have lower functional mobility outcomes and report decreased quality of life.[4,14]

1.2.1 LLA Epidemiology

A total of 44,430 LLAs were performed in Canada between 2006 and 2011, accounting for approximately 7,405 new LLAs annually.[11] More than 50% of these were performed in people aged 50 to 74 years old at the TT level.[11,15] The number of absolute LLAs is expected to increase in part due to the rising prevalence of dysvascular conditions (e.g., diabetes and PVD) which is the primary etiology.[16,17] Importantly, people are living longer with these chronic conditions, further driving the rates of LLAs performed.[18,19] Overall, the number of people living with an LLA worldwide is expected to double by the year 2050.[18,20,21]

The average age of people with new LLAs is approximately 65 years old in Canada, and the risk of acquiring an LLA increases with age and the presence of multiple comorbidities.[11,22,23] This is due to dysvascular etiology and multiple comorbidities being highly prevalent in older age groups.[11,23] Relevant comorbidities include: hypertension, kidney disease, osteoarthritis, anxiety, and depression.[24] These comorbidities present distinct challenges throughout diagnosis, treatment and recovery as they often exacerbate each other.[25] Men have a higher probability of receiving an LLA than women, and women who acquire an LLA are approximately 8 years older on average.[26] This is consistent with findings that the number of reconstructive or limb-salvage attempts prior to an LLA is lower in women.[22,26] It is possible that women are undertreated for dysvascular conditions due to misdiagnosis and/or differential treatment of symptoms based on sex.[27] Men are additionally at a higher risk for dysvascular conditions due to heightened risk factors such as obesity, alcohol consumption and smoking.[26]

1.2.1.1 Diseases Leading to an LLA

As already mentioned, diabetes and PVD are dysvascular conditions that represent the most common etiology for LLAs in Canada, accounting for over 80% of all amputations.[19] This is consistent with findings that the average person with an LLA is older, since dysvascular disease is common in older adults.[11,19,23] It is expected that the prevalence of dysvascular disease will increase due to the predicted growth of the proportion of people aged 65 and older.[28,29]

Almost 12 million Canadians are currently living with diabetes or pre-diabetes.[28] The global prevalence of diabetes for all age-groups is estimated to be 4.4% by the year 2030, almost double the rate from 2000 (2.8%).[28,30] Chronic diabetes can ultimately lead to an LLA due to poor or unsuccessful management of complications.[30] The most common complication is diabetic neuropathy, a type of nerve damage that causes numbness and weakness in the legs.[31,32] Circulation issues are associated with slow wound healing, which is exacerbated by the loss of protective sensation in the foot.[31] Individuals may continue to ambulate on an infected foot, unaware of worsening infections.[31,32] People who present with diabetes-related deep compartment abscess, extensive foot gangrene and/or sepsis often require a major LLA.[32] Acquiring a new LLA is 20 times more common in people living with diabetes compared to people living without the condition.[32,33]

The risk of developing PVD is higher in people diagnosed with diabetes and increases with age.[34,35] People aged 80 and over are the highest risk population, with a greater than 20% chance of developing PVD.[36] Importantly, these older age groups are also likely to have a high number of other comorbidities, contributing to complex symptomology.[36,37] PVD causes restriction of blood flow in the legs and about 33% of people with PVD develop vascular claudication.[36] This is characterized by a tight squeezing pain in muscles of the leg that typically presents with activity and improves with rest.[36-38] People who report frequent episodes of vascular claudication are at risk for developing critical limb ischemia (CLI), which occurs when the reduction in blood flow to the lower extremity reaches a threshold that threatens viability of the limb.[39-41] While revascularization attempts are made in 90% of people with CLI, 20-30% will ultimately undergo limb loss.[41]

Non-dysvascular causes of an LLA include traumatic injury and cancer. An LLA due to trauma is the most common etiology after dysvascular causes, making up about 10-20% of all cases.[41] In Canada, a total 2,679 trauma-related LLAs were performed from 2006 to 2011.[11] Traumatic causes include motor vehicle collisions, workplace injury, and high-voltage electrical burns, which may lead to an LLA due to extensive and irreparable damage of the lower limb.[42] Cancer and tumor-related amputations are generally uncommon, only accounting for about 3.0% of LLAs in Canada and 0.8% worldwide.[43] Younger age groups (10-20 years old) are more likely to have an LLA due to this etiology and tend to live longer with limb loss compared to older age groups with dysvascular causes.[43,44] Cancer and tumor-related amputations are usually preceded by attempts to remove the tumor through chemotherapy, radiation and/or other non-amputation surgical procedures.[45]

1.3 Rehabilitation After a Lower Limb Amputation

1.3.1. Acute Post-Surgical Phase

The acute post-surgical phase of LLA rehabilitation immediately after surgery involves wound healing, pain control and emotional support.[21] Prediction of the extent of healing for a person with a recent LLA can be difficult and requires comprehensive post-operative care, tissue perfusion, and surgical technique.[2,4] Post-operative dressings are critical during this phase and unique to the individual's amputation incision. They are used to reduce the risk of infection, decrease edema (swelling), and shape the residual limb.[4,14] Adequate wound care and pain control has been shown to contribute to better baseline functioning prior to entering mobility focused rehabilitation.[2,4,14]

The multiple disease processes that may lead to an LLA contribute to the occurrence of complications and recovery considerations post-surgery. For example, prognosis following a major LLA due to CLI is particularly poor, with increased chances of mortality compared to those who did not report CLI.[2] These rates are especially high for people aged 70 and older, with a 44% chance of mortality within 1 year of an LLA.[46] Wound healing for people with dysvascular etiology is typically slower due to poor circulation, which also increases the chances for infection during the acute phase.[2,47] This is particularly seen in older people with an LLA as dysvascular conditions are more prevalent amongst this group.[2,4] People with traumatic LLAs often have an increased risk of developing anxiety and post-traumatic stress disorder (PTSD) because they are linked with feelings of intense fear from the incident event.[48,49] Undergoing chemotherapy and radiation prior to an LLA results in a higher rate of skin infections post-surgery which contributes to prolonged acute recovery.[4,47,50] Clinicians will account for these challenges and provide resources related to emotional and physical adjustments as preparation for sub-acute rehabilitation.[51]

1.3.2 Pre-Prosthetic Phase

The sub-acute stage of rehabilitation occurs after hospital discharge and involves three phases: pre-prosthetic, prosthetic, and community integration.[51] Individuals face an initial loss of functional mobility after an LLA due to limitations related to ambulating independently and safely in their environment to achieve daily tasks.[47,51] Assistance is provided with residual limb and wound care strategies to alleviate potential medical complications.[47,49]

Complications with wound healing, such as infection, affect the structure of the residual limb which may negatively impact an individual's recovery progress.[47,51,52] Wound healing is typically deemed sufficient approximately 6 to 8 weeks after an LLA, at which point individuals are considered for participation in prosthetic rehabilitation programs (prosthetic phase).[51] As preparation, individuals are encouraged to perform mobilization techniques to move and strengthen the residual limb and associated musculature.[47,52] Examples of mobilization techniques for individuals with an LLA include range of motion and stump strengthening exercises.[52] Inadequate movement of the residual limb for a prolonged duration may lead to deconditioning, which results in functional losses including decreased muscle mass.[47] Declines in muscle mass and strength contribute to range of motion loss, an increased risk for falls and an overall loss of functional independence.[53] Further, individuals with an LLA are effectively non-weight bearing on one side of their body, and this uneven distribution of weight results in poor balance control.[47,51,52] Assessment and progression towards the prosthetic phase may be delayed due to pain issues, difficulties learning positioning techniques, and development of contractures (rigid tightening of muscle, tendons, ligaments and/or skin).[51,52] Reducing the risk of contractures is especially important as the absence of contractures is associated with successful ambulation in the LLA population.[54]

1.3.3 Prosthetic Phase

1.3.3.1 Purpose and Initial Assessment

The prosthetic phase of rehabilitation is multi-faceted and involves an assessment of an individual's motivations and expectations related to walking, prescription of a prosthetic device, transfers, and gait training.[55] A prosthetic device is an artificial limb that is attached to the residual limb at the site of an LLA to facilitate walking.[51,52] Prosthetic rehabilitation programs are administered in a clinical setting where participants reside for the duration of the program.[52] These programs teach participants techniques for walking safely with a prosthesis and adaptive ambulation techniques for community integration.[52,54-56] Apart from walking, individuals may be accepted for the purpose of prosthetic transfer training (i.e. moving from a sit to stand position with a prosthesis).[54] This important component of rehabilitation allows for independent living after discharge and relieves a potential burden for caregivers. The overall goal is to maximize independence with considerations to a participant's lifestyle, expectations, and medical status.[57]

There is no standardized eligibility checklist for accepting participants to a program and assessments may vary across rehabilitation centers as centers may have different resources and/or expertise. Evaluation is more subjective in nature, making it difficult to predict factors that will lead to an acceptance or rejection for an individual into a program.[56,57] Clinicians will generally evaluate physical status (e.g., medical stability, wound healing, and prior functional level), social support, and motivation to use a prosthesis as indicators of a successful candidate.[51,52,56] An individual may also be assessed on cognitive function as they must demonstrate the capacity to learn techniques for walking with a prosthesis.[51] Clinicians must believe that the individual demonstrates potential to successfully complete and ultimately benefit from the program.[52,56] Training plans for the program are most effective when developed together with pre-established goals of the individual and support from a multidisciplinary healthcare team consisting of a physiatrist, physical therapist, and prosthetist at a minimum.[52]

1.3.3.2 Prosthesis Fitting

Prior to commencing prosthetic rehabilitation gait training, a prosthetic device must be prescribed to the individual. The goal of prosthetic prescription is to optimize function which provides a mechanism to restore mobility.[47,51] Clinicians must perform a thorough assessment to ensure that edema is substantially resolved and that the amputation wound has adequately healed.[52] The residual limb may need further shrinking and/or shaping to ensure a better prosthetic fit.[51] Compression socks may be prescribed to facilitate reduction in tissue swelling.[10] Inaccurate assessments or complications at the site of an LLA may lead to difficulties progressing through the prosthetic rehabilitation program as it can make walking with a prosthesis painful.[51,52] Prosthetic devices aim to compensate for lost functionality by providing a mechanism for walking.[47] The basic components of an LLA prosthesis include: a prosthetic foot, pylon, socket, suspension system, and a knee component if required.[55] The prosthetic foot allows for walking by providing a method of propulsive force and creating a base of support while standing.[55] Sockets connect the residual limb to the prosthetic device and relieve pain by distributing pressure equally throughout the residual limb. Sockets may be used in conjunction with liners to relieve pain from daily swelling and compression changes of the residual limb.[55,57]

The residual limb gradually shrinks over the course of a few months of walking with a prosthesis due to consistent weight-bearing forces.[51,58] It is crucial that adjustments to the prosthesis are made throughout the program duration to account for these changes to maximize rehabilitation potential of the participant. Prosthetic suspension systems keep the residual limb connected to the prosthetic socket, which reduces gait deviations and enhances energy transfers for walking.[57] Knee prosthetic components are essential for people with TF amputations and facilitate both stance and swing control during gait, allowing for precise flexion and extension movements.[51,57] This is an important consideration for older adults with TF amputations since they are at an increased risk for falls compared to individuals with TT amputations.[47,51]

The type of prosthesis prescribed is dependent upon potential to regain functioning, amputation level, and available funding.[52] Prosthetic devices are costly, and it is important that a thorough assessment of functional goals and motivation for walking are performed prior to prescription.[51,52] Participants are instructed to gradually increase wear time and introduce weight-bearing activities to help adapt to the prosthesis.[52] It is important to note that despite being deemed eligible for a program, prosthetic prescription and rehabilitation to learn to use a prosthesis for mobility is not always successful. Although technology for prosthetic components have become advanced throughout the years to accommodate the various complexities of an

LLA, an individual may not demonstrate the capacity to use a prosthesis.[51] Having dysvascular etiology, higher levels of amputation, and advanced age may further complicate prosthetic prescription.[55] Participants may also experience a change in medical status between the time of acceptance into a program and prosthesis fitting, resulting in the person not being fitted with a prosthetic device.[51,57] Clinicians will routinely evaluate prosthesis fit, pain management, and concerns around prosthesis use throughout this phase and changes may be necessary to ensure participants are ready for gait training.[51]

1.3.3.3 Mobility and Gait Training

A prosthetic device can facilitate recovery of functional mobility through gait.[52] Walking ability is the most important factor contributing to quality of life in the LLA population and is therefore a critical outcome of rehabilitation.[58,59] At the outset of commencing training, clinicians will aim to establish baseline functioning. Establishing baseline functioning (e.g., physical and/or psychological characteristics participants present with at admission) gives clinicians an idea of prognostic expectations for successful gains during the program.[47,55] Important baseline factors include types of comorbidities, cognitive functioning, and number of falls since the amputation.[51] These characteristics provide context for creating realistic mobility goals for the participant and informs any adjustments or support that may be required to facilitate these goals.[47,51,56]

Participants are first taught different techniques for effectively donning and doffing the prosthetic device to reduce the risk of skin issues, a potential complication to successful gait training.[51,59] This complication often derives from the soft tissue flap of the residual limb as it does not adapt easily to the increased force of ambulating with a prosthesis and may cause irritation.[51,52] Participants face a variety of gait issues after an LLA including movement asymmetry and changes in force and joint movements.[57] This may contribute to decreased balance, a higher falls risk, and possible chronic complications including degenerative joint disease.[57,59] Maintaining balance control is important for mobility recovery and will improve other aspects of gait training.[47,51] Poor balance may lead to falls, and more than 52% of people with an LLA report a fall each year.[47,60] A subsequent development of a fear of falling has been associated with decreased prosthesis use and limitations in activities of daily living.[47,51,60] Training for balance control with a prosthesis involves ambulating on stable and unstable surfaces and includes fall training and floor recovery as adaptive measures.[52] Muscle strengthening, endurance, and balance training while using a prosthesis further compensates for gait variabilities.[52,57]

Prosthetic rehabilitation is also focused on providing training for walking independently in a community environment depending on individual goals and functional level.[47,52] Participants are encouraged to walk with a prosthesis on uneven surfaces, elevations (i.e., curbs) and during transfers (i.e., moving from a sit to stand position).[52] Gait training is facilitated through a progressive framework with the use of assistive devices such as a walker, crutches, or a cane. [51] As the participant progresses through training, the use of assistive devices is gradually decreased to have the least amount of support that is needed for successful gait.[51,52]

Success of prosthetic rehabilitation and attainment of goals can be assessed using outcome measures. Both performance-based and participant-reported measures should be used to capture the functional status of the participant.[61] Performance-based measures provide information on different domains of functional gains by asking participants to perform a set task. This is often done through obtaining objective measurements (e.g., distance completed in a set amount of time) and comparing them against a pre-established threshold of normative scores.[61,62]

Participant-reported measures provide a subjective assessment of functioning, providing insight into their own feelings about their status and ability.[62]

1.3.3.4 Potential Complications

Progression through an inpatient prosthetic rehabilitation program is not a linear process and may involve multiple re-evaluations of physical and psychological capabilities that will modify a participant's goals.[52] Participants may undergo a formal re-evaluation in the event of a significant change in medical status or if short-term goals are consistently unmet.[57] Higher levels of an LLA require greater energy expenditure from the cardiovascular system for prosthetic gait.[52] This may be challenging for participants who have complex comorbidities such as cardiovascular disease or pulmonary issues.[51,52] These issues are especially pertinent in older adults as they often have multiple comorbidities coincident with an LLA.[52] The presence of multiple comorbidities is also associated with decreased prosthetic mobility in this population.[63] Participants with dysvascular etiology may have persisting symptoms of their condition such as low vision, swelling, and fatigue which can further delay functional mobility gains.[47,51,52] Cognitive impairments make it difficult to conceptualize and perform adaptations to issues encountered in walking with a prosthesis and are therefore associated with decreased prosthesis use and mobility.[64]

These potential complications make it clear that prosthetic rehabilitation programs are best facilitated when curated towards the needs of people with an LLA, and their changing characteristics at admission must be understood to inform rehabilitation goals. It is expected that the number of new LLAs in Canada will increase in the future, resulting in a higher number of people participating in prosthetic rehabilitation programs.[55] However, it is unclear how the characteristics of people with an LLA are changing over time in Canada, especially as demographic and clinical factors are related to various complications impacting successful prosthetic rehabilitation.

1.3.4 Community Integration Phase

The average length of stay at an inpatient prosthetic rehabilitation program in Canada ranges from 3 to 6 weeks before participants are discharged.[47] Community integration is focused on the resumption of roles in the community, performing recreational and/or professional activities, and facilitating coping strategies related to physical and emotional adjustments.[47,55] Discharge destinations are variable and must be planned in accordance with an individual's level of social support and current medical status.[47,51] Participants may be discharged to a long-term care home if they require an advanced level of medical care that may not be possible at home. This may be due to the support required for complex health conditions that coincide with an LLA after an inpatient program.[47] The likelihood of this discharge destination increases with age and higher levels of amputation.[47,57] Being discharged home is considered an indicator of successful prosthetic rehabilitation.[64] This is not only dependent on achieving rehabilitation goals but also involves having an accommodating living arrangement including some level of external support.[52,64]

After discharge, multiple outpatient visits to an amputee clinic are usually required to evaluate ambulation with a prosthesis in a community environment.[47] People with LLAs are still expected to continue to work towards their long-term goals related to walking with a prosthesis.[52,55] Frequent use of the prosthesis throughout daily life is known to be associated with higher levels of function in a community environment and an overall improved quality of life.[65] Stability in both functional status and prosthesis use are typically observed at 2 months post-discharge, while stability in walking ability and quality of life are observed at 6 months post-discharge.[66,67] Clinicians may evaluate prosthesis fit, achievement of activities of daily living, and walking ability during outpatient visits.[51] People with dysvascular etiology are at a greater risk of additional amputation during the first five years after an LLA, and follow-up visits are essential to evaluate and assess for this risk.[47,51]

Prosthetic rehabilitation programs aim to foster a smooth transition into the community environment by teaching people how to safely ambulate or facilitate transfers with a prosthesis.[51] Recovery and rehabilitation after an amputation is a continual process that requires adequate support throughout this stage. It is essential to account for changes in the LLA population to maximize chances for successful long-term rehabilitation.

1.4 The Oldest Old

1.4.1 Evolving Demographic

Worldwide population trends including declining fertility rates and longer life spans contribute to the population aging phenomenon in which people are living longer into later stages of life.[68] As a result, the total number of older adults aged 65 and older is expanding exponentially on a global scale, and their numbers are expected to reach 1.5 billion by 2050.[6,68] An individual who is 65 years or older in North America is predicted to live an additional 17 years on average as of 2020.[68] The fastest-growing age group in Canada are the oldest old, and their numbers are expected to triple over the next 25 years to total 2.5 million.[6,69]

Alongside population aging is the observed rising trend of chronic conditions, which requires ongoing medical care and limits an individual's ability to perform activities of daily living.[6,68] The four most prominent chronic conditions globally are heart disease, cancer, chronic respiratory illness, and diabetes.[6] The oldest old experience a significant burden of chronic disease and many will be living with the consequences over an extended period of time.[6,68,69] Each chronic condition brings about a unique level of complexity to providing care for an individual in relation to their general health, quality of life, and independence.[68-70] Considerations regarding impact of symptomology on overall wellbeing and projections of future risks and/or complications are important in developing an appropriate treatment plan.[70] Older age groups experience a decline in functional health pertaining to their ability to independently perform daily activities.[68] In terms of the oldest old group specifically, more than 25% live in a collective dwelling environment such as a long-term care home or nursing facility.[68] Despite the complex health-related challenges they face, about 60% of the oldest old subjectively report to be in good to excellent health.[68,71] They remain effective contributors to society while striving to maintain autonomy in matters related to their health and well-being.[68] Overall, the oldest old remain an understudied group in terms of health outcomes, and there are limited healthcare policies aimed at supporting this population.[68,70]

The rate of new LLAs is predicted to increase as dysvascular conditions continue to rise in Canada.[11,72] The prevalence of diabetes in Canada is expected to reach 5 million by 2025, and diabetes increases the chances for developing PVD especially in older populations.[13,16] The oldest old are at the highest risk for PVD and are likely to experience complications such as strokes, restricted mobility, and poor wound healing.[13] Although there have been improvements in medical management for these diseases such as advanced limb salvage procedures, an LLA may be necessary to maximize function and quality of life of the individual.[15,68] Older adults who have experienced complications from these conditions over an extended period may require an LLA to preserve functioning by reducing pain and risk of future vascular issues.[13] Approximately 90% of all new LLAs in older age groups can be attributed to dysvascular conditions.[73] Further contributing to the expected increase in new LLAs is the COVID-19 pandemic.[19] Recent studies suggest that isolation measures and delay in healthcare appointments will inevitably lead to older age groups presenting with end stage vascular complications from chronic conditions.[19] PVD is already under-diagnosed in part due to the lack of symptoms in the early stages, and current disruptions in diagnosis and treatment result in a subsequent high risk for an LLA.[19,34] The combination of global population aging, rise in dysvascular conditions, and predicted increase in the rate of new LLAs lead to the expectation that more people will be acquiring LLAs at advanced ages in the future.[13,68-70] The median 5-year survival rate for the oldest old after an LLA is approximately 19 months.

1.4.2 Age and Prosthetic Rehabilitation

Understanding the influence of age on prosthetic rehabilitation outcomes is important as individuals with an LLA will likely be admitted to these programs at advanced ages in the coming years.[68,69] The rapidly evolving aging population elicits concern of its impact on prosthetic prescription, independent ambulation, community re-integration and overall quality of life for people with LLAs.[51,68] It is known that younger age groups (aged 40 years and younger) with an LLA are more likely to be fitted with a prosthesis and perform successfully in prosthetic rehabilitation programs in areas of balance, strength, and endurance.[51,74] These younger age groups typically have traumatic etiology for their LLA and present with a reduced number of comorbidities compared to older age groups.[74] Further, younger individuals often have stronger lower limb musculature to support and ambulate with a prosthesis, which contributes to better balance and range of motion outcomes.[51,52,74]

In contrast, older age groups with an LLA usually experience delayed wound healing due to a decreased inflammatory response, which negatively affects prosthesis fit and comfort.[73] As mentioned previously, advanced age can potentially complicate prosthetic rehabilitation progress as older adults often have multiple comorbidities that make walking with a prosthesis painful.[47,52] The presence of multiple comorbidities increases with age, and most of these comorbidities are chronic conditions that can exacerbate each other.[53,72] For example, heart disease is prevalent in older age groups and is a significant cause of morbidity and mortality in the oldest old specifically.[68,75] Individuals who report heart disease are 2.6 times more likely to develop cognitive issues such as vascular cognitive impairment or vascular dementia.[75] It has also been shown that delirium may be present in older age groups after a surgical procedure. The clinical presentation includes cognitive deficits such as hallucinations and psychomotor disturbances.[76] Walking with a prosthesis requires the integration of various cognitive faculties such as executive functioning and sensory processing to safely execute the movements required.[64] Vascular and cognitive issues present an added challenge to benefiting from prosthetic training and may result in the modification of individual goals for walking.[64] Older adults participating in rehabilitation or receiving care are also at an overall higher risk for reduced self-efficacy (individual's confidence in their ability to perform a task or behaviour).[77] This is an important consideration as self-efficacy has been shown to be intrinsically linked with performing well in prosthetic rehabilitation programs.[77]

Although advanced age has been shown to be associated with decreased function during prosthetic rehabilitation programs, most of the literature does not account for the oldest old LLA group specifically.[79] Prosthetic rehabilitation may potentially improve functional mobility and quality of life for this group, however, distinct challenges relating to physical and cognitive comorbidities must be considered.[73,79] Current amputee literature has not adequately quantified outcomes for the oldest old group of people with LLAs.[79] Further, their prognostic rehabilitation expectations have not been contextualized in relation to other advanced age groups. The specific outcomes of the oldest old LLA group must be critically assessed to improve healthcare services for this population in the future. This will allow prosthetic rehabilitation programs to be better equipped to maximize rehabilitation potential for this group of people with LLAs to ensure a smooth transition back to the community.

CHAPTER 2:

Study 1 - An eight-year analysis of participant characteristics at admission to inpatient prosthetic rehabilitation following a lower limb amputation: A Canadian perspective

2.1 Introduction

About 7,405 new lower limb amputations (LLAs) are performed annually in Canada, the etiology primarily due to complications of dysvascular conditions such as diabetes and peripheral vascular disease (PVD).[11,80] It is predicted that the average age of people receiving a new LLA will increase in the coming years due to the combination of dysvascular disease prevalence and population aging.[80,6] Importantly, it is expected that the oldest old, adults aged 80 years and older, will comprise a larger percentage of the LLA population as they are the fastest growing segment of the aging Canadian population.[6,68,81] There are currently 1.7 million oldest old living in Canada as of 2021, and their numbers are projected to triple by 2036.[82] Additionally, people are living longer with chronic conditions, and this has important implications for the LLA population as it relates to recovery and rehabilitation after a new LLA.[6,7]

Individuals who acquire an LLA must adapt and cope with an altered physical reality and initial loss of independence while awaiting commencement of prosthetic rehabilitation.[82] Prosthetic rehabilitation programs aim to optimize community reintegration following discharge by providing training on prosthesis use, independent ambulation, and achievement of activities of daily living.[55,83] These outcomes directly contribute to overall quality of life for people with an LLA by maximizing independence and participation.[47,55] Prosthetic rehabilitation programs are most effective when demographic variables at the outset of admission can inform rehabilitation goals and prognostic expectations to align with the person's needs.[55,83] For example, the oldest old with an LLA may present with a complicated medical and psychosocial profile at admission due to the presence of multiple comorbidities that can exacerbate each other.[55,84] Importantly, this challenges the healthcare system to provide care for people with LLAs who experience multiple and complex health-related issues.[6,84]

A recent systematic review investigating prosthetic rehabilitation outcomes for the oldest old highlighted that there is limited research on this sub-group of individuals with LLAs.[78] Despite the predicted increase of LLAs and the anticipated subsequent higher percentage of individuals participating in prosthetic rehabilitation, it is not currently known if we are already seeing the changes in the Canadian LLA population over time at admission to these programs.[6,11,68,80] Studies investigating the changing characteristics of this population that included a large sample of the oldest old are further limited.[78,85-87] A thorough analysis is required to assess if there is an increased number of the oldest old being admitted to prosthetic rehabilitation. An evaluation of how the characteristics of people with an LLA have changed over time at admission to prosthetic rehabilitation is imperative to developing and modifying rehabilitation programs that can adequately address the unique needs of the oldest old in the future.

2.1.1 Purpose

The purpose of this study was to: 1) describe participant characteristics at admission and discharge to inpatient prosthetic rehabilitation across an eight-year period and 2) determine how the characteristics of people admitted for prosthetic rehabilitation have changed over time.

2.1.2 Hypotheses

It was hypothesized that people admitted to inpatient prosthetic rehabilitation will be getting older over time and the majority of people will have LLAs for a dysvascular etiology.

2.2 Methodology

2.2.1 Study Design

This was a retrospective chart audit of consecutive admissions to the inpatient prosthetic rehabilitation program from January 1, 2012, to December 31, 2019, at Parkwood Institute in London, Ontario. Chart reviews were completed between July 2021 and October 2021. This study was approved by the Health Sciences Research Ethics Board at the University of Western Ontario and the Clinical Research Impact Committee of Lawson Institute.

2.2.2 Study Population

Admission criteria to be accepted into the inpatient prosthetic rehabilitation program at Parkwood Institute were: aged 18 years or older, medically stable, had clear rehabilitation goals, and were deemed mentally and physically ready to participate in the program through clinical assessment. Individuals must have been cognitively able to engage in rehabilitation and demonstrated the potential to learn. Participants were admitted from home after the amputation incision was adequately healed. Study eligibility criteria were: aged 18 years and older with a unilateral or bilateral transtibial level LLA or above. The oldest old were operationally defined in this study as individuals aged 80 years and older.[6,81] Individuals with bilateral LLAs either had simultaneous amputations or primary amputations prior to 2012. Only first admissions were included in the final analysis (participants were not included more than once).

2.2.3 Outcome Measures

Admission characteristics extracted from participant charts included: age, gender, primary etiology of amputation, body mass index (BMI), amputation type and level, number of falls pre-admission (between amputation surgery and admission), days between amputation surgery and admission, Montreal Cognitive Assessment (MoCA) score[87] and Functional Comorbidity Index (FCI) score[88]. Montreal Cognitive Assessment Score (MoCA) evaluated the global cognitive status of participants and scores ≥ 26 out of 30 were considered cognitively normal while scores 18 to 25 were indicative of mild cognitive impairment (MCI).[87] The FCI scale quantified number of comorbidities based on the presence or absence of 18 diagnoses. One point was assigned to each diagnosis for a theoretical cumulative maximum of 18 points.[88] Participants were assessed across domains of functional mobility, endurance, and balance confidence at discharge from the inpatient program as indicators of how successfully they could ambulate with a prosthesis. Extracted discharge characteristics were: The L-Test of Functional Mobility (L-Test), 2-Minute Walk Test (2MWT), 6-Minute Walk Test (6MWT), Activities-specific Balance Confidence (ABC) scale, length of stay at the inpatient program and Socket Comfort Score (SCS). The SCS is a numerical rating scale for pain that asked participants to rate the comfort of their socket on a scale from 0 (most uncomfortable) to 10 (most comfortable).[89] Assessments took place 1-3 days prior to discharge.

2.2.3.1 Functional Mobility and Endurance Assessments

The L-Test was developed specifically for people with an LLA to assess functional mobility, and is a modified version of the Timed Up and Go (TUG) test.[90] This test was performed through a standardized 20-meter pathway as follows: 1) participant moved from a sit to stand position on the word 'go', 2) walked three metres, 3) performed a 90 degree turn, 4) walked seven meters, 5) performed a 180 degree turn and 6) walked back the same pathway to return to a seated position. (Appendix C) The total time in seconds to complete the test was recorded with a stopwatch to the to the nearest 100th of a second. Shorter times were indicative of better performance. The L-Test has demonstrated excellent interrater and intrarater reliability for clinical use in this population.[90]

The 2MWT and 6MWT are measures of endurance and functional capacity. [91,92] This was assessed by asking participants to walk as far as they could without compromising safety in two and six minutes respectively. The 6MWT was added as part of discharge assessments in 2013 at Parkwood Institute. While both the 2MWT and 6MWT are easy to administer, the 6MWT involves a higher degree of exercise intensity similar to community ambulation.[92] These tests were conducted separately and through standardized verbal instruction. Participants used a 20-meter path where 180-degree turns were made at the end of each path. The distance was recorded in meters to the nearest tenth of a meter. Longer distances are indicative of better performance. The 2MWT and 6MWT have demonstrated excellent validity and reliability for use in people with LLAs.[91,92]

2.2.3.2 Balance Confidence

Balance confidence was assessed using a self-report measure; the Activities-specific Balance Confidence (ABC) scale.[93] (Appendix C) The ABC scale has 16 items of mobility-focused activities of daily living and asks participants to rate how confident they are in completing these activities without losing their balance or becoming unsteady.[93] Participants were asked to rate their confidence on a scale from 0% (no confidence) to 100% (complete confidence) on a visual analog scale. An overall score was calculated based on the average scores across all 16 activities. The ABC scale has demonstrated excellent test-retest reliability and validity in the LLA population.[93]

2.2.4 Statistical Analysis

Participant admission and discharge characteristics and outcome measure assessments were summarized using means and standard deviations (SD) or frequencies and percentages as appropriate. Normality and outlier evaluations for admission and discharge characteristics were performed using the Shapiro-Wilk test, Q-Q plots, box plots and histograms. Values greater than 1.5 times outside the interquartile range were identified as outliers, while values that were greater than 3.0 times outside were deemed extreme outliers. All admission and discharge characteristics were normally distributed, and participants were not removed as outliers. Information for the total sample and the oldest old sub-group were presented across each admission year from 2012 to 2019 for all admission and discharge characteristics.

Multivariable linear regression modelling was used to determine which admission characteristics (independent variables) were associated with being admitted earlier or later during the eight-year study period (dependent variable). The admission characteristics of interest were age (continuous), gender (dichotomous: male, female), amputation type (dichotomous: unilateral, bilateral), amputation level (nominal: transtibial, transfemoral, transtibial and transfemoral, other), primary etiology of amputation (nominal: diabetes, PVD, traumatic, cancer, other), BMI (continuous), MoCA score (continuous), number of falls pre-admission (continuous), FCI (continuous), and days between amputation surgery and admission (continuous). A numerical value of 1 was assigned to the theoretical first day of clinical admissions which specified the start of the study period; January 1, 2012. The time from study commencement was calculated based on the date each participant was admitted to the program up to a theoretical maximum of day 2899 (December 31, 2019). Ten univariate linear regression models were initially performed for each admission characteristic on the dependent variable of admission time. Admission characteristics that were statistically significant ($p<0.05$) in the univariate analysis were incorporated into a final multivariable linear regression model. All linear regression assumptions were met as assessed by regression diagnostics.

All statistical analyses were performed using the IBM SPSS Statistics version 26.0 (IBM Inc., Chicago, IL, USA) and Excel for MacOS. Statistical significance was set at $p<0.05$ for all above-mentioned analyses.

2.3 Results

2.3.1 Admission Characteristics

2.3.1.1 All Inpatient Admissions

A total of 601 participant charts were included outlining admissions to the inpatient prosthetic rehabilitation program during the relevant time frame. (Table 2.1) The highest number of admissions (n=87) was observed in 2012, while the lowest was in 2017 (n=60). The average age of the total sample was 62.3 ± 14.1 years, and the majority of participants were male (n=434, 72%). More than 77.5% of all admissions were due to LLAs with dysvascular etiology. MCI was evident among participants aged 40 years and older with MoCA scores of less than 26. (Figure 2.1) The average number of falls at pre-admission overall was 2.0 ± 8.6, while FCI scores averaged 2.7 ± 1.4. The longest interval between amputation surgery and admission was observed in 2012 (524 ± 92.0 days), while the shortest was in 2013 (36.7 ± 56.6 days).

2.3.1.2 Oldest Old Sub-Group Inpatient Admissions

The oldest old participants represented 10.5% (n=63) of all inpatient admissions across the eight-year period with ages ranging from 80 to 94 years. (Table 2.2) The majority of participants were male (n = 41, 65.1%) and presented with a dysvascular etiology (93.6%). Average MoCA scores for the eight-year period were consistent with cognitive impairment (22.0 ± 4.1), which was below the average of the overall sample (24.2 ± 3.8). The average number of falls reported pre-admission was 1.0 ± 1.1 across the eight-year period. FCI scores for this age group (2.9 ±1.2) were slightly above the average of the overall sample (2.7 ± 1.4). Time between amputation surgery and admission were highly variable each year, with the longest interval reported in 2012 (516.5 ± 1099.0 days) and shortest interval reported in 2016 (92.7 ± 21.8).

Table 2.1: Demographic characteristics of people with a lower limb amputation at admission to inpatient prosthetic rehabilitation from 2012 to 2019. (n=601)

Characteristic	**Total**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Total admissions (n)	601	87	76	78	68	80	60	78	74
Admission age (years)									
Mean (SD)	62.3 (14.1)	63.2 (14.0)	62.0 (16.0)	62.4 (15.1)	65.0 (14.7)	59.7 (15.0)	60.0 (11.8)	62.3 (13.7)	63.8 (11.5)
Range	18 - 94	22 - 92	21 - 92	18 - 94	27 - 89	20 - 91	21 - 91	26 - 88	30 - 87
Decades (n,%)[†]									
18-29	13 (2.2)	1 (1.1)	3 (3.9)	4 (5.1)	1 (1.5)	2 (2.5)	1 (1.7)	1 (1.3)	0 (0.0)
30-39	26 (4.3)	4 (4.6)	6 (7.9)	1 (1.3)	4 (5.9)	5 (6.3)	0 (0.0)	5 (6.4)	1 (1.4)
40-49	58 (9.7)	10 (11.5)	6 (7.9)	7 (9.0)	5 (7.4)	12 (15.0)	7 (11.7)	6 (7.7)	5 (6.8)
50-59	137 (22.8)	19 (21.8)	11 (14.5)	18 (23.1)	11 (16.2)	14 (17.5)	24 (40.0)	20 (25.6)	20 (27.0)
60-69	196 (32.6)	27 (31.0)	27 (35.5)	25 (32.1)	22 (32.4)	28 (35.0)	18 (30.0)	21 (26.9)	28 (37.8)
70-79	108 (18.0)	18 (20.7)	17 (22.4)	13 (16.7)	14 (20.6)	12 (15.0)	5 (8.3)	17 (21.8)	12 (16.2)
80+	63 (10.5)	8 (9.2)	6 (7.9)	10 (12.8)	11 (16.2)	7 (8.8)	5 (8.3)	8 (10.3)	8 (10.8)
Gender (n, %)									
Males	434 (72.2)	58 (66.7)	59 (77.6)	56 (71.8)	52 (76.5)	54 (67.5)	44 (73.3)	57 (73.1)	54 (73.0)
Females	167 (27.7)	29 (33.3)	17 (22.4)	22 (28.2)	16 (23.5)	26 (32.5)	16 (26.7)	21 (26.9)	20 (27.0)
Amputation type (n, %)									
Unilateral	530 (88.2)	78 (89.7)	63 (82.9)	65 (83.3)	63 (92.6)	69 (86.3)	55 (91.7)	71 (91.0)	66 (89.2)
Bilateral	71 (11.8)	9 (10.3)	13 (17.1)	13 (16.7)	5 (7.4)	11 (13.8)	5 (8.3)	7 (9.0)	8 (10.8)

Amputation level (n, %)									
TT	465 (77.4)	66 (75.9)	56 (73.7)	62 (79.5)	54 (79.4)	59 (73.8)	52 (86.7)	61 (78.2)	55 (74.2)
TF	105 (17.5)	18 (20.7)	12 (15.4)	11 (14.5)	13 (19.1)	17 (21.3)	6 (10.0)	13 (16.7)	15 (20.3)
TT+TF	9 (1.5)	2 (2.3)	1 (1.3)	0 (0.0)	0 (0.0)	2 (2.5)	1 (1.7)	2 (2.6)	1 (1.4)
Other	22 (3.7)	1 (1.1)	7 (9.0)	5 (6.6)	1 (1.5)	2 (2.5)	1 (1.7)	2 (2.6)	3 (4.1)
Etiology of amputation (n,%)									
Diabetes	302 (50.2)	46 (52.9)	35 (46.1)	38 (48.7)	32 (47.1)	43 (53.8)	32 (53.3)	43 (55.1)	33 (44.6)
PVD	164 (27.3)	24 (27.6)	30 (39.5)	17 (21.8)	13 (19.1)	20 (25.0)	15 (25.0)	18 (23.1)	27 (36.5)
Traumatic	59 (9.8)	6 (6.9)	4 (5.3)	12 (15.4)	11 (16.2)	9 (11.3)	6 (10.0)	4 (5.1)	7 (9.5)
Cancer	9 (1.5)	2 (2.3)	0 (0.0)	2 (2.6)	1 (1.5)	1 (1.3)	1 (1.7)	2 (2.6)	0 (0.0)
Other††	67 (11.1)	9 (10.3)	7 (9.2)	9 (11.5)	11 (16.2)	7 (8.8)	6 (10.0)	11 (14.1)	7 (9.5)
BMI (kg/m^2) (mean, SD)	29.4 (8.9)	28.8 (11.5)	28.6 (7.0)	28.5 (7.4)	30.6 (9.6)	31.5 (12.0)	29.6 (7.0)	29.3 (6.7)	28.6 (8.0)
MoCA (mean, SD)	24.2 (3.8)	23.8 (3.4)	24.0 (4.7)	25.2 (3.0)	24.0 (4.6)	24.3 (4.0)	25.4 (3.0)	24.4 (3.3)	23.3 (3.7)
Number of falls pre-admission (mean, SD)	2.0 (8.6)	1.5 (2.5)	1.3 (2.0)	1.1 (1.6)	2.7 (5.0)	4.1 (22.3)	1.3 (2.0)	1.8 (1.9)	1.4 (1.6)
FCI (mean, SD)	2.7 (1.4)	2.5 (1.4)	2.5 (1.6)	2.9 (2.0)	2.5 (1.5)	2.9 (1.6)	2.7 (1.5)	2.9 (1.4)	3.0 (1.5)
Time between amputation surgery and admission date (days), (mean, SD)	270.8 (1193.3)	524.1 (92.0)	36.7 (56.6)	325.2 (666.8)	198.6 (553.3)	225.6 (535.7)	95.0 (69.9)	159.8 (166.1)	143.2 (107.9)

Notes: TT= transtibial, TF=transfemoral, PVD = peripheral vascular disease, BMI = body mass index, MoCA = Montreal Cognitive Assessment, FCI = Functional Comorbidity Index, † = number of participants admitted in each age decade, † † = includes infection and congenital.

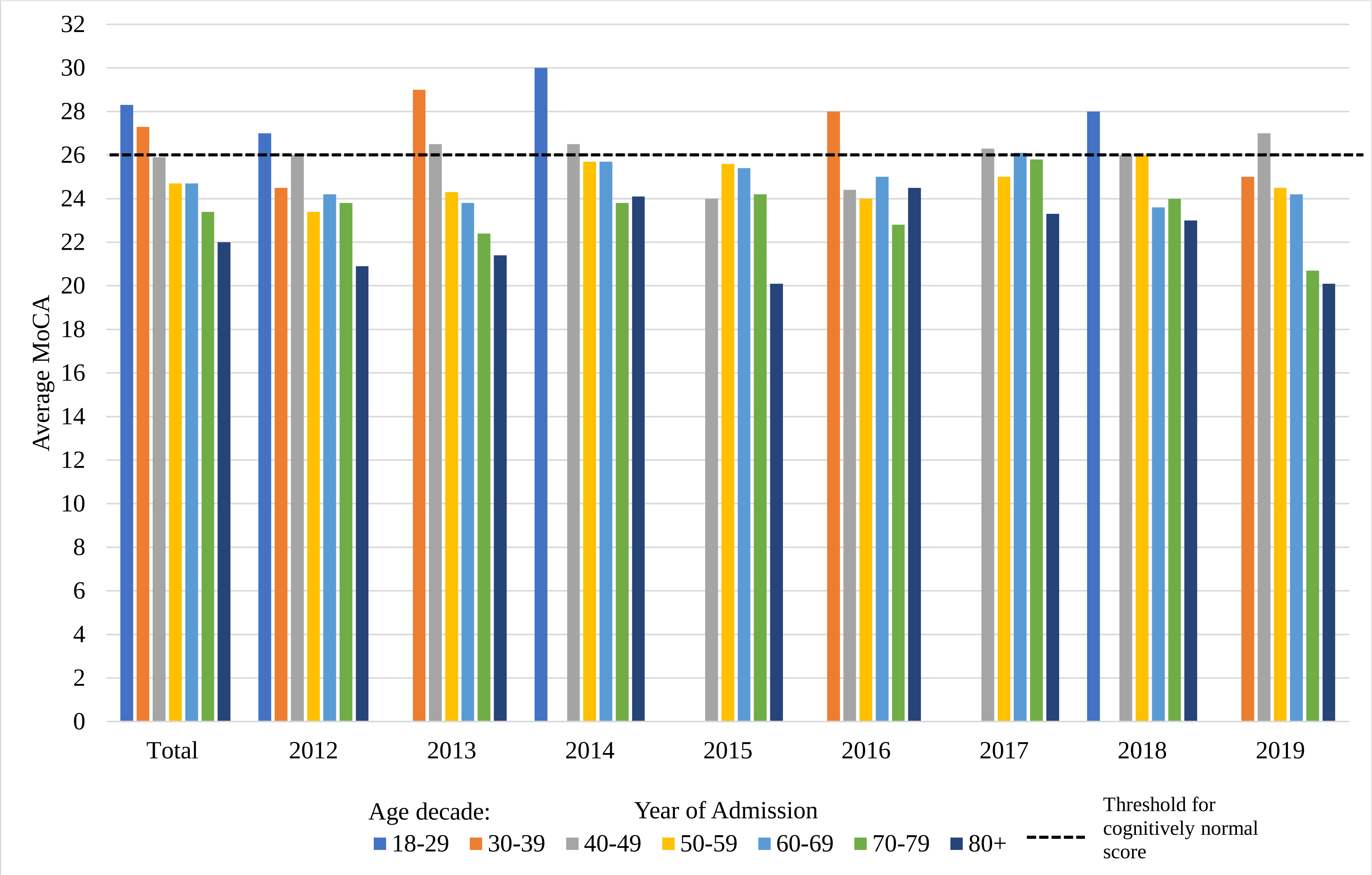


Figure 2.1: Average Montreal Cognitive Assessment (MoCA) at admission to inpatient prosthetic rehabilitation from 2012 to 2019

Table 2.2: Demographic characteristics of people 80 years and older with a lower limb amputation at admission to inpatient prosthetic rehabilitation from 2012 to 2019. (n=63)

Characteristic	**Total**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Total admissions (n)	63	8	6	10	11	7	5	8	8
Admission age (years)									
Mean (SD)	84.9 (3.7)	84.8 (4.0)	88.0 (4.3)	84.6 (5.0)	84.9 (3.0)	85.3 (4.1)	84.1 (3.8)	84.1 (3.2)	83.7 (2.3)
Range	80 – 94	81 – 92	82 – 92	80 – 94	80 – 90	81 – 91	81 – 91	80 – 88	81 – 87
Gender (n, %)									
Males	41 (65.1)	4 (50.0)	4 (66.7)	5 (50.0)	8 (72.7)	6 (85.7)	5 (100.0)	3 (37.5)	6 (75.0)
Females	22 (34.9)	4 (50.0)	2 (33.3)	5 (50.0)	3 (27.3)	1 (14.3)	0 (0.0)	5 (62.5)	2 (25.0)
Amputation type (n, %)									
Unilateral	59 (93.7)	8 (100.0)	6 (100.0)	6 (60.0)	9 (81.8)	6 (85.7)	5 (100.0)	7 (87.5)	7 (87.5)
Bilateral	4 (6.3)	0 (0.0)	0 (0.0)	4 (40.0)	2 (18.2)	1 (14.3)	0 (0.0)	1 (12.5)	1 (12.5)
Amputation level (n, %)									
TT	49 (77.8)	6 (75.0)	6 (100.0)	8 (80.0)	7 (63.6)	5 (71.4)	4 (80.0)	6 (75.0)	7 (87.5)
TF	10 (15.9)	2 (25.0)	0 (0.0)	1 (10.0)	3 (27.3)	1 (14.3)	1 (20.0)	2 (25.0)	1 (12.5)
TT+TF	2 (3.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (14.3)	0 (0.0)	0 (0.0)	0 (0.0)
Other	2 (3.1)	0 (0.0)	0 (0.0)	1 (10.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Etiology of amputation (n, %)									
Diabetes	28 (44.4)	2 (25.0)	1 (16.7)	3 (30.0)	8 (72.7)	4 (57.1)	3 (60.0)	3 (37.5)	4 (50.0)
PVD	31 (49.2)	6 (75.0)	4 (66.7)	6 (60.0)	2 (18.2)	3 (42.9)	1 (20.0)	5 (62.5)	4 (50.0)
Traumatic	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Cancer	2 (3.2)	0 (0.0)	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)
Other†	2 (3.2)	0 (0.0)	1 (16.7)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
BMI (kg/m^2) (mean, SD)	25.6 (5.2)	25.4 (7.6)	26.7 (3.2)	26.2 (6.2)	24.8 (6.0)	25.1 (5.3)	25.0 (2.9)	24.8 (2.8)	26.8 (6.3)
MoCA (mean SD)	22.0 (4.1)	20.9 (5.0)	21.4 (7.1)	24.12 (2.9)	20. 1 (3.1)	24. 5 (4.8)	23.2 (4.4)	23.0 (2.4)	20.1 (2.6)
Number of falls pre-admission (mean, SD)	1.0 (1.1)	1.4 (1.8)	0.8 (1.2)	0.6 (0.8)	0.9 (0.7)	0.9 (1.1)	1.0 (1.4)	1.0 (1.2)	0.5 (0.8)
FCI (mean, SD)	2.9 (1.2)	2.6 (0.7)	2.7 (0.5)	2.1 (0.8)	2.4 (0.6)	3.0 (1.4)	2.6 (1.5)	3.6 (1.6)	3.4 (2.0)
Time between amputation surgery and admission date (days), (mean, SD)	266.2 (90.0)	516.5 (1099.0)	214.0 (411.0)	398.1 (860.33)	352.1 (907.3)	92.7 (21.8)	124.2 (68.4)	144.4 (86.2)	157.6 (64.4)

Notes: TT= transtibial, TF= transfemoral, PVD = peripheral vascular disease, BMI = body mass index, MoCA = Montreal Cognitive Assessment, FCI = Functional Comorbidity Index, †=includes infection and congenital

2.3.2 Discharge Characteristics

2.3.2.1 All Inpatient Discharges

Discharge information was available for 590 people. (Table 2.3) Eleven participants were unable to be fitted with a prosthesis across the eight-year period and did not complete the inpatient prosthetic rehabilitation program. The average length of stay in the program was 29.2 ± 7.0 days with the longest average duration observed in 2014 (36.1 ± 56.7 days) and shortest in 2017 (27.3 ± 9.0 days). L-Test times increased with increasing age; however, this trend was not consistent across each admission year. (Figure 2.2) 2MWT and 6MWT distances were generally invariable across each year. (Figure 2.3 and 2.4) Average ABC scale scores were consistently above 65% over time. Participants in the oldest old category had the lowest ABC scale scores overall while participants aged 18 to 29 had the highest. (Figure 2.5) SCS remained consistently above 7 across all years, indicating good prosthesis fit.

2.3.2.2 Oldest Old Sub-Group Inpatient Discharges

Discharge information was available for 60 people. (Table 2.4) Three participants were unable to be fitted with a prosthesis. The average length of stay at the program for this age group was 42.5 ± 64.5 days, higher than the average for the total sample (29.2 ± 7.0 days). Average L-Test time across the eight-years was longer for this group (98.7 ± 56.9 seconds) when compared to the overall sample (71.9 ± 49.2 seconds). (Figure 2.2) Unlike the overall sample, 2MWT and 6MWT scores fluctuated across the years for this group. Average ABC scale scores for this group were consistently below all other age groups except the years 2017 (71.9 %) and 2018 (67.0 %). SCS remained consistently above 7 across all years, similar to the overall sample.

2.3.3 Admission Characteristics Associated with Admission Date

The univariate linear regression analyses revealed FCI scores and days between amputation surgery and admission were significantly associated with prosthetic rehabilitation admission date. (Table 2.5) These factors were incorporated into a final multivariable linear regression model ($R^2 = 0.23$) which showed a significant association between FCI scores [(95%CI: 20.93, 119.74), p=0.005] and days between amputation surgery [(95%CI: -0.13, -0.02), p=0.011] on admission date. A 1-point increase in FCI score was associated with a 70.34 day increase in admission day. A 1-day increase in days between amputation surgery and admission date was associated with a 0.08 day decrease in admission date independent of FCI score.

Table 2.3: Characteristics and outcomes of people with a lower limb amputation at discharge from inpatient prosthetic rehabilitation from 2012 to 2019. (n=590)

Characteristic	**Total**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
				Mean (SD)					
Length of stay (days)	29.2 (7.0)	27.5 (11.2)	27.4 (10.6)	36.1 (56.7)	29.0 (8.5)	27.7 (11.0)	27.3 (9.0)	25.2 (9.8)	33.0 (43.4)
L-Test (seconds)	71.9 (49.2)	66.0 (40.9)	67.7 (43.6)	92.7 (79.6)	66.5 (38.8)	78.4 (63.3)	65.1 (32.0)	70.9 (39.9)	68.2 (31.8)
2MWT (meters)	55.5 (23.5)	54.2 (23.3)	54.1 (26.1)	50.4 (24.6)	59.4 (21.8)	56.13 (25.9)	61. 5 (21.0)	55.0 (21.9)	54.1 (22.0)
6MWT (meters)	146.7 (81.6)	-*	124.7 (89.0)	141.4 (93.3)	148.5 (77.4)	145.9 (86.9)	168.1 (73.6)	149.4 (73.8)	146.5 (74.6)
ABC scale (%)	70.4 (16.3)	67.7 (21.4)	72.1 (16.1)	68.8 (15.2)	71.4 (14.4)	69.0 (15.8)	73.0 (14.8)	72.4 (14.8)	70.0 (15.8)
SCS									
Right	8.5 (4.1)	9.8 (1.5)	8.2 (1.1)	8.2 (1.3)	8.6 (1.0)	8.3 (1.2)	8.3 (1.2)	8.4 (0.8)	8.1 (1.5)
Left	8.2 (1.4)	8.5 (1.2)	7.8 (1.8)	7.9 (1.4)	8.4 (1.3)	8.6 (1.0)	8.3 (1.2)	8.1 (1.4)	8.0 (1.1)

Notes: L-Test = The L-Test of Functional Mobility, 2MWT = 2-Minute Walk Test, 6MWT = 6-Minute Walk Test, ABC scale = Activities-specific Balance Confidence scale, SCS = Socket Comfort Score, * = Data for 2012 was not available as 6MWT was not part of routine discharge assessments at Parkwood Institute until 2013.

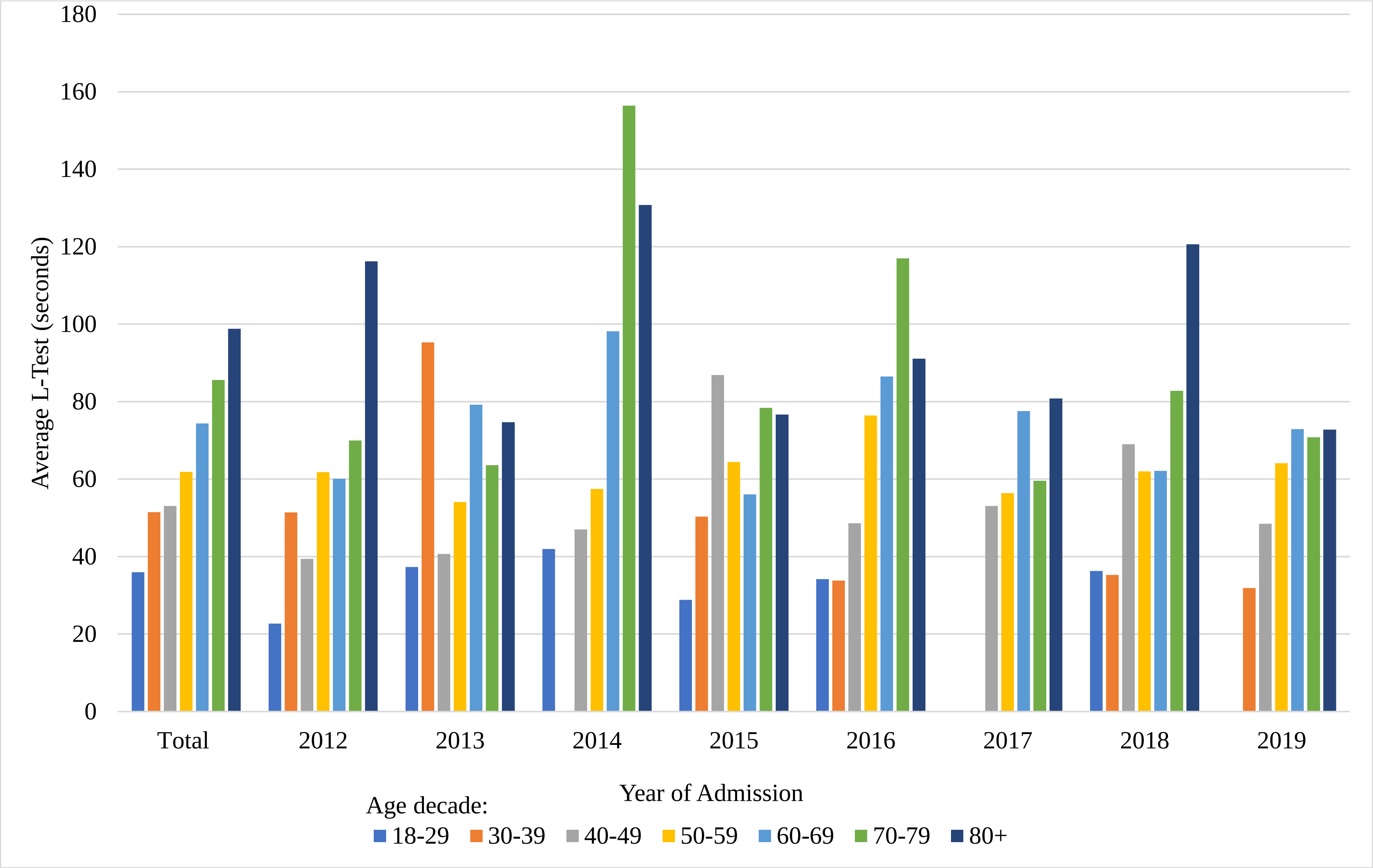


Figure 2.2: Average L-Test of Functional Mobility (L-Test) at discharge from inpatient prosthetic rehabilitation from 2012 to 2019.

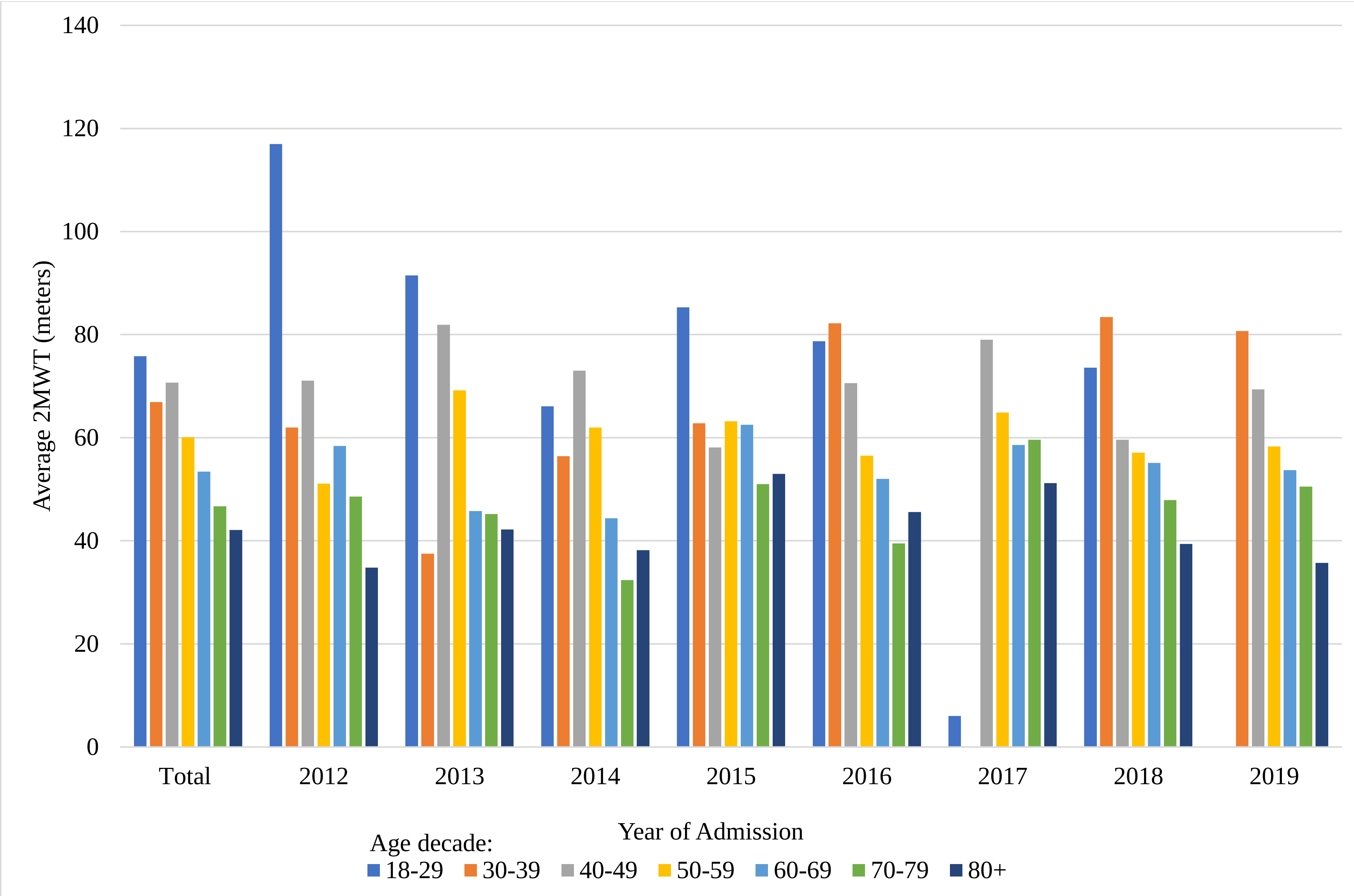


Figure 2.3: Average 2-Minute Walk Test (2MWT) at discharge from inpatient prosthetic rehabilitation from 2012 to 2019.

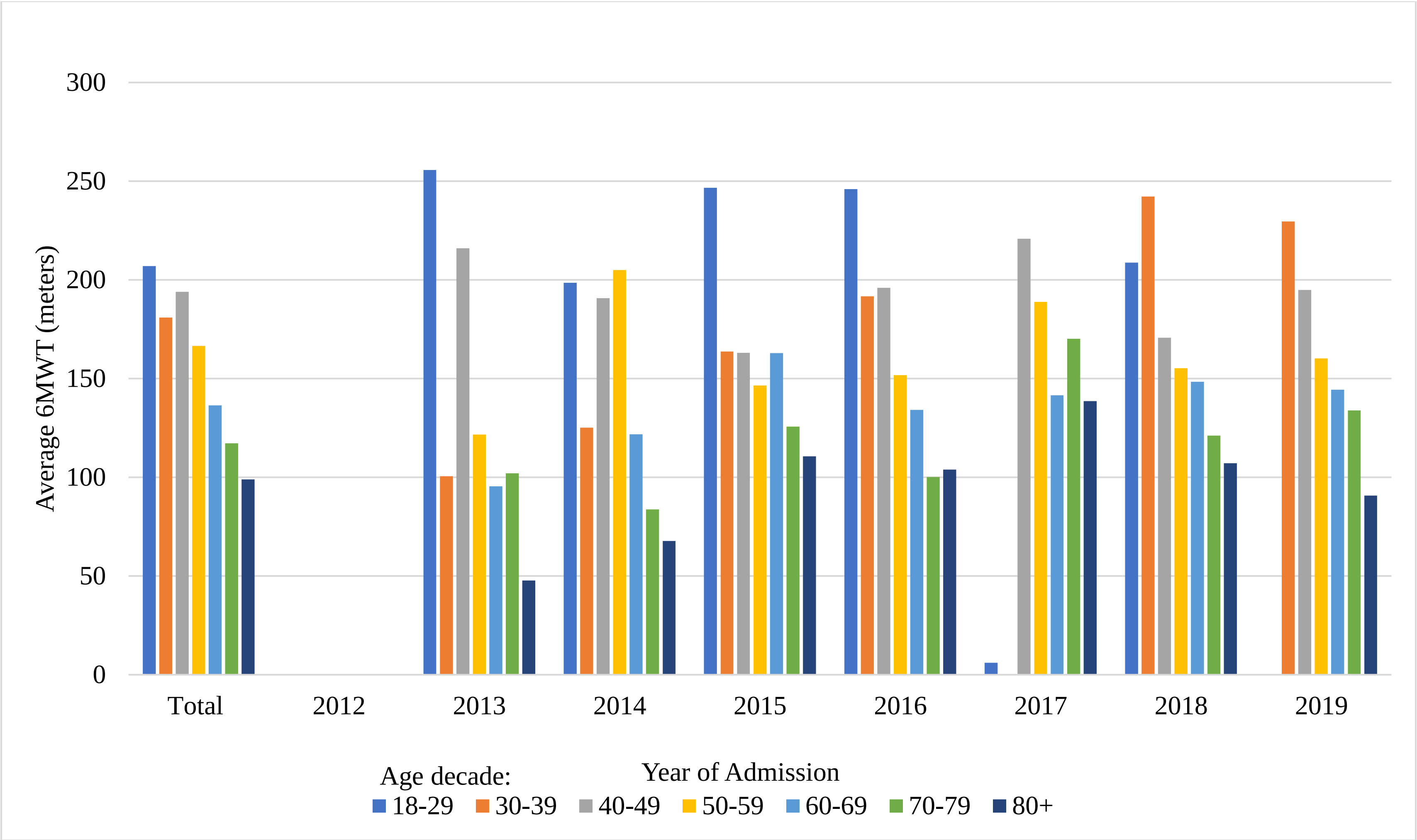


Figure 2.4: Average 6-Minute Walk Test (6MWT) at discharge from inpatient prosthetic rehabilitation from 2012 to 2019.

Notes: Data for 2012 was not available as 6MWT was not part of routine discharge assessments at Parkwood Institute until 2013.

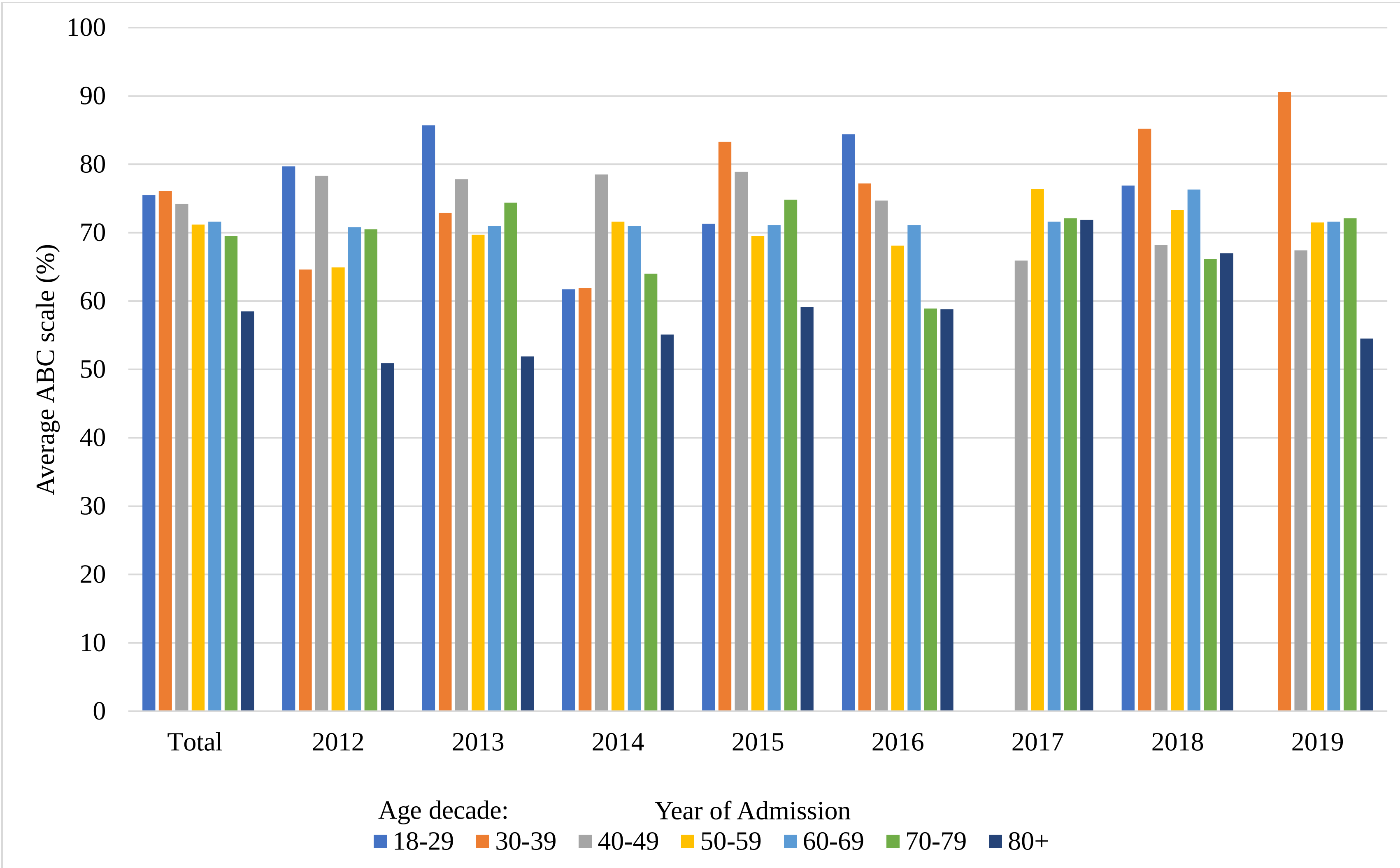


Figure 2.5: Average Activities-specific Balance Confidence (ABC) scale at discharge from inpatient prosthetic rehabilitation from 2012 to 2019.

Table 2.4: Characteristics and outcomes of people 80 years and older with a lower limb amputation at discharge from inpatient prosthetic rehabilitation by calendar year from 2012 to 2019. (n=60)

Characteristic	**Total**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
				Mean (SD)					
Length of stay (days)	42.5 (64.5)	32.1 (16.0)	32.0 (15.0)	64.5 (111.8)	33. 4 (8.2)	32.0 (8.7)	29.0 (9.3)	28.5 (13.4)	76.0 (128.9)
L-Test **(**seconds)	98.7 (56.9)	116.2 (74.3)	75.7 (12.4)	130.8 (89.4)	76.7 (28.2)	91.1 (34.4)	80.8 (30.2)	120.6 (66.8)	72.8 (28.3)
2MWT (meters)	42.1 (18.4)	34.8 (19.1)	42.2 (14.4)	38.2 (22.7)	53.0 (19.0)	45.6 (13.8)	51.2 (14.3)	39.4 (23.7)	35.7 (11.9)
6MWT (meters)	99.3 (63.1)	-*	47.7 (10.0)	67.7 (67.8)	110.7 (77.3)	103.9 (52.9)	138.6 (61.1)	107.2 (69.4)	90.8 (56.0)
ABC scale (%)	58.4 (17.4)	50.8 (17.6)	51.9 (44.1)	55.1 (24.0)	59.1 (16.3)	58.8 (21.0)	71.9 (17.6)	67.0 (6.2)	54.5 (8.8)
SCS									
Right	8.5 (1.1)	10.0 (0.0)	9.0 (0.0)	8.0 (1.1)	8.7 (1.2)	9.0 (1.0)	8.5 (0.7)	8.0 (0.0)	7.3 (0.6)
Left	8.2 (1.4)	8.3 (1.5)	7.2 (3.3)	7.9 (1.1)	8.5 (0.9)	8.4 (0.8)	9.2 (1.4)	8.0 (1.8)	7.5 (0.8)

Notes: L-Test = The L-Test of Functional Mobility, 2MWT = 2-Minute Walk Test, 6MWT = 6-Minute Walk Test, ABC scale = Activities-specific Balance Confidence scale, SCS = Socket Comfort Score, * = Data for 2012 was not available as 6MWT was not part of routine discharge assessments at Parkwood Institute until 2013.

Table 2.5: Univariate linear regression modeling examining the association between characteristics of people with a lower limb amputation at admission to an inpatient prosthetic rehabilitation program on time of admission from 2012 to 2019. (n=601)

	Independent variables	**Adjusted R^2**	**Unstandardized β (95% CI)**	**p-value**
Admission day	Age	-0.002	-0.50 (-5.40 - 4.41)	0.842
	Gender	-0.001	38.16 (-115.80 - 192.12)	0.627
	Primary etiology	0.001		
	Diabetes		-20.82 (-249.70 - 208.07)	0.858
	Peripheral vascular disease		-36.44 (-282.18 - 209.31)	0.771
	Trauma		-32.78 (-335.38 - 269.81)	0.832
	Cancer		-158.61 (-760.32 - 443.11)	0.605
	Other*		-	-
	Body Mass Index	-0.001	1.81 (-6.09 - 9.72)	0.652
	Amputation type	-0.004		
	TT		155.70 (-213.66 - 525.05)	0.408
	TF		137.58 (-259.35 - 534.51)	0.496
	TT+TF		211.84 (-457.99 - 881.67)	0.535
	Other*		-	-
	Amputation level	0.001	133.19 (-80.26 - 346.63)	0.221
	Functional Comorbidity Index	0.014	75.62 (27.31 - 123.94)	**0.002**
	Number of falls pre-admission	-0.002	1.26 (-6.82 - 9.33)	0.760
	Montreal Cognitive Assessment	-0.002	0.57 (-21.05 - 22.18)	0.959
	Days between amputation surgery and admission	0.012	-0.84 (-0.14-0.03)	**0.005**

Notes: TT = transtibial, TF = transfemoral, * = reference category

2.4 Discussion

The average person admitted to the inpatient prosthetic rehabilitation program across the past eight years was an older adult with a unilateral transtibial LLA due to dysvascular etiology. The oldest old group had similar amputation etiology and type to the average participant but had a higher number of comorbidities and longer inpatient stay. Functional outcomes typically decreased with increasing age and were variable amongst the oldest old. Although we did not find that participants got older over time at admission, they presented with a higher number of comorbidities at baseline during the relevant time-period. Participants were also admitted to prosthetic rehabilitation faster over time from amputation surgery.

As predicted, the majority of the total sample and the oldest old sub-group had LLAs due to dysvascular etiology. Despite the expected increase in the oldest old acquiring LLAs, it was found that participants did not get older over time. This observation aligns with two studies analyzing a sample of people with LLAs over a period of seven years conducted by Batten and collegues.[86, 94] These studies were conducted in Australia, which has similar population demographics and healthcare resources to Canada.[95] However, the aforementioned studies concluded that the population did not get older over time likely due to the observed increase in the number of traumatic LLAs, which are generally acquired by younger individuals.[86] A similar observation of change in traumatic etiology did not occur within our study. This was possibly due to dysvascular conditions continuing to be a predominant cause of new LLAs in Canada.[96-98] The proportion of the oldest old who were referred but not accepted to the prosthetic rehabilitation program was unknown. There is a pervasive concern amongst the rehabilitation community that advanced age may be a barrier to being successful in these programs, and it has been shown that biases in healthcare may impact clinical judgements.[99] Future research should investigate the acceptance process for inpatient programs to determine the percentage and reasons for rejecting the oldest old group with LLAs.

Our study expands on existing literature of people with LLAs as it contextualized characteristics of the oldest old group at admission to prosthetic rehabilitation. It highlights the need to focus on cognitive impairments and the presence of a high number of comorbidities in this age group. The investigation of discharge characteristics demonstrated that although functional outcomes generally decreased with increasing age, the oldest old do not always perform the worst when compared with other age groups. However, further studies are still needed to robustly assess discharge characteristics comparatively across different age groups to quantify rehabilitation potential for the oldest old specifically. A systematic review investigating the oldest old with LLAs concluded that research on this group is extremely limited, and studies have not sought to investigate their outcomes separately.[79] Our study has provided novel insight into baseline expectations at admission alongside discharge characteristics for the oldest old LLA population. This can provide clinicians with a better context for prognostic expectations for an age group that is expected to comprise a larger percentage of the LLA population in the future while experiencing unique health challenges.[7,79,83]

The number of comorbidities for people accepted into the program increased over the time frame of interest in our study. This contrasts with the findings from the study conducted by Batten and colleagues.[86] People with an LLA who are diagnosed with multiple comorbidities are known to experience challenges during prosthetic rehabilitation as these conditions can negatively impact gait and prosthesis use.[7,79,82] An increasing burden of disease presents a distinct challenge for clinicians when assessing for and establishing prognostic expectations for prosthetic rehabilitation programs. Batten and colleagues found that cognition improved over time for their sample, stating it was likely due the increased proportion of younger individuals.[86] However, cognitive issues were not only characteristic of our sample, but it was surprisingly evident at a younger age than previously established for individuals with LLAs.[100-101] A greater disease burden combined with cognitive deficits may mean a complex recovery process that requires more individualized support to ensure that goals are met during prosthetic rehabilitation.[82] Future research should investigate the impact of these health issues on functional outcomes after discharge for the oldest old with LLAs.

The variability in time between amputation surgery and admission may have been due to systemic factors such as fluctuating inpatient wait times and the limited number of dedicated inpatient prosthetic rehabilitation centers in Canada.[11,15] However, participants with an LLA were admitted earlier to the prosthetic rehabilitation program from amputation surgery each year overall. The transition between these stages involves post-operative care and assisting the individual through an altered physical reality.[7,55] There has been an increasing emphasis on post-operative care management throughout the years alongside the integration of a multi-disciplinary health care team.[102] Thus, enhancements of resources and support available for the physical and psychological care of individuals with LLAs may have contributed to the reduced transition period.

Shorter intervals between amputation surgery and admission combined with participants experiencing a higher disease burden over time seems contradictory when considering that multiple comorbidities are predictors of a prolonged post-operative period preceding prosthetic rehabilitation.[103] This may be indicative of improved management of acute complications during the post-operative phase, with better education surrounding wound care and skin integrity of the residual limb.[101] Diabetes, PVD and other chronic conditions are still present after an LLA, and continued medical management of these diseases is imperative to preventing adverse consequences and maximizing successful prosthetic rehabilitation. Prosthetic rehabilitation programs are most effective when attuned to the needs of the population, and it is clear from our findings that these needs have changed over time.

There are several strengths to highlight within this study. The use of consecutive admissions across an extended time frame facilitated a representative sample of the LLA population at this institution. Our study was the first to incorporate and analyze characteristics of a large sample of the oldest old LLA group as a separate cohort, providing insight into considerations and supports they might require at admission to prosthetic rehabilitation programs. In terms of limitations, the type of information collected from participant's charts were retrospective in nature. We were unable to control record-keeping practices and outcome measure assessments and therefore had to rely on data available. Although this study investigated all admissions and discharges across an eight-year period to our amputee program, it is not generalizable to the entire LLA population who have participated in inpatient prosthetic rehabilitation programs.

2.5 Conclusion

The average age of individuals who were accepted to prosthetic rehabilitation programs did not get older over time from 2012 to 2019. The number of comorbidities participants presented with at admission increased over time while the time between amputation surgery and admission got shorter. These evolving characteristics can inform clinicians about the needs and level of support required from this population prior to commencing prosthetic rehabilitation. Accounting for these changes will help to maximize rehabilitation potential and future outcomes for individuals with LLAs.

CHAPTER 3:

Study 2 - The impact of advanced age on prosthetic rehabilitation functional outcomes in people with lower limb amputations

3.1 Introduction

The global population aging phenomenon describes an emerging trend in which more people are living longer into later stages of life.[6] By 2050, one in six people will be aged 65 years and older.[6,68] In Canada, the fastest growing of this older adult age group are the oldest old (people aged 80 years and older).[6] Their numbers are expected to exponentially increase over the next 25 years to total 2.5 million.[69] These older age groups experience a high burden of disease including dysvascular conditions such as diabetes and peripheral vascular disease (PVD).[5,71] Complications from these diseases account for over 90% of lower limb amputations (LLAs) in this age demographic.[82] People will be living longer with these conditions as the population continues to age and the rate of dysvascular conditions rise.[6,68,69] It is therefore expected that more LLAs will be performed amongst the oldest old in the future as a result.[6,69,71]

After an initial loss of function due to an LLA, individuals may participate in a prosthetic rehabilitation program to restore mobility.[51] These programs maximize independence, achievement of activities of daily living, and quality of life by teaching individuals how to walk with a prosthesis.[47,51] Functional mobility is the most important factor contributing to quality of life in this population and is therefore a key indicator of successful prosthetic rehabilitation.[104] Rehabilitation progress may be impeded by complications from the presence of multiple cognitive and physical comorbidities that are prevalent in older age groups.[47,51] These include cardiovascular disease, osteoporosis, and sarcopenia; all of which negatively impact mobility and affect the oldest old population the most.[6,47,51] It may be difficult for clinicians to determine rehabilitation potential for this group at baseline especially since these conditions exacerbate each other.[5]

Current amputee literature has recognized that increasing age is associated with worse prosthetic rehabilitation outcomes.[104,105] However, it has not assessed rehabilitation potential for older adults with LLAs as separate groups. The burden of disease affects age groups differently, especially since the population is expected to become older over time.[47,82] Our healthcare system must be adequately equipped to provide care to these older populations and age should not be a blanket contraindication to participation in prosthetic rehabilitation programs. There is limited research surrounding the oldest old with LLAs, as most studies adopted a case study approach or only analyzed a small sample size.[106,107] A recent systematic review concluded the oldest old are capable of successful prosthetic rehabilitation, but it was not uniform across participants.[79] The review further highlighted the need for a thorough assessment of this group on a larger scale to understand their unique requirements. A comprehensive understanding of how the oldest old compare to other older adult age groups commonly participating in prosthetic rehabilitation is required to maximize successful prosthetic rehabilitation outcomes for this population in the future.

3.1.1 Purpose

The purpose of this study was to investigate and compare functional outcomes of the oldest old to other older adult groups (50 to 79 years old) at discharge from an inpatient prosthetic rehabilitation program.

3.1.2 Hypothesis

It was expected that the oldest old participants with LLAs would be similar to other adult groups in prosthetic rehabilitation functional outcomes.

3.2 Methodology

3.2.1 Study Design

A retrospective chart audit was performed for all consecutive admissions to the inpatient prosthetic rehabilitation program from January 1, 2012, to December 31, 2019, at Parkwood Institute in London, Ontario. Participant chart reviews were completed between July 2021 and October 2021. This study was approved by the Health Sciences Research Ethics Board at the University of Western Ontario and the Clinical Research Impact Committee of Lawson Institute.

3.2.2 Study Population

To be accepted into the inpatient prosthetic rehabilitation program at Parkwood Institute, individuals must have met the following criteria: aged 18 years or older, medically stable, had clear rehabilitation goals, and were deemed mentally and physically ready to participate in the program through clinical assessment. Individuals must have been cognitively able to engage in rehabilitation and demonstrated the potential to learn. Participants were admitted from home after the amputation incision was adequately healed. Study eligibility criteria were: aged 50 years or older, unilateral or bilateral transtibial level LLA or above. The oldest old were operationally defined in this study as individuals aged 80 years and older.[6,81] Only first admissions after primary amputation were included into the final analysis (participants were not included more than once).

3.2.3 Outcome Measures

Demographic characteristics extracted from participant charts included: age, gender, primary etiology of amputation, body mass index (BMI), amputation type and level, number of falls pre-admission (between amputation surgery and admission), days between amputation surgery and admission to the inpatient program, Montreal Cognitive Assessment (MoCA) score[87] and Functional Comorbidity Index (FCI) score[88]. MoCA scores evaluated the global cognitive status of participants and scores ≥ 26 out of 30 were considered cognitively normal while scores 18 to 25 were considered indicative of mild cognitive impairment (MCI).[87] (Appendix C) The FCI scale quantified number of comorbidities based on the presence or absence of 18 diagnoses. One point was assigned to each diagnosis for a theoretical cumulative maximum of 18 points.[88] (Appendix C)

About 1-3 days prior to discharge from the inpatient prosthetic rehabilitation program, participants were assessed across domains of functional mobility, endurance, and balance confidence as indicators of how successfully they could ambulate with a prosthesis. Extracted outcome measures at discharge were: The L-Test of Functional Mobility (L-Test), 2-Minute Walk Test (2MWT), 6-Minute Walk Test (6MWT) and Activities-specific Balance Confidence (ABC) scale.

3.2.3.1 Functional Mobility Assessment

The L-Test was developed specifically for people with an LLA to assess functional mobility, and is a modified version of the Timed Up and Go (TUG) test.[90] This test was performed through a standardized 20-meter pathway as follows: 1) on the word 'go', participants moved from a sit to stand position, 2) walked three metres, 3) performed a 90 degree turn, 4) walked seven meters, 5) performed a 180 degree turn and 6) walked back the same L-shaped pathway to return to a seated position. (Appendix C) The total time in seconds to complete the test was recorded with a stopwatch to the nearest 100th of a second. Shorter times are indicative of better performance. The L-Test has demonstrated excellent interrater and intrarater reliability for clinical use in this population.[90]

3.2.3.2 Endurance Assessments

The 2MWT and 6MWT are measures of endurance and functional capacity.[91,92] This was assessed through asking participants to walk as far as possible in two and six minutes respectively without compromising safety. These tests were conducted separately through standardized verbal instruction. Participants used a 20-meter path where 180-degree turns were made at the end of each path. The distance was recorded in meters to the nearest tenth of a meter. Achievement of longer distances indicated better performance . The 6MWT was added as part of discharge assessments in 2013 at Parkwood Institute. While both the 2MWT and 6MWT are easy to administer, the 6MWT involves a higher degree of exercise intensity similar to community ambulation.[92] The 2MWT and 6MWT have demonstrated excellent validity and reliability for use in people with LLAs.[91,92]

3.2.3.3 Balance Confidence

The Activities-specific Balance Confidence (ABC) scale was used to evaluate balance confidence.[93] (Appendix C) The ABC scale includes 16 items of mobility-focused activities of daily living and asks participants to rate how confident they are in completing these activities without losing their balance or becoming unsteady.[93] Participants were asked to rate their confidence on a scale from 0% (no confidence) to 100% (complete confidence) on a visual analog scale. Scores were averaged across all 16 activities for an overall final score. The ABC scale has demonstrated excellent test-retest reliability and validity in the LLA population.[93]

3.2.4 Data Analysis

Demographic and clinical characteristics of included participants were summarized using descriptive statistics (means and standard deviations (SD) or frequencies and percentages) as appropriate. Normality and outlier evaluations for admission and discharge characteristics were performed using the Shapiro-Wilk test, Q-Q plots, box plots and histograms. Values greater than 1.5 times outside the interquartile range were identified as outliers, while values that were greater than 3.0 times outside were deemed extreme outliers. All participant characteristics were normally distributed, and participants were not removed as outliers.

Means and SDs were used to summarize the outcome measure scores. All participants were stratified into 4 categories by age decade: 50-59, 60-69, 70-79 and 80+. One-way analysis of variance (ANOVAs) models evaluated outcome data at discharge for the L-Test, 2MWT, 6MWT, and ABC scale across the stratified age groups for the entire sample. If the ANOVAs were statistically significant, Tukey post-hoc pairwise comparisons were used to evaluate significant differences between the age groups on the outcome measure scores. A second adjusted analysis was performed to evaluate the relationship on the outcomes across the four older adult age groups. The oldest old participants were matched on gender, etiology of amputation, level of amputation, and year of admission (± 1 year) to the 3 older adult age groups (50-59, 60-69 and 70-79). Participants who were not able to be matched across all four variables in each of the three age groups were not included in the analysis. The unmatched participants did not differ significantly from the matched participants on gender, amputation etiology, amputation level, number of comorbidities, and time between amputation surgery and admission ($p>0.05$). The L-Test did not meet the assumption of homogeneity of variance for both analyses as assessed by Levene's test for equality of variance. Thus, the Welch statistic and Games-Howell post-hoc test was used for interpretation.

All statistical analyses were performed using the IBM SPSS Statistics version 26.0 (IBM Inc., Chicago, IL, USA) and Excel for MacOS. Statistical significance was set at $p <0.05$ for all above-mentioned analyses.

3.3 Results

A total of 504 participants aged 50 years and older were admitted to the inpatient prosthetic rehabilitation program across the eight-year period. (Table 3.1) The average age of the sample was 66.7 ± 10.1 years, and 74% (n=374) of the participants were male. The highest number of participants were in the 60 to 69 years old age category (n=196, 32.6%). The majority of LLAs were at the transtibial level (n=390, 77.4%) and the result of dysvascular etiology (n=419, 83.2%). The average length of stay at the inpatient program was 29.2 ± 24.76 days. The oldest old category comprised 10.5% (n=63) of the total sample, with an average age of 84.9 ± 3.7

years. Similar to the total sample, the majority had transtibial level amputations (n=49, 77.8%) with dysvascular etiology (n=59, 93.6%).

Table 3.1: Demographic and clinical characteristics of people with a lower limb amputation at admission to inpatient prosthetic rehabilitation from 2012 to 2019. (n=504)

		Age Decade (Years)			
Characteristic	**Total**	**50-59**	**60-69**	**70-79**	**80+**
Total admissions (n)	504	137	196	108	63
Admission age (years)					
Mean (SD)	66.7 (10.1)	55.1 (3.2)	64.6 (2.8)	74.6 (3.0)	84.9 (3.7)
Range	54-94	50-59	60-69	70-79	80-94
Gender (n, %)					
Males	374 (74.2)	98 (71.5)	155 (79.1)	80 (74.1)	41 (65.1)
Females	130 (25.8)	39 (28.5)	41 (20.9)	28 (25.9)	22 (34.9)
Amputation side (n, %)					
Unilateral	449 (89.1)	124 (90.5)	176 (89.8)	95 (88.0)	59 (93.7)
Bilateral	55 (10.9)	13 (9.5)	20 (10.2)	13 (12.0)	4 (6.3)
Amputation level (n, %)					
TT	390 (77.4)	112 (81.8)	147 (75.0)	82 (75.9)	49 (77.8)
TF	92 (18.3)	18 (13.1)	40 (20.4)	24 (22.2)	10 (15.9)
TT+TF	7 (1.4)	1 (0.7)	3 (1.5)	1 (0.9)	2 (3.1)
Other	15 (3.0)	6 (4.4)	6 (3.1)	1 (0.9)	2 (3.1)
Etiology of amputation (n,%)					
Diabetes	266 (52.8)	79 (57.7)	107 (54.6)	52 (48.1)	28 (44.4)
PVD	153 (30.4)	22 (16.1)	60 (30.6)	40 (37.0)	31 (49.2)
Traumatic	28 (5.6)	13 (9.5)	11 (5.6)	4 (3.7)	0 (0.0)
Cancer	6 (1.2)	2 (1.5)	0 (0.0)	2 (1.9)	2 (3.2)
Other†	51 (10.1)	21 (15.3)	18 (9.2)	10 (9.3)	2 (3.2)
Body Mass Index (kg/m^2) (mean, SD)	29.2 (8.5)	30.4 (8.5)	29.9 (8.4)	28.5 (9.7)	25.6 (5.2)
Montreal Cognitive Assessment Score (mean, SD)	24.0 (3.8)	24.7 (3.1)	24.7 (3.8)	23.4 (4.0)	22.0 (4.1)
Number of falls between surgery and admission to inpatient program (mean, SD)	1.5 (2.5)	1.8 (2.1)	1.4 (2.7)	1.5 (2.8)	1.0 (1.1)
Functional Comorbidity Index (mean, SD)	2.8 (1.4)	2.7 (1.3)	2.8 (1.4)	2.9 (1.4)	2.9 (1.2)

Time between amputation surgery and admission date (days), (mean, SD)	261.5 (1241.9)	306.2 (1583.8)	276.2 (1421.6)	173.9 (350.7)	266.2 (90.0)
Length of stay at the inpatient program (days), (mean, SD)	29.2 (24.8)	26.1 (8.6)	27.5 (10.6)	28.7 (8.8)	42.5 (64.5)

Notes: TT = transtibial, TF = transfemoral, PVD = peripheral vascular disease, † = includes infection and congenital.

Discharge outcome assessment information was available for 494 individuals as ten participants were unable to be fitted with a prosthesis across the eight-year period and did not complete the program. For the first analysis (n=494), the ANOVAs were statistically significant for all four outcome measures with the oldest old as the reference group ($p<0.001$). (Table 3.3) Results for all pairwise comparisons are provided in Appendix B. Post-hoc testing for the L-Test, 2MWT, and 6MWT revealed that the oldest old performed worse than people aged 50 to 69 years old ($p<0.05$), but no significant differences were observed between the oldest old and the 70-79 [(L-Test, p=0.587), (2MWT, p=0.644), (6MWT, p=0.636)] age group. The oldest old reported significantly lower balance confidence compared to all 3 age groups ($p<0.05$).

Table 3.2: Evaluation of discharge outcome assessment differences between the oldest old (80 years and older) and other older adult age groups for participants admitted to an inpatient prosthetic rehabilitation from 2012 to 2019. (n=494)

		Age Decade (Years)				
Outcome measure	**Overall ANOVA**	**50-59**	**60-69**	**70-79**	**80+**	**F**
		Mean (SD)				
L-Test (seconds)	<0.001	61.88 ± 34.46[D]	74.40 ± 49.77[D]	85.65 ± 57.71	98.77 ± 56.90	8.453*
2MWT (meters)	<0.001	59.92 ± 22.57[D]	53.39 ± 23.10[D]	46.67 ± 18.78	42.10 ± 18.43	10.598
6MWT (meters)	<0.001	167.40 ± 81.54[D]	136.49 ± 78.67[D]	117.19 ± 63.80	99.36 ± 63.10	10.433
ABC scale (%)	<0.001	71.09 ± 16.94[D]	71.64 ± 15.13[D]	69.48 ± 14.87[D]	58.46 ± 17.41	8.916

Notes: L-Test = The L-Test of Functional Mobility, 2MWT = 2-Minute Walk Test, 6MWT = 6-Minute Walk Test, ABC scale = Activities-specific Balance Confidence scale, [D] = 80+ years (reference) and age group are significantly different (p<0.05), * = Games Howell and Welch statistic interpreted.

A total of 156 prosthetic rehabilitation participants who successfully completed the program were included in the adjusted one-way ANOVA analysis with 39 oldest old participants matched to one participant in each age group (50-59, 60-69 and 70-79) on all four criteria. The ANOVAs were statistically significant for all four outcome measures (p<0.001). (Table 3.3) Results for all pair-wise comparisons of this sample are provided in Appendix B. Post-hoc testing for the L-Test, 2MWT, and 6MWT demonstrated that the oldest old had reduced performance compared to people aged 50 to 59 years old (p<0.05). However, no significant differences were observed between the oldest old and the 60-69 [(L-Test, p=0.802), (2MWT, p=0.570), (6MWT, p=0.772)] and 70-79 [(L-Test, p=0.148) (2MWT, p=0.338), (6MWT, p=0.300)] age groups. Post-hoc testing for the ABC scale revealed similar results to the total sample analysis (n=504).The oldest old reported significantly lower balance confidence compared to all 3 age groups (p<0.05).

Table 3.3: Evaluation of discharge outcome assessment differences between the oldest old (80 years and older) and other older adult age groups for participants admitted to an inpatient prosthetic rehabilitation from 2012 to 2019 (matched participants). (n=156)

		Age Decade (Years)				
Outcome measure	**Overall ANOVA**	**50-59**	**60-69**	**70-79**	**80+**	**F**
		Mean ± SD				
L-Test (seconds)	<0.001	62.17 ± 29.23[D]	83.63 ± 65.95	72.4 ± 33.79	96.81 ± 59.96	3.826*
2MWT (meters)	<0.001	60.95 ± 21.65[D]	49.66 ± 21.42	51.38 ± 16.20	43.79 ± 18.94	5.006
6MWT (meters)	<0.001	172.02 ± 79.90[D]	123.80 ± 71.07	137.86 ± 51.86	107.40 ± 63.65	5.301
ABC scale (%)	<0.001	71.43 ± 13.38[D]	71.93 ± 15.64[D]	70.76 ± 11.16[D]	59.40 ± 17.49	4.430

Notes: L-Test = The L-Test of Functional Mobility, 2MWT = 2-Minute Walk Test, 6MWT = 6-Minute Walk Test, ABC scale = Activities-specific Balance Confidence scale, [D] = 80+ years (reference) and age group are significantly different (p<0.05), * = Games Howell and Welch statistic interpreted.

3.4 Discussion

This study demonstrated that the oldest old with LLAs had decreased gait performance in areas of functional mobility and endurance compared to people aged 50 to 69 years old. The oldest old showed similar potential for function as participants aged 60-69 years and 70-79 years, who were comparable across gender, amputation etiology, and amputation level. However, this was not observed for balance confidence as all age groups (50-59, 60-69, 70-79) reported higher balance confidence than the oldest old. Importantly, all participants in the oldest old group were able to successfully learn to walk with a prosthesis. While age may impact absolute values on tests, it should not be an absolute barrier to participating in prosthetic rehabilitation programs in the first place.

This was the first study to incorporate a large sample of the oldest old and investigate their rehabilitation outcomes compared to the proximal age groups who are most commonly represented in the literature. The oldest old having reduced gait performance compared to other older adult age groups aligns with findings that increased age is negatively associated with functional mobility gains.[104,105] Further, a longer length of stay was observed for the oldest old participants compared to the other age groups. It may be the case that the oldest old require more time to adjust to walking with a prosthesis. Several studies have also highlighted that the oldest old experience challenges with walking due to the presence of a high number of comorbidities including cognitive impairments.[106,107] MCI was evident in this group, which may explain decreased gait performance since cognitive faculties must be intact to effectively learn how to walk with a prosthesis.[108,109] The different observations for the total sample and matched participants make it clear that clinical factors including amputation etiology, amputation level, and gender are important to consider for progress during prosthetic rehabilitation. Dysvascular etiology and higher amputation levels have been shown to be independently associated with reduced mobility.[51,110,111] Providing appropriate support for the oldest old through accounting for these complexities will be important in the development of future rehabilitation programs. These may include knowledge translation on best practices for managing dysvascular disease while walking with a prosthesis especially as the burden of chronic conditions continues to increase.[5,7,108]

This study provides novel insight into rehabilitation potential for the oldest old prosthetic rehabilitation participants based on outcomes that assessed functional mobility. Our findings contrast previous studies indicating that this group of participants have a low likelihood of being fitted with a prosthesis.[112] Not only were a majority of our sample able to be fitted with a prosthesis, but they demonstrated similar potential in walking ability to the most common group of participants who are typically in their sixties[72]. Individuals in their sixties are capable of successful functional mobility and community re-integration post-rehabilitation, and the oldest old may make similar gains given the appropriate support.[47,51] Previous amputee literature mainly focused on negative outcomes for this age group, with mortality being the most commonly reported.[113,114] Mortality rates for the oldest old with LLAs are the highest in the post-operative period.[113] However, our study has shown that the oldest old who are able to progress to the prosthetic rehabilitation stage are able to participate in these programs at a similar level to some younger groups. A bias may occur when only investigating negative outcomes for older individuals as it perpetuates ageist stereotypes that advanced age means there is a complete inability to regain function.[99] This bias is further problematic when the oldest old are assessed for candidacy into prosthetic rehabilitation programs since this may cause clinicians to disqualify these individuals based on age alone. Our findings show that age should not be a single determining factor for rejection from prosthetic rehabilitation.

The oldest old having lower balance confidence compared to other older adult age groups was surprising considering that the oldest old had comparable scores for functional mobility as the other age groups. This variation is perhaps due to the disconnect between objective and subjective methods of assessing mobility. While there is some evidence to suggest balance confidence is predictive of walking ability,[115] the relationship between balance confidence and specific domains of mobility such as strength and endurance are less clear. Balance confidence is an essential component of rehabilitation in this population as better balance confidence contributes to improved daily prosthesis use and a reduced risk for falls.[116,117] This finding provides further evidence to the fact that self-efficacy tends to decrease with age.[77] More research is needed to understand the impact of age on balance confidence, specifically as it relates to functional mobility. This will have important implications for reducing falls risk and improving overall quality of life for this population.

Despite previous literature findings that age is associated with worse performance on mobility domains and decreased prosthesis use[104,105], there are no consensus guidelines that report age limitations for participating in a prosthetic rehabilitation program. It is clear from this study that the oldest old are comparable to the average participant in terms of walking potential. The ability to make gains in these programs presents differently in older age groups and considerations must be made to comorbidities, self-efficacy, and motivations for walking with a prosthesis. Future research should aim to investigate a clear definition of successful prosthetic rehabilitation in the context to the oldest old group with LLAs. The return to a previous functional level may be different amongst older age groups.[47] Understanding what successful prosthetic rehabilitation means for the oldest old is important to maximize their gains. The oldest old are able to remain active members of the community,[6,68] further solidifying the recommendation that age should not be the sole determining factor in rejecting participants from prosthetic rehabilitation. Rejecting an individual based on the preconceived notion that age automatically contributes to the inability to be successful in rehabilitation will do a disservice to individuals within a potentially vulnerable age group who are capable functional gains. Adaptations to rehabilitation programs for the oldest old should focus on maximizing functional mobility to that of other older adult age groups. Future intervention studies surrounding mobility in older adults with an LLA should investigate outcomes in compartmentalized aged groups to continuously compare and contrast their specific needs.

There are few limitations within this study worth noting. Our study only included the oldest old who were admitted and successful with the prosthetic rehabilitation program. It may have been the case that this specific sample of the oldest old participants had the highest chances for success based on optimal functional capabilities and may not be representative of all oldest old participants. Further, despite the incorporation of a large sample size of participants throughout this study period, the results are not generalizable to all older adults who participate in an inpatient prosthetic rehabilitation program. An important strength of this study was the use of consecutive admissions across an extended time-period. This allowed our findings to be representative of participants at this institution; providing insight into future program adjustments that may be required for older adults and the oldest old. Another strength of this study was the use of multiple reliable outcome measures to comprehensively assess mobility domains both objectively and subjectively, which has not been adequately investigated before in the oldest old population. The adjusted analysis allowed for control of clinical factors which provided a robust assessment of the impact of advanced age on functional outcomes.

3.5 Conclusion

The oldest old group of individuals with an LLA are comparable to the average participant in a prosthetic rehabilitation program (≥ 60 years old) in terms of walking ability. This provides clinicians with a better prognostic outlook for this population in ability to make gains during prosthetic rehabilitation. Advanced age should not be the determining factor in rejecting potential participants from prosthetic rehabilitation programs. Considerations should be given to the unique complexities that the oldest old present with to maximize their rehabilitation potential. Future research should explore long-term prosthetic rehabilitation outcomes to contextualize gains in mobility, independence, and quality of life for the oldest old with LLAs.

CHAPTER 4

4.1 General Summary

This thesis sought to evaluate the oldest old with LLAs; a group which has been largely under-investigated in previous LLA literature. Study 1 assessed the changing characteristics of people with LLAs at admission to a Canadian prosthetic rehabilitation program over the past eight years and included a sub-analysis of the oldest old participants. While it was found that participants did not get older over time at admission to these programs, individuals presented with a higher disease burden each consecutive year. The transition period between amputation surgery and admission to prosthetic rehabilitation decreased throughout the relevant time-period as well. The oldest old primarily had dysvascular amputation etiology and an overall longer inpatient stay compared to the total sample of participants. Study 2 assessed functional prosthetic rehabilitation outcomes of the oldest old comparatively across younger age-stratified groups aged 50 years old and above. With considerations to relevant clinical factors, the oldest old showed similar potential for walking ability as the most common age group of participants (≥ 60 years old) in areas of functional mobility and endurance. However, the oldest old had significantly reduced balance confidence compared to the younger participants.

These findings provide novel insight pertaining to the evolving participant profiles of individuals with an LLA admitted for prosthetic rehabilitation. It further contextualized demographic characteristics and functional outcomes of the oldest old sub-group. Our findings confirm that the oldest old are able to successfully complete prosthetic rehabilitation programs despite the unique health challenges they may face. Developing a comprehensive understanding of their specific needs is key to modifying rehabilitation programs to provide appropriate support and maximize their overall rehabilitation potential. These studies serve as a foundational basis for future research investigating the changing LLA demographic and the oldest old sub-group

CHAPTER 5

5.1 Future Directions

Future studies should continue to investigate demographic changes and prosthetic rehabilitation outcomes comparatively across age-stratified groups. As the population aging phenomenon begins to take a stronger effect on the healthcare system,[6,68] it will be important to understand the challenges each age group experiences with an LLA. This will allow clinicians to develop targeted prognostic expectations and maximize rehabilitation outcomes for participants.

A prospective study design is recommended to assess longitudinal prosthetic rehabilitation outcomes for the oldest old as a follow-up to our retrospective studies. This would facilitate the evaluation of discharge characteristics related to daily prosthesis use, social participation, and overall quality of life at longer follow-up (i.e., up to 12 months) prior to an expected functional plateau. These factors will help inform how the oldest old with LLAs reintegrate back to the community in the immediate time frame after successful completion of the program. An investigation of these characteristics would draw attention to the physical and psychosocial supports required for this group during and after prosthetic rehabilitation.

There is a clear increase in disease burden over time for individuals with an LLA presenting to prosthetic rehabilitation. Future studies should evaluate the impact of multiple comorbidities on rehabilitation progress including goal setting and functional outcomes for the oldest old participants. It would also be of interest to investigate facilitators and barriers to prosthetic rehabilitation specifically for this age group. The inclusion of psychological outcomes for these studies will be useful, specifically as it relates to self-efficacy, body image and mental-health issues. These factors may impact quality of life amongst the oldest old, and more research is required in this regard. This would allow for a better understanding of the modifications required for the oldest old during prosthetic rehabilitation. Both a qualitative and quantitative approach to investigating facilitators and barriers to prosthetic rehabilitation in the oldest old will provide a better context of their functional capabilities. This would also inform our finding of reduced balance confidence amongst the oldest old group. Improving balance confidence will be a critical component to reducing the risk for falls in this age group.

This study only included the oldest old who were referred and accepted for prosthetic rehabilitation after an LLA. An assessment of all LLAs performed in Canada over the recent years with a focus on the oldest old group will be useful in identifying if more LLAs are being performed in advanced age groups, taking the focus beyond a single tertiary rehabilitation center to a national level focus. This would prepare clinicians with a better understanding of the demographic characteristics and challenges that would be expected from this group in the future as there may be regional differences that were not captured in our single site study.

Our findings support the recommendation that advanced age alone should not automatically disqualify the oldest old with LLAs as candidates for prosthetic rehabilitation. However, the number of the oldest old who were screened but ultimately rejected for the program is unknown . It will be important to critically assess the referral and acceptance process to determine if individuals in this advanced age group are being deemed ineligible as participants at a higher percentage based on bias regarding advanced age. It may also be useful to assess clinician's perspectives and attitudes regarding advanced age and prosthetic rehabilitation. This would highlight specific areas of bias and inform future training practices. The oldest old selected to participate in the rehabilitation program demonstrated the capacity to make similar functional gains as some younger participants. Any biases based simply on age must be adequately identified to give the oldest old group a fair chance at participating in prosthetic rehabilitation.

There are multiple avenues for future research amongst the oldest old group with LLAs that may be developed from our studies. Along with an LLA, this group experiences diverse healthcare challenges that will become more apparent as the population continues to live longer and dysvascular disease rates increase. It is important that their needs and rehabilitation potential are understood in context to other age groups in order to better assist this population and provide the best evidence-based care in the future.

REFERENCES

1. Essien SK, Kopriva D, Linassi AG, Zucker-Levin A. Trends of limb amputation considering type, level, sex and age in Saskatchewan, Canada 2006–2019: an in-depth assessment. Arch Public Heal. 2022;80(1):1–9.
2. Braddom, R. L. Physical Medicine and Rehabilitation. Physical Medicine and Rehabilitation (4th ed.). Philadelphia, PA: Elsevier. 2011.
3. Sanders P, Wadey R, Day M, Winter S. Prosthetic Rehabilitation in Practice: An Exploration of Experiential Knowledge in the Multidisciplinary Team. Qual Health Res. 2021;31(2):309–22.
4. DeLisa, J. A. DeLisa´s Physical Medicine & Rehabilitation. (J. A. DeLisa, W. R. Frontera, B. M. Gans, N. E. Walsh, & L. R. Robinson, Eds.) (5th Edit). Philadelphia, PA: Lippincott Williams & Wilkins. 2010.
5. Carmona GA, Hoffmeyer P, Herrmann FR, Vaucher J, Tschopp O, Lacraz A, et al. Major lower limb amputations in the elderly observed over ten years: The role of diabetes and peripheral arterial disease. Diabetes Metab. 2005;31(5):449–54.
6. Nations U. World Population Ageing. Economic and Social Affairs, Population Division. 2019; 1–111
7. Fortington L V., Rommers GM, Geertzen JHB, Postema K, Dijkstra PU. Mobility in Elderly People With a Lower Limb Amputation: A Systematic Review. J Am Med Dir Assoc . 2012;13(4):319–25.
8. Levin AZ. Functional outcome following amputation. Topics In Geriatric Rehabilitation. 2004;20:253–61.

9. Godlwana L, Nadasan T, Puckree T. Global trends in incidence of lower limb amputation : SA Journal Of Physiotherapy. 2008;64:1–5.

10. Agha RA, Muneer H, Alqaseer A, Ismaeel T, Badr O. Major lower limb amputation: causes, characteristics and complications. Bahrain Medical Bulletin. 2017;39:159–61.

11. Imam B, Miller WC, Finlayson HC, Eng JJ, Jarus T. Incidence of lower limb amputation in Canada. Canadian Journal Of Public Health. 2017;108:374–80.

12. Dillingham TR, Pezzin LE, Shore AD. Reamputation, mortality, and health care costs among persons with dysvascular lower-limb amputations. Archives Of Physical Medicine And Rehabilitation. 2005;86:480–6.

13. Seker A, Kara A, Camur S, Malkoc M, Sonmez MM, Mahirogullari M. Comparison of mortality rates and functional results after transtibial and transfemoral amputations due to diabetes in elderly patients-a retrospective study. International Journal Of Surgery. 2016;33,78–82.

14. Neil MJE. Pain after amputation. BJA Education. 2016;16:107–12.

15. Kayssi A, de Mestral C, Forbes TL, Roche-Nagle G. A Canadian population-based description of the indications for lower-extremity amputations and outcomes. Canadian Journal Of Surgery. Journal Canadien De Chirurgie. 2016;59:99–106

16. Boyle JP, Thompson TJ, Gregg EW, Barker LE, Williamson DF. Projection of the year 2050 burden of diabetes in the us adult population: dynamic modeling of incidence, mortality, and prediabetes prevalence. Population Health Metrics. 2010;8:1–12.

17. Mohammedi K, Woodward M, Hirakawa Y, Zoungas S, Colagiuri S, Hamet P, Harrap S, Poulter N, Matthews DR, Marre M, Chalmers J, Group AC. Presentations of major peripheral

arterial disease and risk of major outcomes in patients with type 2 diabetes: results from the advance-on study. Cardiovascular Diabetology. 2016;15:129.

18. Ziegler-Graham K, MacKenzie EJ, Ephraim PL, Travison TG, Brookmeyer R. Estimating the prevalence of limb loss in the united states: 2005 to 2050. Archives Of Physical Medicine And Rehabilitation. 2008;89:422–9.

19. Caruso P, Longo M, Signoriello S, Gicchino M, Maiorino MI, Bellastella G, Chiodini P, Giugliano D, Esposito K. Diabetic foot problems during the covid-19 pandemic in a tertiary care center: the emergency among the emergencies. Diabetes Care. 2020; 43:123–4

20. Valabhji J, Barron E, Vamos EP, Dhatariya K, Game F, Kar P, Weaver A, Verma S, Young B, Khunti K. Temporal trends in lower-limb major and minor amputation and revascularization procedures in people with diabetes in england during the covid-19 pandemic. Diabetes Care. 2021;44:133–5

21. Landry GJ. Functional outcome of critical limb ischemia. Journal Of Vascular Surgery. 2007;45:141–8.

22. Goodney PP, Tarulli M, Faerber AE, Schanzer A, Zwolak RM. Fifteen-year trends in lower limb amputation, revascularization, and preventive measures among medicare patients. JAMA Surgery. 2015;150:84–6.

23. Olin JW, Sealove BA. Peripheral artery disease: current insight into the disease and its diagnosis and management. Mayo Clinic Proceedings. 2010;85:678–92.

24. Aziz F, Reichardt B, Sourij C, Dimai HP, Reichart D, Köhler G, Brodmann M, Sourij H. Epidemiology of major lower extremity amputations in individuals with diabetes

in austria, 2014–2017: a retrospective analysis of health insurance database. Diabetes Research And Clinical Practice. 2020;170.

25. Van der Berg JD, Stehouwer CDA, Bosma H, van der Velde JHPM, Willems PJB, Savelberg HHCM, Schram MT, Sep SJS, van der Kallen CJH, Henry RMA, Dagnelie PC, Schaper NC, Koster A. Associations of total amount and patterns of sedentary behaviour with type 2 diabetes and the metabolic syndrome: The Maastricht study. Diabetologia. 2016;59:709–18.

26. Heikkinen M, Saarinen J, Suominen VP, Virkkunen J, Salenius J. Lower limb amputations: differences between the genders and long-term survival. Prosthetics And Orthotics International. 2007;31:277–86.

27. McGinigle KL, Browder SE, Strassle PD, Shalhub S, Harris LM, Minc SD. Sex-related disparities in intervention rates and type of intervention in patients with aortic and peripheral arterial diseases in the National Inpatient Sample Database. J Vasc Surg. 2021;73(6):2081-2089.

28. Wild, Roglic, Green, Sicree & K. Estimates for the year 2000 and projections for 2030. World Health. 2004;27.

29. Weisman A, Fazli GS, Johns A, Booth GL. Evolving Trends in the Epidemiology, Risk Factors, and Prevention of Type 2 Diabetes: A Review. Can J Cardiol. 2018;34(5).

30. Wu Y, Ding Y, Tanaka Y, Zhang W. Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention. International Journal Of Medical Sciences. 2014;11:1185–200.

31. Pecoraro RE, Reiber GE, Burgess EM. Pathways to diabetic limb amputation basis for prevention an identifiable and potentially preventable pivotal event, in most cases an episode involving minor. Diabetes Care. 1990;13:21.

32. Singh G, Chawla S. Amputation in diabetic patients. Medical Journal Armed Forces India. 2016;62(1):36-9.

33. Balducci, Stefano, Sacchetti, Massimo, Haxhi, Jonida, Orlando, Giorgio, D'Errico, Valeria, Fallucca, Sara, Menini, Stefano, Pugliese G. Physical exercise as therapy for type ii diabetes. Diabetes Metab Res Rev. 2014;1:13-23.

34. Shu J, Santulli G. Update on peripheral artery disease: epidemiology and evidence-based facts. Atherosclerosis. 2018;275:379–81.

35. Jacob-Brassard J, Al-Omran M, Hussain MA, Mamdani M, Stukel TA, Lee DS, de Mestral C. Temporal trends in hospitalization for lower extremity peripheral artery disease in Ontario: the importance of diabetes. Canadian Journal Of Cardiology. 2021;000:1–6.

36. Olin JW, Sealove BA. Peripheral artery disease: current insight into the disease and its diagnosis and management. Mayo Clinic Proceedings. 2010;85:678–92.

37. Aronow WS. Management of peripheral arterial disease of the lower extremities in elderly patients. The Journals Of Gerontology. Series A, Biological Sciences And Medical Sciences. 2004;59:172–7.

38. Kougias P, Bechara CF. Peripheral arterial disease. Cardiology Secrets: Fourth Edition. 2013;163:400–8.

39. Novo S, Coppola G, Milio G. Critical limb ischemia: definition and natural history. Current Drug Targets - Cardiovascular And Haematological Disorders. 2004;4:219–25.

40. Marrocco CJ, Bush HRL. Peripheral arterial disease. High Risk Diabetic Foot: Treatment And Prevention. 2010;358:1–8.
41. Penn-Barwell JG. Outcomes in lower limb amputation following trauma: a systematic review and meta-analysis. Injury. 2011;42:1474–9.
42. Marrocco CJ, Bush HRL. Peripheral arterial disease. High Risk Diabetic Foot: Treatment And Prevention. 2010;358:1–8.
43. De Leur K, Van Zeeland MLP, Ho GH, De Groot HGW, Veen EJ, Van Der Laan L. Treatment for critical lower limb ischemia in elderly patients. World Journal Of Surgery. 2012;36:2937–43.
44. Penn-Barwell JG. Outcomes in lower limb amputation following trauma: a systematic review and meta-analysis. Injury. 2011;42:1474–9.
45. Heikkinen M, Saarinen J, Suominen VP, Virkkunen J, Salenius J. Lower limb amputations: differences between the genders and long-term survival. Prosthetics And Orthotics International. 2007;31:277–86.
46. Peters CML, de Vries J, Veen EJ, de Groot HGW, Ho GH, Lodder P, et al. Is amputation in the elderly patient with critical limb ischemia acceptable in the long term? Clin Interv Aging. 2019;14:1177–85.
47. Equenazi A, Flack M, Yoo S. Basic Principles in the Rehabilitation of Persons with Limb Amputation. Princ Rehabil Med. 2019
48. Esquenazi A, Meier RH. Rehabilitation in limb deficiency. 4. limb amputation. Archives Of Physical Medicine And Rehabilitation. 1996;77:18–28.
49. Bhuvaneswar CG, Epstein LA, Stern TA. Reactions to amputation: recognition and treatment. Primary Care Companion To The Journal Of Clinical Psychiatry. 2007; 9:303-8

50. Misaghi A, Goldin A, Awad M, Kulidjian AA. Osteosarcoma : a comprehensive review. Sicot J. 2018;4:12.

51. O'Keeffe B, Rout S. Prosthetic rehabilitation in the lower limb. Indian J Plast Surg. 2019;52(1):134–44.

52. Ustal, H. Lower Limb Amputation, Rehabilitation, & Prosthetic Restoration. Current Diagnosis & Treatment: Physical Medicine & Rehabilitation Eds. Ian B. Maitin, and Ernesto Cruz. McGraw Hill. 2014.

53. Gailey R, Allen K, Castles J, Kucharik J, Roeder M. Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use. J Rehabil Res Dev. 2008;45(1):15–30.

54. Munin MC, Espejo-De Guzman MC, Boninger ML, Fitzgerald SG, Penrod LE, Singh J. Predictive factors for successful early prosthetic ambulation among lower-limb amputees. J Rehabil Res Dev. 2001;38(4):379–84.

55. Esquenazi A. Amputation rehabilitation and prosthetic restoration. From surgery to community reintegration. Disabil Rehabil. 2004;26(14–15):831–6.

56. Barr S, Howe TE. Prosthetic rehabilitation for older dysvascular people following a unilateral transfemoral amputation. Cochrane database Syst Rev. 2018;10.

57. Brigham and Women's Hospital. Standard of Care : Lower Extremity Amputation. Brigham Women's Hosp Dep Rehabil Serv. 2011;1–46.

58. Sinha R, Van Den Heuvel WJA, Arokiasamy P. Factors affecting quality of life in lower limb amputees. Prosthet Orthot Int . 2011;35(1):90–6.

59. Highsmith MJ, Kahle JT, Miro RM, Orendurff MS, Lewandowski AL, Orriola JJ, et al. Prosthetic interventions for people with transtibial amputation: Systematic review and meta-

analysis of high-quality prospective literature and systematic reviews. J Rehabil Res Dev. 2016;53(2):157–83.

60. Miller WC, Deathe AB, Speechley M. Psychometric properties of the activities-specific balance confidence scale among individuals with a lower-limb amputation. Archives Physical Med Rehabil. 2003;84(5):656–61.

61. Hebert JS, Wolfe DL, Miller WC, Deathe AB, Devlin M, Pallaveshi L. Outcome measures in amputation rehabilitation: ICF body functions. Disabil Rehabil. 2009;31(19):1541–54.

62. Cella D, Hahn E, Jensen S, Butt Z, Nowinski C, Rothrock N, et al. Patient-Reported Outcomes In Performance Measurement. Research Triangle Park. 2015.

63. Cutson TM, Bongiorni DR. Rehabilitation of the older lower limb amputee: a brief review. J Am Geriatr Soc.1996;44(11):1388–93.

64. Lee DJ, Costello MC. The effect of cognitive impairment on prosthesis use in older adults who underwent amputation due to vascular-related etiology: A systematic review of the literature. Prosthet Orthot Int. 2018;42(2):144–52.

65. Dillingham TR, Pezzin LE, MacKenzie EJ. Discharge Destination after Dysvascular Lower-Limb Amputations. Archives of Physical and Medical Rehabilitation. 2003;84(11):1662–8.

66. Webster JB, Hakimi KN, Williams RM, Turner AP, Norvell DC, Czerniecki JM. Prosthetic fitting, use, and satisfaction following lower-limb amputation: A prospective study. J Rehabil Res Dev. 2012;49(10):1493–504.

67. Van Twillert S, Stuive I, Geertzen JHB, Postema K, Lettinga AT. Functional performance, participation and autonomy after discharge from prosthetic rehabilitation: Barriers, facilitators and outcomes. J Rehabil Med. 2014;46(9):915–23.

68. Bloom DE, Luca DL. The Global Demography of Aging 1st ed. Vol. 1, Handbook of the Economics of Population Aging. Elsevier B.V. 2016;3–56

69. Paper D, Un S, Légaré J, Montréal U, Deslandes K, Carrière Y. Canada's Oldest Old: A Population Group which is Fast Growing, Poorly Apprehended and at Risk from Lack of Appropriate Services. Conf Popul Chang Life Course Tak Stock Look to Futur. 2015;3(1).

70. Fleury AM, Salih SA, Peel NM. Rehabilitation of the older vascular amputee: a review of the literature. Geriatr Gerontol Int. 2013;13(2):264–73.

71. Healthy Aging and Wellness Working Group. Healthy Aging in Canada : A New Vision , A Vital Investment. 2006;21.

72. Hamamura S, Chin T, Kuroda R, Akisue T, Iguchi T, Kohno H, et al. Factors affecting prosthetic rehabilitation outcomes in amputees of age 60 years and over. J Int Med Res. 2009;37(6):1921–7.

73. Silva ADM, Furtado G, Dos Santos IP, da Silva CB, Caldas LR, Bernardes KO, Ferraz DD. Functional capacity of elderly with lower-limb amputation after prosthesis rehabilitation: a longitudinal study. Disabil Rehabil Assist Technol. 2021;16(5):556-560

74. Burger H, Marinček Č. The life style of young persons after lower limb amputation caused by injury. Prosthet Orthot Int. 1997;21(1):35–9.

75. Madhavan M V., Gersh BJ, Alexander KP, Granger CB, Stone GW. Coronary Artery Disease in Patients ≥80 Years of Age. J Am Coll Cardiol. 2018;71(18):2015–40.

76. Vijayakumar B, Elango P, Ganessan R. Post-operative delirium in elderly patients. Indian J Anaesth. 2014;58(3):251–6.

77. Resnick B. Geriatric rehabilitation: the influence of efficacy beliefs and motivation. Rehabil Nurs. 2002;27(4):152-159.

78. Bilodeau S, Hebert R, Desrosiers J. Lower limb prosthesis utilisation by elderly amputees. Prosthet Orthot Int. 2000;24(2):126–32.

79. Frengopoulos C, Fuller K, Payne MWC, Viana R, Hunter SW. Rehabilitation outcomes after major lower limb amputation in the oldest old: a systematic review. Prosthet Orthot Int. 2021;45(6):446-456.

80. Jaul E, Barron J. Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population. Front Public Heal. 2017;5:1–7.

81. Public Health and Aging: Trends in Aging—United States and Worldwide. MMWR. 2003; 52(6): 101–106.

82. Statistics Canada. Table 17-10-0005-01. Population estimates on July 1st, by age and sex**.** March 2022.

83. Fletcher DD, Andrews KL, Hallett Jr. JW, Butters MA, Rowland CM, Jacobsen SJ, et al. Trends in rehabilitation after amputation for geriatric patients with vascular disease: Implications for future health resource allocation. Archive Physical Medicine and Rehabilitation. 2002;83(10):1389–93.

84. Moxey PW, Gogalniceanu P, Hinchliffe RJ, Loftus IM, Jones KJ, Thompson MM, et al. Lower extremity amputations - a review of global variability in incidence. Diabet Med. 2011;28(10):1144–53.

85. Ida K, Neven K, Ognjen Ž, Vedrana M, Marina A, Zoran V, et al. Rehabilitation of lowerlimb amputees. Period Biol. 2015;117(1):147–59.

86. Miller KL, Flynn M. Case report for FM A 95-year-old male with primary transtibial amputation: avoiding ageism. GeriNotes. 2014;21(1):24-25.

87. Batten H, Kuys S, McPhail S, Varghese P, Mandrusiak A. Are people with lower limb amputation changing? A seven-year analysis of patient characteristics at admission to inpatient rehabilitation and at discharge. Disabil Rehabil. 2019;41(26):3203–9.

88. Frengopoulos, C., Burley, J., Viana, R., Payne, M. W., & Hunter, S. W. Association Between Montreal Cognitive Assessment Scores and Measures of Functional Mobility in Lower Extremity Amputees After Inpatient Rehabilitation. Archives of Physical Medicine and Rehabilitation. 2017;98(3): 450–455.

89. Kabboord, A. D., Godfrey, D., Gordon, A. L., Gladman, J. R. F., Van Eijk, M., van Balen, R., & Achterberg, W. P.The modified functional comorbidity index performed better than the Charlson index and original functional comorbidity index in predicting functional outcome in geriatric rehabilitation: A prospective observational study. BMC Geriatrics. 2003;20(1):114.

90. Hanspal, R., Fisher, K., & Nieveen, R. (2003). Prosthetic socket fit comfort score. Disability and Rehabilitation. 2003;25(22):1278–1280

91. Deathe AB, Miller WC. The L test of functional mobility: measurement properties of a modified version of the timed “up & go” test designed for people with lower-limb amputations. Physical therapy. 2005;85(7):626-35.

92. Brooks, D., Parsons, J., Hunter, J. P., Devlin, M., & Walker, J. The 2-minute walk test as a measure of functional improvement in persons with lower limb amputation. Archives of Physical Medicine and Rehabilitation. 2001;82(10):1478–1483.

93. Lin, S. J., & Bose, N. H. Six-minute walk test in persons with transtibial amputation. Archives of Physical Medicine and Rehabilitation. 2008;89(12), 2354–2359.

94. Powell LE, Myers AM. The Activities-Specific Balance Confidence (ABC) scale. Journals Gerontol - Ser A Biol Sci Med Sci. 1995.

95. Batten HR, Kuys SS, McPhail SM, et al. Demographics and discharge outcomes of dysvascular and non-vascular lower limb amputees at a subacute rehabilitation unit: a 7-year series. Aust Health Rev. 2015;39:76–84

96. Canadian Institute for Health Information. International Comparisons: A Focus on Diabetes. 2015.

97. Sunner SS, Welsh RC, Bainey KR. Medical Management of Peripheral Arterial Disease: Deciphering the Intricacies of Therapeutic Options. CJC Open. 2021;3(7):936–49.

98. Uzzaman MM, Jukaku S, Kambal A, Hussain ST. Assessing the long-term outcomes of minor lower limb amputations: a 5-year study. Angiology. 2011;62(5):365–71.

99. Anand SS, Bell AD, Szalay D. The Time Has Come for Vascular Medicine in Canada. Can J Cardiol. 2021;37(10):1677.

100. Martinez-Arnau FM, Lopez-Hernandez L, Castellano-Rioja E, Botella-Navas, M, Perez-Ros, P. Interventions to improve attitudes toward older people in undergraduate health and social sciences students. A systematic review and meta-analysis. Nurse. Educ. Today. 2022;110:1-16.

101. Taylor SM, Kalbaugh CA, Blackhurst DW, Hamontree SE, Cull DL, Messich HS, et al. Preoperative clinical factors predict postoperative functional outcomes after major lower limb amputation: An analysis of 553 consecutive patients. J Vasc Surg. 2005;42(2).

102. Miller MJ, Hoffman RM, Swink LA, Barnes DE, Christiansen CL. Postamputation Cognitive Impairment Is Related to Worse Perceived Physical Function Among Middle-Aged and Older Prosthesis Users. Archives of Physical and Rehabil.2022;03.

103. Fatima H, Chaudhary O, Krumm S, Mufarrih SH, Mahmood F, Pannu A, et al. Enhanced Post-Operative Recovery with Continuous Peripheral Nerve Block After Lower Extremity

Amputation. Ann Vasc Surg. 2021;76:399–405.

104. Misfeldt R, Suter E, Mallinson S, Boakye O, Wong S, Nasmith L. Explorer le contexte et les facteurs qui façonnent les politiques des équipes de soins primaires dans trois provinces canadiennes : une analyse comparative. TT - Exploring Context and the Factors Shaping Team-Based Primary Healthcare Policies in Three Ca. Heal Policy. 2017;13(1):74–93.

105. Kerstein M, Zimmer H, Dugdale F, Lerner E. What influence does age have on rehabilitation of amputees? Geriatrics. 1975;30(12):67-71.

106. Steinberg F, Sunwoo I, Roettger R. Prosthetic rehabilitation of geriatric amputee patients: a follow-up study. Archives of Physical Medicine and Rehabilitation. 1985;66(11):742-745.

107. Cole E. Training elders with transfemoral amputations. Top Geriatr Rehabil. 2003;19(3):183-190.

108. Highsmith M, Kahle J, Fox J, Shaw K. Decreased heart rate in a geriatric client after physical therapy intervention and accommodation with the C-leg. J Prosthetics Orthot. 2009;21(1):43-47.

109. Fletcher D, Andrews K, Butters M, et al. Rehabilitation of the geriatric vascular amputee patient: a population-based study. Arch Phys Med Rehabil. 2001;82(6):776-779.

110. Frykberg R, Arora S, Pomposelli FBJ, LoGerfo F. Functional outcome in the elderly following lower extremity amputation. J Foot Ankle Sur*g*. 1998;37(3):181-265.

111. Pohjolainen T, Alaranta H. Predictive factors of functional ability after lower-limb amputation. Ann Chir Gynaecol. 1991;80(1):36-39

112. Hamilton EA, Nichols PJ. Rehabilitation of the elderly lower-limb amputee. Br Med J. 1972;2(5805):95-99.

113. Siriwardena G, Bertrand P. Factors influencing rehabilitation of arteriosclerotic lower limb

amputees. J Rehabil Res Dev. 1991;28(3):35-44.

114. Uustal H. Prosthetic rehabilitation issues in the diabetic and dysvacular amputee. Phys Med Rehabil Clin N Am. 2009;20(4):689-703.

115. Cummings V, Anderson AD, Levine SA, Tobis JS. The elderly medically ill amputee. Archives of Physical Medicine and Rehabilitation. 1963;44:549-554.

116. Harris PL, Read F, Eardley A, Charlesworth D, Wakefield J, Sellwood RA. The fate of elderly amputees. Br J Sur*g*. 1974;61(8):665-668.

117. Bäck-Pettersson S, Björkelund C. Care of elderly lower limb amputees, as described in medical and nursing records. Scand J Caring Sci. 2005;19(4):337-343.

APPENDICES

Appendix A: Ethics Approval Notices

Western Research

Date: 31 May 2021

To: Dr. Susan Hunter

Project ID: 118832

Study Title: The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old

Application Type: HSREB Initial Application

Review Type: Delegated

Full Board Reporting Date: 08/June/2021

Date Approval Issued: 31/May/2021

REB Approval Expiry Date: 31/May/2022

Dear Dr. Susan Hunter

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. **All other required institutional approvals and mandated training must also be obtained prior to the conduct of the study**.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
AS_Oldest old LLA study_study protocol_v2	Protocol	20/May/2021	2
Data Collection Form_v2	Other Data Collection Instruments	20/May/2021	2

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Ms. Jhananiee Subendran, Ethics Coordinator on behalf of Dr. Joseph Gilbert, HSREB Vice-Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Date: 4 May 2022

To: Dr. Susan Hunter

Project ID: 118832

Study Title: The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

Date Approval Issued: 04/May/2022

REB Approval Expiry Date: 31/May/2023

Dear Dr. Susan Hunter,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

The Office of Human Research Ethics

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

LAWSON
HEALTH RESEARCH INSTITUTE

LAWSON FINAL APPROVAL NOTICE

LAWSON APPROVAL NUMBER: R-21-265

PROJECT TITLE: The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old

PRINCIPAL INVESTIGATOR: Dr. Susan Hunter

LAWSON APPROVAL DATE: 8/06/2021

ReDA ID: 11130

Overall Study Status: Active

Please be advised that the above project was reviewed by Lawson Administration and the project was approved.

"COVID-19: Please note that Lawson is continuing to review and approve research studies. However, this does not mean the study can be implemented during the COVID-19 pandemic. Principal Investigators, in consultation with their program leader or Chair/Chief, should use their judgment and consult Lawson's research directive and guidelines to determine the appropriateness of starting the study. Compliance with hospital, Lawson, and government public health directives and participant and research team safety supersede Lawson Approval."

Please provide your Lawson Approval Number (R#) to the appropriate contact(s) in supporting departments (eg. Lab Services, Diagnostic Imaging, etc.) to inform them that your study is starting. The Lawson Approval Number must be provided each time services are requested.

Dr. David Hill
V.P. Research
Lawson Health Research Institute

Appendix B: Supplementary Tables

Supplementary Table 1: Evaluation of discharge outcome assessment differences between four older adult age groups for participants admitted to an inpatient prosthetic rehabilitation from 2012 to 2019. (n=494)

		Age Decade (Years)				
Outcome measure	**Overall ANOVA**	**50-59**	**60-69**	**70-79**	**80+**	**F**
		Mean SD				
The L-Test of Functional Mobility (seconds)	<0.001	61.88 ± 34.46[CD]	74.40 ± 49.77[D]	85.65 ± 57.71[A]	98.77 ± 56.90[AB]	8.453*
2-Minute Walk Test (meters)	<0.001	59.92 ± 22.57[CD]	53.39 ± 23.10[D]	46.67 ± 18.78[A]	42.10 ± 18.43[AB]	10.598
6-Minute Walk Test (meters)	<0.001	167.40 ± 81.54[BCD]	136.49 ± 78.67[AD]	117.19 ± 63.80[A]	99.36 ± 63.10[AB]	10.433
Activities-specific Balance Confidence scale (%)	<0.001	71.09 ± 16.94[D]	71.64 ± 15.13[D]	69.48 ± 14.87[D]	58.46 ± 17.41[ABC]	8.916

Notes: [A] = 50-59 years (reference) and age group are significantly different (p<0.05), [B] = 60-69 years (reference) and age group are significantly different (p<0.05), [C] = 70-79 years (reference) and age group are significantly different (p<0.05), [D] = 80+ years (reference) and age group are significantly different (p<0.05), * = Games Howell and Welch statistic interpreted.

Supplementary Table 2: Evaluation of discharge outcome assessment differences between four older adult age groups for participants admitted to an inpatient prosthetic rehabilitation from 2012 to 2019 (matched sample). (n=156)

		Age Decade (Years)				
Outcome measure	**Overall ANOVA**	**50-59**	**60-69**	**70-79**	**80+**	**F**
		Mean ± SD				
The L-Test of Functional Mobility (seconds)	<0.001	62.17 ± 29.23[D]	83.63 ± 65.95	72.4 ± 33.79	96.81 ± 59.96	3.826*
2-Minute Walk Test (meters)	<0.001	60.95 ± 21.65[D]	49.66 ± 21.42	51.38 ± 16.20	43.79 ± 18.94	5.006
6-Minute Walk Test (meters)	<0.001	172.02 ± 79.90[D]	123.80 ± 71.07	137.86 ± 51.86	107.40 ± 63.65	5.301
Activities-specific Balance Confidence scale (%)	<0.001	71.43 ± 13.38[D]	71.93 ± 15.64[D]	70.76 ± 11.16[D]	59.40 ± 17.49	4.430

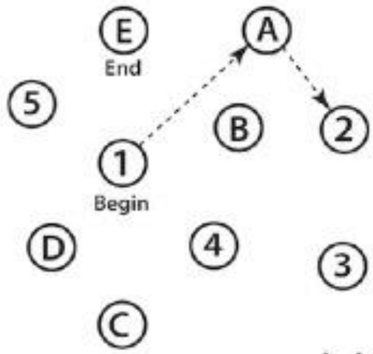
Notes: [D] = 80+ years (reference) and age group are significantly different (p<0.05), * = Games Howell and Welch statistic interpreted.

Appendix C: Outcome Measures

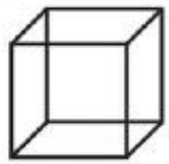
MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE



[ ]



Copy cube

[ ]

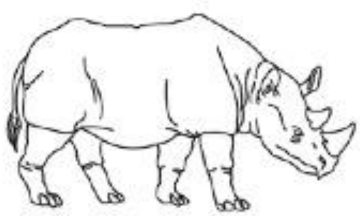
Draw CLOCK (Ten past eleven)
(3 points)

[ ] Contour [ ] Numbers [ ] Hands

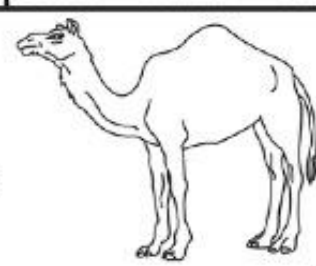
POINTS ___/5

NAMING

[ ]



[ ]



[ ]

___/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2 ___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B ___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** ___/3

LANGUAGE

Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] ___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words) ___/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler ___/2

DELAYED RECALL

		FACE	VELVET	CHURCH	DAISY	RED	
	Has to recall words WITH NO CUE	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUED recall only ___/5
Optional	Category cue						
	Multiple choice cue						

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City ___/6

 www.mocatest.org Normal ≥26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ______________________________

Functional Comorbidity Index

Items	1. Arthritis (rheumatoid and osteoarthritis) 2. Osteoporosis 3. Asthma 4. COPD, ARDS 5. Angina 6. Congestive heart failure or heart disease 7. Heart attack 8. Neurological disease 9. Stroke or transient ischemic attack 10. Diabetes types I and II 11. Peripheral vascular disease 12. Upper gastrointestinal disease 13. Depression 14. Anxiety or panic disorders 15. Visual impairment 16. Hearing impairment 17. Degenerative disk disease 18. Obesity and/or BMI of >30 kg/m^2
Weights	None One point is given for every "yes" answer
Score	Sum of "yes" answers

COPD, chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome; BMI, body mass index; acquired immunodeficiency syndrome.

<u>The Activities-specific Balance Confidence (ABC) Scale*</u>

<u>Instructions to Participants:</u>
For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports. If you have any questions about answering any of these items, please ask the administrator.

The Activities-specific Balance Confidence (ABC) Scale*

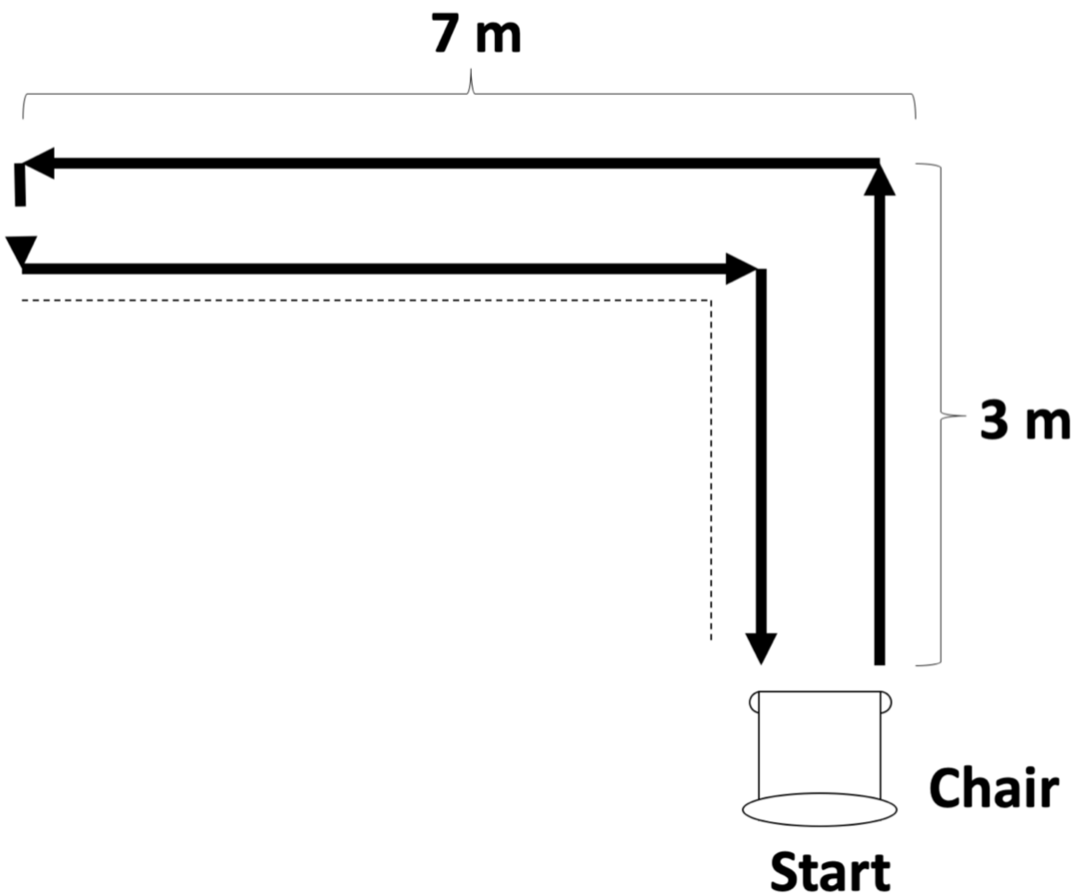
For <u>each</u> of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90 100%
no confidence completely confident

"How confident are you that you will <u>not</u> lose your balance or become unsteady when you…

1. …walk around the house? ____%
2. …walk up or down stairs? ____%
3. …bend over and pick up a slipper from the front of a closet floor ____%
4. …reach for a small can off a shelf at eye level? ____%
5. …stand on your tiptoes and reach for something above your head? ____%
6. …stand on a chair and reach for something? ____%
7. …sweep the floor? ____%
8. …walk outside the house to a car parked in the driveway? ____%
9. …get into or out of a car? ____%
10. …walk across a parking lot to the mall? ____%
11. …walk up or down a ramp? ____%
12. …walk in a crowded mall where people rapidly walk past you? ____%
13. …are bumped into by people as you walk through the mall?____%
14. … step onto or off an escalator while you are holding onto a railing? ____%
15. … step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%
16. …walk outside on icy sidewalks? ____%

*Powell, LE & Myers AM. The Activities-specific Balance Confidence (ABC) Scale. *J Gerontol Med Sci* 1995; 50(1): M28-34



Pathway of The L-Test of Functional Mobility

Appendix D: Curriculum Vitae

ASHVENE SURESHKUMAR

Post-Secondary Education

University of Western Ontario: 2020-present
Subject: Health and Rehabilitation Science, Physical Therapy Stream
Degree: Master of Science, (in progress)

University of Western Ontario: 2016-2020
Subject: Health Science
Degree: Honors Specialization in Health Science (BHSc) with minor in Classical Studies

Academic Employment History

Position: Teaching Assistant (Functional Neuroscience in Special Populations)
Description: Hold office hours, answer student inquiries, and write exam questions
Department: Faculty of Health Sciences
Institution: University of Western Ontario
Dates: January 2022 – April 2022

Position: Teaching Assistant (Anatomy)
Description: Prepare and teach virtual labs, monitor student forums and address student questions
Department: Faculty of Health Sciences
Institution: University of Western Ontario
Dates: January 2021 – April 2021

Position: Research/Lab Assistant
Description: Prepare buffer solutions, assist with imaging and cryostat mouse brain sectioning
Department: Medical Science
Institution: University of Western Ontario
Dates: September – December 2018

Academic Distinctions and Awards

1. 2022/3, Top MSc Presenter in Collaborative Specializations in Musculoskeletal and Health Research Award, Health and Rehabilitation Science Conference (100.00)
2. 2021/7, Parkwood Institute Research Student Endowment – Joseph A. Scott Studentship Award (10,000)
3. 2021/4, Ontario Graduate Scholarship Award (15,000)
4. 2021/2, Top MSc Presenter in Community and Population Health for Older Adults Award, Health and Rehabilitation Science Conference (50.00)
5. 2019/10, UWO In-Course Scholarships Year IV (700.00)
6. Deans Honor List 2019 - 2020, University of Western Ontario
7. Deans Honor List 2018 - 2019, University of Western Ontario
8. Deans Honor List 2017 - 2018, University of Western Ontario

9. 2016/6, Gifted Program Certificate of Accomplishment
10. 2016/6, Rouge Valley Ajax and Pickering Auxiliary Bursary (100.00)
11. 2016/6, The Western Scholarship of Distinction, University of Western Ontario (1,000.00)
12. 2015/8, Kumon Math Program Completion Award and Bursary (100.00)

Certifications

1. 2020/10, TA E-Learning Series Certificate, Centre for Teaching and Learning University of Western Ontario
2. 2020/9, "Good Clinical Practice (GCP) Canada", Collaborative Institutional Training Initiative (CITI) Certificate
3. 2020/9, WHIMIS Training Certificate
4. 2019/9, Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2: CORE)
5. 2019/6, Making Head Way In Sport Certificate, National Coaching Certification Program
6. 2019/5, FUNdamentals "In Training" Basketball Coach, National Coaching Certification Program

Conference Presentations

1. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The impact of advanced age on prosthetic rehabilitation gait outcomes following a lower limb amputation. International Society of Posture and Gait Research 2022 World Congress. [International Conference], Ontario, Canada. July 4, 2022. [*Poster presentation*].
2. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The impact of advanced age on prosthetic rehabilitation gait outcomes following a lower limb amputation. Canadian Geriatrics Society Annual Scientific Meeting. [National Conference], Ontario, Canada. April 9, 2022. [*Virtual oral presentation*].
3. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. An eight-year analysis of participant characteristics at admission to inpatient prosthetic rehabilitation following a lower limb amputation. Health and Rehabilitation Sciences Graduate Student Society Conference. [Western University Conference], Ontario, Canada. February 2-3, 2022. [*Virtual poster presentation*].
4. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old. London Health Research Day. [Local Conference], Ontario, Canada. May 11, 2021. [*Virtual poster presentation*].
5. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old. Ontario Association of Amputee Care Conference. [Provincial Conference], Ontario, Canada. May 7, 2021. [*Virtual poster presentation*].
6. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old. Parkwood Institute Research Day. [Local Conference], Ontario, Canada. April 22, 2021. [*Virtual poster presentation*].
7. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old. Western

Research Forum. [Western University Conference], Ontario, Canada. March 17-18, 2021. [*Virtual oral presentation*].

8. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old. Health and Rehabilitation Sciences Graduate Student Society Conference. [Western University Conference], Ontario, Canada. February 3-4, 2021. [*Virtual poster presentation*].
9. **<u>Sureshkumar A</u>**, Omana H, Frengopoulos C, Payne M, Viana R, Hunter SW. Concern of falling and its association with future mobility, quality of life and social satisfaction in people with lower extremity amputations: A prospective study. Canadian Association of Physical Medicine & Rehabilitation (CAPM&R) Scientific Meeting [National Conference], Charlottetown, Canada. May 29, 2020. [*Virtual poster presentation*].
10. **<u>Sureshkumar A</u>**, Omana H, Frengopoulos C, Payne M, Viana R, Hunter SW. Concern of falling and its association with future mobility, quality of life and social satisfaction in people with lower extremity amputations: A prospective study. Western Student Research Conference (WSRC) [Western University Conference], Ontario, Canada. March 27, 2020. [*Poster presentation*]. **cancelled due to COVID-19*

Peer Reviewed Conference Abstract Publications

1. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The impact of advanced age on prosthetic rehabilitation gait outcomes following a lower limb amputation. International Society of Posture and Gait Research 2022 World Congress. [International Conference], Ontario, Canada. July 4, 2022. [*Poster presentation*]. ***Accepted***
2. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The impact of advanced age on prosthetic rehabilitation gait outcomes following a lower limb amputation. Canadian Geriatrics Society Annual Scientific Meeting Book of Abstracts. [National Conference], Ontario, Canada. April 9, 2022. [*Virtual oral presentation*]. ***Accepted***
3. **<u>Sureshkumar A</u>**, Payne M, Viana R, Hunter SW. The investigation of prosthetic rehabilitation outcomes following a lower limb amputation in the oldest old. Western Research Forum. [Western University Conference], Ontario, Canada. March 17-18, 2021. [*Virtual oral presentation*]. ***Accepted***
4. **<u>Sureshkumar A</u>**, Omana H, Frengopoulos C, Payne M, Viana R, Hunter SW. Concern of falling and its association with future mobility, quality of life and social satisfaction in people with lower extremity amputations: A prospective study. Canadian Association of Physical Medicine & Rehabilitation (CAPM&R) Scientific Meeting [National Conference], Charlottetown, Canada. May 29, 2020. [*Virtual poster presentation]*. ***Accepted***
5. **<u>Sureshkumar A</u>**, Omana H, Frengopoulos C, Payne M, Viana R, Hunter SW. Concern of falling and its association with future mobility, quality of life and social satisfaction in people with lower extremity amputations: A prospective study. The Western Student Research Conference (WSRC). London, Ontario, Canada. March 27, 2020. [*Poster presentation*]. ***Accepted*** ** cancelled d/t COVID-19*

Policy Papers

1. Acheson J, Sureshkumar A, Hunter SW. Scoping review of the reliability of the Single Leg Stance Test in older adults. Canadian Centre for Activity & Aging. October 2020.

Manuscripts in Progress

1. Madou E, **Sureshkumar A**, Payne M, Viana R, Hunter SW. The effect of exercise interventions on gait in individuals with a lower limb amputation: A systematic review and meta-analysis. June 2022.
2. Omana, H, **Sureshkumar A**, Aijo M, Hunter SW. Attitudes and beliefs of physiotherapists and physiotherapy students towards working with older adults: A systematic review. TBD

Memberships

1. 2020/8-present, Board Member (Director), VV'S Adult Support Centre Corp.
    - Non-profit organization based in Ajax, ON with mission of supporting older adults in the community through development of interactive programs
    - Attend monthly board meetings, prepare, and develop programs, apply for community grants, and write progress reports