Falls Post-Stroke: A Setback on the Road to Recovery?

by

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Abstract
Accidental falls are common among individuals with stroke. Falls can have significant physical and psychosocial consequences, including injury, fear of falling, and reduced activity. The impact of falls on post-stroke recovery is not clear. The current work is comprised of two studies. The first study aimed to investigate how falls during in-patient stroke rehabilitation affected length of stay, functional status, and discharge destination. Individuals who fell had a longer length of stay compared to those who did not fall; however, both groups achieved similar functional levels, and were discharged home. The second study aimed to determine how falls among community-dwelling stroke survivors affected outcomes of stroke recovery after six months post-discharge from hospital. Performance in balance and motor recovery were compromised among individuals who fell compared to those who did not fall. The results of both studies suggest that falls may delay post-stroke recovery.
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List of Abbreviations

ABC – Activities-specific Balance Confidence scale

ADL – Activities of daily living

ALC – Alternative level of care

BBS – Berg Balance Scale

CMSA – Chedoke-McMaster Stroke Assessment

FOF – Fear of falling

FIM – Functional Independence Measure

ICC – Intraclass correlation coefficient

LOS – Length of stay

MoCA – Montreal Cognitive Assessment

PASIPD – Physical Activity Scale for Individuals with Physical Disabilities

RPG – Rehabilitation Patient Group

SD – Standard deviation
1. Introduction

Stroke is the leading cause of adult disability in Canada.\textsuperscript{1} Each stroke is different and the effects of stroke can include physical problems affecting balance and mobility,\textsuperscript{2} cognitive deficits such as memory and thinking,\textsuperscript{3} and emotional challenges like depression.\textsuperscript{4} Stroke-related impairments can interfere with participation in activities of daily living (ADL),\textsuperscript{5} and put an individual at an increased risk of falls.\textsuperscript{6,7} Recovery after stroke is an ongoing process that spans a number of health care settings and can take place over months and even years.\textsuperscript{8}

Falls are common at all stages after stroke, with 4-22\% of individuals falling at least once while in acute care hospital,\textsuperscript{9,10} between 12-47\% during in-patient rehabilitation,\textsuperscript{11-16} and up to 73\% of stroke survivors experiencing a fall within the first six months of returning to the community.\textsuperscript{17-19} Many studies have attempted to identify risk factors for falls post-stroke,\textsuperscript{12,15-17,19-28} for example, Teasell and colleagues compared individuals who fell to those who did not, and found that balance impairment, dependence in ADL, and greater motor impairment were significantly associated with a high risk of falls during in-patient stroke rehabilitation.\textsuperscript{16} The high falls incidence is of concern for one’s level of independence and can compromise quality of life of an individual, as the physical and psychosocial consequences of falls may compound the existing stroke-related impairments.\textsuperscript{29} Regardless of the immediate consequences of a fall (i.e. physical injury), individuals with stroke who fall are likely to develop fear of falling (FOF),\textsuperscript{30} which may also lead to reduced physical activity. However, physical activity is important for
promoting ongoing stroke recovery. Therefore, the issue of falls after stroke presents a challenge to recovery and rehabilitation.

With the existing research on the incidence of falls after stroke, rehabilitation professionals have a good understanding that individuals with stroke are at a high risk of falls, and that these falls may have serious consequences. Since most recovery of function takes place early after stroke (i.e. within the first six months post-stroke onset), it is important to explore how falls may influence the recovery process to inform health services planning and delivery. However, there have been no studies, to our knowledge, that have attempted to investigate the impact of falls on stroke recovery; this is the overall aim of this work. The general hypothesis is that falls experienced during the critical period of in-patient rehabilitation and early community rehabilitation would be a setback on stroke recovery, which would have implications for important rehabilitation outcomes. The current work is comprised of two distinct studies that investigate the impact of falls on stroke recovery in two settings: in-patient rehabilitation and community living. By understanding the recovery profile of individuals who fall across different post-stroke stages, the rehabilitation team can reduce the consequences of falls (e.g. injury, FOF, decreased physical activity), and provide more informed post-fall management to individuals with stroke to maximize recovery and enable patients to realize their full potential.
2. Literature Review

2.1 Stroke in Canada

There are approximately 50,000 new strokes each year in Canada, and the burden of stroke is expected to rise with the aging population. Stroke is the leading cause of adult disability with more than 315,000 Canadians living with mild, moderate or severe stroke-related disability. The population of Canadians 65 years or older is estimated to double in the next 25 years; therefore, there will likely be an increase in the overall number of individuals who will suffer a stroke. In addition, the number of individuals who survive after stroke will increase as a result of advancements in knowledge and improvements in acute stroke care. Together, these circumstances will lead to an increase in the absolute number of people living with the effects of stroke in the coming years. As a result, there is an urgent need for appropriate health services to support stroke survivors and improve quality of life.

Stroke has a significant impact on Canadians, their families, and the health care system. According to the Public Health Agency of Canada, it is estimated that the cost of stroke management is $3.6 billion per year, reflecting both direct and indirect costs (i.e. health care costs and lost economic output, respectively). Initial treatment and care for stroke occurs in hospital, and generally requires a longer length of stay (LOS) than other health conditions; for instance, the median LOS in Canada when stroke was the primary diagnosis was nine days compared with four days for all acute care in-patients. Despite an increased demand for post-stroke rehabilitation, access to in-patient stroke rehabilitation services is limited by available funding in the Canadian
health care system. In 2010-2011, the estimated cost of one in-patient rehabilitation bed day in Ontario was $603. Therefore, a single day reduction in mean LOS during in-patient stroke rehabilitation could save the Ontario health care system an estimated $2 million annually. Stroke will continue to be a major burden to society, as the effects of stroke are numerous and long-lasting.

2.2 Effects of stroke

Up to 40% of stroke survivors are left with moderate to severe long-term disabilities. A combination of sensory, motor, cognitive, and emotional impairments can affect an individual’s ability to perform activities of daily living (ADL). Sensorimotor impairment after stroke is common, and can be regarded as a limitation of function in motor control or movement, or a limitation in mobility. Motor impairment typically affects the face, arm, and leg of one side of the body, and is present in about 80% of patients. Hemineglect occurs in 23% of individuals with stroke, and can lead to decreased awareness on the side opposite of the brain lesion, translating to difficulty executing tasks or navigating the environment.

Balance impairment is a major problem after stroke. Compared with age-matched controls, individuals with stroke have impaired standing balance control, which is associated with a high incidence of falls. The ability to maintain balance is fundamental to daily movements requiring upright mobility, such as transfers and walking, performance of ADL, and reduced fall risk. Control of sitting and standing balance have been shown to be important in stroke recovery and as such a focus of rehabilitation is the facilitation of balance control. In addition, muscle weakness can
contribute to deficits in balance and falls, where reduced strength from hemiparesis is associated with limitations of functional activities.\textsuperscript{50} Further, impairment of lower-limb motor function and balance are significantly associated with performance in a six-minute walk test post-stroke.\textsuperscript{51}

Approximately 30-39\% of stroke survivors experience cognitive deficits,\textsuperscript{3,52} such as disturbances of attention, orientation, and memory, when assessed using the Mini-Mental State Examination and a battery of neuropsychological tests. Previous studies have found that cognitive deficits are indicators of poor prognosis and may negatively influence the rehabilitation process and increase the risk of falling.\textsuperscript{3,53} Individuals may be less able to anticipate and adapt to environmental stimuli or react to balance disturbances in addition to other impairments post-stroke. Cognitive impairment is also significantly associated with functional dependence after hospital discharge.\textsuperscript{3}

Finally, emotional changes after stroke may not be obvious and can include feelings of fear, anxiety, frustration, and sadness alongside the physical and cognitive deficits. Depression is prevalent after stroke with 31\% of patients affected within the first year, and the risk of occurrence is stable across all stages of recovery.\textsuperscript{4} Depressive symptoms and anxiety are linked to fear of falling (FOF),\textsuperscript{54} and a study of hospitalized older adults found that 38\% of participants with moderate to severe FOF had a depressive disorder compared to only 4\% of those who were not fearful.\textsuperscript{55}

As described in more detail below, falls are complex occurrences with many potential underlying causes. Therefore, as a result of the numerous effects of stroke these individuals are at a high risk of falling.
2.3 Recovery and rehabilitation after stroke

2.3.1 Time course of recovery

Like the effects of stroke, recovery from stroke is highly variable. Both the effects of stroke and recovery are influenced by stroke characteristics (e.g. type, size and location of stroke, time post-stroke) and sociodemographic characteristics (e.g. age, gender).\textsuperscript{33,47} Spontaneous neurological recovery early after stroke is often a result of brain repair and re-organization, including the resolution of edema surrounding the injury, and reperfusion of the ischemic penumbra.\textsuperscript{56} Neuroplasticity, referring to the remapping of injured neural networks, as a result of structural and functional changes in brain circuits is associated with stroke recovery.\textsuperscript{57,58} Neurological recovery peaks within the first three months post-stroke and reduces the extent of neurological damage.\textsuperscript{59,60} On the other hand, functional recovery is demonstrated by the improved ability to perform activities (e.g. ADL, motor tasks).\textsuperscript{61} Individuals will strive to regain full function to their pre-morbid levels. Functional recovery depends on many factors, including the individual’s motivation, ability to learn, and the quality and intensity of the therapy.\textsuperscript{61} As such, the extent of recovery is modifiable by interventions.

Previous research has pointed to critical periods of time for improvement after stroke, particularly in the sub-acute phase after stroke (i.e. less than three months post-stroke). In a large study from Denmark, Jorgensen and colleagues concluded that the best functional recovery was reached in 80% of patients within six weeks, and in 95% within 12.5 weeks after stroke.\textsuperscript{62} Furthermore, Kwakkel and Kollen stated that on average, stroke recovery plateaus three to six months after stroke onset.\textsuperscript{33} It has also been reported that by six months post-stroke, physical recovery is complete and that additional gains are a result of learning, practice, and confidence.\textsuperscript{63} However, a
systematic review of rehabilitation interventions initiated in the chronic phase of stroke (i.e. more than six months post-stroke) showed that individuals with stroke can continue to make significant improvements in the long-term.\textsuperscript{64} For example, providing lower limb resistance training to community-dwelling individuals increased comfortable gait speed and total distance walked.\textsuperscript{65} Therefore, despite the understanding of a plateau in recovery, there is evidence to suggest that recovery can persist beyond the sub-acute phase of stroke, and that more attention over the long-term is required to manage this chronic disease.\textsuperscript{66}

\subsection*{2.3.2 Stroke rehabilitation}

The aim of stroke rehabilitation is to enable an individual with impairment to reach his or her optimal physical, cognitive, emotional, communicative, and social functional level through a progressive, goal-oriented process.\textsuperscript{67} Rehabilitation is essential for stroke recovery, and can take place across various health care settings.\textsuperscript{8}

In acute care hospital, the focus is on providing interventions to reduce damage to the brain and stabilize the medical condition. As stroke survivors become medically stable, rehabilitation therapy (e.g. physiotherapy, occupational therapy, or speech-language therapy) is initiated, and readiness for transfer to a specialized in-patient stroke rehabilitation program for active interventions is determined.\textsuperscript{68} In 2011-2012, after a median acute hospitalization of six days, 55\% of stroke patients in Ontario returned home with or without services, 13\% were transferred to acute care or complex continuing care, 6\% were discharged to long-term care, and approximately 24\% of were discharged to in-patient rehabilitation.\textsuperscript{69} At the national level, the percentage of stroke
patients accessing in-patient rehabilitation remains low, and ranges from 16-19% of all patients.\textsuperscript{1,70}

As stated in the previous section, recovery is most rapid in the sub-acute phase after stroke (i.e. less than three months post-stroke),\textsuperscript{71,72} which is when patients typically attend in-patient rehabilitation. A specialized rehabilitation unit with multidisciplinary teams and individualized in-patient therapy can help patients relearn skills that may have been affected by the stroke.\textsuperscript{73} In a controlled study, patients treated on a stroke rehabilitation unit had lower mortality rates and shorter hospital stays compared to patients treated on a general medical unit.\textsuperscript{74} The established benefits of in-patient stroke rehabilitation include reduced mortality for patients with more severe strokes, and improved functional outcomes for moderate strokes.\textsuperscript{75,76} Therefore, individuals with moderate stroke tend to make better functional gains during in-patient stroke rehabilitation, and as a result are more likely to access rehabilitation compared to those with severe stroke.\textsuperscript{77-80} The Canadian Best Practice Guidelines for Stroke Care state that patients should receive a minimum of one hour of direct therapy by each discipline (e.g. physiotherapy, occupational therapy, and speech-language therapy), as required, five days per week following an individualized treatment plan based on their needs and rehabilitation goals.\textsuperscript{67} Independence when walking has been consistently reported as a rehabilitation goal that is important and meaningful to patients,\textsuperscript{81,82} therefore, appropriate lower limb function and balance ability would be essential elements to achieve independent mobility. In order to return home and reintegrate into community life, patients must achieve a level of functional independence.
Indeed, the majority of patients (64-83%) are discharged to the community following rehabilitation. Therefore, there is a need for community-based services to further improve functional abilities, prevent deterioration, and assist with the transition back to pre-morbid activities. Ongoing rehabilitation in the form of out-patient services, such as therapy-based rehabilitation, can reduce poor outcomes (e.g. hospital readmission), and improve ADL. Performance in ADL enables individuals to participate in social and domestic roles, and promotes quality of life. While a large number of resources are dedicated to the acute and sub-acute phases after stroke, physiotherapy interventions have been shown to be effective for improved functional outcomes and appropriate in the chronic phase (i.e. more than six months post-stroke).

2.4 Falls after stroke

2.4.1 Falls incidence

A fall is defined as any time an individual comes to rest unintentionally on the ground, floor, or other lower level. The issue of falls is important in the stroke population, as individuals with stroke are more likely to sustain a hip fracture due to a fall than those without stroke, and more often lose independent mobility. Accidental falls are common in all post-stroke settings (i.e. acute care hospital, in-patient rehabilitation, and community). In-hospital falls are one of the most common medical complications post-stroke, with 4-22% of individuals with stroke falling at least once during acute care. During in-patient rehabilitation, studies report that between 12-47% of individuals fall at least once. The higher incidence of falls during in-patient rehabilitation compared to acute hospitalization could be a result of increased mobilization and regained abilities.
with recovery, and/or due to a longer LOS compared to the time spend in acute care, and therefore, an increased 'opportunity' to fall. Among stroke survivors returning to the community following rehabilitation, 37-73% fall within the first six months.\textsuperscript{17-19} Falls appear to be most prevalent during the initial one to two months post-discharge,\textsuperscript{91} possibly because individuals are adjusting to their home environment with persistent limitations during the transition home. With limited available evidence for the effectiveness of falls prevention interventions after stroke across acute care, rehabilitation, and community settings,\textsuperscript{92,93} the issue of falls will continue to be an important topic.

2.4.2 Risk factors
Individuals with stroke fall more often than age-matched controls.\textsuperscript{29} Much work has been done in the area of identifying stroke survivors who are at increased risk of falling. Lower performance in ADL has been found to be a common risk factor during in-patient rehabilitation\textsuperscript{12,14,15} as well as community living.\textsuperscript{17,47} A study by Suzuki and colleagues used the Functional Independence Measure (FIM) to assess the level of ADL during hospital rehabilitation, and noted that the motor and cognitive subscales as well as the total FIM score were significantly lower for those who fell than those who did not fall.\textsuperscript{14} One study found that the ability to transfer (e.g. moving from bed to chair or chair to toilet) was important among patients who fell within the first five days of admission.\textsuperscript{94} Previous falls are a strong risk factor for future falls, specifically, falling in-hospital is a predictor of falling at home.\textsuperscript{17,19}

Balance deficits may be a result of stroke-related impairments, such as muscle weakness, sensory loss, and attention deficits, which put an individual at risk for falls.\textsuperscript{32}
Impaired balance has been found in the literature to be the factor most often associated with falling in hospital,\textsuperscript{16,95} and in the community after stroke.\textsuperscript{17,19,20} Specifically, two studies concluded that lower scores on the Berg Balance Scale (BBS) were significantly associated with increased fall risk;\textsuperscript{16,95} however, other studies did not find the same results.\textsuperscript{46,96} Instead, Pang and colleagues determined that fall-related self-efficacy, rather than balance and mobility performance, was the most important determinant of falls among stroke survivors.\textsuperscript{96} Falls often occur while walking as a result of perturbations to standing balance;\textsuperscript{17} therefore, the greater ability to respond to internal and external perturbations is linked to reduced falls risk.\textsuperscript{97,98}

A few studies have reported that individuals with post-stroke cognitive impairment are at increased risk of falls during in-patient rehabilitation.\textsuperscript{14,16,99} However, other studies have not reached the same conclusion,\textsuperscript{15,25,26} as Rapport and colleagues found that behavioural impulsivity was only moderately associated with falls.\textsuperscript{26} Patients with cognitive deficits may attempt activities beyond their capabilities. Fifty eight percent of falls occurred after patients failed to heed instructions regarding physical activity, which was hypothesized to be an issue of cognitive impairment;\textsuperscript{13} for example, an individual with memory or attention deficits who is unable to walk may attempt to do so without assistance.

In addition to individual risk factors for falls, it is important to acknowledge the extrinsic and environmental factors that may play a role in falls after stroke. In the general elderly population, impairments of vision, hearing, and memory tend to increase the number of trips and stumbles.\textsuperscript{100} Medication use is also an extrinsic risk factor for falls in older adults;\textsuperscript{101} however, studies in the stroke population have not found medications to be
related to fall frequency. The use of a walking aid among stroke survivors was associated with increased risk of falls. Individuals with stroke are likely to have multiple identifiable risk factors for falls and the complex interaction of individual risk factors and exposure to hazards of the environment leads to an increased likelihood of falling.

2.4.3 Circumstances of falls
Falls often coincide with periods of greater activity, such as during the day when individuals are most active. Previous studies have found that in-hospital falls were likely to occur while transferring and using a wheelchair. On the other hand, falls in the community setting most frequently occurred while walking with up to 51% of individuals falling during walking. In terms of the causes of falls, intrinsic risk factors are more common among individuals with stroke compared to age-matched population controls, likely due to the multisystem effects of stroke. Intrinsic factors dominate with a high percentage of falls (20-30%) caused by a “loss of balance” with no apparent external/environmental cause; however extrinsic causes (e.g. slips and trips, obstacles) are also common (11-34%).

2.4.4 Consequences of falls
Among individuals with stroke, 8-55% of falls result in injury, with the highest injury rates occurring in community-dwelling stroke survivors. Given this wide range of injury rates, it is difficult to interpret the extent of the problem when comparing multiple studies because injuries vary in severity from minor (e.g. cuts or bruises) to serious (e.g. fractures). While a relatively small proportion (2-4%) of falls post-stroke resulted in a fracture or other serious injury, individuals with stroke are approximately four times
more likely to suffer a hip fracture than age-matched controls, which is often due to a loss in bone mineral density on the more affected side.\textsuperscript{90} Fall-related psychological issues are not as obvious as physical injuries but are an emerging issue after stroke.\textsuperscript{107} Fear of falling (FOF) is one such construct, defined as a lasting concern about falling that leads one to avoid activities that he/she remains capable of performing,\textsuperscript{108} that has been investigated. Among stroke survivors who fell in the community, 88% of patients reported developing FOF.\textsuperscript{30} Fear of falling often leads to reduced physical activity and develops over the course of recovery after stroke.\textsuperscript{107} Balance confidence, on the other hand, is the confidence in one’s ability to maintain balance and remain steady.\textsuperscript{109} The construct of balance confidence reflects perceived balance ability and is a situation-specific form of self-efficacy.\textsuperscript{110} Balance self-efficacy has been shown to predict physical function and perceived health status after stroke,\textsuperscript{111} and may influence the types of activities an individual engages in. In a study by Mackintosh and colleagues, 44% of individuals with stroke living in the community reported restricting their activity as a result of a fall.\textsuperscript{91} A high proportion of individuals may then go on to experience physical decline, as reported in studies of older adults.\textsuperscript{112-114} Therefore, reduced physical activity and mobility due to falling may hinder ongoing recovery and further compound deficits in physical function.

2.4.5 Falls prevention after stroke

Various interventions within community-dwelling healthy older adults have been found to reduce fall risk (e.g. group and home-based programs containing strength and balance exercises, Tai Chi, and home safety modifications),\textsuperscript{115} however, the same cannot be said for the stroke population. Currently, there is little evidence that any intervention effectively prevents falls in people with stroke.\textsuperscript{93} Ten randomized controlled
trials have been conducted to date examining the effect of exercise, medication (i.e. vitamin D, and alendronate), assistive devices (i.e. single lens distance vision glasses), or multi-factorial interventions on falls in the chronic stage of stroke, with the exception of one study that looked at treadmill walking with body weight support in the acute and sub-acute stages. No significant differences were found in the rate of falls or the number of fallers between the exercise or assistive device intervention and control groups, although there was a benefit for the two medication groups compared to the control groups. Research in the area of falls prevention after stroke is currently lacking. There have been few studies focused on preventing falls as the primary objective (only 10 randomized controlled trials), a lack of a standard definition of falls, and the method of falls monitoring varied between studies. Furthermore, the majority of the randomized controlled trials to date have only focused on preventing falls in the chronic stage of stroke recovery, with little work focused on preventing falls during in-patient rehabilitation.

2.4.6 Conceptual model of falls after stroke and impact on recovery

In the current work, a ‘faller’ refers to an individual who experiences at least one fall, whereas a ‘non-faller’ refers to an individual who does not experience a fall during the specified time period. As previously described, stroke can leave an individual with physical, cognitive, and emotional impairments. Beyond the initial effects of stroke, falls potentially contribute to injury, FOF, and reduced physical activity, and a ‘downward spiral’ of deconditioning, functional decline, and further increases in fall risk among stroke survivors.
Figure 2.1 illustrates the relationship of falls and the major effects of stroke, individual risk factors, and consequences of falls among stroke survivors. As a result of stroke-related impairments, an individual is at an increased risk of falls. After a fall occurs, there may be negative consequences, such as physical injury, the development of FOF and/or reduced physical activity. It is hypothesized that these consequences affect an individual's participation in activities (e.g. physical rehabilitation or ADL) and lead to deconditioning and declines in function, further predisposing an individual to falls. The relationship between falls, fear of falling, and reduced physical activity is important to establish, as falls may contribute to poor function and recovery after stroke.

**Figure 2.1: Conceptual model of falls after stroke.** Stroke can lead to physical, cognitive, and emotional deficits, which can put an individual at high risk for falls. Experiencing a fall has consequences, such as fear of falling, which may lead to decreased physical activity and eventually, loss of independence, and further decline.
Following the model described in Figure 2.1, Figure 2.2 shows a hypothetical time course of functional recovery in a patient following stroke. The time course of recovery is strongly related to initial stroke severity and disability, as individuals with more severe strokes typically recover slower than those with moderate or mild strokes. Following the onset of stroke, there is a high rate of recovery of function within the first month in which the individual undergoes formal rehabilitation. If an adverse event, such as a fall, occurs during this time, the individual may experience a slower recovery as a result. The same assumption holds if instead the individual experiences a fall in the community, where the fall may be considered a setback and then takes on a different course of recovery. While substantial recovery takes place in the first three months post-stroke, there is evidence of continued functional recovery beyond this critical time window and the potential for many factors to impact the course. In conclusion, recovery after stroke begins right away, can occur over months and years, and stroke rehabilitation is a major influence on patient outcomes.
Figure 2.2: Recovery patterns after stroke and the proposed impact of falls. A hypothetical stroke patient is presented in the following scenarios: non-faller (blue line), in-patient faller (red line), and community faller (green line). All profiles begin at the time of stroke onset (0 months) and extend to eight months post-stroke across the different health care settings (i.e. acute care, in-patient rehabilitation, community-dwelling). Recovery is expressed as a percentage of the individual’s pre-morbid ability using an outcome measure of choice. The asterisk (*) indicates when the fall occurs. Over time, the scenarios when the individual experiences a fall are worse off in terms of recovery than the non-faller. In addition, the faller during in-patient rehabilitation is at a lower functional level than the community faller.
2.5 Objectives

The overall aim of the current work was to investigate the impact of falls on post-stroke recovery. To do this, the following questions were investigated in two separate studies:

1. Do falls experienced during in-patient stroke rehabilitation affect length of stay, functional status, and discharge destination?

2. Do falls among community-dwelling stroke survivors impact recovery six months after discharge from in-patient stroke rehabilitation?

The objective of the first study was to compare length of stay, functional status and discharge destination among individuals who fell and those who did not fall. It was hypothesized that individuals who experienced a fall in-hospital would have a longer length of stay, be at a lower functional level at discharge, and be less likely to be discharged home when compared to individuals who did not fall.

The primary objective of the second study was to compare motor and cognitive outcomes of stroke recovery between individuals who fell in the six months post-discharge from in-patient stroke rehabilitation and those who did not fall. It was hypothesized that individuals who fell in the community would have worse motor and cognitive outcomes than those who did not fall when assessed six months after discharge from hospital. The secondary objective was to explore potential underlying mechanisms for the relationship between falls and recovery of motor and cognitive function. It was hypothesized that poor motor and cognitive outcomes would be associated with decreased balance confidence and reduced physical activity levels.
3. Study 1: Do falls experienced during in-patient stroke rehabilitation affect length of stay, functional status, and discharge destination?

3.1 Introduction

Falls are common post-stroke, with 12-47% of individuals falling at least once during in-patient stroke rehabilitation.\textsuperscript{12-16} Individual risk factors for falls among stroke survivors are numerous and interrelated,\textsuperscript{32} and can include impaired performance of activities of daily living,\textsuperscript{12,14,15} inability to transfer,\textsuperscript{94} decreased balance control,\textsuperscript{16,20} and not following instructions.\textsuperscript{13,26} Falls after stroke can have significant immediate physical and psychological consequences,\textsuperscript{29} including injuries\textsuperscript{13-15,91} such as hip fractures,\textsuperscript{90} fear of falling,\textsuperscript{30} reduced physical activity,\textsuperscript{91} and depression.\textsuperscript{17} In-hospital falls have been identified as one of the most common medical complications after stroke,\textsuperscript{9,11} which can negatively influence stroke rehabilitation and recovery.\textsuperscript{13}

In-patient rehabilitation is a health care setting where patients are focused on improving function and maximizing their abilities. It is typically delivered during the sub-acute stage of stroke recovery (i.e. less than three months post-stroke) when patients are likely to receive the most benefit from intensive therapy.\textsuperscript{71,72} Unfortunately, there is limited available evidence for the effectiveness of falls prevention interventions after stroke across acute care, rehabilitation, community, and institutional care settings.\textsuperscript{92,93} Thus, the incidence of falls will remain of concern, as it may not be possible to prevent every fall.
Little evidence exists on the impact of falls on rehabilitation outcomes; therefore, it is important to understand the effect that falls have on the course of patient recovery and delivery of care during the critical sub-acute phase of stroke. The primary objective of this study was to compare length of stay, functional status, and discharge destination between individuals who fell during in-patient stroke rehabilitation and those who did not fall. It was hypothesized that patients who fell would have poorer recovery compared to those who did not fall. This would be demonstrated by a longer length of stay, worse functional outcomes at discharge, and less likely to be discharged home following the rehabilitation stay among individuals who fell.

3.2 Methods

3.2.1 Study design

A retrospective cohort study involving a chart review was conducted. The chart review involved consecutive admissions to the specialized stroke unit at the Toronto Rehabilitation Institute from October 1, 2009 to September 30, 2012. The Toronto Rehabilitation Institute Research Ethics Board approved this study, and a waiver of patient consent for the purpose of this review was obtained.

3.2.2 Participants

The in-patient stroke rehabilitation unit housed 20 to 23 beds during the time of data collection, and admitted patients who were medically stable and had the endurance to participate in the program. Patients received multidisciplinary care including individualized physiotherapy, occupational therapy, and speech-language therapy for one hour per discipline per day, five days per week over a typical length of stay of four
to six weeks. Excluding duplicate admissions for another stroke and individuals without imaging (n=20), 504 patients with confirmed stroke were admitted to the stroke unit during the three year period. Patients were excluded from the analysis if they were not living at home before their acute stroke hospitalization (n=18), and/or if their Functional Independence Measure (FIM) scores on admission were missing (n=17). The study sample was created by matching all individuals who fell at least once during in-patient rehabilitation (i.e., “fallers”) with a randomly-selected sample of individuals who did not fall (i.e., “non-fallers”). A fall was defined as any time an individual came to rest unintentionally on the ground, floor, or other lower level. Matching was necessary because, on average, fallers and non-fallers tend to differ on measures of function and impairment on admission that are predictive of the current study’s primary outcomes. The sample of non-fallers was matched to fallers by stratified random sampling according to the Rehabilitation Patient Group (RPG) and age. The RPG algorithm was developed to provide a case-mix classification system to estimate in-patient rehabilitation costs, and is often used to determine length of stay (LOS) (i.e., one of the primary outcomes). Admission FIM scores and age (i.e. <40, 40-59, 60-79 and >80 years) were used to stratify all individuals. Due to the distribution of the study sample, the two lowest RPG categories from the original algorithm were combined, representing patients with a motor score of 12 to 38, leaving six possible RPG categories (Figure 3.1).
3.2.3 Data extraction

All data were recorded in patients’ clinical charts during their rehabilitation stay by clinical staff (medical and allied health professionals), and extracted by trained research staff using a chart review form. Data were checked for inconsistencies and logical errors that may have arisen due to errors in extraction and were corrected, as necessary. The following variables were extracted to describe the cohort: age, sex, Berg Balance Scale (BBS)\(^ {127}\) score on admission, and the date and type of stroke. Falls experienced during in-patient rehabilitation were captured from hospital incident reports, nursing notes, and patient interviews that were part of routine care at discharge from rehabilitation.\(^ {128}\) Where available, information on each fall was recorded, which included details of the

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**Figure 3.1: The Rehabilitation Patient Group (RPG) classification system.** The RPG algorithm is based on admission Functional Independence Measure (FIM) scores, using the motor FIM score (minus tub/shower transfer) and the cognitive FIM score to divide patients into groups. Each RPG is then used to predict performance measures such as length of stay, and resource utilization.
activity undertaken at the time of fall, where and when the fall occurred, and if any injury resulted. During the in-patient rehabilitation length of stay, patients may have had the opportunity to go home on a weekend pass; therefore, any falls that took place in the home of the patient were also included. Details of falls experienced on a weekend pass were collected through patient interviews, as these events were not recorded by the hospital incident reporting system. The three primary outcomes of this study are described below.

Length of stay (LOS) was determined by the total number of days spent on the in-patient stroke rehabilitation service (i.e. the number of days between admission and discharge date). Occasionally, patients were placed on alternative level of care (ALC; i.e. when patients no longer required the level of care provided in the given hospital setting) while waiting for a discharge plan to be finalized (e.g. if the patient was on a waiting list for long-term care). Thus, a patient's discharge date was the date that the patient left the rehabilitation hospital permanently. If a patient was temporarily transferred to another location for at least one overnight stay (e.g. to an acute care facility for treatment), LOS was adjusted by subtracting the number of days spent off the stroke unit.

Functional status was measured at admission and discharge from rehabilitation using the Functional Independence Measure (FIM). The FIM instrument is a standardized measure of motor and cognitive disability, and rates an individual's level of independence in 18 tasks on a scale from 1 to 7, with 1 corresponding to full dependence, and 7 corresponding to complete independence. Total FIM scores can range from 18 to 126; the motor domain ranges from 13 to 91 and the cognitive domain
ranges from 5 to 35. The FIM has been studied extensively and has been found to have acceptable inter-rater and test-retest reliability in rehabilitation populations. The minimal clinically important difference for the FIM is a 22-point change, which reflects a significant improvement in functional independence among patients with stroke.

Discharge destination after in-patient rehabilitation was defined dichotomously, home or not home. If an individual was not discharged home, other possible discharge destinations included a retirement home, acute care hospital (transferred and did not return to the rehabilitation facility), convalescent care (for additional therapy), long-term care, and another rehabilitation facility (to be closer to home).

3.2.4 Statistical analysis
Characteristics of non-fallers and fallers were compared on admission to in-patient rehabilitation using the Mann-Whitney U test for continuous or ordinal data, and the chi-square or Fisher’s exact test for nominal data. The alpha level for comparing baseline characteristics of the two groups was set at 0.05. To test the outcomes of interest, the non-fallers and fallers were compared on LOS, discharge FIM scores using the Mann-Whitney U test, and discharge destination (i.e. home or not home) was compared using the chi-square test. Non-parametric testing (i.e. Mann-Whitney U test) was necessary for LOS and FIM scores after assumptions of normality were violated (i.e. Shapiro-Wilk test, quantile-quantile plot). To examine the three primary outcome measures, a one-tailed test was used and an alpha was set at 0.017 (i.e., Bonferonni-corrected for multiple comparisons; 0.05 divided by three primary outcome measures). Statistical analyses were carried out using SAS version 9.2.
3.3 Results

Of the 469 patients attending in-patient stroke rehabilitation, 113 patients (24%) were classified as fallers; therefore, a pool of 356 patients was available to select a matched sample of non-fallers. A final sample of 212 participants (106 non-fallers and 106 fallers) was included in the analysis; seven fallers were excluded because no non-faller match was found. Over half (51%) of the participants were in the lowest RPG category, representing severe disability. There were no significant differences on demographic and stroke characteristics between non-fallers and fallers on admission to rehabilitation (Table 3.1).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients not included (n=257)</th>
<th>Study sample</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-fallers (n=106)</td>
<td>Fallers (n=106)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>69.4 (13.6)</td>
<td>67.3 (13.6)</td>
<td>67.8 (12.9)</td>
</tr>
<tr>
<td>Number of women</td>
<td>117 (46)</td>
<td>48 (45)</td>
<td>47 (44)</td>
</tr>
<tr>
<td>Time post-stroke (days)</td>
<td>20.2 (28.9)</td>
<td>21.9 (28.8)</td>
<td>26.4 (28.3)</td>
</tr>
<tr>
<td>Type of stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischemic</td>
<td>205 (80)</td>
<td>81 (76)</td>
<td>81 (76)</td>
</tr>
<tr>
<td>Hemorrhagic</td>
<td>36 (14)</td>
<td>19 (18)</td>
<td>14 (13)</td>
</tr>
<tr>
<td>Ischemic &amp; hemorrhagic</td>
<td>3 (1)</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Transforming to hemorrhagic</td>
<td>13 (5)</td>
<td>5 (5)</td>
<td>10 (9)</td>
</tr>
<tr>
<td>Total FIM (points)</td>
<td>88.4 (18.5)</td>
<td>65 (21)</td>
<td>61.9 (18.1)</td>
</tr>
<tr>
<td>Motor</td>
<td>64 (16.5)</td>
<td>43.1 (18.3)</td>
<td>61.9 (18.1)</td>
</tr>
<tr>
<td>Cognitive</td>
<td>24.4 (5.9)</td>
<td>21.9 (6.5)</td>
<td>21.6 (5.9)</td>
</tr>
<tr>
<td>Berg Balance Scale (0-56 points)</td>
<td>35.7 (16.4)*</td>
<td>19.1 (15.5)</td>
<td>14.6 (13.9)</td>
</tr>
</tbody>
</table>

NOTE: Values are means (standard deviation) for continuous or ordinal variables, and counts (% rounded to the nearest integer) for categorical variables. The p value is for the Mann-Whitney U test, chi-square or Fisher’s exact test comparing non-fallers to fallers on admission.

* Berg Balance Scale scores missing for two patients.
A total of 157 falls were recorded, and 31/106 fallers (29%) fell more than once. The average time from admission to an individual’s first fall was 20.5 days (standard deviation (SD)=18.3 days), and 30/157 falls (19%) took place within the first week of rehabilitation (Figure 3.2).

**Figure 3.2: Timing of falls during in-patient rehabilitation (n=157 falls).** Each fall was included with reference to the admission date among 106 fallers.

Circumstances of in-patient falls are presented in Table 3.2. Fifty-four falls of the 157 falls (34%) occurred during transfers (e.g. from bed to wheelchair), 78/157 falls (50%) took place in the patient’s room in the hospital, and no injury was observed in 106/157 falls (68%).
Table 3.2: Circumstances of in-patient falls (n=157 falls).

<table>
<thead>
<tr>
<th>Activity at time of fall</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transferring</td>
<td>54 (34)</td>
</tr>
<tr>
<td>Reaching, bending or turning</td>
<td>30 (19)</td>
</tr>
<tr>
<td>Walking</td>
<td>14 (9)</td>
</tr>
<tr>
<td>Sitting</td>
<td>9 (6)</td>
</tr>
<tr>
<td>Standing</td>
<td>9 (6)</td>
</tr>
<tr>
<td>Lying</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Not available</td>
<td>39 (25)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location of fall</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td>137 (87)</td>
</tr>
<tr>
<td>Patient’s room</td>
<td>78</td>
</tr>
<tr>
<td>Bathroom, tub room</td>
<td>41</td>
</tr>
<tr>
<td>Common area</td>
<td>10</td>
</tr>
<tr>
<td>Therapy area</td>
<td>8</td>
</tr>
<tr>
<td>Home of patient</td>
<td>11 (7)</td>
</tr>
<tr>
<td>Bedroom</td>
<td>5</td>
</tr>
<tr>
<td>Bathroom</td>
<td>3</td>
</tr>
<tr>
<td>Kitchen</td>
<td>1</td>
</tr>
<tr>
<td>Outdoors</td>
<td>1</td>
</tr>
<tr>
<td>Not specified</td>
<td>1</td>
</tr>
<tr>
<td>Not available</td>
<td>9 (6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injury after fall</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No injury</td>
<td>106 (68)</td>
</tr>
<tr>
<td>Cuts or bruises</td>
<td>17 (11)</td>
</tr>
<tr>
<td>Pain (e.g. back, hip, shoulder)</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Hit head*</td>
<td>3 (1)</td>
</tr>
<tr>
<td>Head injury</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Not available</td>
<td>23 (15)</td>
</tr>
</tbody>
</table>

NOTE: Values are counts (% rounded to the nearest integer) for categorical variables. *No confirmed head injury; however, the interdisciplinary team initiated a head injury routine as per protocol.
The average LOS for fallers was 11 days longer than non-fallers (W(1)=9963, Z=-2.97, p=0.0017; Table 3.3). Fourteen patients were placed on ALC and when removing these patients and their matched pairs, differences in LOS remained highly significant between non-fallers and fallers (non-fallers: 42.4 days; fallers: 51.1 days; W(1)=7858, Z=-2.75, p=0.0033). There were no differences in discharge total FIM scores between non-fallers and fallers (W(1)=10981.5, Z=0.87, p=0.19). When analyzed on FIM subscales, the groups did not significantly differ at discharge on the FIM motor subscale (W(1)=11181, Z=1.33, p=0.093) or the FIM cognitive subscale (W(1)=10333, Z=-0.64, p=0.26). Likewise, a similar proportion of non-fallers and fallers were discharged home after in-patient rehabilitation (non-fallers: 77%; fallers: 74%; p=0.52; Table 3.3). Details of the breakdown of discharge destination are provided in Table 3.3.
Table 3.3: Differences in outcome measures at discharge from in-patient stroke rehabilitation.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Non-fallers</th>
<th>n</th>
<th>Fallers</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of stay (days)</td>
<td>106</td>
<td>43.8 (24.8)</td>
<td>106</td>
<td>54.8 (29.7)</td>
<td>0.0017*</td>
</tr>
<tr>
<td>Total FIM (points)</td>
<td>102</td>
<td>97.3 (21)</td>
<td>105</td>
<td>96.4 (18.5)</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>69.8 (17.3)</td>
<td></td>
<td>68.4 (14.8)</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cognitive</td>
<td></td>
<td></td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27.5 (5.6)</td>
<td></td>
<td>28 (5.5)</td>
<td></td>
</tr>
<tr>
<td>Discharge destination</td>
<td>106</td>
<td></td>
<td>106</td>
<td></td>
<td>0.52</td>
</tr>
<tr>
<td>Home</td>
<td></td>
<td>82 (77)</td>
<td></td>
<td>78 (74)</td>
<td></td>
</tr>
<tr>
<td>Not home</td>
<td></td>
<td>24 (23)</td>
<td></td>
<td>28 (26)</td>
<td></td>
</tr>
<tr>
<td>Retirement home</td>
<td></td>
<td>7 (7)</td>
<td></td>
<td>3 (3)</td>
<td></td>
</tr>
<tr>
<td>Acute care</td>
<td></td>
<td>6 (6)</td>
<td></td>
<td>4 (4)</td>
<td></td>
</tr>
<tr>
<td>Convalescent care</td>
<td></td>
<td>6 (6)</td>
<td></td>
<td>8 (8)</td>
<td></td>
</tr>
<tr>
<td>Long-term care</td>
<td></td>
<td>4 (4)</td>
<td></td>
<td>13 (12)</td>
<td></td>
</tr>
<tr>
<td>Another rehab facility</td>
<td></td>
<td>1 (1)</td>
<td></td>
<td>0 (0)</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Values are means (standard deviation) for continuous or ordinal variables, and counts (% rounded to the nearest integer) for categorical variables. The p value is for the Mann-Whitney U test and for the chi-square test comparing both groups at discharge.

*p value is significant, where p<0.017 (Bonferroni-corrected for multiple comparisons).

There were 24/106 fallers (23%) who experienced an injury. When the injured fallers and their non-faller matches were analyzed separately, LOS was no longer significantly different between the two groups (non-fallers: 40.9 days; fallers: 53.6 days; W(1)=515, Z=-1.5, p=0.071). For the total FIM scores at discharge, the injured fallers had a higher but not statistically significant mean score than their non-faller matches (non-fallers: 91.9 points; fallers: 99.1 points; W(1)=528, Z=-0.5, p=0.31).

3.4 Discussion

In support of the hypothesis, patients who fell had a longer LOS than those who did not fall. The course of rehabilitation may have been extended for fallers due to setbacks in
physical recovery that required additional resources or modifications to discharge planning. It is also possible that fallers were fearful of experiencing another fall, which in turn influenced recovery and hospital LOS.\textsuperscript{131} Waiting periods for patients on ALC may have contributed to a prolonged LOS, where active rehabilitation and discharge planning is complete.

Contrary to the hypothesis, both groups had similar functional scores at discharge from rehabilitation, despite the increased LOS for fallers. A potential reason for this result could be that the rehabilitation team kept the patient beyond the targeted discharge date in order for the patient to reach an appropriate functional level before discharge. Since groups were similar on functional status on admission, this finding suggests that fallers required more time to achieve the same level of function as non-fallers. This level of functional improvement was clinically significant, as both groups, on average surpassed the minimal clinically important difference of 22 points on the FIM.\textsuperscript{130} With a limited number of rehabilitation beds available, information regarding the impact of falls is essential to optimize efficiency of in-patient stroke rehabilitation services. Even though fallers had a longer LOS, and thus greater costs associated with care,\textsuperscript{38} small improvements in functional status may have significant benefits in quality of life and future health care utilization. Likewise, there were no differences in the proportion of individuals who returned home following their rehabilitation stay between non-fallers and fallers. Participants included in this study lived at home prior to hospitalization for stroke; therefore, it would be expected that individuals would return to their premorbid residence when their medical and functional status improved, and their rehabilitation goals were met.
Both groups of non-fallers and fallers in this study averaged a longer LOS than the median LOS for stroke rehabilitation in Canada (i.e., 35 days). This was likely because the sample of individuals included in this analysis represents a lower-functioning subset of the institution’s stroke rehabilitation unit, as measured by the FIM (e.g., see Table 3.1). Thus, the results of this study apply to lower-functioning individuals receiving in-patient rehabilitation post-stroke. With greater dependence in ADL, these stroke survivors are at high risk of falling; however, individuals in the current study were able to achieve benefits from in-patient rehabilitation with a longer LOS.

Similarly, it appears as though fallers were admitted to rehabilitation later post-stroke than non-fallers, which may have been due to a longer LOS in acute care as a result of comorbidities or medical complexities. In addition, fallers averaged lower balance scores than non-fallers as measured by the Berg Balance Scale (BBS) on admission. Data on discharge suggests that fallers continued to have lower BBS scores than non-fallers but this was not statistically significant (p=0.057). Since balance impairment is an important risk factor for falls among individuals with stroke, and balance is essential for performing ADL, those who were more affected by stroke (and therefore more prone to falls) required longer in-patient treatment.

Overall, the rate of falls was within the range of other studies reporting falls during in-patient stroke rehabilitation (i.e. 113 out of 469 patients fell; rate: 24%). The proportion of fallers with more than one fall (‘multiple fallers’; rate: 29%) was in line with other studies of patients attending stroke rehabilitation (rates: 5-51%), as was the presence of injuries (rates: 8-29%). Falls while transferring are common in the in-
patient rehabilitation setting, and typically take place in the patient’s room or bathroom, which was the case in the current study. Falls were most prevalent during the first week of admission to rehabilitation, as reported in previous studies, making this a critical time point. There was also an increase in the frequency of falls in the fourth week of stay (i.e. 21-27 days from admission). Falls may have become more frequent as individuals recovered and may correspond with increased levels of mobility and exposure to risk-taking activities.

Lastly, the sub-analysis of injured fallers revealed that there was no statistically significant difference in LOS between injured fallers and their non-faller matches. Even though injured fallers stayed an average 12.7 days longer, this result may have been due to a low sample size (n=48). Interestingly, the injured fallers finished with a higher, though not significantly different, mean FIM score; however, this may have been as a result of the additional time on the unit.

This research study is unique because it is the first to our knowledge to examine the link between falls during in-patient stroke rehabilitation and their impact on length of stay and functional status at discharge. Compared to earlier uncontrolled efforts aimed at determining the consequences of falls in the stroke rehabilitation population, the current study matched on admission FIM using the RPG classification and age to ensure that the groups were comparable on admission and, therefore, the main difference between groups was the occurrence of a fall during in-patient rehabilitation.

3.4.1 Study limitations

This study has several potential limitations. Data were collected from a single hospital and may not be representative of other rehabilitation centres. The retrospective nature
of the methodology limited data collection to what was available in the medical chart, and this information extracted from medical charts was written for purposes other than research.\textsuperscript{135} For instance, there are factors other than falls that may have contributed to an increased LOS, such as comorbidities and psychosocial status that were not measured in the present study. In addition, injuries were classified dichotomously, as there were not enough details available to measure the severity among the types of injury; therefore, all falls were treated equally. Finally, the incidence of falls may have been low as a result of underreporting due to unwitnessed falls or events that staff did not perceive as reportable.

3.4.2 Conclusions
The results of this study suggest that falls may extend in-patient stroke rehabilitation length of stay. Longer length of stay can influence the overall individual recovery path of the patient, and have large economic consequences to the health care system. However, individuals who fell achieved a similar functional level at discharge and were equally likely to be discharged home compared to those who did not fall. These results shed light on how stroke recovery may be impacted by falls during this critical time for rehabilitation after stroke.
4. Study 2: The impact of falls on recovery after discharge from in-patient stroke rehabilitation.

4.1 Introduction

Compared to individuals with severe stroke, those with moderate stroke tend to benefit more from in-patient stroke rehabilitation,\textsuperscript{77-79} where patients receive specialized care from an interdisciplinary team. Patients typically attend in-patient rehabilitation in the sub-acute phase after stroke (i.e. less than three months post-stroke), and most recovery takes place in the first three to six months after stroke.\textsuperscript{71} The majority of stroke survivors attending in-patient rehabilitation (64-83\%) are discharged to community living.\textsuperscript{79,83,84} Thus, functional recovery, demonstrated by the improved ability to perform activities (e.g. activities of daily living (ADL), and motor tasks),\textsuperscript{61} continues after discharge. In addition, there is evidence that mobility can continue to improve with ongoing physical activity in the chronic phase of stroke recovery (i.e. more than six months post-stroke).\textsuperscript{87}

Individuals with stroke are at a high risk of falls,\textsuperscript{32} and the highest rates (37-73\%) occur within the first six months after discharge from hospital.\textsuperscript{17-19} Several studies have investigated risk factors for falls among community-dwelling stroke survivors,\textsuperscript{17,19,43,46,47} however, only a few have documented the consequences of falling beyond injury. Falls may lead to psychological concerns such as developing fear of falling, which was reported in 88\% of stroke survivors who fell in the community,\textsuperscript{30} and impaired balance self-efficacy, which has been shown to predict physical function and perceived health status after stroke.\textsuperscript{111} Falls among individuals with stroke can result in activity
restriction,\textsuperscript{91} and reduced social activity and depression,\textsuperscript{17} which can accelerate deconditioning and put an individual at further risk for falls.\textsuperscript{32} It is not yet known what the implications of these consequences are on the functional level of individuals returning home from hospital after stroke. Thus, because of the potential for fear, decreased activity, and social consequences of falls, it is possible that even falls that do not result in a physical injury may adversely affect continued recovery after stroke. Improving motor and cognitive deficits is important in order to regain the highest level of functioning after stroke.

The primary objective of this study was to compare motor and cognitive outcomes between individuals who fell in the six months post-discharge from in-patient stroke rehabilitation and those who did not fall. We hypothesized that individuals with stroke who fell in the community would have worse motor and cognitive outcomes (i.e. functional balance, motor recovery of the lower extremities, gait speed, and cognitive status) than those who did not fall when assessed six months after discharge from hospital. The secondary objective was to explore potential mechanisms underlying the relationship between falls and recovery of motor and cognitive function. It was hypothesized that poor motor and cognitive outcomes would be associated with decreased balance confidence and reduced physical activity levels.

4.2 Methods

4.2.1 Study design

This study involved secondary analysis of a prospective cohort study,\textsuperscript{136} which aimed to determine if measures of reactive balance control, as assessed at discharge from in-
patient rehabilitation, predicted falls in the six months post-discharge among individuals with stroke. Recruitment took place on the stroke rehabilitation unit at the Toronto Rehabilitation Institute – University Health Network between October 20, 2010 and March 21, 2013. This study was approved by the Toronto Rehabilitation Institute Research Ethics Board, and all participants provided written informed consent.

4.2.2 Participants
Participants were recruited at discharge following a course of in-patient stroke rehabilitation if they ambulated independently, completed a balance assessment in a specialized clinic, and returned home after discharge (n=95). For the purpose of this study, participants were excluded from the analysis if they did not return to the hospital for a follow-up assessment at the end of the six-month falls monitoring period (n=30 excluded).

4.2.3 Falls monitoring
Falls monitoring took place for six months post-discharge; participants were asked to report any falls or near falls using postcards mailed back to the investigators every two weeks. All participants were mailed monthly newsletters to remind them to return their completed postcards. A fall was defined as any time an individual came to rest unintentionally on the ground, floor, or other lower level. Participants were contacted by phone to complete a structured falls questionnaire, modified from one used by Maki and colleagues, to gather more details about the fall (Appendix). Falls and near falls were reclassified by study investigators according to the participant’s description of the event, if necessary (e.g. one participant reported a near fall when they lost their footing and
lowered themselves into a chair; however, a chair is considered a lower level, and therefore this event was re-classified as a fall).

4.2.4 Data collection

Information to describe the study cohort was collected from the patient chart: age, sex, date of stroke, and stroke type. In addition, the National Institutes for Health Stroke Scale\textsuperscript{138} was administered by study staff at enrolment. To address the primary objective of falls on stroke recovery, measures of motor and cognitive function were administered at discharge from in-patient stroke rehabilitation and again six months later, and are described below.

Functional balance was assessed using the Berg Balance Scale (BBS),\textsuperscript{139} which is a 14-item observational rating scale. Participants were asked to perform each of the 14 tasks and their ability to perform the task was rated on a scale from 0 to 4, up to a maximum score of 56. The maximum score indicates good balance, and a score below 45 indicates increased fall risk in the elderly population.\textsuperscript{127} The BBS is a reliable and valid measure of functional balance in the stroke population,\textsuperscript{140} with excellent inter-rater reliability (intraclass correlation coefficient (ICC)=0.98).\textsuperscript{139} The Chedoke-McMaster Stroke Assessment (CMSA)\textsuperscript{141} leg and foot sub-scales were used to determine participants' motor recovery. Each sub-scale was rated between stages 1 to 7, where lower scores indicate more impairment and 7 indicates full or almost full recovery of function. These assessments were completed as part of a routine battery of tests by the treating physiotherapist at discharge, and repeated by a research physiotherapist at the follow-up assessment. Excellent inter-rater reliability of the CMSA has been reported among stroke patients on a rehabilitation unit (ICC=0.97).\textsuperscript{141}
Gait speed is an objective measure that is sensitive to change over time, and has been used as a key indicator of community ambulation among stroke survivors. Assessment of gait was performed using the GAITRite walkway system (CIR Systems Inc., Clifton, New Jersey, USA), which is a four-metre long pressure-sensitive mat that records the placement and timing of each footfall. Participants started walking at least one metre away from the mat and walked across the mat until they reached at least one metre from the end of the mat to account for acceleration and deceleration. Each participant walked at their preferred pace and completed enough passes to allow for at least 18 footfalls to be captured by the pressure-sensitive mat (approximately two to four passes). Gait speed was subsequently calculated using the GAITRite software, where all passes of self-selected pace were grouped into one trial. The GAITRite system has been shown to have good concurrent validity in a rehabilitation population, good test-retest reliability (ICC=0.72-0.98), and good inter-(ICC>0.81) and intra-reliability (ICC>0.77) at comfortable walking speeds among individuals with stroke.

Cognitive deficits are common after stroke, and can influence quality of life and independence. The Montreal Cognitive Assessment (MoCA) is a screening tool for mild cognitive impairment that examines visuospatial skills, executive function, memory, attention, and orientation. The maximum score for the test is 30 points, and a total score less than 26 is considered an indicator of potential cognitive deficit. The MoCA was administered by a research assistant at discharge and follow-up. Excellent test-retest reliability (ICC=0.92) and excellent concurrent validity with the Mini-Mental State Examination (r=0.87) was demonstrated for the MoCA among patients with and without mild cognitive impairment.
In addition to the primary outcomes, secondary measures of balance confidence and physical activity were assessed to understand the potential mechanisms underlying the hypothesized relationship between falls and functional recovery. The Activities-specific Balance Confidence (ABC) scale\textsuperscript{109} is a 16-item questionnaire that determines confidence in maintaining balance while performing 16 everyday tasks. Participants were asked to rate each item on a scale from 0-100%, where 0% indicates no confidence, and 100% indicates the highest confidence. The items were averaged to obtain an overall balance confidence score ranging from 0% to 100%. The ABC scale was administered by a research assistant at both the discharge and follow-up assessments to detect changes in balance confidence. In geriatric populations, ABC scale scores have been shown to correlate with performance on balance measures and risk for falls.\textsuperscript{150,151} The construct validity of the ABC scale with measures of balance and physical function has been established in the stroke population,\textsuperscript{152} and the test-retest reliability of the scale is excellent (ICC=0.85).\textsuperscript{153} The Physical Activity Scale for Individuals with Physical Disabilities (PASIPD)\textsuperscript{154} is a 13-item questionnaire that assesses physical activity by reporting the number of days a week and hours per day an individual participates in recreational, household, and occupational activities over the last seven days. Each question was scored by multiplying the average hours per day by a metabolic equivalent value associated with the intensity of the activity.\textsuperscript{154} The total score was calculated by taking the sum of items 2 to 13. In this study, the PASIPD was conducted over the phone at three time points during the six-month falls monitoring period (i.e. approximately every two months). The PASIPD has good test-retest reliability ($r=0.77$) and the criterion validity against accelerometers has been shown to be comparable to other self-report questionnaires in a rehabilitation population.\textsuperscript{155}
4.2.5 Statistical analysis
The sample was divided into non-fallers (i.e. participants who did not fall in the community; n=39) and fallers (i.e. participants who fell at least once in the community; n=26). A matched sample of non-fallers to fallers was achieved through stratified random sampling on categories of BBS scores at discharge (i.e. 0-35, 36-45, 46-55, 56 points) and age (i.e. <40, 40-59, 60-79, >80 years) in order to create two comparable groups. Characteristics of non-fallers and fallers were compared at discharge from inpatient rehabilitation using the Mann-Whitney U test for continuous or ordinal data, and the chi-square or Fisher’s exact test for nominal data. The alpha level for comparing baseline characteristics of the two groups was set at 0.05. To test the outcome measures of interest, non-fallers and fallers were compared using the Mann-Whitney U test on all measures, except for gait speed which was compared using a Student’s t-test. Non-parametric testing was necessary after assumptions of normality were violated. To examine the primary hypothesis, a one-tailed test was used, and an alpha was set at 0.01 (i.e., Bonferonni-corrected for multiple comparisons; 0.05 divided by five primary outcome measures). Associations between the change in balance confidence, physical activity levels, and each of the primary outcomes were analysed using Spearman’s rank correlation coefficients. For these correlations, an alpha level of 0.0167 determined statistical significance (i.e. Bonferonni-corrected for multiple comparisons; 0.05 divided by three comparisons). In the case of missing data at discharge or follow-up, the participant was removed from the analysis of that particular outcome. Statistical analyses were conducted using SAS version 9.2.
4.3 Results

A sample of 46 participants (23 non-fallers and 23 fallers) matched on BBS categories and age was formed. Nineteen participants were not included (non-fallers=16, fallers=3; age: 62.7 years, time post-stroke: 46.9 days); three fallers were lost as a result of not having a non-faller match (10 falls; one faller experienced 8 falls). There were no significant differences on demographic and stroke characteristics between non-fallers and fallers at discharge from rehabilitation (Table 4.1).

Table 4.1: Participant characteristics at discharge from rehabilitation.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Non-fallers (n=23)</th>
<th>Fallers (n=23)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>64.8 (12.6)</td>
<td>65.4 (10.4)</td>
<td>0.96</td>
</tr>
<tr>
<td>Number of women</td>
<td>10 (43)</td>
<td>9 (39)</td>
<td>0.76</td>
</tr>
<tr>
<td>Time post-stroke (days)</td>
<td>47.4 (19.2)</td>
<td>53.4 (19.6)</td>
<td>0.14</td>
</tr>
<tr>
<td>Length of in-patient rehabilitation stay (days)</td>
<td>30.2 (11.1)</td>
<td>35.9 (13.7)</td>
<td>0.17</td>
</tr>
<tr>
<td>Type of stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischemic</td>
<td>20 (87)</td>
<td>18 (78)</td>
<td>0.74</td>
</tr>
<tr>
<td>Hemorrhagic</td>
<td>2 (9)</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Transforming to hemorrhagic</td>
<td>1 (4)</td>
<td>2 (9)</td>
<td></td>
</tr>
<tr>
<td>National Institutes of Health Stroke Scale (score)</td>
<td>2.7 (2.0)</td>
<td>3.0 (2.9)</td>
<td>0.96</td>
</tr>
<tr>
<td>Berg Balance Scale (0-56 points)</td>
<td>51.2 (3.4)</td>
<td>49.1 (4.1)</td>
<td>0.079</td>
</tr>
</tbody>
</table>

NOTE: Values are means (standard deviation) for continuous or ordinal variables, and counts (% rounded to the nearest integer) for categorical variables. The p value is for the Mann-Whitney U test, chi-square or Fisher’s exact test comparing non-fallers to fallers at discharge.

A total of 43 falls were reported during the six-month monitoring period, and eight fallers (35%) fell more than once. Eleven fallers (11/23, 48%) experienced their first fall within one month of discharge, and 15/43 of all falls (35%) took place in the first two months
Thirty-one of the 43 falls (72%) took place in the participant’s home, and 10/43 falls (23%) resulted in injuries (e.g. cuts or bruises, joint sprain or dislocation).

The follow-up assessment was conducted at an average time post-stroke of 7.7 months.

The Mann-Whitney U test revealed that non-fallers and fallers differed on BBS (W(1)=657.5, Z=2.58, p=0.0066) and CMSA foot scores (W(1)=573, Z=2.85, p=0.0033) at the six-month follow-up assessment when adjusted for multiple comparisons. Fallers averaged lower CMSA leg scores, demonstrated slower gait speed, and scored lower on the MoCA than non-fallers at follow-up; however, these differences were not statistically different (p>0.049; Table 4.2).
Table 4.2: Differences in outcome measures at discharge from in-patient stroke rehabilitation and six months post-discharge.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group</th>
<th>n</th>
<th>Non-fallers</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Berg Balance Scale (points)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>23</td>
<td>51.2 (3.4)</td>
<td>23</td>
<td>49.1 (4.1)</td>
</tr>
<tr>
<td>Follow-up</td>
<td>23</td>
<td>53.2 (2.8)</td>
<td>23</td>
<td>50.2 (4.0)</td>
</tr>
<tr>
<td><strong>Chedoke-McMaster – leg (stage)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>21</td>
<td>5.2 (0.9)</td>
<td>22</td>
<td>4.9 (1.1)</td>
</tr>
<tr>
<td>Follow-up</td>
<td>21</td>
<td>5.7 (0.6)</td>
<td>22</td>
<td>5.2 (0.9)</td>
</tr>
<tr>
<td><strong>Chedoke-McMaster – foot (stage)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>21</td>
<td>5.0 (1.2)</td>
<td>22</td>
<td>4.7 (1.4)</td>
</tr>
<tr>
<td>Follow-up</td>
<td>21</td>
<td>5.7 (0.7)</td>
<td>22</td>
<td>4.8 (1.0)</td>
</tr>
<tr>
<td><strong>Gait speed (metres/second)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>23</td>
<td>0.86 (0.3)</td>
<td>23</td>
<td>0.80 (0.4)</td>
</tr>
<tr>
<td>Follow-up</td>
<td>23</td>
<td>0.97 (0.3)</td>
<td>23</td>
<td>0.90 (0.4)</td>
</tr>
<tr>
<td><strong>Montreal Cognitive Assessment (points)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>9</td>
<td>22.1 (3.7)</td>
<td>11</td>
<td>22.3 (3.6)</td>
</tr>
<tr>
<td>Follow-up</td>
<td>9</td>
<td>24.4 (2.7)</td>
<td>11</td>
<td>22.8 (4.2)</td>
</tr>
</tbody>
</table>

**NOTE:** Values are means (standard deviation) for continuous or ordinal variables. The p value is for the Mann-Whitney U test comparing both groups for all measures except for gait speed, which was calculated using a Student’s t-test.

* p value is significant, where p<0.01 (Bonferroni-corrected for multiple comparisons).
At follow-up, non-fallers reported an average balance confidence score of 79% (standard deviation (SD)=19.6%), whereas fallers reported 76.9% (SD=15.9%). Fallers averaged a score of 8.4 points (SD=7.7 points) on the PASIPD, compared to 9.9 points (8.2 points) by non-fallers at the third time point, which occurred at an average time post-discharge of 5.3 months. There was no significant relationship between change in balance confidence scores and change in physical activity levels among all participants from the first and third questionnaire ($r=0.27$, $p=0.08$). Correlations of physical activity with functional balance and motor recovery of the foot for all participants are presented in Table 4.3. There was a significant positive correlation between change in physical activity and change in functional balance as measured by the BBS (Figure 4.2 A). However, there no relationship was found between change in physical activity and change in motor recovery of the foot as measured by the CMSA (Figure 4.2 B).

<table>
<thead>
<tr>
<th>Table 4.3: Spearman correlation coefficients between physical activity and outcomes at six-month follow-up for all participants.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in ABC</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Change in PASIPD</td>
</tr>
<tr>
<td>$p=0.08$</td>
</tr>
</tbody>
</table>

NOTE: ABC=Activities-specific Balance Confidence scale; BBS=Berg Balance Scale; CMSA=Chedoke-McMaster Stroke Assessment; PASIPD=Physical Activity Scale for Individuals with Physical Disabilities. *Statistically significant correlation at alpha<0.0167 (Bonferroni-corrected for multiple comparisons).
Figure 4.2: Correlations of change in physical activity scores with functional balance and motor recovery of the foot for all participants. A significant relationship was found in the change in Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) scores and Berg Balance Scale (BBS) scores (A) but not Chedoke-McMaster Stroke Assessment (CMSA) foot scores (B).

4.4 Discussion

In partial support of our hypothesis, we found that individuals with stroke who fell in the six months post-discharge from in-patient rehabilitation performed worse on some motor
outcomes (i.e. BBS and CMSA foot) than individuals who did not fall. Conversely, CMSA leg scores, gait speed, and cognitive function (MoCA scores) were not significantly different between fallers and non-fallers. These findings agree with those of Blennerhassett and colleagues who completed a follow-up observational study post-discharge from in-patient stroke rehabilitation, and found that fallers had lower scores on balance and mobility tests at follow-up. However, in this previous study, the groups differed on these outcome measures at baseline, and the follow-up assessment occurred at a median time of 14.5 months post-discharge. By matching fallers to non-fallers on important measures retrospectively we minimized the differences between groups at baseline and provide stronger support for the hypothesis that the occurrence of falls delays recovery from stroke.

Almost half of all fallers (11/23 fallers; 48%) experienced their first fall within the first month after discharge home from in-patient rehabilitation. We hypothesized that falls occurring early post-discharge would lead participants to develop fear of falling and reduced physical activity over time, and that reduced physical and social activity would result in lower performance scores at the six-month follow-up. However, this hypothesis was not fully supported. The results suggest that balance confidence was not reduced among those individuals who experienced a fall, and reduced balance confidence (ABC scores) did not translate to reduced physical activity (PASIPD scores). Nevertheless, individuals who decreased physical activity over the course of the follow-up period demonstrated smaller changes in BBS scores.

The ABC scale measures balance confidence, which is defined as confidence in one's ability to maintain balance and remain steady. Balance confidence is a situation-
specific form of self-efficacy that is linked to perceived balance ability.\textsuperscript{110} While not a direct measure of fear of falling, the ABC scale provides an indication of one’s confidence when completing various ambulation tasks. On average, individuals may have declined in balance confidence post-discharge as a result of attempting to execute certain activities since returning home to the community that they may not have been exposed to in hospital; thus reducing their confidence based on experience and increased insight into post-stroke limitations. As Simpson and colleagues suggested, balance confidence may mediate an effect on falls through the interaction with other variables.\textsuperscript{156} For example, balance confidence may help to explain what types of activities an individual with a certain level of mobility may engage in, which could then influence the risk of falling. However, this study did not find similar results. Levels of physical activity may play a role in stroke recovery, and the reason for inactivity can include factors such as post-stroke fatigue, availability of social support, and the residual deficits that impair mobility.\textsuperscript{157} The low level of physical activity for both groups in this study was not surprising, and the correlation of the changes with BBS scores does not aid in the directionality of the relationship between falls and activity. It is possible that falls led to restricted physical activity, as reported in previous work,\textsuperscript{22,91} or that deconditioning as a result of low activity increased the risk of falls. Self-reported activity decreased in both groups, which may have been due to a reduction in self-directed activity or the conclusion of formal out-patient rehabilitation. With increased physical activity, greater change in mobility measures may have followed.\textsuperscript{87} Therefore, a potential area for intervention to influence stroke recovery is increasing balance confidence and physical activity, both of which are modifiable factors at the individual level.
Both non-fallers and fallers were high-functioning at discharge from in-patient rehabilitation, leaving little room for individuals to improve at follow-up. For example, the mean BBS scores were less than six points from the maximum score of 56, suggesting a possible ceiling effect for many individuals. The BBS measures static and dynamic aspects of balance and is known for its ceiling effects and inability to discriminate between higher functioning individuals. Therefore, the BBS may be a tool more suitable for individuals in the acute and sub-acute stages of stroke. This problem may be addressed by incorporating a balance measure that is less susceptible to ceiling effects, such as the Community Balance and Mobility Scale; however, this measure was not conducted as part of the primary study, and was therefore not available for secondary analysis. Similarly, the average gait speed for both non-fallers and fallers was high, and participants enrolled in this study were independently walking at the time of discharge. Walking speed of stroke survivors has been classified by Perry and colleagues into functional categories: household ambulation (less than 0.4 m/s); limited community ambulation (0.4 to 0.8 m/s); and community ambulation (greater than 0.8 m/s). Achieving levels of community ambulation is important for recovery due to the relationship between improved gait speed and improved participation and quality of life. Gait speed has been termed the sixth vital sign and therefore, should be monitored among fallers to ensure continued recovery after stroke.

Physical impairment of the lower extremities, as measured by the CMSA, improved on average for both groups at follow-up; however, only the foot domain was significantly lower for fallers than non-fallers. The CMSA is a performance-based measure that is able to detect change in disability, as well as classify individuals based on motor recovery. While it was hypothesized that falls lead to fear of falling and reduced
physical activity, and therefore, less capacity for ongoing recovery, it is possible that fallers were simply on a slower recovery trajectory than non-fallers. This difference could have been due to factors affecting stroke severity, such as genetics, type, size, and location of stroke, which are also predictive of post-stroke outcomes.\textsuperscript{33} Thus, while CMSA scores were not different between the two groups at discharge, it is possible that fallers had lower foot scores than their non-faller matches at the time of the fall, and the fall was potentially due to a trip that resulted from poor foot clearance when walking as many falls (14/43; 33\%) resulted from tripping.

Previous studies of cognitive deficits after stroke suggest that improvement in cognitive function is possible over time, especially within six months post-stroke,\textsuperscript{160-162} however, another study suggested that cognitive deficits remain stable in the sub-acute phase of stroke.\textsuperscript{163} In this study, assessing cognitive status using the MoCA did not reveal any significant differences between non-fallers and fallers six months post-discharge. At discharge, 16/20 participants (80\%) scored less than 26 on the MoCA, which indicates potential cognitive impairment, and the proportion dropped slightly to 14/20 (70\%) on follow-up. Traditionally, research in outcomes of stroke recovery has focused on improving physical, rather than cognitive impairments. The discrepancy may exist because physical deficits are more apparent and easier to measure compared to cognition, which incorporates multiple domains, and the gold standard for assessing cognitive impairment is an extensive and time-consuming battery of neuropsychological exams.\textsuperscript{164} Nevertheless, recovery of cognitive deficits after stroke remains important, as difficulties with attention and perception can influence falls risk and negatively impact an individual's ability to complete daily activities and participate in social roles.
As individuals return home with the lingering effects of stroke, they may be adjusting to a new environment with reduced supervision and assistance compared to the hospital setting.\textsuperscript{91} Despite being at a sufficient functional and social level to return home, falls early on are likely due to individuals dealing with persistent limitations that may affect balance and mobility, which could in turn increase the risk of falling. However, Yates and colleagues found that individuals with accumulated impairments may be less mobile, and therefore at a reduced risk of falls.\textsuperscript{43} Hyndman and colleagues studied individuals with chronic stroke (average time post-stroke: 50 months), and found that falls in the community were associated with reduced rehabilitation potential and functional recovery;\textsuperscript{47} however, the current study aimed to determine the impact of falls on recovery earlier after stroke in what may be a critical time for regaining function.

### 4.4.1 Study limitations

This study may have limited ability to detect differences between groups due to small sample size. Post-hoc power analysis was conducted for all non-significant results using meaningful differences in means from the literature and standard deviations from the current study. It was determined that given an alpha of 0.01, there was 63.3\% power to detect a significant difference of one stage on the CMSA leg score; therefore, a total sample of 62 would be required to have 80\% power. The current sample size for gait speed was not large enough to compare a clinically important change of 0.18 metres per second between groups\textsuperscript{165} with sufficient power (alpha=0.01, power=24.2\%). A sample of 168 participants would be needed to reach 80\% power in order to analyze whether walking speed was significantly different between non-fallers and fallers. Using estimates of the average difference in MoCA scores between groups of individuals with stroke obtained from the literature,\textsuperscript{166,167} a sample size of 140 participants would be
required to detect a two point difference with 80% power. As a result, the analysis performed in this study was underpowered for cognitive status (alpha=0.01, power=11.7%). Across both groups, data were missing frequently for the MoCA as many participants spoke English as a second language, could not complete the assessment due to scheduling difficulties, or declined. Therefore, additional studies may be required to further investigate the effect of falls on these important motor and cognitive outcomes.

This study only included participants from the original study who returned for the six-month follow-up assessment. There may be differences between those who were included and the participants who were not assessed. Poor recovery in function may be one reason why participants did not return for the follow-up assessment, among other reasons (e.g. passed away, lived a far distance from hospital). However, of those who completed the full falls monitoring period, it does not appear as though fallers were less likely to return (8/34, 24%) than non-fallers (22/61, 36%).

4.4.2 Conclusions
The current study found that performance in balance and motor recovery of the foot were compromised in fallers compared to non-fallers at six months post-discharge from in-patient stroke rehabilitation. These differences may be mediated by reduced activity following a fall, resulting in either deconditioning or decreased capacity for ongoing motor recovery. Stroke survivors may benefit from supported discharge including post-falls management strategies.
5. General Discussion

As more individuals with stroke survive the initial event, the greatest health effect lies in the long-term consequences for stroke survivors and their families. Most research in the field of stroke rehabilitation has looked at the effect of specific interventions on recovery of stroke-related impairments\(^8\) in order to enable individuals to regain function and return to pre-morbid activities. As previous work has shown, falls are common after stroke, and can lead to serious consequences, such as physical injury, fear of falling, and reduced physical activity.\(^{29,32}\) The purpose of this work was to investigate the impact of falls on post-stroke recovery.

The current work has demonstrated that falls may interfere with an individual’s stroke recovery in terms of length of stay (LOS). The first study showed that individuals who fell had a significantly longer LOS than those who did not fall. Falls may have led individuals to modify activity and behaviour, and therapists to modify treatment plans or take additional precautions; as a result, fallers required more time to achieve their rehabilitation goals. An increased length of stay for fallers can be interpreted from two perspectives. On one hand, a longer LOS equates to greater hospital costs; however, it may allow patients more time and opportunity to achieve the best functional outcomes. A causal connection between decreasing LOS during rehabilitation and increasing hospital readmission rate was found in a study by Ottenbacher and colleagues.\(^{168}\) Therefore, the pressure to reduce LOS during in-patient rehabilitation to meet quality performance measures may not be cost-saving in terms of the physical and emotional burdens placed on stroke survivors and their caregivers. The positive news is that
fallers ultimately returned home, rather than a more costly destination (e.g. long-term care), thus the cost of a longer LOS may have been beneficial to enable individuals to meet their rehabilitation goals and achieve a functional level to be discharged home. Potential confounders as it relates to LOS and eventual discharge destination may include family, social, and cultural influences.

Results of both studies provide additional information surrounding the occurrence of falls as a potential setback for recovery. Falls may delay recovery in the sub-acute phase after stroke; however, fallers may have been on a slower trajectory to begin with. Fallers (and non-fallers) may benefit from post-fall management interventions that target increasing balance confidence and physical activity in order to protect against further physical declines. There is also a trend toward predicting repeat fallers (i.e. two or more falls), as Hyndman and colleagues performed a sub-analysis of repeat fallers and found a trend of greater mobility deficits and reduced abilities to perform activities of daily living among recurrent fallers. Therefore, there must be a balance between promoting independence and mobility during recovery, and avoiding the potential consequences of falls.

Across both studies, the outcome measures were selected based on priority and suitability of the health care setting. For example, the National Reporting System in Canada collects data from in-patient rehabilitation units from hospitals, such as LOS and the Functional Independence Measure (FIM) data, to support decision-making and planning of services. Therefore, for the purpose of study 1, the FIM was used as key rehabilitation outcomes, whereas a variety of clinical tests were selected to examine recovery of individuals with stroke in the community for study 2. Together the two
studies investigated individuals with stroke at baseline and following the groups over time and compared non-fallers to fallers on important measures.

Revisiting Figure 2.1, the conceptual model of falls after stroke, the potential mechanisms underlying the relationship between falls and post-stroke recovery are unclear as a result of the current findings. Figure 5.1 describes the relationship between falls and physical, cognitive, and emotional function that resulted in both study 1 and 2; however, the black box that surrounds the pathway represents the fact that these concepts that may explain the setbacks are not clear.

**Figure 5.1: Revised conceptual model of falls after stroke.** As a result of the current work, falls appear to delay recovery after stroke. However, more work is needed to understand the potential mechanisms underlying the relationship between falls and recovery, as depicted by the black box.
It is understood that the first three months is a critical period of time for recovery after stroke,\textsuperscript{62} and that recovery plateaus between three to six months;\textsuperscript{33} therefore, both studies investigated an important time to intervene and improve patient outcomes. By understanding the effect of falls during this time, and addressing the consequences of falls (e.g. injury, reduced balance confidence, physical activity), individuals with stroke may achieve better recovery and less long-term disability. Although fallers had a longer LOS than non-fallers during in-patient rehabilitation, they were able to achieve similar functional levels before being discharged home. Stroke survivors returning to the community after discharge from hospital continued to recover; however, the results of this study demonstrated that falls may complicate recovery during a critical time period after stroke.

5.1 Limitations

A major limitation of this work is the retrospective nature of the first study. While there were advantages to conducting a retrospective chart review to address the research question (e.g. ease of a matched comparison between non-fallers and fallers, use of existing records, study of rare occurrences), some issues included missing or incomplete data, variability in assessments completed by multiple health professionals, and medical charts lacking specific patient information.

Another limitation of this work is the lack of data on comorbidities and psychosocial factors. Experiencing a fall is one of many factors that may contribute to one’s functional recovery following a stroke. It is important to consider the bigger picture and take other factors such as the presence of medical complications other than stroke (e.g.
hypertension, diabetes), psychosocial circumstances of the individual (e.g. presence of family supports to be discharged home), as well as the type and availability of health care services that may affect one’s progression after stroke.

On that note, both studies included patient data from and recruited patients from a single, specialized stroke rehabilitation unit in Ontario, Canada. This may affect the generalizability of the results, as the length of stay and health care resources may be dependent on the policies of the institution and region.

For both sources of data, falls may have been underreported. Within the in-patient rehabilitation setting, the likelihood of reporting near misses or non-injurious falls may have been lower than significant falls captured by clinicians. Unwitnessed falls, events with few details, and the lack of a standard definition of a fall may also underestimate the number of falls reported. For the community-dwelling participants, information on falls was obtained by self-report. Even though participants were provided calendars to monitor their falls, some details were missed due to a lapse in time of fall to the administration of the falls questionnaire; however, using postcards as the method of data collection is considered the gold standard.

In this work, efforts were made to balance the comparison groups (i.e. non-fallers and fallers); however, the type and specific location of the stroke were not considered in these studies. Since the effects of stroke are heterogeneous and recovery is complex, it is difficult to assume that all stroke survivors would follow the same recovery profile.
5.2 Future directions

The next step towards understanding the recovery of individuals who fall would be to conduct a prospective study beginning early after stroke onset until at least six months post-stroke to confirm some of the current findings of this study. It would also be useful to understand the current procedures for falls management during this critical time of rehabilitation, which was not possible using a retrospective study design. Following individuals across different post-stroke stages would provide a solid description of how the occurrence of falls may interfere with recovery, and the objective monitoring of falls and the potential explanations for these observations, such as fear of falling and physical activity levels, would strengthen the case for improvements to existing post-stroke falls management strategies. In order to enable stroke survivors to return to pre-morbid activities and prevent long-term stroke sequelae, the clinical significance of this work is equally important to preventing falls in the first place.

5.3 Conclusions

This is the first work to our knowledge that investigated the impact of falls on post-stroke recovery. While attending in-patient rehabilitation, individuals who fell had an increased length of stay; however, they achieved a functional level similar to individuals who did not fall, and were equally likely to be discharged home. Among stroke survivors returning home to the community after discharge from in-patient rehabilitation, individuals who fell performed poorly on functional balance and motor recovery outcomes compared to those who did not fall when measured at six months post-discharge. Additional work is needed to fully understand the potential mechanisms for the consequences of falls on stroke recovery.
References


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Appendix

COMMUNITY FALLS REPORT

Subject Identification #: _____________

Date of Interview: ________________ Date of Fall: ________________

Please describe what happened during your MOST RECENT fall:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
DETAIL OF FALL

1. What do you think caused you to fall?
   - (0) Don't know/cannot recall
   - (1) Tripped (i.e. unexpected /unintentional blocking of movement of lower limbs; specify obstacle impeding movement):
   - (2) Slipped (i.e. unexpected /unintentional and uncontrolled movement of lower limbs; specify cause of slip, e.g. ice, wet surface):
   - (3) Missed (overstepped) a stair/step/curb
   - (4) Missed the seat when sitting down
   - (5) Bumped into something
   - (6) Pushed (by someone/something/wind)
   - (7) Knees “gave way”
   - (8) Just collapsed (felt faint/dizzy/weak)
   - (9) Fainted (lost consciousness)
   - (11) Just “tipped over” (None of the above responses apply)
   - (12) Other, specify: ______________

2a. What were you doing when you fell (movement/posture)?
   - (0) Cannot recall
   - (1) Sleeping
   - (2) Lying (awake but not moving)
   - (3) Sitting
   - (4) Standing (not moving)
   - (5) Walking on level surface
   - (6) Walking up stairs/steps/curb
   - (7) Rising out of (circle one):
         bed chair wheelchair toilet bath
   - (8) Getting into:
         (a) bed (b) chair
         (c) wheelchair (d) toilet (e) bath
   - (9) Turning around
   - (10) Reaching for something
   - (11) Bending over
   - (12) Other, specify: ______________

2b. What were you doing when you fell (cognitive/distracting)?
   - (0) Cannot recall
   - (1) Nothing
   - (2) Talking in person
   - (3) Talking on phone/Blackberry/iPod
   - (4) Using electronic device (Blackberry/iPhone, not talking)
   - (5) Focused on other task, specify:
   - (6) Otherwise distracted, specify:

3. Where did the fall occur?
   - (0) Cannot recall
   - (1) Indoors, own home
         Specify room: ______________
   - (2) Indoors, hospital
         Specify room: ______________
   - (3) Indoors, other
         Specify location: ______________
   - (4) Outdoors:
         Specify:_______________________

4. When did the fall occur?
   - (0) Cannot recall
   - (1) Overnight (11pm – 7am)
   - (2) Morning (7am – 12pm)
   - (3) Afternoon – evening (12pm – 6pm)
   - (4) Late evening – night (6pm – 11pm)

5. Were you using an assistive device when you fell?
   - (0) Cannot recall
   - (1) N/A never use one
   - (2) No
       If No, what do you use normally?
       (a) Cane (b) Walker (c) Wheelchair
   - (3) Cane(s)
   - (4) Walker
   - (5) Wheeled Walker
6. Were you holding onto a handrail or grab-bar before/when you started to fall?
   - (0) Cannot recall
   - (1) No
   - (2) Yes

7. Did you have anything in your hands before/when you started to fall?
   - (0) Cannot recall
   - (1) No
   - (2) Yes, one hand
   - (3) Yes, both hands

8. Did you try to stop yourself from falling to the ground/floor?
   - (0) Cannot recall
   - (1) No
   - (2) Yes, tried to grab something
   - (3) Yes, tried to step/foot movement
   - (4) Yes, ‘in-place’ response

9. Did you put out your arms or hands to protect yourself?
   - (0) Cannot recall
   - (1) No
   - (2) Yes

10. In what direction did you fall?
    - (0) Cannot recall
    - (1) Sideways; (a) Left (b) Right
    - (2) Forward
    - (3) Backward
    - (4) Straight down
    - (5) Other, specify:________________

11. What part of your body hit the ground first?
    - (0) Cannot recall
    - (1) Hip/side of body; (a) Left (b) Right
    - (2) Knees
    - (3) Hands or arms
    - (4) Buttocks
    - (5) Back
    - (6) Other, specify:________________

12. Upon what surface did you fall?
    - (0) Cannot recall
    - (1) Ground/floor
    - (2) Chair, toilet, wheelchair (i.e. ‘sitting’ object)
    - (3) Bed
    - (4) Other furniture, specify:
    - (5) Other, specify:________________

13. What was your body position after you fell?
    - (0) Cannot recall
    - (1) Lying on side; (a) Left (b) Right
    - (2) Lying on back
    - (3) Lying on stomach
    - (4) Kneeling
    - (5) Sitting
    - (6) On “all fours”
    - (7) Other, specify:________________

14. How long did you lie on the floor or ground before you were able to get up?
    - (0) Cannot recall
    - (1) A few minutes or less
    - (2) Less than one hour
    - (3) One hour or more

15. Did you need to help to get up after you fell?
    - (0) Cannot recall
    - (1) No
    - (2) Yes
16. Describe your injuries or medical consequences (if any) of the fall (check all that apply).
- (0) Cannot recall
- (1) No injuries
- (2) Cuts or bruises
- (3) Joint sprain or dislocation
- (4) Dehydration
- (5) Pneumonia
- (6) Wrist fracture
- (7) Hip fracture
- (8) Other fracture, specify:________
- (9) Head injury, specify: __________
- (10) Other, specify: _____________

17. Did you receive or seek medical treatment as a result of the fall?
- (0) Cannot recall
- (1) No injuries
- (2) Injured but did not seek treatment
- (3) Saw family physician
- (4) Saw other health-care professional, specify:___________
- (5) Treated at hospital emergency room
- (6) Admitted to hospital
- (7) Other, specify: _______________

18. Interviewer, please comment on the reliability of the information or any other concerns:
____________________________________________________________________
____________________________________________________________________

FEAR OF FALLING

1a. After your MOST RECENT fall, are you afraid of falling?
- (0) Unable to say
- (1) No, not at all
- (5) Yes, but only in certain circumstances, specify:___________________
- (6) Yes, all the time

1b. How fearful are you of falling, on a scale from 0-10?

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
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<tbody>
<tr>
<td>Not fearful</td>
<td>Very fearful</td>
<td></td>
<td></td>
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</tbody>
</table>

2. Are you more afraid of falling now than you were before your most recent fall?
- (0) Unable to say
- (1) No
- (5) N/A, No Falls Reported
- (6) Yes

3. Has fear of falling made you avoid any activities that you used to do?
- (0) No
- (1) Yes, specify: _____________________________________________
- (2) Not applicable (no fear)