Relationships among Patients' Cognitive Status, Hospital Ambulation Frequency and Physical Performance in Hospitalized Older Adults

by

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Abstract

This research determined the relationships among patients' cognitive status, hospital ambulation frequency and physical performance at discharge for hospitalized older adults. A descriptive longitudinal design was used to investigate the association among cognitive status, patterns of hospital ambulation frequency, and the usual gait speed. Comparisons of participant characteristics with hospital ambulation frequency and cognitive cohorts were also conducted. Twenty-seven participants from a Veterans Administration (VA) Hospital in Wisconsin participated. Participants were enrolled from a medical inpatient unit between January and March, 2017. The participants were between 65 - 87 years old, primarily male and required assistance for ambulation assistance, with an average length of stay of 4.3 days and body mass index around 31.8 lb/in^2. Ten had cognitive impairment.

Data consist of participants' cognitive status, number of steps taken, usual gait speed and clinical information, which were collected via assessments, observation and electronic chart review. The data were analyzed using Fuzzy clustering, mediation regression, discontinuity and comparative analyses. The results showed that there were two clusters of hospital ambulation frequency: high and low. The participants in the high ambulation cluster tended to have intact cognition, shorter lengths of stay, discharge to home, without need for human assistance in ambulation or need for supplemental oxygen. The participants with cognitive impairment were more likely to have a higher fall risk score, need human assistance for ambulation, and lower gait speeds. The participant with delirium experienced two types of delirium (hyperactive and hypoactive) with the accelerometer data aligning with the two distinct patterns in the linear trajectory. There was no sufficient statistical evidence of the mediation effect of hospital ambulation frequency on the relation of cognitive status and physical performance at discharge. Usual gait speed did not show differences between ambulation frequency clusters. However, it is

worth noting that gait speed was significantly lower in participants with cognitive impairment at both admission and discharge.

In this study, fuzzy clustering and discontinuity analysis efficiently identified patterns and subtle changes in the dataset. This study suggests the importance of providing ambulation support to patients with cognitive impairment as these participants are more likely to have slower gait speeds, higher fall risk, and need assistance in ambulation. A future study with a larger sample could focus design of interventions to improve ambulation of older adults, particularly for those with cognitive impairment.

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Chapter 1: Introduction

Ambulation is a fundamental activity of daily living and is physiologically beneficial for older adults' health, contributing to improvements in muscle strength and maximum oxygen uptake (Ferrucci et al., 2000). However, in hospital settings, older adults infrequently ambulate (Brown, Friedkin, & Inouye, 2004; Callen, Mahoney, Grieves, Wells, & Enloe, 2004). Limited ambulation for older adults during hospital stay results in loss of functional independence, increased risk for falls, new nursing home placement and increase in length of stay (Brown, Williams, Woodby, Davis, & Allman, 2007; Counsell et al., 2000; Covinsky, Pierluissi, & Johnston, 2011; Fisher, Kuo, Graham, Ottenbacher, & Ostir, 2010). Older patients spent 83% of their hospital stay in bed (Brown et al., 2004), and the limited ambulation could lead to loss of ambulation independence (Covinsky et al., 2011). Ambulation during hospitalization is particularly important for persons with cognitive impairment. There is increasing evidence that patients with cognitive impairment have lower levels of ambulation and greater physical decline during hospitalization (Scherder et al., 2007). The ability to ambulate is associated with cognitive functioning (Inouye, Westendorp, & Saczynski, 2014; Lichtenberg & Nanna, 1994; Ruchinskas, Singer, & Repetz, 2000), so ambulation during a hospital stay is believed to be one way to prevent cognitive decline and delirium in older adults (Reuben, Inouye, & Bogardus, 2000).

In the United States, more than 13,000 adults over 65 years old are admitted to hospitals each year (Centers for Disease & Prevention, 2010). Approximately 40% of these older persons have cognitive impairment (Boustani et al., 2010; Naylor & Stephens, 2005), and 18-27% have a confirmed dementia diagnosis (Maslow, 2005; Naylor & Stephens, 2005). Cognitive impairment is the most noticeable characteristic of dementia, which is due to neurological disorders in the brain (Cecil, Goldman, & Schafer, 2012). Neuropsychiatric and physical functioning declines gradually occur in persons with cognitive impairment until they lose functional independence

(Cecil et al., 2012; Reisberg, Ferris, de Leon, & Crook, 1982). Another highly prevalent cognitive disorder in hospitalized older adults is delirium. Up to 60% of hospitalized older patients may develop delirium (Inouye & Charpentier, 1996; Inouye & Foreman, 2001; Naylor & Stephens, 2005; Rockwood, Cosway, & Carver, 1999). The risk factors of delirium during a hospital stay are multifaceted, triggered by medications, physiological and physical impairment, disease, or environmental factors (Burns, Gallagley, & Byrne, 2004; Inouye & Charpentier, 1996; Rockwood et al., 1999).

Several studies have identified multiple negative health outcomes in patients with cognitive impairment at discharge. Hospitalized older patients with cognitive impairment experience greater declines in daily living activities (Sands et al., 2002), increased falls and risk for falls (Clyburn & Heydemann, 2011; Härlein, Halfens, Dassen, & Lahmann, 2011; Vogt, Wieland, Bach, Himmelreich, & Banzer, 2008), and greater loss in ambulation independence (Mahoney, Sager, & Jalaluddin, 1998).

Researchers have recently begun to emphasize the importance of maintaining ambulation in patients with cognitive impairment since retaining ambulation ability during a hospital stay critically impacts older patients' functional outcomes (Covinsky et al., 2011; Graf, 2006; Sager et al., 1996) and subsequent outcomes after discharge (Mahoney et al., 1998). In hospital settings, monitoring older patients' functional status including ambulation is particularly important for predicting patients' health outcomes (Brown et al., 2004; Davis et al., 1995; Inouye et al., 1998; St Pierre, 1998) both during and after discharge.

To date, very little research has been conducted on ambulation of patients with cognitive impairment during a hospital stay (Inouye, Bogardus Jr, et al., 1999; Munoz et al., 2010). Ambulation ability and gait problems in older adults with cognitive impairment are emphasized (Allali et al., 2016; Sorond et al., 2015) among a variety of health concerns such as falls, declines in activities of daily life and cognitive decline (Beauchet et al., 2009; Sands et al., 2002). Social Cognitive Theory (SCT), a framework describing the links among personal, environmental factors, and human behavior, can be used to understand the relationship between cognitive status as it relates to ambulation throughout a hospital stay and admission and discharge gait speed (King & Bowers, 2011; St Pierre, 1998; Wanich, Sullivan - Marx, Gottlieb, & Johnson, 1992).

Social Cognitive Theory serves as the theoretical framework to guide the exploration of how older patients' cognitive status (personal cognitive characteristics) links to their ambulation (physical performance behavior) frequency during hospitalization. According to SCT, human *behaviors* are impacted by a dynamic framework consisting of *personal factors* and *environmental factors* (Bandura, 2011). The target behavior in this study is hospital ambulation frequency, steps taken by patients from hospital admission to discharge. In this study, ambulation frequency will be measured by a research-grade accelerometer placed on the patient's ankle. Patients' cognitive status refers to the basic function of memory, reasoning, and judgment and any acute change of cognition occurring during a hospital stay. Cognition and cognitive changes will be measured using the Montreal Cognitive Assessment (MoCA) - Blind and Confusion Assessment Method (CAM). Patients' physical performance, able to walk with or without assistance, will be measured by gait speed using a 4-meter walk.

The purpose of this study is to investigate the relationship among cognitive status, frequency of hospital ambulation, and physical performance in older adults (age ≥65) during hospitalization. The specific aims include:

Aim 1: To determine the relationship between cognitive status (baseline cognitive function) and hospital ambulation (the trajectory of cumulative number of steps taken by older patients) during hospitalization.

Sub-aim: To explore if changes in cognition (i.e. delirium) produces a change in ambulation frequency.

Aim 2: To determine how hospital ambulation frequency explains the relationship between cognitive status and physical performance at discharge.

Chapter 2: Literature Review

In this chapter, the clinical background of hospitalized older adults' physical and cognitive functioning, theoretical framework guiding this study (Social Cognitive Theory), review of the literature of interventions for promoting ambulation for older adults with and without cognitive impairment, and health outcomes will be presented.

Older Patients' Ambulation in Hospitals

Hospitalization-associated disability. Hospitalized older adults (age≥65) commonly experience loss of physical function, identified as decreased ability to perform activity of daily living (ADLs), during a hospital stay (Covinsky et al., 2011). More concerning, up to 65% of older adults experience loss of independent ambulation during hospitalization (Hirsch & Sommers, 1990; Mahoney et al., 1998). In addition, hospitalization-associated disability, particularly loss of independent ambulation, during a hospital stay leads to negative outcomes such as mortality (Mahoney et al., 1998), long-term institutionalization, and an increased need for physical assistance (Mahoney et al., 1998; Sager et al., 1996) for older adults. Limited ambulation during a hospital stay is the most predictable and preventable cause of loss of independent ambulation for older adults (Sourdet et al., 2015).

Low rates of ambulation for hospitalized older patients. Although ambulation has been shown to improve or maintain ambulation independence (Zisberg et al., 2011), studies have identified that older adult patients infrequently ambulate during their hospital stay. Callen, Mahoney, Grives, Wells, and Enole (2004) found that in 118 hospitalized older adults on inpatient medical units, 72.9% never walked at all, 18.6% walked once, and only 3.4% walked more than twice during observation periods. Further, Fisher et al. (2011) examined ambulatory activity in 35 hospitalized older patients and found that patients only walked a total of 623 steps per hospital day. Another study of 45 hospitalized older patients reported that patients stood or walked for only 43 minutes per day and were in bed for 83% of the hospital stay (Brown, Redden, Flood, & Allman, 2009).

Low rates of healthcare professionals' assistance with patient ambulation. The majority of hospitalized older adults (85%) relied on their physicians' advice or judgment as to whether they needed to exercise (So & Pierluissi, 2012), and only 27% of hospitalized older patients talked about exercise with their physicians. However, bed rest orders are common for older adult patients (Brown et al., 2004), and it is often the nursing staff in hospital settings that remind physicians to update activity orders to better reflect what the older patients are capable of doing in terms of ambulation (King, 2006). Callen et al. (2004) demonstrated that even when older adults could ambulate, their frequency of ambulation with nursing staff was only 9% during a hospital stay. King et al. (2014) found that nurses primarily engaged patients in low levels of mobility (i.e., standing, transferring to a chair) and infrequently initiated patient ambulation. Due to the low rates of patient ambulation and little nurse assistance with patient ambulation, a search of the existing ambulation intervention studies was conducted to understand how patient ambulation was carried out and how it related to the measured outcomes such as physical function. The studies were described as shown in below.

Intervention Studies

Several studies have been conducted on the impact of ambulation on improving functional outcomes for older adults and healthcare utilization. Of these studies, interventions have included ambulation assistance or promotion as a component of physical activity. The relationship between ambulation and cognition will be addressed by summarizing the results of literature focused on physical activity, including ambulation, in older patients with or without cognitive impairment. The literature review includes 16 intervention studies, seven from the United States (U.S.), and nine from other countries. Of the 15 studies, only two studies included patients with dementia (Padula, Hughes, & Baumhover, 2009; Vogt et al., 2008), and only three used patient ambulation solely as the intervention to investigate patients' health outcomes (Hastings, Sloane, Morey, Pavon, & Hoenig, 2014; Killey & Watt, 2006; Tucker, Molsberger, & Clark, 2004). In all of the studies, ambulation was included as one component among other components of physical activity (e.g., strength and balance training). Below is a discussion of the six outcome variables used in the 16 studies.

1. **Physical status and independence.** Of the 16 studies, nine found statistically significant improvement in activities of daily living (ADL) performance and/or gait speed and ambulation distance at discharge when there was ambulation (Brovold, Skelton, & Bergland, 2013; Coleman et al., 2012; Courtney et al., 2009; Courtney et al., 2012; Inouye, Bogardus Jr, et al., 1999; Killey & Watt, 2006; Landefeld, Palmer, Kresevic, Fortinsky, & Kowal, 1995; Siebens, Aronow, Edwards, & Ghasemi, 2000; Vogt et al., 2008) while two studies showed no group difference in physical function (de Morton, Keating, Berlowitz, Jackson, & Lim, 2007; Nolan & Thomas, 2008). The studies' designs also varied; six used randomized clinical trials (RCTs) with a sample size ranging from 115 to 1531 (Brovold et al., 2013; Counsell et al., 2000; Courtney et al., 2009; Courtney et al., 2012; Landefeld et al., 1995; Siebens et al., 2000) and 11 used quasi-experimental designs with a comparison group (Brovold et al., 2013; Courtney et al., 2009; Courtney et al., 2012; de Morton, Keating, Berlowitz, et al., 2007; Inouye, Bogardus Jr, et al., 1999; Killey & Watt, 2006; Landefeld et al., 1995; Nolan & Thomas, 2008; Padula et al., 2009; Siebens et al., 2000; Vogt et al., 2008). Most of the studies revealed the benefits of mobility interventions (including walking, gait balance, and stretching training) in hospitalized older adults' physical function.

2. **Length of hospital stay (LOS) and discharge destination.** The findings related to LOS and discharge destination are mixed. Only Padula et al. (2009) reported a statistically significant decrease in LOS in the mobility intervention group while the other researchers (Counsell et al., 2000; Hastings et al., 2014; Landefeld et al., 1995; Nolan & Thomas, 2008; Siebens et al., 2000) did not find any significant difference. For discharge destination, one study (Courtney et al., 2009) demonstrated significantly fewer hospital readmissions while three studies (de Morton, Keating, Berlowitz, et al., 2007; Hastings et al., 2014; Nolan & Thomas, 2008) reported no difference in readmission. Four studies showed a significantly lower rate of nursing home admissions (Counsell et al., 2000; Hastings et al., 2014; Nolan & Thomas, 2008) and more discharges to home (Hastings et al., 2014). The mixed results related to LOS and nursing home placement may be due to other factors which were not controlled for, such as patient diagnosis, comorbidity, age, financial status, or health insurance policies of the patients (Marcantonio et al., 1999). Without appropriate consideration of covariates, the outcomes (LOS and nursing home placement) may not truly reveal impact of the intervention.

3. **Self-efficacy and quality of life.** Killey and Watt (2006) used frequency of ambulation to evaluate changes in the exercise self-efficacy of hospitalized older adults. The nurse-led and ambulation-targeted intervention study enrolled 53 older patients from three medical units. The study utilized supervision and assistance in patient ambulation with the goals to walk patients twice a day, seven days a week, and reach a maximum distance patients were able to ambulate. The researchers did not find a significant improvement in exercise self-efficacy after the ambulation promotion intervention (Killey & Watt, 2006). However, other researchers (Brovold

et al., 2013; Coleman et al., 2012; Courtney et al., 2009) have found a statistically significant increase in reported quality of life for hospitalized older adults who participated in a structured exercise program, which consisted of a series of physical training such as balance, stretching, transferring, and ambulation. Although a relatively small number of studies have been conducted, it appears that ambulation during a hospital stay has a positive psychosocial impact on hospitalized older patients.

4. **Cognitive-related outcomes.** Only Inouye et al. (1999) tested cognitive-related outcomes related to physical activity in hospitalized older adults on 852 hospitalized older adults. The intervention consisted of daily orientation, therapeutic activities, early mobilization, and sleep enhancement (Inouye, Bogardus Jr, et al., 1999). Their findings indicate that patients in the intervention group who were engaged in early mobilization had less cognitive decline and a lower incidence of delirium. Although participants were not randomly assigned, the large sample size (N=852) and rigorous analysis (matching) improved the strength of the study results.
5. **Fall-related outcomes.** Only two studies examined the effect of gait and stair climbing interventions on fall-related outcomes (de Morton, Keating, Berlowitz, et al., 2007; Vogt et al., 2008). de Morton et al. (2007) enrolled 236 older patients and conducted an intervention using progressive activities from bed exercise, transfer, and standing to stair exercise. Vogt and colleagues (2008) enrolled 109 older patients with intact cognition and 70 patients with dementia to test the relationship between fall risks and cognitive impairment. Results showed that the gait and stair climbing rehabilitation intervention did not reduce fall risks for patients with cognitive impairment, although the majority of the sample had an improvement in physical

function (Vogt et al., 2008). de Morton et al. (2007) showed that a progressive exercise intervention (bed, sitting, standing and stairs exercise programs) did not improve the number of falls in older hospitalized patients (n=236). This finding could be explained by the complex mechanism that causes falls and fall risks in hospitalized older adults. Falls and fall risks are often multifactorial and associated with factors related to the patients and the hospital environment (Hignett, Sands, & Griffiths, 2013; Morgan, Mathison, Rice, & Clemmer, 1985; Schwendimann, Bühler, De Geest, & Milisen, 2008).

6. **Feasibility of interventions.** Tucker et al. (2004) enrolled 72 older patients to measure health professionals' (nurses and physical therapists) satisfaction with an intervention involving trained escorts to assist with patient ambulation, as well as patient and family education about remaining mobile and creating walking opportunities. The results demonstrated a high level of healthcare providers' satisfaction with the ambulation program for patients (Tucker et al., 2004). Nolan and Thomas (2008) enrolled 220 older patients and reported a high degree (70%) of patient compliance with an individual exercise program which consisted of strength, balance, and functional walking. Hastings et al. (2014) enrolled 92 older patients and intervened using early assessment, supervised ambulation and education about the importance of daily ambulation for patients and their family members. Their results demonstrated that an ambulation program for hospitalized older adults is feasible with a 62% referral rate to the program within one business day of hospital admission, and 74% of assessments were performed within one day of referral. The program reported two falls not associated with the study. These findings demonstrated that an

organizational-level intervention to improve older adult patients' ambulation is feasible and acceptable for both patients and healthcare providers.

King et al. (2016) conducted a study, Mobilizing Older adult patients VIa a Nurse-driven intervention (MOVIN), a unit based intervention which targeted nurse psychomotor skills training, communication tools to improve information sharing, creating ambulation pathways, increasing ambulation opportunities for patients, and developing an ambulation culture to establish nurse ownership and sustainability of patient ambulation. The results demonstrated that there was high nursing staff engagement and acceptance of the intervention, a statistically significant increase in total occurrences of patient ambulation and total distances patients walked, and that the intervention components could be implemented simultaneously (King et al., 2016). Results of these studies suggest that interventions to improve patient ambulation could be clinically applied by healthcare professionals (nurses, physical therapist (PTs) and physicians) in a hospital setting.

Most of the studies have demonstrated that an ambulation-related intervention during hospitalization for older patients is beneficial. Of the studies reviewed, three enrolled patients with dementia (Inouye, Bogardus Jr, et al., 1999; Padula et al., 2009; Vogt et al., 2008). The study by Vogt et al. (2008) found that although patients with dementia had high fall risks during the hospital stay, their Performance Oriented Mobility Assessment improved with the gait and stairclimbing training. Inouye et al. (1999) concluded that the decline of cognitive functioning was significantly lower in the intervention group; however, there was no comparison between the cognitive cohorts. Although Padula, Hughes, and Baumhover (2009) enrolled four patients with dementia, no results were reported on these participants. All other intervention studies excluded patients with cognitive impairment from their intervention studies.

Summary. The studies conducted on maintaining patients' physical functioning in hospital settings provide evidence that ambulation-related physical activity benefitted older patients' functional independence during a hospital stay, as well as maintaining their cognitive function and preventing delirium during a hospital stay. Although these studies are few in number, many used rigorous designs (e.g., RCT, large sample size and group comparisons with pre and post tests). Overall, the quality of the studies was good. However, in de Morton et al. (2007), there was a high rate of missing data (25% and 29%) at posttest leading to problems with statistical power and estimate errors (Dong & Peng, 2013). The study by Landefeld et al. (1995) used a simplified measure (better, worse, and unchanged) of ambulation ability between admission and discharge. Nevertheless, the majority of the results supported the effect of ambulation-related interventions in hospitalized older patients' physical function including mobility and independence.

Only one study, Inouye et al. (1999), showed less incidence of delirium and a slower rate of cognitive decline in hospitalized older adults who were ambulated early in their hospital stay. This finding suggests that ambulation may be an important strategy to decrease the incidence of delirium or further cognitive decline for hospitalized older patients. Unfortunately, the majority of the studies on ambulation of hospitalized older adults excluded patients with cognitive impairment. Therefore, a significant gap in knowledge exists about the frequency of ambulation in hospitalized older adults with cognitive impairment and the impact of ambulation on cognitive function in hospitalized older adult patients.

Cognition and Mobility

Evidence that early ambulation prevented cognitive decline in hospitalized older adults is convincing (Inouye, Bogardus Jr, et al., 1999). However, changes in older adults' cognition and how they relate to ambulation or gait functioning are dynamic and multifactorial (Montero-

Odasso, Verghese, Beauchet, & Hausdorff, 2012). In hospital settings, a high percentage of older adults may have cognitive impairment or delirium (Boustani et al., 2010; Inouye & Charpentier, 1996; Inouye & Foreman, 2001; Naylor & Stephens, 2005; Rockwood et al., 1999), and about 50% require ambulation assistance such as use of an ambulation assistive device or human assistance to ambulate (Callen et al., 2004). In addition, higher levels of ambulation ability were associated with higher cognitive status (Sager et al., 1996). These studies show that there is a relation between cognition and mobility.

Cognition critically influences older adults' ambulation ability since older adults have to experience both cognitive and motor processes simultaneously to walk (Hall, Echt, Wolf, & Rogers, 2011; Hausdorff, Yogev, Springer, Simon, & Giladi, 2005). The relationship between cognition and gait problems (including impairment in gait speed, gait abnormality, and balance) has been identified in numerous studies (Hall et al., 2011; Holtzer, Verghese, Xue, & Lipton, 2006; Simoni et al., 2013). Distractions or disturbances in cognitive process can cause problems in ambulation performance (Beauchet et al., 2009; Hausdorff et al., 2005). Older adults with neurologic gait problems were also more likely to develop cognitive impairment (Verghese et al., 2002). Due to the close relation between cognition and gait status, ambulation performance has been proposed as a marker to predict dementia (Abbott et al., 2004; Montero-Odasso et al., 2012; Verghese et al., 2002).

Gait speed is clinically important in predicting older adults’ functional independence (Potter, Evans, & Duncan, 1995). Lower cognitive function is associated with greater gait speed decline (Atkinson et al., 2007). Older adults with slower gait speed tend to have lower executive function performance (McGough et al., 2011) and are more likely to develop mild cognitive impairment (Buracchio, Dodge, Howieson, Wasserman, & Kaye, 2010). Cognitive impairment may also pose more balance and gait problems in older adults due to a decline in attention, memory, executive function, and sensor motor function (Merory, Wittwer, Rowe, & Webster, 2007; Munoz et al., 2010; Scherder et al., 2007). Reisberg (1982) found that patients with severe cognitive impairment may lose their ability to ambulate altogether. The presence of cognitive impairment and balance disturbances are also linked to falls (Beauchet et al., 2009), which are associated with injuries, hospital admissions, and mortality (Mirelman et al., 2012; Shaw, 2002; Taylor, Ketels, et al., 2012; van Iersel et al., 2006).

Not only can cognition affect ambulation ability, but ambulation ability can also influence cognitive status. A meta-analysis suggested that regular physical activity, including walking, could help maintain cognitive and physical function and positive behavior in older adults with cognitive impairment (Heyn, Abreu, & Ottenbacher, 2004). Despite the evidence supporting ambulation for hospitalized older patients, assistance with patient ambulation seems to not be incorporated into clinical practice (Callen et al., 2004; King et al., 2014; So & Pierluissi, 2012), and it is still unclear what barriers impact ambulation of patients, in particular those with cognitive impairment in hospital settings.

Cognitive Impairment and Potential Barriers in Patient Ambulation

Dementia and delirium are the most prevalent cognitive disorders in hospitalized older patients (Naylor & Stephens, 2005). Patients with dementia tend to have greater risks for experiencing delirium during their hospital stay (Burns et al., 2004). In hospitalized older adults in the U.S., about 35-40% of patients have cognitive impairment (Boustani et al., 2010; Naylor & Stephens, 2005), 18-27% have a confirmed dementia diagnosis (Maslow, 2005; Naylor & Stephens, 2005) and up to 60% experience delirium (Inouye & Charpentier, 1996; Inouye & Foreman, 2001; Naylor & Stephens, 2005; Rockwood et al., 1999). Lichtenberg (1994) demonstrated that the level of dementia in hospitalized older adults is significantly related to their ability to perform activities of daily living and ambulation. Sands et al. (2003) also found hospitalized patients with cognitive impairment reported less improvement in their daily activities and mobility. Worse physical functioning such as immobility and the use of physical restraints and bladder catheters were found in patients with delirium, which could further limit patients' ambulation during a hospital stay (Burns et al., 2004; Inouye, 1994; Inouye & Charpentier, 1996; Inouye, Schlesinger, & Lydon, 1999; Young & Inouye, 2007). In addition, nurses were more concerned about patient safety while ambulating patients with cognitive impairment (King & Bowers, 2011).

Delirium is a cognitive disorder with clinical features of an acute change of cognition, perception, emotion such as anxiety and depressed mood, confusion, memory loss, attention, psychomotor slowing, or irritability (Burns et al., 2004; Sandberg, 1999; Taylor & Lewis, 1993). Delirium is associated with fall and fall risks (Lakatos, Capasso, & Mitchell, 2009), which is a great concern for nurses when deciding to ambulate patients (Brown et al., 2007; King & Bowers, 2011).

In patients experiencing delirium during a hospital stay, about 37% of the occurrences were in the afternoon and 40% were in the morning (Sandberg, 1999). Behavioral characteristics of delirium include hyperactive, hypoactive, and mixed and unclassified delirium, which involves patients' perceptual changes and motor movements (Kozak-Campbell & Hughes, 1996; Williams & Holloway, 1979; Young & Inouye, 2007). The occurrence rate of hypoactive delirium (26%) was higher than hyperactive delirium (22%) (Sandberg, 1999). Wandering behavior is a common feature in hyperactive delirium (Young & Inouye, 2007). Patients with hypoactive delirium are inactive and it is less likely to be detected (Inouye & Foreman, 2001; Long, Brown, Ames, & Vincent, 2013; Young & Inouye, 2007).

Ambulation ability in cognitive impairment. Suttanon et al. (2012) found that standing balance was significantly impaired in older adults with Alzheimer's disease. Studies have identified that older adult patients' ability to ambulate and independently perform activities of daily living during hospital stays are positively correlated with length of time and frequency of patient ambulation (Callen et al., 2004; Killey & Watt, 2006). Patients' illness factors such as symptoms (i.e., weakness, pain or fatigue), severity of the illness, and cognitive status have been identified as barriers to patient ambulation (Brown et al., 2007; Hoyer & Brotman, 2015; King & Bowers, 2011). Although Fisher and colleagues (2011; 2010) did not find any significant correlation between older patients' daily steps and illness severity, two other studies found that patient health status influenced nurses' and patients' perceptions of safety during ambulation (Brown et al., 2007; King & Bowers, 2011). Whereas gait abnormality is apparent, patient characteristics such as impaired cognitive function or physical strength are influential factors that impact nurses' perceptions of patients' physical ability to ambulate, patient and nurse safety, and a perceived need for assistance with ambulation (Brown et al., 2007; King & Bowers, 2011; Park, Delaney, Maas, & Reed, 2004).

Hospitalized older patients with cognitive impairment commonly have comorbidities (Park et al., 2004) and lower functional status, which has been attributed to increased physical decline during hospitalization due to neurodegenerative consequences (Axer, Axer, Sauer, Witte, & Hagemann, 2010; Gallucci, Limbucci, Catalucci, & Caulo, 2008; Mahoney et al., 1998; Sands et al., 2002; Wittwer, Webster, & Hill, 2014). Current ambulation studies have shown a lower scope of daily steps taken by patients with cognitive impairment or confusion/delirium (469.9 - 921 steps/day) (Fisher, Goodwin, et al., 2011; Loevezijn, Cameron, Kurrle, & Bodegom, 2014) than steps taken by patients with intact cognition (580 -1493 steps/day) (Agmon et al., 2016; Fisher, Goodwin, et al., 2011). Older patients with decreased cognitive capacity and lower levels of ambulation ability also have greater difficulty getting out of bed (Capezuti et al., 1999) and consequently, increased fall risk (Clyburn & Heydemann, 2011; Härlein et al., 2011; Vogt et al., 2008) indicating greater need for mobility resources for ambulation.

Increased need for assistance. In general, older adult patients require more nursing support during ambulation (Boltz, Capezuti, & Shabbat, 2011). However, patients' need for assistance is a barrier for healthcare professionals due to lack of staff and time constraints (Brown et al., 2007). Patients with cognitive impairment or delirium require even greater nursing support due to behavior and communication challenges (Belloni, Faccio, Costa, & Iudici, 2014; Borbasi, Jones, Lockwood, & Emden, 2006; Inouye, Schlesinger, et al., 1999). Thus, increasing the likelihood that nurses will forgo initiating ambulation with this group of older adults.

Hospitalized patients with dementia are also more likely to experience delirium (Elie, Cole, Primeau, & Bellavance, 1998) and therefore have an increased need for assistance to maintain physical function and independence (Belloni et al., 2014; Fessey, 2007). The presence of delirium and the increased need for assistance with ambulation may act as a barrier to ambulation during hospitalization.

Nurses' perceptions of patients with cognitive impairment. Nurses play an important role in assisting older patients with ambulation (King, 2006). This is especially true for patients with cognitive impairment. Nurses' perceptions and care activities regarding ambulation have been noted in several studies (King & Bowers, 2011; Park et al., 2004). King and Bowers (2011) demonstrated that nurses view patients as high risk for injury during ambulation if they have greater illness severity and lower physiological, physical, and cognitive capacity. Another study found that nurses rated patients with cognitive impairment as having a greater risk of injuries (48%) and impaired physical mobility (34%) (Park et al., 2004). Further, only 31.4% of nurses considered ambulation as an intervention for patients with cognitive impairment to address impaired physical mobility (Park et al., 2004).

Use of physical restraints. Researchers demonstrated that patients most likely to be restrained were older age with dementia and those with a lower level of physical independence (Bower, McCullough, & Timmons, 2003; Gallinagh et al., 2002; Minnick, Mion, Leipzig, Lamb, & Palmer, 1998). Nurses also were most likely to use restraints if they were concerned about a patient's fall risk or safety (Goethals, Dierckx de Casterlé, & Gastmans, 2013). Old age and cognitive impairment are two characteristics used to identify patients at high risk for falls (Deandrea et al., 2013; Hitcho et al., 2004; Mirelman et al., 2012). The fall rate for hospitalized older adults with cognitive impairment is 12.9%, which is higher than older adults without cognitive impairment (4.2%) (Härlein et al., 2011). In a recent study, nurses described restricting patient ambulation as a common strategy to decrease the fall rate on their inpatient units (King et al., 2016). Patients with cognitive impairment were seen as having an even greater risk for falls and were thus further restricted in ambulation (Beauchamp et al., 2014). Risk for falls may result in low ambulation opportunities or increase the use of physical restraints in patients with cognitive impairment.

Organization culture. In general, there is very little information on the impact of organizational culture and patient ambulation. Of the studies that exist, the focus has been on patients without cognitive impairment. However, available studies have found that attitudes among hospital providers impact the frequency of patient mobility (Czaplijski, Marshburn, Hobbs, Bankard, & Bennett, 2014; King & Bowers, 2011). Czaplijski, Marshburn, Hobbs, Bankard, and Bennett (2014) argued that attitudes, collaboration, and communication among healthcare professionals and patients led to the inefficient use of physical (PT) and occupational therapy (OT) services. Therefore, they developed an interdisciplinary program targeting mobility assessment, communication, education, and documentation to change the culture in hospital setting. Their results showed positive outcomes such as a reduced number of unnecessary PT/OT consults and initiation of early patient mobility (Czaplijski et al., 2014). Markey and Brown (2002) also identified barriers to patient mobility at a unit level such as ambiguous roles among health care professionals related to patient mobility and a lack of patient mobility guidelines. King et al. (2016) incorporated a culture of ambulation (shifting ownership, feeling supported, making ambulation visible) in a multicomponent intervention improve patient ambulation on an inpatient adult medical unit. Findings indicated a statistically significant increase in total ambulation occurrences and distances patient ambulated on the pilot unit. These findings have been sustained for greater than 2 years.

Environmental factors. Adapting the hospital environment to improve patient mobility has been shown to improve patient function during their hospital stay (Inouye, Bogardus Jr, et al., 1999; Landefeld et al., 1995; Padula et al., 2009). Environmental adaptations that have been used to improve patient ambulation include noise reduction, removing clutter from the hallways, and installing handrails. Environmental factors for patient ambulation in hospitals have also been discussed in qualitative studies (Brawley, 2001; Digby & Bloomer, 2014). In particular, researchers have suggested that considerations in hospital design may affect patient mobility. Brawley (2001) asserted that patients with Alzheimer's disease need environmental adaptation such as increased lighting, non-slip flooring surfaces, interesting and safe ambulation routes, and handrails for ambulation support. Older patients have identified external lines, such as intravenous or urinary catheters as environmental barriers, that prevent them from ambulation during their hospital stay (Brown et al., 2007). Although there is evidence that altering the physical environment may impact patient mobility, only one study (Inouye, Bogardus Jr, et al., 1999) has specifically identified the unique needs of patients with cognitive impairment to promote mobility during their hospital stay.

Gaps in the Literature

Research is sparse on ambulation during a hospital stay in persons with cognitive impairment. Sparse research on ambulation frequency in patients with cognitive impairment compared to patients with intact cognition, create a significant gap in understanding the impact of cognition and ambulation ability during hospitalization. It is unclear whether hospitalized older patients with cognitive impairment retain their ability to independently ambulate based on how often they ambulate during a hospital stay. Further, limited research has been conducted on the relationship between frequency of ambulation during hospitalization and gait speed (physical performance) in persons with cognitive impairment. Thus, by understanding hospital ambulation frequency and physical performance at discharge in older persons with and without cognitive impairment, we may be able to develop interventions to improve mobility activity, maintain functional independence, and improve hospital care for older adults with cognitive impairment. The gaps in the literature include the following:

1. **Few studies on ambulation of older adults with cognitive impairment during a hospital stay.** Although the importance of early ambulation has been noted along with a description of the barriers in maintaining ambulation ability and its benefits in cognitive and physical function in hospitalized older adults, little is known about the ambulation frequency of patients with cognitive impairment during a hospital stay. In this study, the hospital ambulation frequency of older adults with cognitive impairment is examined and compared with patients without cognitive impairment.
2. **Feasibility of recruiting older patients with cognitive impairment or delirium to examine their ability to ambulate and ambulation frequency.** The number of older adults with cognitive impairment is rapidly increasing (Boustani et al., 2010; Centers for Disease Control and Prevention, 2010; Maslow, 2005). Ambulation ability of patients

with cognitive impairment may be lower than cognitively intact older patients. However, the number of studies that have examined the effect of ambulation interventions on cognitively intact older patients greatly exceeds the number of intervention studies that involve patients with cognitive impairment. Few studies have been conducted on the implementation and observation of hospitalized older adults with cognitive impairment. Patients with cognitive impairment have been excluded from ambulation studies largely due to the unpredictable characteristics of cognitive incompetency. Only one study using gait training enrolled patients with dementia (Vogt et al., 2008). This dissertation study will demonstrate the ability to recruit patients with cognitive impairment or delirium and the process of data collection in persons with cognitive impairment.

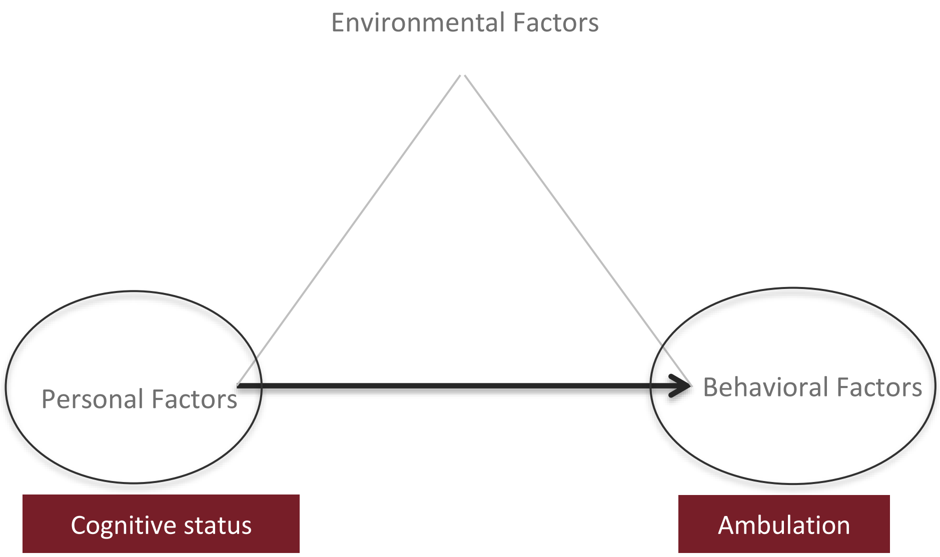
Maintaining ambulation routines for older patients during hospital stays is important. Although many studies have demonstrated that cognitive capacity is physiologically linked to ambulation performance for gait and balance, they have not captured how patients' ambulation can be initiated and maintained during a hospitalization stay. Although physical activity interventions including ambulation can improve hospitalized older patients' health, most previous studies have excluded patients with cognitive impairment. Therefore, the extent to which patients with cognitive impairment may benefit from mobility interventions remains unknown. My dissertation study sought to lay a foundation and fill in gaps in the literature by first comparing the number of steps taken by older adults with and without cognitive impairment during their hospital stay and exploring the potential impact of cognitive function on patients' physical performance at discharge.

Social Cognitive Theory

To explore the relationships among patients' cognitive status, hospital ambulation frequency and physical performance, SCT was used as a theoretical framework to guide the study design. SCT, developed by Bandura, highlights the dynamic relation between an individual's behaviors and the interactions among personal and environmental factors (Bandura, 2001). SCT postulates that an individual's cognition and personal change (known as *person*) in their ability to complete a behavior, and the surrounding physical or social situation (*environment*) could determine the initiation and persistence of a difficult task (*behavior)* (Bandura, 2004).

A review article targeting theory-guided physical activity demonstrated that SCT has been widely used as a framework to explain individuals' socio-structural and personal influences (Dzewaltowski, 1990). The influences build their self-regulation and self-efficacy which refer to the subjective beliefs and adjustment in achieving tasks (Bandura, 2011). SCT provides a view in the health research that emphasizes the goals of health promotion and disease prevention (Bandura, 2004). Knowledge about the advantages or disadvantages of health changes is a precursor for individuals to develop a health behavior (Bandura, 2004). Figure 2.1 illustrates SCT with examples of ambulation in hospitalized older patients.

Figure 2.1 *The Theoretical Framework*



Patients' hospital ambulation may greatly rely on the status of their neurophysiological mechanism over time. Persons with cognitive impairment have a decline in attention, memory, and visual-spatial sensory and motor functioning (Breitner, 2006; Cecil et al., 2012; Reisberg et al., 1982). Hospital ambulation frequency, as a behavior in a special context, could be influenced by cognitive function and the physical and social environment. Ambulation during a hospital stay for older patients with cognitive impairment also involves personal factors such as cognitive decline (Hermann, Muck, & Nehen, 2015; King & Bowers, 2011; Wald, Leykum, Mattison, Vasilevskis, & Meltzer, 2015).

The purpose of this descriptive, longitudinal study is to investigate the relationship among patients' cognitive status, hospital ambulation frequency, and physical performance of older adults (age ≥65) during a hospital stay. The conceptual framework of this study is shown in Figure 2.2.

Cognitive status (*person*). Person refers to the characteristics that drive one's effort to approach tasks which could involve motives or social influence (Bandura, 2001). The ability to maintain personal change is a focus in SCT and involves how individuals overcome barriers (Bandura, 2004).

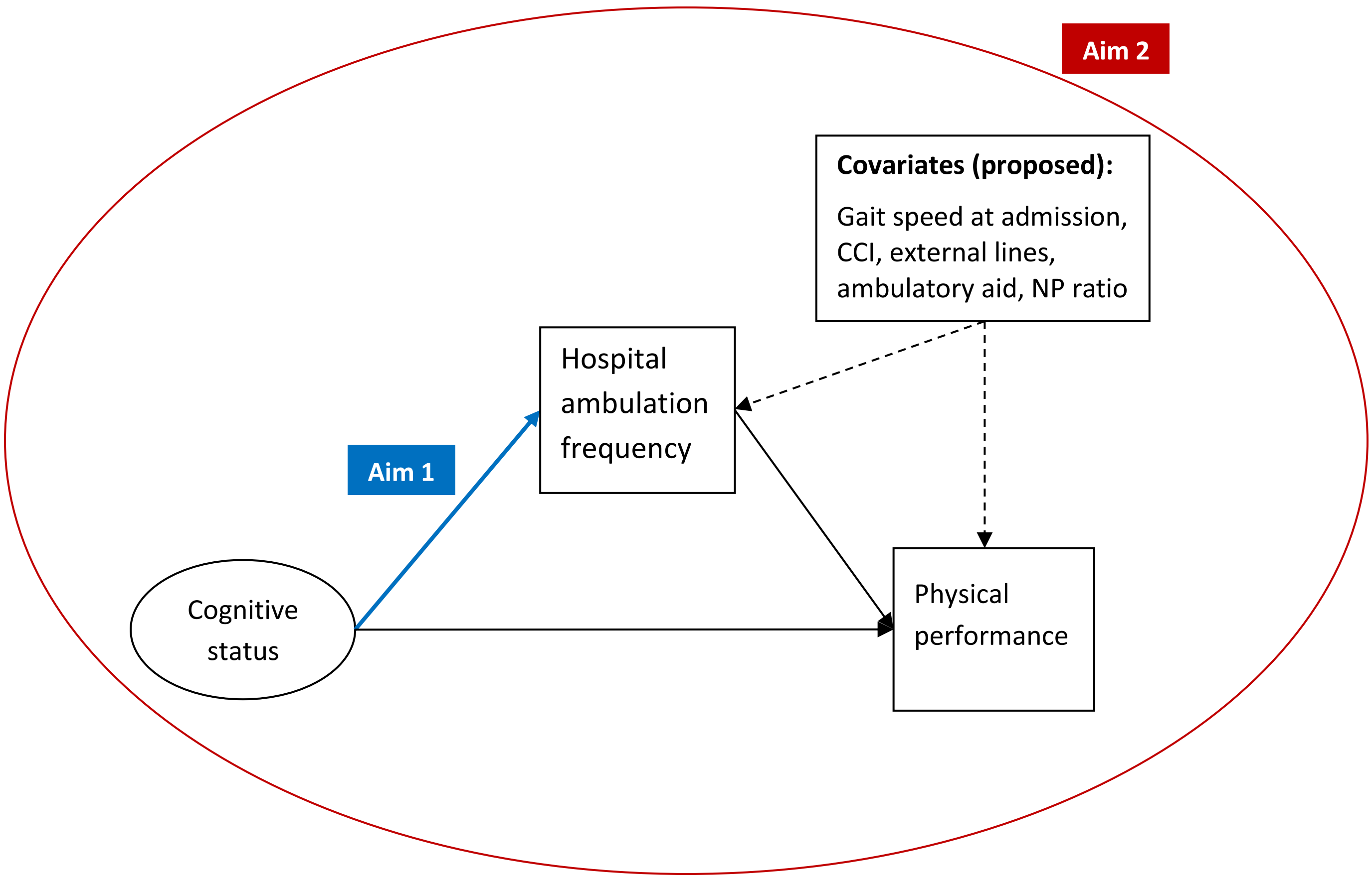
It is important to consider an individual's cognitive function when researching patient ambulation due to the neurophysiological influence of cognition on balance and gait performance. For example, patient conditions, such as disease, have been identified as barriers to patient ambulation (Brown et al., 2007). In this study, patients' cognitive status is the primary predictor variable. Other patient characteristics such as risk of falls (Rubenstein, 2006), comorbidity (Corcoran, 1991; Fisher, Galloway, et al., 2011) and body mass index (Yamakawa, Tsai, Haig, Miner, & Harris, 2003) were collected as covariates for statistical control.

Hospital ambulation and physical performance *(behavior).* Ambulation during hospitalization was the target physical activity in this study. Gait speed reflects the actual patient physical performance for ambulation, and is appropriate to represent the behavior capacity domain in the SCT framework. Ambulation, as a physical behavior, indicates a pattern of daily activity or a human movement within a specific context (Bussmann & van den Berg-Emons, 2013). Although cognitive impairment is a risk for hospitalization-associated disability (Covinsky et al., 2011), it is unknown whether gait speed and hospital ambulation frequency is altered in older patients with cognitive impairment. Patients' gait speed between admission and discharge and whether it relates to cognitive function is a critical issue to identify in order to support patients' ambulation over time. In this study, the point of view of ambulation was not simply to quantify the number of steps within a specific timeframe (i.e., daily steps), but also to identify the level in changes of ambulation frequency during hospitalization as the ambulation indicator. The outcome variable, gait speed, was measured to determine patients' capacity for physical performance of ambulation.

Ambulatory aid, external lines and nurse-to-patient ratio as covariates (*environment*). Both the physical and social environments are explained in SCT (Bandura, 2004). Behavior could partially be regulated by the environment or social reactions it evokes. Social approval and disapproval of the behavior is produced within one's interpersonal relationships. Studies on frequency of ambulation for hospitalized older adults have identified several *social environment* barriers that may impact whether or not patients are engaged in ambulation. Some environmental barriers identified are, lack of nursing staff which increases nurses' workload (Rogers, Hwang, Scott, Aiken, & Dinges, 2004), need for nursing staff to assist with patient ambulation (Brown et al., 2007), and heightened concerns about patient falls (King, 2006; King et al., 2016). The influence of the nurse-to-patient ratio can be treated as a covariate in this study since patients with cognitive impairment require more assistance with ambulation and have different demands for care as compared to cognitively intact patients (Belloni et al., 2014; Brawley, 1997). In addition, physical attachment to medical devices such as intravenous lines (Brown et al., 2007; Hoyer & Brotman, 2015) and the use of assistive ambulatory devices (Brown et al., 2007) are also identified as external factors that restrict patient ambulation during a hospital stay. Assistive ambulatory devices such as walkers and canes are common tools patients use for ambulation. The use of a walking device not only determines patient functional ability, but also predicts the risk for falls (Bateni & Maki, 2005) and functional decline (Mahoney, Sager, & Jalaluddin, 1999) during a hospital stay. Three environmental factors, use of assistive ambulatory devices, presence of external lines, and the nurse-to-patient ratio were measured as covariates. Other environmental factors such as noise, light, and the physical hospital structure were not considered in this study due to insufficient evidence in the literature.

This study was conducted on an inpatient unit, which can be considered a controlled environment in terms of lighting, noise, and physical structure.

Figure 2.2 *Study Conceptual Framework*



Note. CCI: Charlson Comorbidity Index. NP ratio: Nurse-to-patient ratio.

Summary and Aims

Limited ambulation during a hospital stay is a critical concern for older adults (Brown et al., 2007) and often associated with negative outcomes such as loss of functional status, an increased risk for falls both during and after discharge, new nursing home placement, readmission, and increased lengths of stay (Counsell et al., 2000; Fisher, Goodwin, et al., 2011; Fisher et al., 2010; Mahoney et al., 1998). Most studies conducted on ambulation of hospitalized older adults have excluded persons with cognitive impairment, a population that may be at even greater risk for functional decline and negative outcomes. Of the few studies on patient ambulation that have included patients with cognitive impairment, improvements in cognition and a decrease in delirium have been reported (Inouye, Bogardus Jr, et al., 1999). Having limited information on hospitalized patients with cognitive impairment is a barrier to understanding the role of cognitive function and hospital ambulation frequency on influencing health outcomes for persons with cognitive impairment.

The purpose of this study was to investigate the relationship among cognitive status, hospital ambulation frequency, and physical performance in older adults (age ≥65) during hospitalization and is accomplished through the following specific aims:

Aim 1: To determine the relationship between cognitive status (baseline cognitive function) and hospital ambulation frequency (the trajectory of the cumulative number of steps) taken by older patients during hospitalization. Baseline cognitive function was measured with the MoCA-Blind assessment at admission. Participants were grouped into two categories as the baseline cohort: those with and those without cognitive impairment. Hospital ambulation frequency was defined by the trajectory of the cumulative number of steps taken during a hospital stay.

Sub-aim: To explore if changes in cognition (i.e. delirium) produces a change in ambulation frequency.

Aim 2: To determine how hospital ambulation frequency explains the relationship between cognitive status (baseline cognition) and physical performance. The trajectory of hospital ambulation frequency as a mediator was analyzed to explain the relationship between cognitive status and physical performance. Cognitive status was categorized into two groups: cognitive impairment and non-cognitive impairment. Physical performance (measured as gait speed) at discharge was the outcome variable.

Chapter 3: Method

Overview of Design

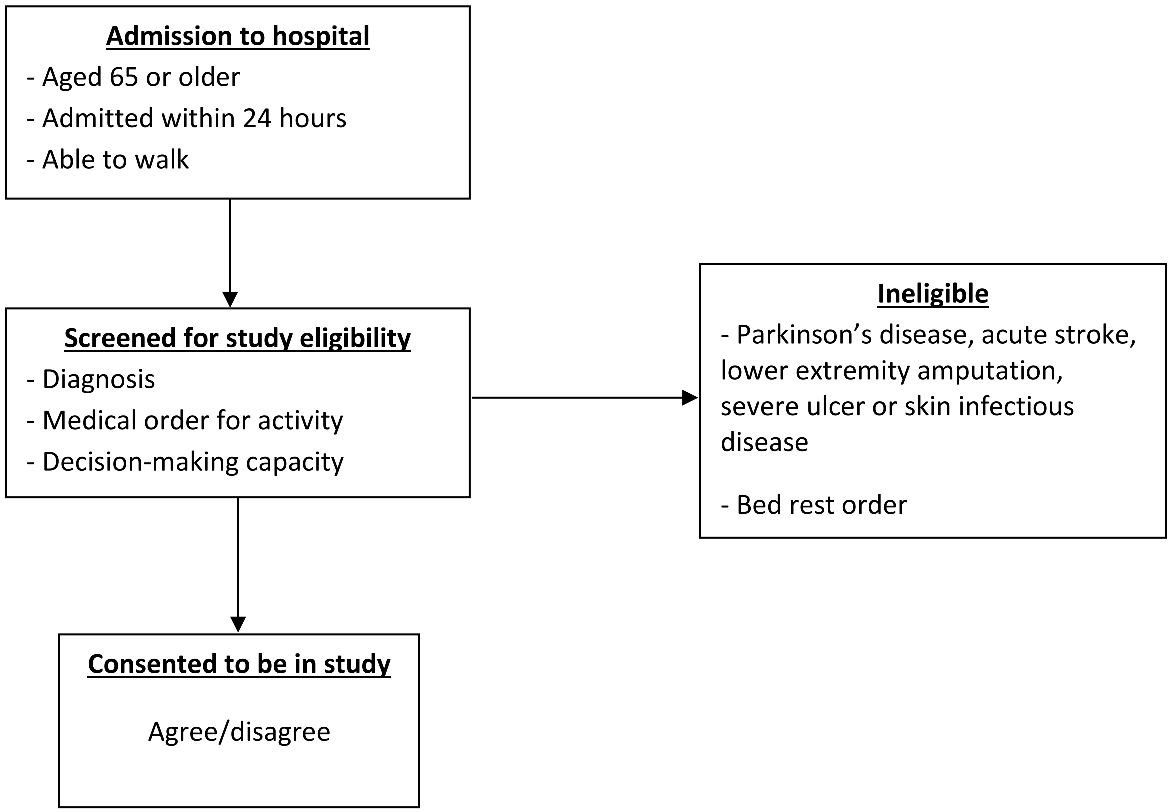
A descriptive study using longitudinal data analysis was conducted to address two specific aims: (1) to determine the relationship between cognitive status (baseline cognitive function) and hospital ambulation frequency (the trajectory of the accumulative number of steps taken) of older patients during hospitalization. Sub-aim: To explore if changes in cognition (i.e., delirium) produces a change in ambulation frequency, and (2) to determine how hospital ambulation frequency explains the relationship between cognitive status (baseline cognition and the presence of delirium groups) and physical performance (gait speed) at discharge. The trajectory of hospital ambulation frequency as a mediator was analyzed to explain the relationship between cognitive status and physical performance. Human subject approval for this study was obtained from the University of Wisconsin-Madison Health Sciences Institutional Review Board (IRB) and the VA Research and Development (R&D) Committee. This chapter describes the analytical approaches and procedures to address these specific aims.

Sample and Setting

Twenty-seven participants were enrolled to participate in the study. Inclusion criteria consisted of (1) age 65 or older, (2) able to walk with or without assistance, and (3) having decision-making capacity. Exclusion criteria included diagnosis of Parkinson's disease, acute stroke, lower extremity amputation, severe lower extremity skin ulcer or infection, bed rest order, and any activated power of attorney (POA). Participants could be patients with or without cognitive impairment.

Participants were enrolled from a non-ICU medical inpatient unit in a 129-bed Veterans Administration (VA) Hospital that serves around 130,000 veterans in south-central Wisconsin and northwestern Illinois. A graphic flowchart of recruitment is shown in Figure 3.1.

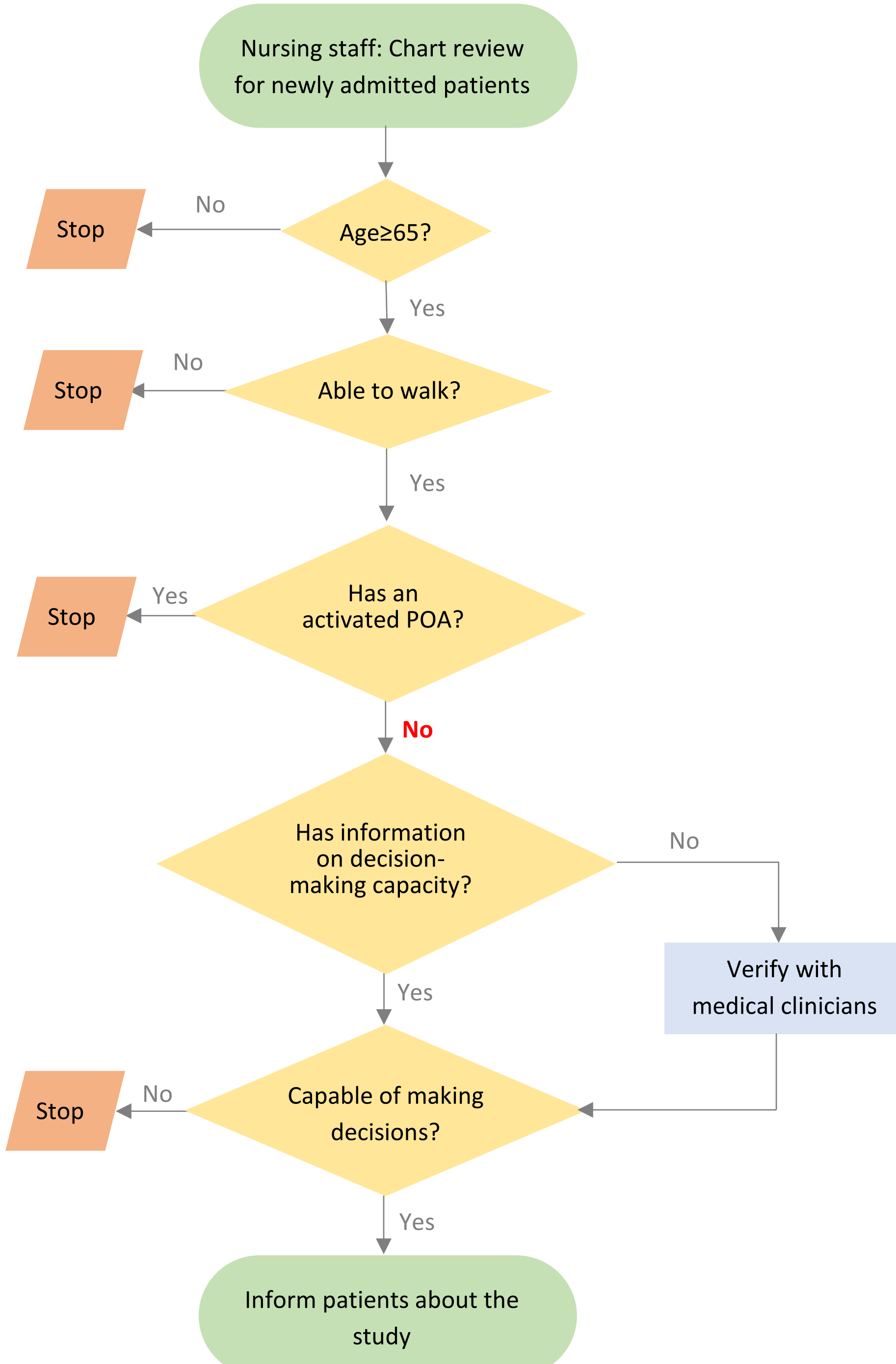
Figure 3.1 *Flowchart of Recruitment Process*



Recruitment

Identification of patients' decision-making capacity. Using the cutoff point of 17 or lower as cognitive impairment (Wittich, Phillips, Nasreddine, & Chertkow, 2010), 10 patients were identified as having cognitive impairment at baseline. Given the level of cognitive function and the progressive nature of cognitive impairment, many individuals with mild to moderate cognitive impairment retain their decision-making capacity and are able to provide reliable responses (Feinberg & Whitlatch, 2001). Only participants who were confirmed by clinicians to have decisional capacity and had no activated POA were enrolled. A flowchart was used to explain the screening process to recognize potential participants (see Figure 3.2).

Figure 3.2 *Screening Process (Nursing Staff)*



Nurse-patient ratio on the study inpatient unit. During the data recruitment period, the unit maintained about 20 patients per day. The nursing staff worked standard shifts: day shift (7am-3pm), afternoon shift (3-7pm) and night shift (11pm – 7am). During the day shift, there were seven registered nurses (RNs), one served as the charge nurse and six provided direct patient care. On the afternoon shift, there were six RNs providing direct patient care. On the night shift, there were four RNs providing direct patient care. The nurse-patient (NP) ratio was 1: 3-4 during the day and afternoon shifts, and 1:5 during the night shift. The same number of Certified Nursing Assistants (CNAs) were assigned in the unit. There were no differences in nurse-to-patient ratio between weekday and weekend shifts. Based on the theoretical framework, the environmental factor in this study was determined by the nurse-patient (NP) ratios on the unit. The ratios were consistent throughout the days of the week and among shifts. Therefore, the NP ratios were not taken into account in the analysis.

Recruitment and consent procedures. In accordance with VA R&D and the IRB policy, a staff member of the VA system was required first approached patients to see if they were interested in hearing more about the study. The student principal investigator (SPI), Fanglin Kuo, stopped by the inpatient unit daily to see patients who wanted to learn more about the study. The SPI verified with the nursing staff that patients had decision-making capacity. For those patients who had decision-making capacity and were interested in hearing more about the study, the SPI met with them individually in the privacy of their hospital rooms, explained the study, answered questions, and obtained written consent. All participants were given ample time to review the consent form and ask questions. The study purpose, process, risks, benefits, contact information, and the patient’s right to withdraw at any time during the research were described and discussed. Every participant was given a copy of the consent form.

After the participant gave consent, the researcher assessed the participant's skin around the ankle region to ensure that there were no open areas or rashes present. Once intact skin was confirmed, an accelerometer was placed around the participant's ankle using a Velcro strap. A training task was performed by the researcher to provide further teaching, adjustment, and identification of potential problems with the accelerometer. The training task took about three minutes involving demonstrations of correct/incorrect accelerometer placement, and how and when to take the accelerometer off and put it back on. A flyer identifying the patient was wearing an accelerometer was placed in a visible location in the patient's room.

Ethical Consideration for Recruiting Patients with Cognitive Impairment

This study took into account whether patients with cognitive impairment had sufficient decision-making capacity. Patients with mild to moderate cognitive impairment were reported as retaining the ability to answer questions and make decisions consistently during hospitalization and when participating research (Feinberg & Whitlatch, 2001). The procedures for recruitment of participants with cognitive impairment followed the methods described in the literature (Appelbaum, 2007) and IRB recommendations (University of Wisconsin-Madison, 2016) to ensure protection of human rights for vulnerable population. Clinicians informed the researcher of the patients' decision-making capacity to determine the patients' capacity to participate in the study. Only patients who met the two criteria, capable to make decisions and no activated POA, were invited to participate in the study. All participants were able to briefly answer the four questions about the study: purpose, assessments, risks, and having the right to drop out of the study. These questions to determine decision-making capacity were recommended by Appelbaum (2007).

For patients who developed delirium during the study, their participation would stop if the patient expressed any intention to drop out of the study, showed signs of distress in continuing with the study, or the nurse perceived inappropriateness for the patient to continue in the study. One patient in this study experienced a 3-day delirium event. The patient's nurses determined that participant in this study did not cause any distress or concern to the patient during the delirium event and the patient stated he was willing to continue in the study. Therefore, the patient with delirium remained in the study until discharge.

Variables and Measures

A summary of the concepts, measurements, and analysis is provided in Table 3.1.

Main predictive variable: cognitive status. The main predictor is cognitive status as a baseline and a time-varying variable. Baseline cognitive function was used to determine the cognitive impairment cohort at admission, and the time-varying cognition was measured based on the presence and severity of delirium. Cognitive functioning involves memory ability, reasoning, language, judgment, visuospatial skills, and attention (Albert et al., 2011; Petersen et al., 2014). In this study, baseline cognitive function was measured by the Montreal Cognitive Assessment-Blind (MoCA-Blind). Time-varying cognition was detected based on delirious symptoms using the Confusion Assessment Method (CAM) rather than MoCA-Blind to prevent possible learning bias and practice effects (Cunje, Molloy, Standish, & Lewis, 2007).

Baseline cognitive function. Baseline cognitive function was measured by MoCA-Blind and used to classify participants into groups with and without cognitive impairment using a cutoff point of 17 (Wittich et al., 2010). The relationship with the outcome measures was made based on the baseline cohort. The baseline cognitive function determined the participants' performance in short-term memory, orientation and reasoning tasks according to the criteria of MoCA-Blind. The MoCA-Blind is a shortened version of the MoCA-full and targets older patients with visual impairment (Nasreddine et al., 2005; Wittich et al., 2010) to detect their cognitive impairment. The test-retest reliability of MoCA demonstrates a good correlation coefficient (0.92, $p < .001$) for detecting mild cognitive impairment (Nasreddine et al., 2005). The internal consistency indicates strong reliability with a Cronbach α=0.83 (Nasreddine et al., 2005). Compared with another well-known instrument, Mini Mental State Examination (MMSE), MoCA shows a high correlation in content validity (r =0.87, $p < 0.001$) and better sensitivity (90%-100%) and specificity (87%) (Aggarwal & Kean, 2010; Nasreddine et al., 2005). MoCA-Blind consists of six domains: memory, attention, language, abstraction, delayed recall and orientation. The maximum total score of MoCA-Blind is 22 with a range of 18-22 as indicative of intact cognition (Wittich et al., 2010). The sensitivity (94%) and specificity (98%) of MoCA-Blind to detect cognitive impairment remain good (Wittich et al., 2010). MoCA-Blind requires approximately 10 minutes to complete.

Time-varying cognition. Time-varying cognition was detected based on the presence of delirium. Delirium is defined as a fluctuating and rapid onset of changes in cognition accompanied by a disturbance of consciousness, a shift in attention, disorganized thinking, and emotional distress or restlessness (Naylor & Stephens, 2005; Young & Inouye, 2007). Presence, severity, and type of delirium during the participant's hospital stay was determined by the Confusion Assessment Method (CAM) (Inouye & Foreman, 2001; Inouye & Van Dyck, 1990). The CAM consists of ten symptom items (onset and fluctuation, inattention, disorganized thinking, consciousness, disorientation, memory, perceptual disturbances, two psychomotor types, and sleep-wake cycle) (Inouye & Kosar, 2014). The researcher rated each delirium symptom category other than fluctuation as absent (0), mild (1), or marked (2). Acute onset and fluctuation was only rated as absent (0) or present (1). The total score of the CAM ranges from 0-19 with a higher score indicating greater severity. The instrument also allows clinicians to identify hyperactive or hypoactive delirium by observing patients' psychomotor features which include unusual increased or decreased physical activity and sensitivity to verbal or environmental stimuli (Inouye & Foreman, 2001; Sandberg, 1999; Young & Inouye, 2007).

The CAM has been used in both clinical settings and in research to identify older patients' acute cognitive changes, and has a reported sensitivity of 94-100% and specificity of 84% across studies and healthcare settings (Inouye & Van Dyck, 1990; Wei & Fearing, 2008). The interrater reliability is high, 0.81-1.0 (Inouye & Van Dyck, 1990). The convergent validity is moderate with MMSE (0.64) (Inouye & Van Dyck, 1990) and high with the Delirium Rating Scale (0.92) (Wei & Fearing, 2008).

Mediator: Hospital ambulation frequency (number of steps, as measured by an accelerometer). In this study, patients' ambulation frequency is the mediator in patients' cognition impact on gait speed at discharge. Accelerometers have been used in multiple studies of older adults, across clinical settings (Bassett, Mahar, Rowe, & Morrow, 2008; Cheung, Gray, & Karunanithi, 2011; Loevezijn et al., 2014). Accelerometer use has reported excellent precision by testing five repeated measures for two optional wearing placements, three velocities, and two areas of walking (sign-corrected disagreement= 0.04 - 0.18), and excellent accuracy by comparing it with manual counts (intraclass correlation coefficient=0.9995) (Foster & Lanningham-Foster, 2005). The StepWatch-Step Activity Monitor (SAM) device was used in this study. It is a small, light-weight uniaxial monitor that has been recognized as an excellent instrument to record the number of steps and walking speeds of older adults (Bergman, Bassett, & Klein, 2008; Jr & John, 2010; Karabulut, Crouter, & Jr, 2005; McCullagh, Dillon, O'Connell, Horgan, & Timmons, 2017). The SAM has demonstrated high test–retest reliability (r = 0.96) (Bergman et al., 2008) and relatively higher accuracy than other types of accelerometer with 3% in error or less (Bergman et al., 2008; McCullagh et al., 2017).

Outcome variable: physical performance (Gait speed at discharge). The level of physical performance plays a unique role in the evaluation of older patients' health and prognosis outcomes after hospitalization (Francis & Kapoor, 1992; Naylor & Stephens, 2005; Sager et al., 1996). Physical performance refers to the ability of an individual to physically perform important tasks or activities to maintain independence in daily life (Francis & Kapoor, 1992; Naylor & Stephens, 2005). Gait speed, based on ambulation ability, has been identified as an important component of physical function in older patients (Beckett & Brock, 1996; Potter et al., 1995; Studenski & Perera, 2003) and is a more sensitive parameter to estimate patients' LOS and discharge destination than ADLs (Ostir & Berges, 2012). In Aim 2, gait speed is determined using the 4-meter walk test to measure the time it takes an individual to walk four meters at a usual pace. The interrater reliability ($r>0.9$) and 2-week test-retest reliability ($r=0.723$-0.9) were good to excellent (Studenski & Perera, 2003).

Demographic information and clinical information. Data on participants' demographic and clinical information at baseline was collected from the participants' electronic medical records (see the Appendix). Demographic and clinical data included age, sex, medical diagnoses, length of hospital stay, residence before admission to the hospital, discharge destination, ability to complete basic activities of daily living (e.g., bathing, dressing, eating, toileting), use of a walking device, fall risk score, physical therapy consult, presence of external lines (e.g., intravenous line or Foley catheter), medication profile, and cognitive changes that occurred during the hospital stay. The Charlson Co-Morbidity Index was completed based on chart reviews.

Comorbidity: Charlson Comorbidity Index (CCI). CCI is a classification tool used to measure an individual's comorbid conditions and to predict the risk of mortality (Charlson, Pompei, Ales, & MacKenzie, 1987). It is a weighted index that calculates the number and severity of 19 comorbid conditions with age. Comorbid diseases are listed with different scores 0, 1, 2, 3, and 6 weighting for severity. Content and construct validity, and test-retest reliability of CCI has demonstrated validity in a variety of populations (de Groot, Beckerman, Lankhorst, & Bouter, 2003). CCI was validated based on the predictor risk of comorbid death and weighted with a well-developed comorbidity index by Kaplan and Feinstein regarding the survival rate (Charlson et al., 1987). Both of the methods showed an identical variance in predicting patients with a very low risk of mortality (Charlson et al., 1987). The correlation coefficient with the Burden of Disease instrument was 0.43 (Mulrow & Gerety, 1994). A complete timeline and process of recruitment and data collection is shown in Figure 3.3.

The outcomes measured for each cohort are hospital ambulation frequency (as measured by the accumulative number of steps) and physical performance (as measured by gait speed).

Data Collection

The main independent variable, cognitive function, was measured by MoCA-Blind with six dimensions. The dependent variable was usual gait speed at discharge, measured by the time required to walk 4 meters. The mediating variable was the ambulation frequency, measured by the standardized slopes of the accumulative number of steps.

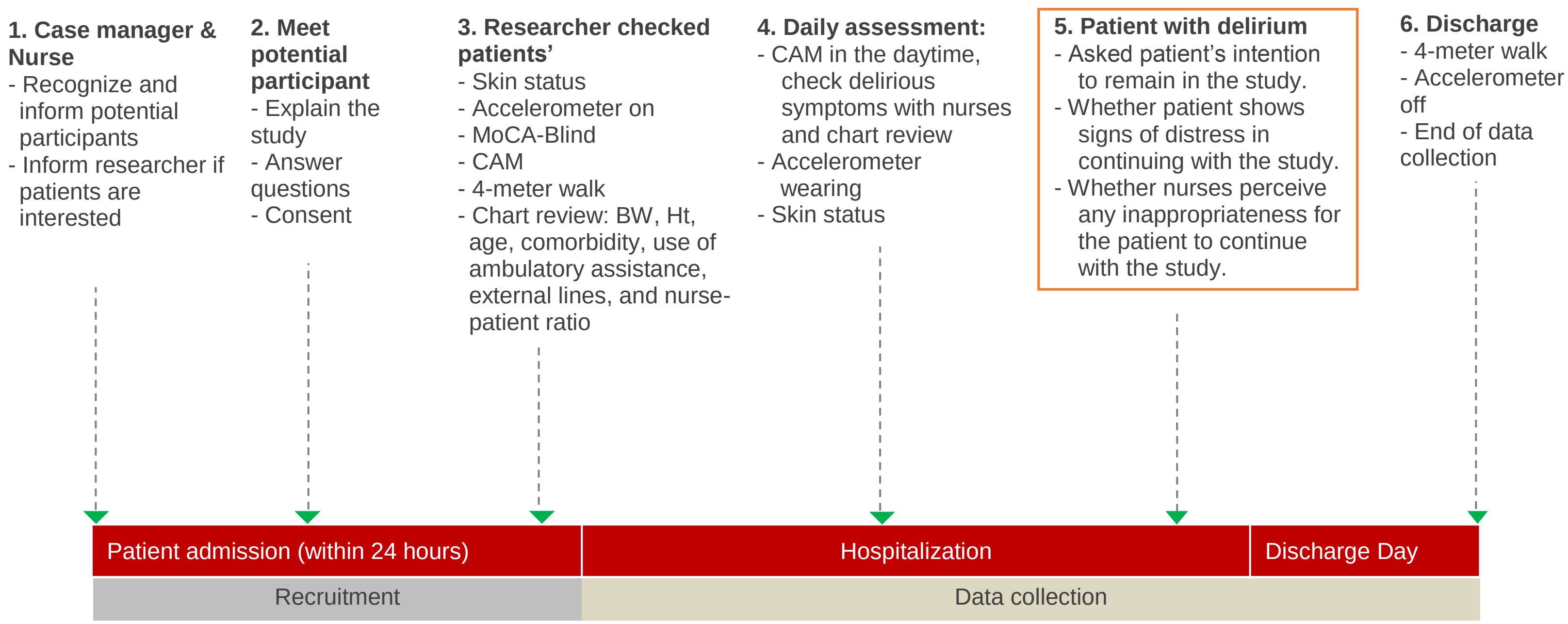
Given that the cutoff point of 17 or lower indicates cognitive impairment, nine patients had cognitive impairment at baseline with two having diagnosed dementia. Participants received a series of cognitive and functional assessments immediately after enrollment. Data were obtained from performance measures (MoCA-Blind, gait speed, accelerometer monitor), electronic chart review (demographic and health information, delirium episode), and observation (CAM with verification by nursing staff and chart review). The baseline assessments were made on admission (within 24 hours of admission). The primary outcome measure was physical performance as measured by gait speed at discharge. Demographic and health information for the covariates (age, body weight, height, comorbidity using the CCI from medical chart review) were collected by chart review.

Table 3.1 *Concepts, Measurements, Data Collection and Analysis*

Aim	Measures	Data collection method	Time	Data analysis
Aim 1: Relationship between baseline cognition and hospital ambulation frequency	Ambulation: The StepWatch 3 Activity Monitor (SAM)	SAM worn on the ankle	From enrollment to discharge: 24H/Day	1. Obtain standardized coefficient of each case's trajectory of cumulative number of steps (β1) over time, and standardized mean hourly steps 2. Describe the variance of the slopes for the trajectory and fuzzy cluster analysis for subgroup 3. Group CI and NCI with cutoff 17 of MoCA-Blind 4.Comparison of the clusters and cognitive cohorts
	MoCA-Blind	Researcher	One-time at enrollment	
Sub aim: To explore if changes in cognition (i.e.delirium) produce a change in ambulation frequency.	CAM	Observation by researcher, verification with nurse, and chart review for delirium episodes	Daily in the daytime during hospitalization	1. Determine the episode timepoints and types of delirious symptom 2. Obtain the coefficients (β) of the trajectory of cumulative number of steps based on the delirious timepoints 3. Describe the variance of the slopes for the trajectory
Aim 2: How hospital ambulation frequency explains the relation between cognitive status and physical performance	Usual Gait speed (GS): 4-meter walk	Researcher	Two times: enrollment and discharge	1. Test mediation: Regression analysis of β1, standardized mean hourly steps on GS at discharge over the cognitive cohorts 2. CCI, device use, external line and GS at admission were proposed as covariates for the analysis
Demographic and health information:	Body weight, height, diagnosis, age, sex, nurse-to-patient number, assistance, Morse, external lines	Researcher	At enrollment	Descriptive and comparative analyses

Note. CI: Cognitive impairment, NCI: Non-cognitive impairment

Figure 3.3 *Timeline and Process of Participant Recruitment and Data Collection*



Analysis

The analyses were carried out in several steps. Descriptive analysis was used to characterize the demographic and clinical information of the study sample. The data collected using the accelerometers represented the number of steps per minute patients took during their hospital stay. In order to explore each individual's linear trajectory of the cumulative steps over time, and the properties of similarity and dissimilarity among the sample, ordinary least square (OLS) regression and fuzzy clustering were used to analyze the relationships of cognitive function, ambulation frequency and physical performance at discharge, and to identify the subgroups on the time-varying data. Regression discontinuity analysis on an individual with delirium was used to investigate how the event influenced the trajectories of the patient's ambulation frequency. Between-group comparisons were performed using t-test or proportional analysis. Simple mediation regression exploring the association among the cognitive status (independent variable), usual gait speed at discharge (dependent variable), and standardized slope of ambulation frequency (mediator) adjusted on the admission gait speed and other patient characteristics (walker use/assistance need) were performed. Outcomes were evaluated by *p*-value and Cohen's *d*, Cohen's *h* or Becker effect sizes (Becker, 1988; Cohen, 1988). A *p* level ≤ 0.05 was considered statistically significant. The effect sizes were calculated to present the magnitude of group mean differences with a cutoff of *d or h* value in 0.2 as a small effect size, 0.5 as a medium effect size, and 0.8 as a large effect size (Cohen, 1988). The statistics were performed using NCSS9, Mplus7 and StataSE14. The approaches in detail are described below.

Data transformation. Twenty-seven enrolled participants wore the SAM device during their hospital stay. One accelerometer data set was missing due to incorrect wearing and was removed from the statistical analysis. A total of 26 participants were included in the analysis. The data collected by the accelerometers represent the number of steps per minute patients took during their hospital stay. Many patients exhibited few steps per time period, which presented a non-monotonic change structure. To detect the change points and maintain the properties of change periods, the cumulative sum technique was used. With this technique, the data were aggregated into 1-hour intervals for analysis. In addition, MoCA-Blind scores were categorized into a binary variable using a cutoff score of 17 to distinguish cognitive impairment (n=9) and non-cognitive impairment (n=17) group.

Ordinary least squares (OLS). First, participants' accumulative steps during hospitalization until discharge were analyzed using OLS regression to identify the change patterns of the number of steps in 1-hour intervals including the intercepts and slopes. The trajectories were conceptualized as predictor-outcome relations (accumulative steps-hour) on regressions. The outputs were reported as standardized regression coefficients (β) indicating the change in standard deviation (SD) units in the outcome (accumulative steps) that occurs as a result of each SD unit change in the predictor (hourly time). Standardized regression coefficient (β) quantifies the strength of the association between the accumulative number of steps and hourly time which eliminates the influence of matrices (various lengths of stay). To determine whether relations of cognitive function and gait speed changed due to ambulation frequency, the standardized coefficient was entered in the models to test the relationship.

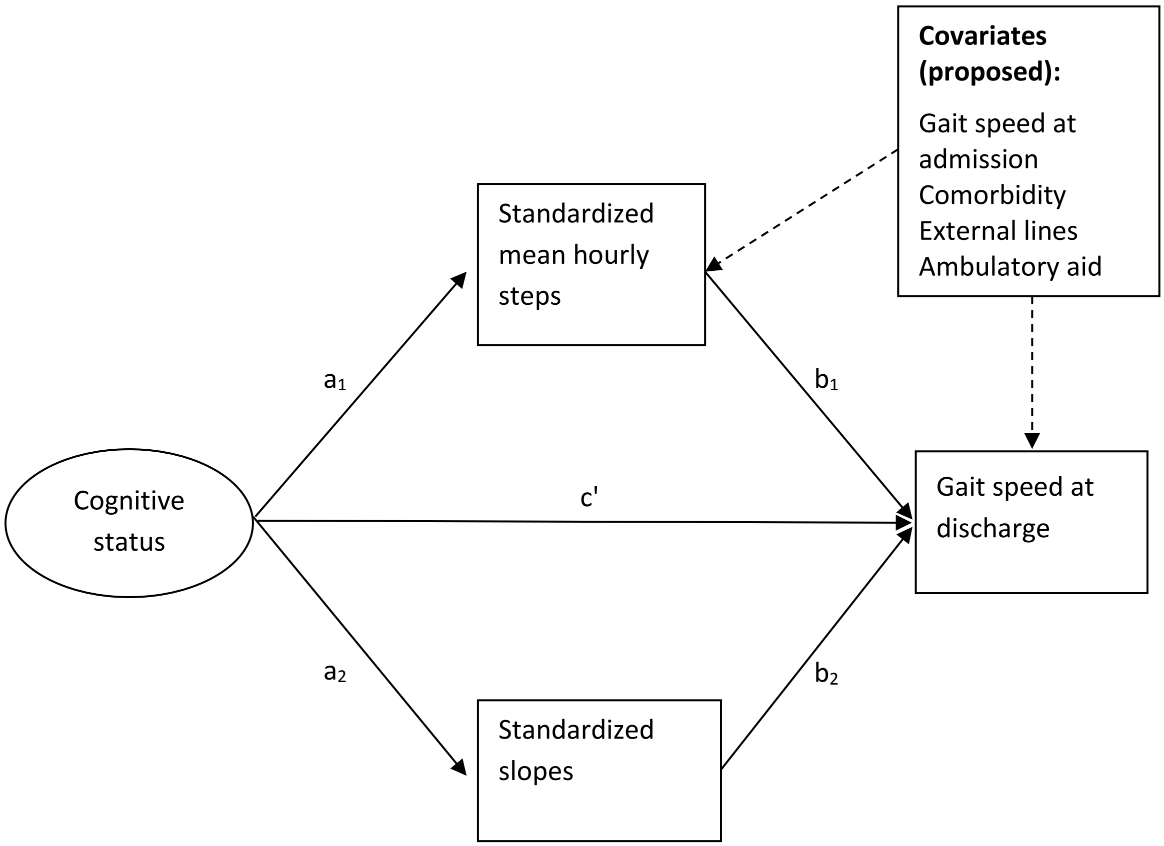
Fuzzy clustering analysis. Cluster analysis is a descriptive analysis to identify homogenous groups of cases within the data. Related to the purpose to understand the hospital ambulation frequency of older patients, we used fuzzy clustering analysis to evaluate the trends of ambulation frequency among the sample. Fuzzy clustering was conducted based on the properties of the sample's patterns of ambulation steps. Fuzzy clustering is a partitioning generating approach to identify subgroups in a dataset by assigning membership to each data point based on their relative distance (Kaufman & Rousseeuw, 1990). There is no predetermined number of clusters in fuzzy clustering analysis (Kaufman & Rousseeuw, 1990). The membership coefficients represent the degree of belonging for a data point in the assigned cluster. The distance of each data point toward the cluster center is calculated. More membership for the particular data center indicates that more data is closer to the cluster, and the sum of the membership of each data point is 1 (Kaufman & Rousseeuw, 1990). *Medoid* represents the central data point of each cluster and its average distance to all other points of the same cluster is being minimized (Kaufman & Rousseeuw, 1990). The algorithm of fuzzy clustering is to seek the minimized function: $\sum_{v=1}^{k} \frac{\sum_{i,j=1}^{n} u_{iv}^2 u_{jv}^2 d_{ij}}{2\sum_{j=1}^{N} u_{jv}^2}$ (u_{iv} refers to membership of the object *i* in cluster *v*; d_{ij} refers to dissimilarity between *i* and *j*) (Kaufman & Rousseeuw, 1990).

Average silhouette, normalized Dunn's partition coefficient Fc(U), and normalized Dc(U) partition coefficient were used to select the cluster solutions (Kaufman & Rousseeuw, 1990). The maximized average silhouette and normalized Dunn's partition coefficient represent the optimum of dissimilarities between individuals and the unambiguous levels, while the minimized value of normalized Kaufman partition coefficient, Dc(U), defines the best quality of the clustering by average squared error of a fuzzy clustering to the closest hard clustering (Kaufman & Rousseeuw, 1990). After computing the fuzzy cluster analysis, the best solution is implemented based on the goodness-of-fit criterion.

In fuzzy clustering analysis, the standardized regression coefficients (β) and standardized (z-transformation) mean hourly steps were analyzed for comparative purposes to provide indicators for patients' ambulation changes over time. A standardization regression coefficient is a transformation of the coefficients which represent the change in standard deviations of the dependent variable for one standard deviation change of the independent variable. The removal of intercepts allow for extracting the magnitude in how the accumulative number of steps and hourly time are related for each individual. The mean hourly steps, which is the number of steps taken per hour during the hospital stay, represents the individuals' definite level of ambulation frequency. To reduce the influence of a different metric (Kaufman & Rousseeuw, 1990), the mean hourly steps are standardized to a unitless variable (also known as z-transformation) in fuzzy clustering analysis using $z = \frac{x_i - \bar{x}}{s}$ ($\bar{x}$ refers to the sample mean, s indicates the sample standard deviation). Finally, to learn the patient characteristics in the clustering, comparisons of patient characteristics between the subgroups were conducted using t-tests and a test for proportions.

Mediation regression. The main focus of this study was to explore the relation of cognitive function on usual gait speed at discharge, both directly and through ambulation frequency. To account for other relevant variables that could affect both ambulation and gait speed at discharge, a covariate was proposed to adjust the mediator and outcome variable. A mediating variable is an intermediate that explains part or complete of the relation between the independent variable and dependent variable (MacKinnon, 2000). The proposed mediation regression model in this study is illustrated in Figure 3.4. Standardized mean hourly steps and standardized slopes are used as indicators for hospital ambulation frequency. In Figure 3.4, a_1 and a_2 refer to the standardized coefficients of the hospital ambulation frequency regressed on cognitive status, and b_1, b_2 and c' indicate the conditional standardized coefficients of gait speed at discharge on hospital ambulation frequency and cognitive status. That is, c' represents the conditional direct effect of cognitive status on gait speed at discharge and $(a_1 * b_1) + (a_2 * b_2)$ refers to the total indirect effect through hospital ambulation frequency.

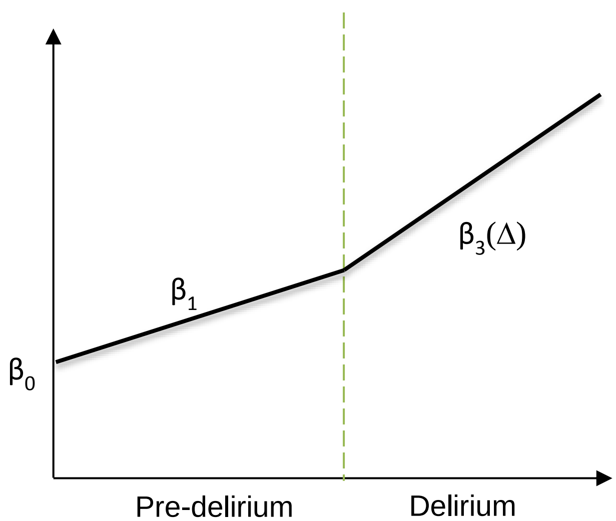
Figure 3.4 *Mediation Regression*



Regression-discontinuity analysis. How the linear trajectory of ambulation frequency changes for the participant with delirium was analyzed using regression-discontinuity analysis. Discontinuity analysis is an interrupted time-series analysis that allows for comparisons in the levels and trends of a time-varying variable (Jena et al., 2016; Linden, 2015). In this study, a regression-discontinuity analysis was conducted to compare each participant's linear trajectories of accumulative steps in 1-hour intervals across each delirious episode. The incident time of each delirium episode was determined and used as the cut-off time point of the accumulative number of steps. How the linear trajectory of accumulative steps changed across the time points is described. Without a comparison group, a one-group discontinuity analysis was conducted. The regression model assumed that the aggregated outcomes variable is explained by $Y_t = \beta_0 + \beta_1 T_t +$

$\beta_2 X_t + \beta_3 X_t T_t + \varepsilon_t$ (Linden, 2015) (Y_t is the aggregated outcome variable measured at each time point t, Tt is the time from beginning, Xt is the indicator variable representing the delirium episode, XtTt is an interaction term, β_0 is the starting level of Y, β_1 is the slope, β_2 is the change in the level of the outcome after a delirious episode occurs, β_3 is the difference between pre-delirium and post-delirium slopes of the outcome. The difference between pre-delirium and post-delirium slopes of ambulation frequency (β_3) is described with delirium episodes. The discontinuity analysis is illustrated in Figure 3.5.

Figure 3.5 *Regression-Discontinuity Analysis*



Comparative analyses. To compare differences in patient characteristics with the clusters and with cognitive cohorts, comparative (independent sample t-test, paired samples t-test, and test of proportion) analyses were conducted. An independent sample t-test was conducted to compare the means of continuous variables between groups. A paired sample t-test is to determine the difference of repeated measures on each participant. In this study, the paired t-test was used to compare usual gait speed between admission and discharge. A test for proportion was also conducted to compare the proportions of the dichotomous variable among groups. A p level ≤ 0.05 was considered statistically significant. The effect sizes were calculated to present the magnitude of group mean differences with a cutoff of *d*, *h* and Becker value (Becker, 1988) in 0.2 as a small effect size, 0.5 as a medium effect size, and 0.8 as a large effect size (Cohen, 1988).

Chapter 4: Results

This exploratory, longitudinal, descriptive study was conducted to investigate the relationships among cognitive status, hospital ambulation frequency, and physical performance at discharge of hospitalized older adult patients. Participants were assessed using standardized instruments with established reliability and validity. Cognition was measured using MoCA-Blind (Including six subscales: Memory, attention, language, abstraction and delayed recall) and CAM (including nine items: acute onset, inattention, disorganized thinking, altered consciousness, disorientation, memory impairment, perceptual disturbances, psychomotor agitation and retardation, and altered sleep-wake cycle). Physical performance was measured using a 4-meter walk test. The StepWatch 3 (SAM) was used to measure the number of steps participants took during their hospital stay. Hospital ambulation frequency was measured as the number of steps per minute and transformed to the accumulative number of steps in 1-hour intervals.

Twenty-seven participants aged 65 and older were enrolled from an adult medical-surgical unit at the William S. Middleton Memorial Veterans Administration (VA) Hospital in Madison, Wisconsin from January to March, 2017. Of 27 participants, three participants did not complete the 4-meter walk at discharge and one participant's accelerometer did not capture steps. Surprisingly, there were few missing data given the nature of illness and accelerometer wearing. Because the aims of this study relied on accelerometer data to reflect hospital ambulation, the participant with missing accelerometer data was removed from the analysis. The remaining 26 participants' data were used in the analysis. Results from this study included demographic and health information and ambulation frequency (measured as number of steps) of participants during their hospital stay, and then determined the relationships of cognitive status, hospital ambulation frequency, and physical performance. The results of the descriptive analysis were used to describe patient characteristics based on the cognitive cohorts. Fuzzy cluster analysis and comparative analyses were conducted to determine subgroups in relation to hospital ambulation frequency and differences of patient characteristics among the groups. Mediation regression was used to determine the mediator role of hospital ambulation frequency in the relation to cognitive status and physical performance.

Demographic and Health Information

Descriptive statistics (e.g., mean standard deviation, maximum and minimum, frequency, and proportion) were used to describe characteristics of the sample (Table 4.1). The average age was 73.19 (SD= 6.75), the majority of participants were male (96.15%), and most required a mobility assistive device (76.92%) and human assistance (65.38%) with ambulation. The average length of stay was 4.28 (SD= 3.97) days. All participants were admitted from home. Only 19 participants (73.08 %) were discharged to home while four (15.4 %) were discharged to a nursing home, and three were transferred to another hospital or ICU for further treatment (11.5 %).

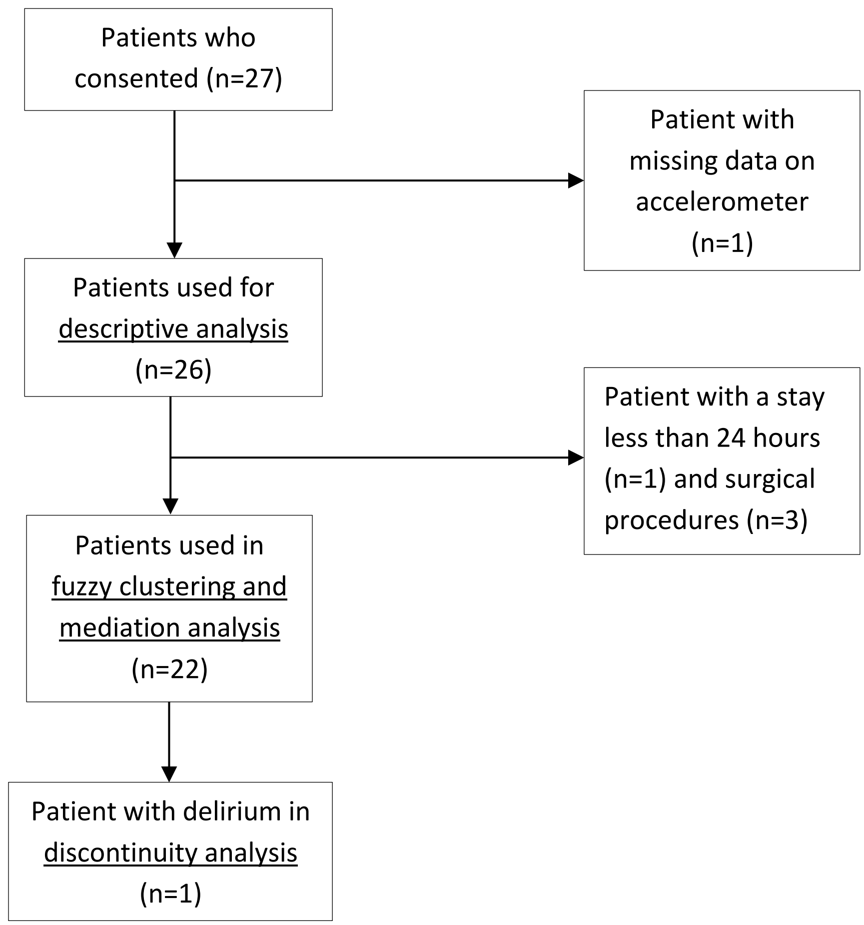
Comparison of usual gait speed at admission and at discharge. The mean usual gait speed at discharge (0.58 ± 0.20) was slightly higher than the gait speed at admission (0.54 ± 0.19 m/s). A paired t-test showed a marginally significant improvement in gait speed at discharge with a small estimate effect size (t= -2.0169, p=0.056, Becker effect size= 0.3812, 95% CI= [-0.16, 0.92]).

Table 4.1 *Demographic and Clinical Characteristics of Total Sample*

Characteristics	Mean ± SD / N (%), n= 26	Minimum - Maximum
Age (yr)	73.19231 ± 6.752891	65 - 87
Male sex	25 (96.15%)	
Body mass index (lb/in^2)	31.75 ± 8.83	17.70 – 54.39
Body weight	209.41 ± 62.57	109.7 - 347.8
Height	67.96 ± 2.95	62 – 74.5
Length of stay (Day)	4.28 ± 3.97 days 102.69 ± 95.25 Hours	7 hours - 16 days 7 – 384 hours
MoCA-Blind	18.31 ± 2.60	12 – 22
Admission usual gait speed (m/s)	0.54 ± 0.19	0.28 – 1.08
Discharge usual gait speed (m/s)	0.58 ± 0.20	0.27 – 1.02
Mean fall risk score (Morse)	53.27 ± 24.04	0 – 100
Charlson Comorbidity Index (CCI)	5.5 ± 2.04	3 - 9
Oxygen tank use	3 (11.54%)	
Walking device use	20 (76.92%)	
Person assistive walking	17 (65.38%)	
Home dwelling prior admission	26 (100%)	
Discharge destination		
Discharge to home	19 (73.08%)	
Discharge to nursing home	4 (15.4%)	
Transfer to another hospital or ICU	3 (11.5%)	

Patient selection. For fuzzy cluster analysis and mediation regression, four participants were excluded from the analysis. One participant had only a 7-hour stay and three participants had undergone surgical procedures. To establish analyses, at least 24 hours of ambulation frequency, and no time periods with restriction on ambulation were needed. Therefore, 22 participants' data were used in the analysis. Of the 22 participants, one had cognitive impairment at baseline and experienced delirium. Given the small percentage (0.04%) of delirium occurrence in the sample, the participant with delirium was included in the cognitive impairment group instead of creating a separate category for delirium. However, a regression-continuity regression analysis was conducted to explore the pattern of this participant's delirious event along with the trajectory of the accumulative number of steps. The sample size for each analysis is shown in Figure 4.1.

Figure 4.1 *Sample Size for Each Analysis*



Cognition status during hospital stay. The MoCA-Blind scores of the sample ranged from 12-22 with an average score of 18.24 (SD=2.63). At admission, 10 out of 26 participants (38.5%) had cognitive impairment with an average MoCA-Blind score of 15.7 (SD=1.83), and 16 (61.5%) participants had intact cognition with an average MoCA-Blind score of 19.94 (SD=1.39). Two of the participants with cognitive impairment had a diagnosis of dementia and were treated with Donepezil. Participants were categorized into two cognitive cohorts for analyzes: one group with cognitive impairment and one group with intact cognition.

Delirium. Among the sample, one participant with cognitive impairment had experienced delirium from day 5 to day 7 of hospitalization. The participant was receiving daily dose of morphine. The participant had a CAM score of 2 on day 5 and 6, and a score of 3 (with missing features) on day 7. The participant's cognition improved to baseline in the afternoon of day 7 after the morphine was stopped. Since the sample size for delirium was small (n=1), the sub-aim to investigate the change of cognition and hospital ambulation frequency is described using regression-discontinuity analysis.

Comparison of patient characteristics between the two cognitive cohorts. Table 4.2 shows that results of comparative analysis between patients with and without cognitive impairment. The gait speeds, Morse fall risk scores, and proportion of human assistance needed for ambulation demonstrated a difference between the two groups. An independent sample t-test (2-tailed) demonstrated that gait speed at admission (t=2.06, p=0.05, d=0.80) and gait speed at discharge (t=2.26, p=0.035, d=0.97) were significantly higher in patients with intact cognition. The estimate effect size indicated that the Morse fall risk score was higher in patients with cognitive impairment (t= -1.99, p= 0.058, d= -0.78). The test of proportion demonstrated patients who needed human assistance in ambulation tended to have cognitive impairment (t= -2.09, p=0.037, h= -0.93).

Table 4.2 *Comparative Analysis of Patient Characteristics between Cognitive Cohorts*

Variable	Mean ± SD / N (%) Intact cognition (n=16)	Cognitive impairment (n=10)	Difference	T-statistics Z-statistics *p*-value	Effect size
Age	72.13 ± 6.17	74.9 ± 7.61	-2.775	t= -1.0202 *p*= 0.32	-0.40
Stay (hours)	95.63 ± 81.86	114 ± 117.48	-18.38	t= -0.47 *p*= 0.642	-0.18
BMI	32.59 ± 10.93	30.40 ± 3.76	2.19	t= 0.73 *p*= 0.471	0.24
CCI	5.69 ± 2.12	5.2 ± 1.99	0.49	t= 0.58 *p*= 0.565	0.23
Admission gait speed	0.60 ± 0.21	0.45 ± 0.13	0.15	t= 2.06 *p*= 0.050	**0.80**
Discharge gait speed	0.65 ± 0.18	0.47 ± 0.18	0.18	t= 2.26 ***p*= 0.035***	**0.97**
Morse	46.25 ± 24.93	64.5 ± 18.48	-18.25	t= -1.99 *p*= 0.058	**-0.78**
Female	1 (6.25%)	0 (0%)	0.06	t= 0.806 *p*= 0.4201	0.50
Arthritis	1(6.25%)	1 (10%)	-0.04	t= -0.349 *p*= 0.727	-0.14
Discharged to home	13 (81.25%)	6 (60%)	0.21	Z= 1.19 *p*= 0.234	0.47
Human assistance needed	8 (50%)	9 (90%)	-0.40	Z= -2.09 ***p*= 0.037***	**-0.93**
Walking device use	11 (68.75%)	9 (90%)	-0.21	Z= -1.25 *p*= 0.211	-0.54
Oxygen use	2 (12.50%)	1 (10%)	0.03	Z= 0.19 *p*= 0.85	0.08
Foley use	1 (6.25%)	2 (20%)	-0.14	Z= -1.07 *p*= 0.286	-0.42
PT consult	10 (62.50%)	8 (80%)	-0.18	Z= -0.94 *p*= 0.347	-0.39

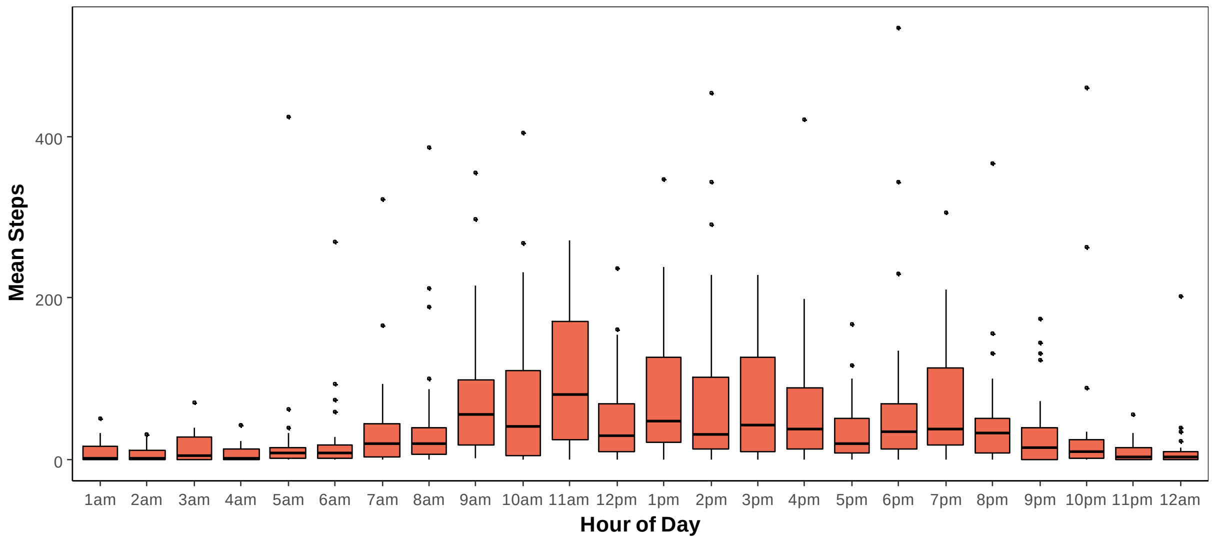
Mean hourly and daily ambulation. Descriptive analysis was used to demonstrate the average hourly steps participants took during their hospital stay and the average daily steps for participants who had data from at least one complete 24-hour day after enrollment. The mean number of steps of the sample was 50.13 (n=26, SD=36.82) steps/hour for the entire hospital stay. Overall, the mean daily ambulation among all participants was 838.50 ± 732.70 steps/day. The mean daily number of steps per person for the first 24-hour observation period was 1241.76 (n=25, SD=1403.08), 1248.39 steps (n= 18, SD=1553.23) during the second 24-hour observation period and 1598.27 (n=11, SD= 3434.39) steps for the third 24-hour observation period. The distribution of mean steps showed a wide variation in the hourly and daily steps among the participants (see Table 4.3).

Table 4.3 *Daily and Hourly Mean Number of Steps*

Observation period	Number of steps	Minimum - maximum
1st 24-hour steps (n=25)	1241.76 ± 1403.08	20 - 6833
2nd 24-hour steps (n=18)	1248.39 ± 1553.226	0 - 5252
3rd 24-hour steps (n=11)	1598.27 ± 3434.39	0 - 11878
Mean Hourly Steps	50.27 ± 36.79	1.91 - 143.93

Ambulation during each hour of the day. A Whisker-box plot was used to describe the distribution of patients' number of steps on average during the day. The graphic demonstrates that patients were most active between 9am to 8pm (see Figure 4.2).

Figure 4.2 *Mean Hourly Steps during the Day*



Aim 1: Determine the Relationship between Cognitive Status and Hospital Ambulation Frequency Taken by Older Patients during Hospitalization

Descriptive, fuzzy cluster analysis, and comparative (independent sample and paired t-tests and proportional test) analyses were calculated to determine subgroups of hospital ambulation frequency and how groups are different based on cognitive status and other participant characteristics. The demographic and clinical characteristics of the sample are shown in Table 4.4.

Table 4.4 *Demographic and Clinical Characteristics of 22 Participants Analyzed for Fuzzy Clustering and Mediation Regression Analysis*

Characteristics	Mean ± SD / N (%), n= 22	Minimum - Maximum
Age (year)	73.95 ± 7.07	65 - 87
Male sex	21 (95.45%)	
Body mass index (lb/in^2)	31.71 ± 9.59	17.70 – 54.39
Body weight	208.75 ± 67.96	109.7 - 347.8
Height	67.85 ± 2.70	63 – 74.5
Length of stay	3.82 ± 3.59 days 91.73 ± 86.20 Hours	1 - 16 days 24 – 384 hours
MoCA-Blind	18.14 ± 2.73	12 – 22
Admission gait speed (m/s)	0.52 ± 0.16	0.28 – 1.03
Discharge gait speed (m/s)	0.58 ± 0.21	0.27 – 1.02
Mean fall risk score (Morse)	55.23 ± 23.12	0 – 100
Charlson Comorbidity Index (CCI)	5.82 ± 2.04	3 – 9
Oxygen tank use	3 (13.64%)	
Walking device use	19 (86.36%)	
Person assistive walking	16 (72.73%)	
Discharge to Home	15 (68.18%)	
Home dwelling	22 (100%)	
Discharge destination		
Discharge to home	15 (68.18%)	
Discharge to nursing home	4 (18.18%)	
Transfer to another hospital or ICU	3 (13.64%)	
Linear trajectory indexes		
Standardized slop	0.93 ± 0.07	0.72 – 1.00
Standardized mean hourly steps	-0.08 ± 0.95	-1.41 – 3.16

Trajectories of patients' accumulative number of steps. Twenty-two participants' accelerometer data were used to analyze their linear trajectories on accumulative number of steps. Age ranges for the 22 participants were 65-87 years (M=73.95, SD=7.07). Of the 22 participants, nine exhibited cognitive impairment (MOCA-Blind score 12-17). Ordinary least squares regression was used to determine the linear trajectory of patient ambulation. The standardized slopes refer to the number of standard deviations of accumulative step changes per standard deviation increase in the time period (1 hour). A higher standardized slope indicates a greater increase in the standard deviation of accumulative steps over time hourly. Standardized slopes characterize the magnitude of the relationship between accumulative steps and the hourly time. The mean hourly steps of the entire hospital stay define the level of ambulation frequency. Values are standardized to a unitless variable (z-transformation) to reduce the influence of the metric (Kaufman & Rousseeuw, 1990). Both the standardized regression coefficients and standardized mean hourly steps were used in fuzzy cluster analysis and mediation regression. Higher standardized mean hourly steps indicate a greater number of steps taken every hour during the hospital stay. The standardized regression coefficients ranged from 0.72 to 1.00 (mean=0.93, SD=0.07) and the standardized mean hourly steps ranged from -1.41 to 3.16 (mean= -0.08, SD=0.95).

Cluster patterns and comparisons. In order to understand the group patterns based on the accumulative number of steps over time, the trajectories of the 22 participants' ambulation were analyzed using fuzzy clustering to identify subgroups. Two- to four-class solutions were computed and the best fitting solution was selected by the criteria of average silhouette, Fc(U) and Dc(U). After comparing the cluster results based on the maximum average silhouette, maximum Fc(U) and minimum Dc(U), a two-group classification was considered the best solution (Table 4.5).

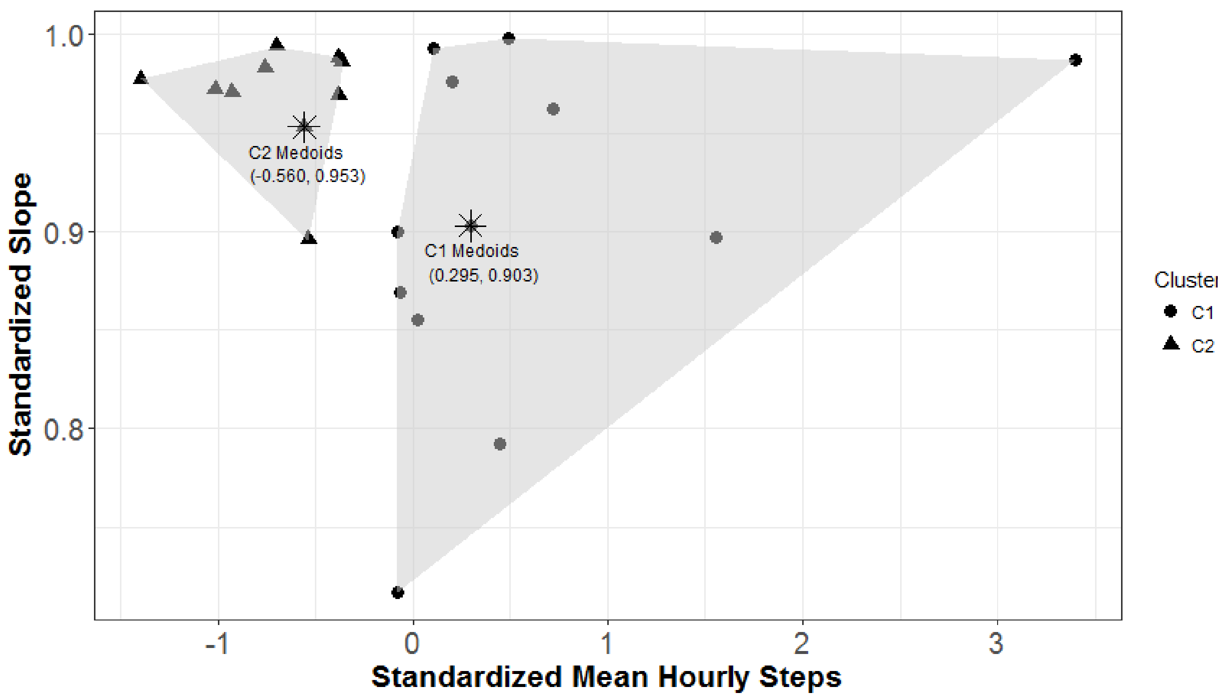
Table 4.5 *Summary of Goodness-of-fit for the 2- to 4-Class Solutions*

Classes	Membership counts and proportions	Fit index		
		Average silhouette	Fc(U)	Dc(U)
2	12 (55%) 10 (45%)	0.425538*	0.3314*	0.2500*
3	5 (23%) 7 (32%) 10 (45%)	0.378679	0.3012	0.3141
4	5 (23%) 7 (32%) 5 (23%) 5 (23%)	0.351192	0.3289	0.2866

Note. *Best fitting solution.

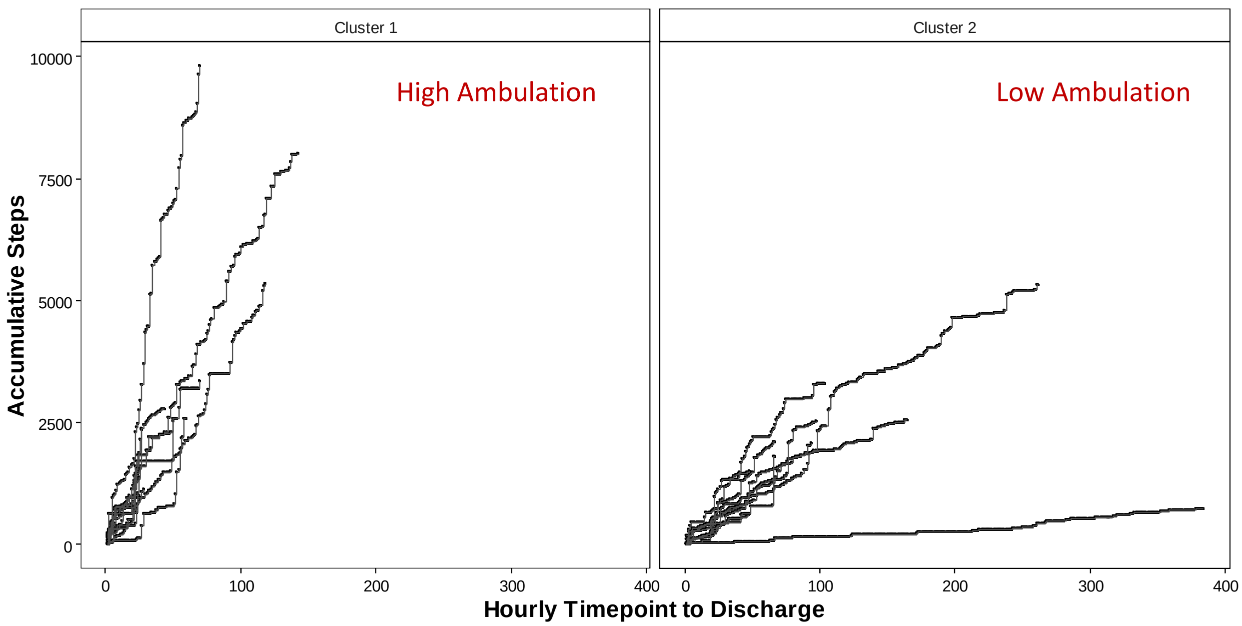
Two groups were determined based on the standardized slopes and standardized mean hourly number of steps, which represent the level and magnitude of participants' linear growth in hospital ambulation frequency. The results of the cluster analysis are shown in a cluster plot (Figure 4.3). The Medoid values, the central data points in each cluster, were 0.295 and 0.903 in Cluster 1, and -0.560 and 0.953 in Cluster 2 in the standardized mean hourly steps and standardized slopes, respectively.

Figure 4.3 *Cluster Plot*



In the distinctive clusters, the trajectories of hospital ambulation frequency in Cluster 1 had a significantly higher level of mean hourly steps (t=3.9387, p=0.00) than Cluster 2. Because the participants in Cluster 1 ambulated much more every hour than Cluster 2, we label Cluster 1 *High Ambulation*, and Cluster 2 *Low Ambulation* (Figure 4.4).

Figure 4.4 *Trajectories of Accumulative Number of Steps in Two Clusters*



To explore how cognitive impairment and other participant characteristics were related to the clusters, a test for proportion was computed. There was no significant statistical difference between the two clusters on cognitive function. However, the effect size estimate showed that participants with cognitive impairment were more likely to be in the low ambulation cluster (z=1.663, *p*=0.096, Cohen *h*= 0.725).

Comparative analyses (independent sample t-test and test for proportion) were conducted to demonstrate the difference of demographic and clinical characteristics between the two clusters (see Tables 4.6 and 4.7). Out of the seven dichotomous variables (cognitive status, discharge destination, human assistance need for ambulation, walking device use, oxygen use, Foley use, and PT consult) and seven continuous variables (length of stay, age, BMI, CCI, admission gait speed, discharge gait speed, Morse score), the low ambulation cluster had a significantly higher proportion of supplemental oxygen use (z= 2.042, *p*= 0.0412, *h* =0.341) and longer length of stay (z=2.2711, *p*=0.03, *d*= 0.94). The high ambulation cluster demonstrated a higher proportion of discharge to home (z= 1.671, *p*=0.096, Cohen *h*= 0.730) and less human assistance needed for ambulation (z=-1.663, *p*=0.097, Cohen *h*= -0.760) based on the larger effect sizes.

Table 4.6 *Comparison of Dichotomous Variables between Clusters*

Dichotomous variable	High ambulation (%)	Low ambulation (%)	Difference (p1-p2)	z-statistics *p*-value	Effect size
Cognitive impairment	25%	60%	-0.35	z= -1.66 *p*= 0.09	**-0.725**
Discharged to home	83.33%	50%	0.333	z= 1.67 p= 0.095	**0.730**
Human assistance needed	58.33%	90%	-0.317	z= -1.66 *p*= 0.10	**-0.760**
Walking device use	91.67%	80%	0.12	z= 0.79 *p*= 0.43	0.342
Oxygen use	0%	30%	-0.3	z= -2.04 ***p*= 0.04***	**-1.160**
Foley use	8.33%	20%	-0.117	z= -0.79 *p*= 0.43	-0.342
PT consult	75%	80%	-0.05	z= -0.28 *p*= 0.78	-0.120

Table 4.7 *Comparison of Continuous Variables between Clusters*

Continuous variable	High Ambulation (M ± SD)	Low Ambulation (M ± SD)	95% CI Difference (m1-m2)	t-statistics *p*-value	Effect size 95% CI [upper, lower]
Length of stay	56.92 ± 38.60	133.5 ± 109.37	-76.58 [-146.92, -6.24]	t= 2.09 ***p*= 0.03***	**-0.94** [-1.82, -0.05]
Age	75.83 ± 6.99	71.7 ± 6.83	4.13 [-2.05, 10.31]	t= 1.40 *p*= 0.18	0.57 [-0.28, 1.43]
BMI	33.00 ± 10.81	30.16 ± 8.18	2.84 [-5.84, 11.52)	t=0.68 *p*=0.50	0.28 [-0.56, 1.12]
CCI	6.17 ± 1.99	5.4 ± 2.12	0.77 [-1.06, 2.60]	t= 0.87 *p*= 0.39	0.36 [-0.49, 1.21]
Admission gait speed	0.56 ± 0.18	0.47 ± 0.13	0.09 [-0.06, 0.23]	t=1.26 *p*=0.22	0.52 [-0.33, 1.37]
Discharge gait speed	0.59 ± 0.21	0.57 ± 0.22	0.023 [-0.18, 0.23]	t=0.24 *p*=0.81	0.10 [-0.78, 0.99]
Morse	56.25 ± 26.64	54 ± 19.41	2.25 [-18.88, 23.38]	t=0.22 *p*= 0.83	0.09 [-0.75, 0.93]

Sub-aim: To Explore if Changes in Cognition (i.e. Delirium) Produces a Change in Ambulation Frequency

One participant, a 77-year old with cognitive impairment (MoCA-Blind score 17) and a length of stay of 10.9 days, experienced delirium between days 5 to 7. Information recorded in the participant's medical record that outlines the participant's delirium is presented in Table 4.8. The participant's accumulative number of steps was analyzed using regression-discontinuity analysis to investigate whether the linear trajectory changed with the participant's delirious event. The characteristics of the participant's delirium were (1) day 5 – day 6: confusion during the morning hours and delusional at night, slow to answer questions, and disoriented about place and year. The CAM score over the two days was 2/19. (2) On Day 7: the patient became somnolent and was only arousable by sternal rub at 6:30am, but by 1:31pm the patient was more awake (discontinue morphine) and by 3:44pm the participant was back to baseline. The CAM score for day 7 was acute onset (score: 1); marked stupor (score: 2) with the rest of the scoring features missing. On day 8, the patient had improved mental status with a CAM score of 0. Prior to the occurrence of delirium on day 1 to day 4, the linear trajectory of the accumulative number of steps was 17.30 (β_1). On day 5 and day 6, the trajectory increased to 52.15 (β_2). On day 7 the slope decreased to 7.32 (β_3). By day 8, the participant's hospital ambulation frequency increased to 16.503 (β_4) which is similar to β_1. The participant's separate regression coefficients for the linear trajectory of accumulative number of steps is shown in Figure 4.5.

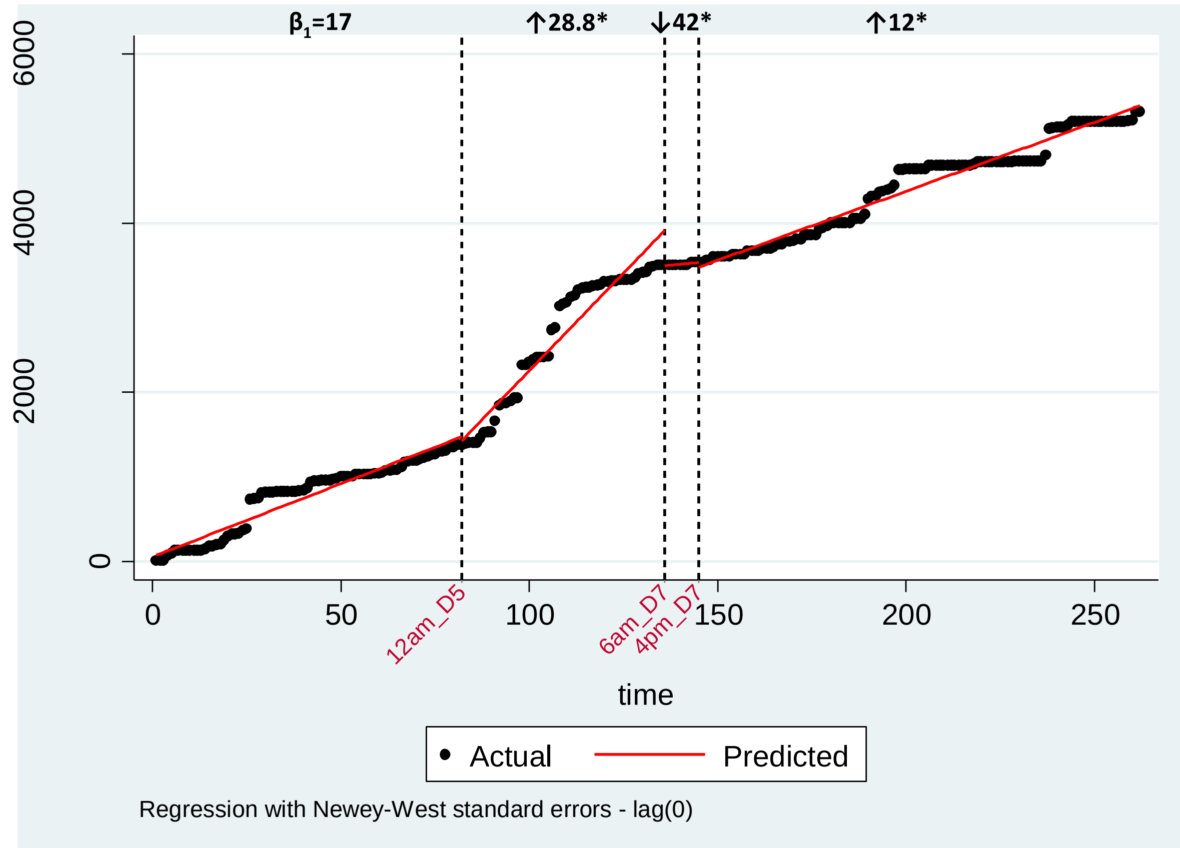
Table 4.8 *Electronic Chart Review of Information about the Participant's Cognition*

Day (Episode)	Note time	Clinical notes related to cognition	Tx and Opioid Medication
Day 1	22:30	Cognition and sensation intact. Patient pleasant, cooperative walking short distance with walker	▪ Outpatient medication: morphine 15mg. ½ - 1 tab PO, QID as needed ▪ Foley placed due to not able to void ▪ Morphine TAB IR 15mg PO, QID PRN
Day 2	03:25	Clinical Institute Withdrawal Assessment- Alcohol (CIWA)=0	▪ Morphine TAB IR 15mg
	07:41	CIWA=4 (Sweating score 3; Tremor not visible, but can be felt to fingertip, score 1)	
	16:06	CIWA=0	
Day 3	06:08	CIWA=1 (sweating: palms moist, score 1)	▪ Morphine TAB IR 15mg
	09:40	CIWA=0; Discontinue CIWA	
Day 4	01:46	Patient stating "I thought I heard an angel calling my name, but it was you I guess, trying to wake me up"	▪ Morphine TAB IR 15mg QID
	18:04	Patient stating "I have been sleeping all day and I don't know why, I wish I could be more awake"	
Day 5 **(Episode1)**	03:32	Nursing note: Patient woke at about 0100. Sat at edge of bed till ~0230. **When he returned to bed, reporting hallucinations of a man in his room with a tray and BP cuff, reporting being aware that it's not real.** Not sleeping well tonight, talking much very loudly while sleeping. Patient reports this to be baseline for him.	▪ Morphine TAB IR 15mg QID
	06:21	MD note: Patient stating he's having bad dreams, **more confused this morning**. Patient states breathing feels "alright". Ready to get up and walk hallway today. **Possible delirium**	

Day 6 **(Episode 1-continued)**	06:34	Nursing note: Patient stating “I was just going to go to the lobby to visit with my brother” at 0230 Patient stating “go to the breakfast hall” at 0430. Easily re-direction with each episode. Patient awake majority of this shift (11pm-7am)	
	11:30	Nursing note: **Thought he saw his brother in hallway.** This AM. MD note: Decrease dose of morphine and Gabapentin **Patient A&O*1. Slow to answer questions. Has been having delirium at night**.	▪ Morphine 7.5 Mg PO QID
Day 7 **(Episode 2)**	06:00	Nursing note: **Hard to arouse**→ MD to bedside to assess→ 0.1 mg Narcan IV→ get ABG, labs, EKG → hit the staff	▪ Morphine 7.5 Mg PO QID
	06:27	**Somnolent this morning**, responding to Narcan, transferred to ICU	
	07:45	Patient aroused thrashing and conversing with staff, however, not oriented	
	08:14	ICU Nursing note: Not alert, forgetful, confused, not sociable, agitated, withdrawn, combative	
	13:31	MD note: More awake now, mild hypoxia Altered mental status: patient with recurrent night-time hallucinations. Likely opioid intoxication in setting of diminished kidney function.	▪ **Discontinue Morphine**
	15:44	Nursing note: Sociable and alert Not present: forgetful/confused/agitated/withdrawn/combative **Back to baseline**	
Day 8-12		Cognition and sensation intact. Patient pleasant and cooperative	

Note. A&O*1: Alert and Oriented to person only

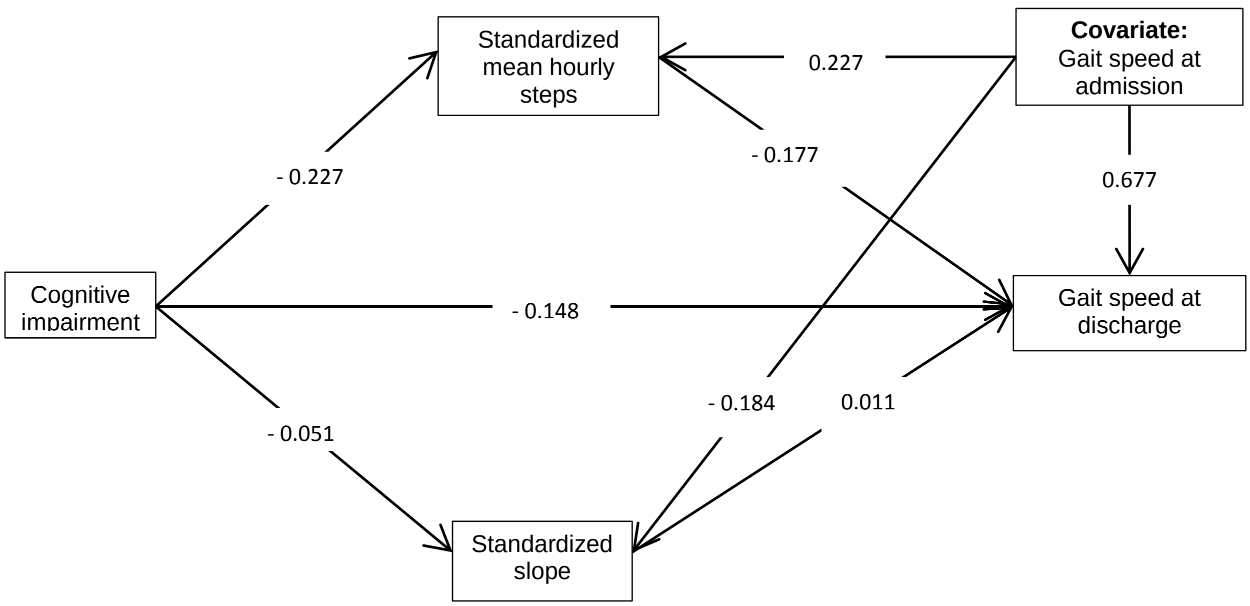
Figure 4.5 *Patient's Trajectory of Accumulative Number of Steps with Delirious Episodes Time*



Aim 2: Determine How Hospital Ambulation Frequency Explains the Relationship between Cognitive Status and Physical Performance

Mediation regression was used to test the mediation role of participants' hospital ambulation (standardized slope of accumulative number of steps and standardized mean hourly steps) on the relation between cognitive function and gait speed at discharge with the gait speed at admission adjusted. The results did not show statistical significance in the indicators among cognitive status, hospital ambulation frequency, and gait speed at discharge (Figure 4.6).

Figure 4.6 *Results of the Mediation Regression Model with Standardized Coefficients*



The standardized coefficients were used to demonstrate the relative impact of the parameters (Fox, 2008) and address Aim 2 (Table 4.9). The direct effect indicates that cognitive impairment has a slightly negative impact on gait speed at discharge (-0.148, p=0.570). Cognitive impairment was negatively associated with the standardized mean hourly steps (-0.227, p=0.225) and standardized slope (-0.051, p=0.839). The association of the two hospital ambulation variables (standardized slope and standardized mean hourly steps) with gait speed were mixed. Standardized mean hourly steps negatively impacts the gait speed at discharge (-0.177, p=0.450) and standardized slope positively impacts gait speed at discharge (0.011, p=0.952). From the analyses presented above, the hospital ambulation frequency (standardized slopes and standardized mean hourly steps) did not show an effect on the relationship between cognitive impairment and gait speed at discharge, nor was there statistical evidence of the direct effect between cognitive impairment and gait speed at discharge. Results did not support the mediation function of hospital ambulation frequency in the model due to a small sample size (n=22). Further, the statistical evidence was not considered stable enough to explain the model.

Table 4.9 *Summary of the Mediation Regression Results*

Variable	Unstandardized coefficient	95% CI Lower, Upper	Standard error	*p*	Estimate standard error
Direct effect					
Discharge gait speed					
Cognitive impairment	-0.060	-0.270, 0.136	0.107	0.570	-0.568
Indirect effect					
Discharge gait speed					
Standardized slope	0.030	-0.684, 1.178	0.494	0.952	0.060
Standardized mean hourly steps	-0.036	-0.150, 0.047	0.048	0.450	-0.755
Admission gait speed	0.862	0.274, 1.820	0.344	0.012	2.507
Standardized slope					
Cognitive impairment	-0.007	-0.073, 0.075	0.037	0.839	-0.203
Admission gait speed	-0.084	-0.539, 0.076	0.126	0.506	-0.665
Standardized mean hourly steps					
Cognitive impairment	-0.450	-1.313, 0.188	0.371	0.225	-1.214
Admission gait speed	1.720	-0.031, 10.431	2.432	0.479	0.707
Specific indirect					
Discharge gait speed Standardized mean hourly steps Cognitive impairment	0.016	-0.010, 0.103	0.024	0.492	0.688
Discharge gait speed Standardized slope Cognitive impairment	0.000	-0.036, 0.038	0.021	0.992	-0.010

Chapter 5: Discussion

As the portion of older adults increases in the U.S., it is expected that the number of older adults who are admitted to hospitals will sharply increase (Centers for Disease & Prevention, 2010). Older adults commonly experience multiple negative outcomes, such as loss of ability to independently ambulate, related to their hospital stay (Covinsky et al., 2011; Sager et al., 1996). Loss of independent ambulation has been identified in the literature as a hospitalization-associated disability (Covinsky et al., 2011; Hirsch & Sommers, 1990; Mahoney et al., 1998) and associated with high mortality (Mahoney et al., 1998; Sager et al., 1996), falls (Gill et al., 2004) and new nursing home placement (Counsell et al., 2000). While ambulation is believed to preserve older adult patients' physical function and is impacted by their cognitive function, few studies have focused on hospital ambulation and physical performance at discharge of older adults who have cognitive impairment.

This study used repeated measures to investigate the relationship of older adults' cognitive function, hospital ambulation frequency, and physical performance during a hospital stay. The aims of this study were (1) to describe the relationship between older patients' hospital ambulation frequency (accumulative number of steps) with their cognitive functioning, and (2) to examine the relationships among cognitive functioning, hospital ambulation frequency, and physical performance (gait speed) at discharge.

The results of the clustering analysis demonstrated that different patterns of ambulation frequency exist in the sample. Furthermore, differences in patient characteristics among the clusters were identified, which provides additional information about the situation in which higher or lower ambulation might occur. The mediation regression did not provide sufficient evidence of the function of hospital ambulation frequency on the relation of cognitive status and physical performance at discharge due to the small sample size. In the following sections, the details are discussed.

Overall Number of Steps during Hospitalization and Previous Studies

The daily numbers of step found in this study are consistent with results reported in the literature. In this study, the average daily ambulation among all participants was 838.50 ± 732.70 steps/day. Participants with intact cognition had 1022.6 ± 851.82 steps/day, while participants with cognitive impairment had fewer steps, 564.47 ± 326.33 steps/day. Similarly, other studies have reported 478 -1493 steps/day taken by older adults with intact cognition during a hospital stay (Agmon et al., 2016; Fisher, Goodwin, et al., 2011; Ostir et al., 2013), and 469.9 - 921 steps/day taken by patients with cognitive impairment or confusion/delirium (Fisher, Goodwin, et al., 2011; Loevezijn et al., 2014).

Analytical approaches of ambulation frequency are diverse among studies. the majority of ambulation studies in hospitalized older adults used total number of steps taken per day (Agmon et al., 2016; Fisher, Goodwin, et al., 2011; Fisher et al., 2010; Ostir et al., 2013). Three studies discussed reference standards of daily step numbers to determine patient characteristics. Fisher et al. (2010) described changes in numbers of steps taken between two different days and identified that older patients with a 600-step increase during hospitalization were independent ambulators. Agmon et al. (2016) proposed 900 steps/day as an identifier for patients who were frail. Ostir et al. (2013) demonstrated that each 100-step increase between first day to last day of hospitalization was associated with the lower risk of death. No research has described the daily number of steps older adult patients take throughout their entire hospitalization.

In this study, patients' ambulation frequency was considered a continuous activity maintained over the entire hospital stay. To determine the trend of ambulation frequency changes, accumulative numbers of steps over time (in 1-hour intervals) was computed and used to represent the linear growth trajectory of ambulation frequency during the hospital stay. Considering the large variance and standard deviation and wide range of the mean numbers of steps among existing studies, a cluster analysis can be a reasonable approach to explore patterns of accelerometer data. The standardized coefficient, as the relative effect of the slope of accumulative number of steps, demonstrated the magnitude of the linear growth. Combined with the mean hourly number of steps (standardized), the two indicators were used to conduct the fuzzy clustering analysis. To learn whether different patterns of ambulation frequency exist in the sample, and how patterns linked to patient characteristics, allows researchers to identify subgroups who are more likely to have low ambulation frequency. Clustering analysis could help identify underlining patterns in a dataset that allows researchers to test newly explored variables/factors that might exist in patient populations.

Cognitive Functioning and Hospital Ambulation Frequency

Cognition is a key function when an individual is ambulating (Hall et al., 2011; Hausdorff et al., 2005). Research has identified that persons with cognitive impairment have a decline in ambulation ability and increased fall risk (Beauchet et al., 2009; Lichtenberg & Nanna, 1994). Hospitalization is a sentinel event for older adults in that all too often they lose their ability to independently ambulate (Mahoney et al., 1998). However, the majority of studies on interventions to maintain functional independence in hospitalized older adults have excluded persons with cognitive impairment (Courtney et al., 2009; Courtney et al., 2012; Killey & Watt, 2006; Taylor, DeMers, Vig, & Borson, 2012). Other research that has focused on cognitive function of older adults during a hospital stay has demonstrated that patients with cognitive impairment tended to have lower ambulation ability, which is associated with declines in physical function at discharge (Sands et al., 2003). Several studies on early hospital ambulation have demonstrated positive outcomes such as improvement in patients' ability to perform ADLs and a decrease in the length of the hospital stay (Counsell et al., 2000; Hastings et al., 2014; Pashikanti & Von Ah, 2012). However, these studies focused on specific populations including general older adults, but excluded persons with cognitive impairment.

In this study, ten of the 26 participants (38.5%) had cognitive impairment at admission, which is consistent with previous studies (Boustani et al., 2010; Naylor & Stephens, 2005). Two participants with cognitive impairment had a confirmed diagnosis of dementia. Interestingly, delirium only occurred in 3.8 % (n=1) of the participants, which was relatively low compared to existing research (3% - 63% in hospital-based sample) (Inouye & Charpentier, 1996; Inouye & Foreman, 2001; Naylor & Stephens, 2005; Rockwood et al., 1999). Participants with cognitive impairment were found to have a higher fall risk score and human assistance needed for ambulation. As stated in Chapter 2, participants with cognitive impairment may be restricted in ambulation due to nurse concerns for falls, need for assistance, and nurses' time constraints (Brown et al., 2007; King & Bowers, 2011). The results of this study suggest the importance of providing support to patients with cognitive impairment, as these participants were more likely to have slower gait speeds. Slow gait speeds are associated with increased risk for other negative outcomes, such as increase in mortality and falls (Studenski et al., 2011; Van Kan et al., 2009).

Clusters of Ambulation Frequency and Patient Characteristics

Fuzzy clustering analysis detected two clusters that represented groups with different levels of ambulation frequency. Cluster 1 had a higher number in ambulation steps over time while Cluster 2 demonstrated a lower number in ambulation steps. A comparison of the two clusters did not show significant differences in cognitive status, but the analysis did demonstrate a medium to large effect size estimate (Cohen h= 0.725), indicating the proportion of patients with cognitive impairment may be larger in the low ambulation cluster than in the high ambulation cluster. Fuzzy clustering analysis was an efficient method to identify homogeneous clusters in the ambulation dataset. The identified clusters could be compared with participant characteristics and revealed further features. Clustering analysis is a reasonable approach for clinical research in which the data points may widely dispersed within a population.

From the comparative analyses, use of supplemental oxygen and human assistance needed were found to be significantly higher in the low ambulation cluster. Although supplemental oxygen has not been identified in the literature as a barrier to ambulation, it can be considered an external tether. Use of other tethers such as intravenous lines and Foley catheters have been associated with lower rates of ambulation (Markey & Brown, 2002; So & Pierluissi, 2012). The findings from this study verified that tethers impede patient ambulation. All of the participants were admitted from home, but participants in the high ambulation cluster were more likely to have a shorter length of stay, and be able to return home rather than discharge to a nursing home or require more advanced hospital care. Similarly, existing research has found that older patients who engaged in ambulation during a hospital stay had shorter lengths of stay (Fisher et al., 2010) and less nursing home placements (Counsell et al., 2000). Shorter lengths of stay or discharged to home were associated with less functional decline (Inouye et al., 1993; Sager et al., 1996) as well as reduced expenditures in health care services (Fried, Bradley, Williams, & Tinetti, 2001). Promoting ambulation in hospitalized older adults, particularly for patients with cognitive impairment, may improve health outcomes for older persons and decrease healthcare utilization.

In this study, the delirium occurrence rate was lower (3.8%) than anticipated. This single case showed two different distinct delirium presentations, hyperactive and hypoactive. Using discontinuity analysis, distinct changes in ambulation frequency were identified and were consistent with the delirium types and evolution of its presentation. Discontinuity analysis is an important analytic strategy for investigating how two time-varying variables change together. As patients with cognitive impairment tend to have lower ambulation frequency, the trend was not seen in the case of the participant with delirium. The findings from the discontinuity analysis imply that (1) ambulation frequency might not always remain low with delirium and may vary based on the delirious symptoms. In this case, the patient with delirium experienced two types of delirium (hyperactive and hypoactive) with the accelerometer data aligning with the two distinct patterns in the linear trajectory. Cognitive variation may be a predictor in changes in ambulation frequency. (2) Since ambulation and cognitive function varied together, the discontinuity analysis provides a feasible approach to detect the change pattern of ambulation trajectory along with cognitive changes for future research.

Causes for delirium in hospitalized older adults are multifaceted and complex; thus, managing delirious patients is challenging in acute care settings. This study captured a distinct change in ambulation frequency during the trajectory of the delirium event. Therefore, using patient ambulation frequency as a marker for identification of fluctuation in cognition may be important for early intervention. Additional research is needed to investigate if changes in ambulation frequency should be considered a “vital sign” that could prompt clinicians to look for presence of cognitive changes in hospitalized older adults.

Comparison of Gait Speeds among Time Points and Groups

Gait speed has been identified as a key clinical marker for determining patients' care needs, risk for falls and prognosis (Ostir & Berges, 2012), and survival rates (Studenski et al., 2011). To understand changes in gait speed of older adults during their hospital stay, comparing gait speeds with participant characteristics and different time points can be a reasonable approach. Researchers have proposed gait speed of 0.6 m/s as a reference standard to identify slow gait or gait abnormality in older adults (Ostir & Berges, 2012; Studenski & Perera, 2003; Van Kan et al., 2009). In this study, gait speeds were measured at two time points: at admission and at discharge. Participants' gait speeds were 0.52 m/s at admission and 0.58 m/s at discharge, which were slightly higher than gait speeds reported by Ostir and Berges (2012) and Graham (2010) who found hospitalized older adults had gait speeds between 0.43-0.53 m/s. However, gait speeds found in this study appear to be at a slow/abnormality level based on the cutoff of 0.6 m/s. Marginally significant improvements were found in gait speed at discharge compared with admission in this study. Furthermore, the gait speed of participants with cognitive impairment was lower than participants with intact cognition at both time points: admission and discharge. Although gait speeds did not show any difference between the high ambulation and low ambulation clusters, it does not mean that ambulation is undesirable for older adults. Changes in gait speed could be a result of patients' biomechanical or neuromuscular problems (Whittle, 2014). Therefore, patients' progress of illness recovery might impact the gait speed as well. Thus, promoting ambulation for hospitalized older adults will be important to support patients' cognitive and physical functioning (Fisher, Graham, Brown, & Galloway, 2012; Inouye, Bogardus Jr, et al., 1999). In addition, gait speed can be considered a valid and change-sensitive measure to characterize older adults' gait during their hospital stay.

The mediation regression analysis indicates no statistically significant evidence of the mediation effect of hospital ambulation frequency on the relation between cognitive impairment and physical performance at discharge. Due to the small sample size and complexity of older adults' health, the factors that impact patients' hospital ambulation could be multifactorial. These results suggest that additional research is needed to better understand barriers and facilitators for older adult patients' ambulation during a hospital stay.

Feasibility to recruit participants with cognitive impairment.

Limited research has been conducted on the impact of cognitive impairment on the ambulation frequency in hospitalized older patients. Given the increasing numbers of older patients with cognitive impairment (Boustani et al., 2010; Centers for Disease & Prevention, 2010; Naylor & Stephens, 2005), and the association between cognitive impairment and functional decline, falls and need for ambulation assistance during hospitalization, increased efforts to recruit this population in mobility research should be employed (Clyburn & Heydemann, 2011; Härlein et al., 2011; Mahoney et al., 1998; Vogt et al., 2008). However, many researchers exclude persons with cognitive impairment from studies due to the consenting process and the potential for cognitive changes during hospitalization (Taylor, DeMers, et al., 2012). In this study, two types of vulnerable population were enrolled, older adults and older adults with cognitive impairment. Conducting a cognitive assessment at baseline and determining decisional making capacity allowed us to enroll persons with cognitive impairment. Daily assessment of cognitive status and accelerometer placement enabled us to track patient's decision-making capacity as well as validate the accelerometer data. Twenty-seven out of 36 referred patients (75%) consented and completed the study. We only had 1 missing accelerometer data and 3 missing data for discharge gait speed. This study demonstrated it is feasible to recruit hospitalized older adults with and without cognitive impairment and measure their ambulation frequency and gait performance during a hospital stay. Our recruitment process may be important to boost enrollment of persons with cognitive impairment for future studies.

Ethical Considerations

Decision making capacity. Given the health complexity of hospitalized older adults, an important consideration is to minimize the harm and risks for them to participate in research. One particularly challenging factor is addressing cognition in older patients. A considerable percentage of hospitalized older adults have cognitive impairment upon admission and an even higher percentage will develop delirium during a hospital stay (Elie et al., 1998; Inouye, Schlesinger, et al., 1999). Thus, determining decision-making capacity at the time of recruitment and providing ongoing cognitive monitoring during a study are necessary to protect patients' rights. For this study, staff nurses provided the first level of protection by identifying patients if patients possessed decision-making capacity and whether or not an activated power of attorney was in place. A second level of protection was implemented during data collection. The researcher performed a daily check of patients' cognitive status by asking the nurse assigned to care for the participant if the individual had experienced acute changes in cognition over the last 24 hours. If the patient developed a change in cognition, both the nurse and patient were approached by the researcher to determine the patient's ability to continue in the study. If the patient expressed that they wanted to withdraw from the study or if the staff nurse assigned to care for the patient determined that it was inappropriate for the patient to continue in the study based on cognitive status, the patient would be withdrawn. Based on the protocol, no patients were withdrawn from the study. Our protocol provided rigorous screening and human subjects protection to maintain older adult participants autonomy. The use of well-defined screening and ongoing tracking procedures for older adults with cognitive impairment will increase our abilities to include this important population in future research studies on ambulation frequency of older adults during a hospital stay.

Accelerometer use and skin protection. The accelerometer was attached by a Velcro strap around the participants' ankle and required a specific orientation (rounded edge up) to capture and record steps patients took. Brief training was provided to the nursing staff and to patients when the device was placed on participants' ankles. The training included how and when the accelerometer could be taken off (procedures, bathing), or moved to the other ankle (skin irritation) and how to reapply the accelerometer, if needed. There was also confirmation of patients' understanding of the use of the accelerometer after the training. Additionally, a laminated flyer showing the right orientation and placement of the accelerometer was displayed in each participant's hospital room. The researcher also examined the participant's skin daily to assess for skin irritation and to see if the accelerometer was correctly in place. Participants had a high adherence rate (96.3%) of accelerometer wearing during the hospital stay. Only one patient did not put the accelerometer back on in the right direction resulting in missing data.

The Velcro strap was replaced if it became wet or worn. There were no episodes of skin irritation or falls in persons enrolled in the study during the entire study period. A plan was in place in case skin irritation occurred from the Velcro strap and consisted of rotating the accelerometer to the opposite ankle daily or using a Lycra sleeve instead of a Velcro strap to attach the device to the participant's ankle. After removing the accelerometer from participants, the device was cleaned with isopropyl alcohol, air-dried and stored in a zip-locked bag marked as cleaned. Velcro straps and Lycra sleeves were treated as single use items.

In summary, the results from a small sample of hospitalized older patients with cognitive impairment demonstrated that these individuals ambulated less and had slower gait speeds compared with patients with intact cognition. Additional research is needed to investigate the mediator role of hospital ambulation frequency, along with other factors influencing patients' physical function, for patients with cognitive impairment. It is also expected that the findings of this study may provide guidance for potential intervention strategies to increase hospitalized older adults' ambulation.

Limitations

There were some limitations associated with this study. Data was only collected on patients who were admitted to a VA Hospital in Madison, Wisconsin. VA hospitals are not bound by Diagnosis Related Groups (DRGs) that influence length of stay as seen in non-federal hospitals. Therefore, the findings from this study may not be generalizable to other non-VA hospital systems. The majority of participants were male; female veterans are estimated to be only 9-10% of the patient population (National Center for Veterans Analysis and Statistics, 2014). Thus, the results of this study may not be applicable to female patients.

This study also utilized a non-randomized design. Convenience sampling was used for recruitment, which may reduce external validity. This study had a small sample size, which limits the ability to control for important confounding variables such as other illness indicators. Thus, insufficient evidence may weaken the variable relationships.

Although the nurse-patient ratio was proposed to be a social environment factor in the study, it was not incorporated into the analyses because the ratios were consistent among the shifts and across days. However, since the hospital setting is a new environment for older patients, physical or social environment factors, such as fear of a patient falling or environmental barriers in hospital settings (Brown et al., 2007), may impact patient ambulation frequency during the hospital stay. Future studies on ambulation frequency should include environmental/systems barriers that impact whether or not patients are encouraged to ambulate during their hospital stay.

Finally, as a requirement of our IRB, nurses had to first approach patients to see if they were interested in talking to the researcher about the study. It is possible that nurses only approached patients who they felt would get up to walk during their hospital stay or patients who were less acuity ill. Therefore, bias in the sample could exist limiting the representativeness to hospitalized older adults. Representativeness to capture older adults who may experience changes in cognition during hospitalization could be improved by including persons with an activated POA.

Conclusion

In summary, results from this small sample study of hospitalized older patients identified that patients with cognitive impairment ambulated less often and had lower gait speed compared with patients who had intact cognition., Efforts to investigate the mediator role of hospital ambulation for patients with cognitive impairment are needed to further clarify the relationship between ambulation frequency on cognition and physical performance at discharge. Given the growing numbers of older adults who are hospitalized, it may be more efficient to identify high risk patients who require a targeted ambulation intervention to improve outcomes both during a hospital stay and post discharge.

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Appendices

Appendix A. The Montreal Cognitive Assessment (MoCA) - BLIND

MONTREAL COGNITIVE ASSESSMENT / MoCA-BLIND
Version 7.1 Original Version

Name:
Education:
Sex:
Date of birth:
Date:

MEMORY		FACE	VELVET	CHURCH	DAISY	RED	**POINTS**
Read list of words, subject must repeat them. Do 2 trials even if 1st trial is successful. Do a recall after 5 minutes.	1st trial						No points
	2nd trial						

ATTENTION Read list of digits (1 digit/sec.) Subject has to repeat them in the forward order [ ] 2 1 8 5 4 Subject has to repeat them in the backward order [ ] 7 4 2	__/ 2
Read list of letters. The subject must tap with his hand at each letter A. No point if ≥ 2 errors [ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B	__/ 1
Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65 4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**	__/ 3
LANGUAGE **Repeat:** I only know that John is the one to help today. [ ] The cat always hid under the couch when dogs were in the room. [ ]	__/ 2
Fluency / Name maximum number of words in one minute that begin with the letter F. [ ] _______ (N ≥ 11 words)	__/ 1
ABSTRACTION **Similarity between** e.g. banana - orange = fruit [ ] train - bicycle [ ] watch - ruler	__/ 2

DELAYED RECALL	Has to recall words	FACE	VELVET	CHURCH	DAISY	RED		
	With no cue	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUED recall only	__/ 5
Optional	Category cue							
	Multiple choice cue							
ORIENTATION	[ ] Date	[ ] Month	[ ] Year	[ ] Day	[ ] Place	[ ] City		__/ 6

 www.mocatest.org Normal ≥ 18 / 22 TOTAL __/ 22
Add 1 point if ≤ 12 yr edu

Administered by:______________________________

Appendix B. The Confusion Assessment Method (CAM)

CAM-S DELIRIUM SEVERITY SCORING

The CAM can be used to determine both a CAM-S Long Form and CAM-S Short Form delirium severity score.

Feature	Severity Score		
Scoring the CAM-S: Rate each symptom of delirium listed in the CAM as absent (0), mild (1), marked (2). Acute onset or fluctuation is rated as absent (0) or present (1). Add these scores into a composite. Higher scores indicate more severe delirium.			
	Not Present	**Present (mild)**	**Present (marked)**
1. ACUTE ONSET & FLUCTUATING COURSE	0	1	
2. INATTENTION	0	1	2
3. DISORGANIZED THINKING	0	1	2
4. ALTERED LEVEL OFCONSCIOUSNESS	0	*vigilant/lethargic:* 1	*stupor or coma:* 2
5. DISORIENTATION	0	1	2
6. MEMORY IMPAIRMENT	0	1	2
7. PERCEPTUAL DISTURBANCES	0	1	2
8. PSYCHOMOTOR AGITATION	0	1	2
9. PSYCHOMOTOR RETARDATION	0	1	2
10. ALTERED SLEEP-WAKE CYCLE	0	1	2
Short Form SEVERITY SCORE:	Add the scores in rows 1-4. Range is 0-7. ☐		
Long Form SEVERITY SCORE:	Add the scores in rows 1-10. Range is 0-19. ☐		

 Reference: Inouye SK et al. The CAM-S: Development and Validation of a New Scoring System for Delirium Severity in 2 Cohorts. Ann Intern Med. 2014; 160:526-533.

Appendix C. 4-meter Walk Test

4-Meter Walk Test **Subject Identification Number: ______**

Measurement point:

___ At enrollment

___ Discharge Day

Time: __________ AM/PM

Equipment: A stopwatch, measuring tape, tape to mark start and end points

Set-Up Instructions: Measure a 4-meter distance and mark the start and end points on the floor. Be sure the walkway is clear of any obstacles or changes in surface material.

Assessment Instructions: Have the patient begin at the start point or, with a few feet before the start point.

Verbal Instructions to Patient: After I say "begin", please walk at your usual walking pace until I tell you that you may stop.

Say "**Ready, begin**" and begin timing on the stopwatch when the subject begins walking. Stop timing on the stopwatch when the subject reaches/crosses the 4- meter mark. Say "**Stop**" after the patient has crossed the end point.

Walk with the subject along the path while he/she is walking for safety.

Complete the walking trial two times. For each of the two trials, record the time (to the nearest tenth of a second, 0.0 sec) that it took the patient to walk four meters.

Record the patient's gait speed (in meters/second) as the average of the two trials:

Trial 1:

Gait speed: 4 meters / (time to walk four meters _____ seconds) = ______m/s

Trial 2:

Gait speed: 4 meters / (time to walk four meters _____ seconds) = ______m/s

AVERAGE GAIT SPEED: _______m/s

Appendix D. Charlson Comorbidity Index

Patient ID:_____________ Date:_______________

Charlson Comorbidity Index

One Point

☐ Myocardial infarction (history, not ECG changes only)

☐ Congestive heart failure

☐ Peripheral disease (includes aortic aneurysm >= 6 cm)

☐ Cerebrovascular disease: CVA with mild or no residua or TIA

☐ Dementia

☐ Chronic pulmonary disease

☐ Connective tissue disease

☐ Peptic ulcer disease

☐ Mild liver disease (without portal hypertension, includes chronic hepatitis)

☐ Diabetes without end-organ damage (excludes diet-controlled alone)

Two Points

☐ Hemiplegia

☐ Moderate or severe renal disease

☐ Diabetes with end-organ damage (retinopathy, neuropathy, nephropathy, or brittle diabetes)

☐ Tumor without metastasis (exclude if > 5 y from diagnosis)

☐ Leukemia (acute or chronic)

☐ Lymphoma

Three Points

☐ Moderate or severe liver disease

Six Points

☐ Metastatic solid tumor

☐ AIDS (not just HIV positive)

Age: ___ yrs; For each decade > 40 years of age, a score of 1 is added to the above score.

Total score: ______

Charlson, M. E., Pompei, P., Ales, K. L., & MacKenzie, C. R. (1987). A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *Journal of Chronic Diseases*, *40*(5), 373–383.

Appendix E. Chart Review Form

Patient's Chart Review Form **Patient Identification number: ________**

At admission

Part I - Background	
1. Age	______
2. Sex	☐ Female ☐ Male
3. Body weight	_________ lb
4. Height	_________ inch
5. Residence prior to admission	☐ Home ☐ Assisted Living ☐ Nursing Home
6. Discharged destination	☐ Home ☐ Assisted Living ☐ Nursing Home ☐ Acute Inpatient Rehabilitation
7. Arthritis diagnosis	☐ Yes ☐ No type
8. Needs assistance to walk	Yes : ☐ 1 ☐ 2 ☐ 3 ☐ 4 Persons No ______
9. Use of walking-assisted devices?	Yes _____ No _____ ☐ Use of walker ☐ Use of cane ☐ Other ________
10. Needs assistance with 1 or more ADLs	Yes _____ No _____ ☐ Bathing ☐ Dressing ☐ Feeding ☐ Transferring ☐ Toileting ☐ Continence
11. External lines present	Yes _____ No_____ ☐ Oxygen ☐ IV line ☐ Foley catheter ☐ Other
12. Psychoactive medication:	☐ Tranquilizers ☐ Antidepressants ☐ Sedatives ☐ Cardiotonics: antihypertensives or diuretics

Patient's Chart Review Form **Patient Identification number: ________**

Complete this form daily Date: ________

Part II - Current hospital stay	
1. Fall risk score (Morse scale)	________
3. Current falls during hospital stay?	☐ Yes: ________number of falls ☐ No
4. Physical Therapy consult made	☐ Yes ☐ No
5. Skin assessment: Any signs of redness to skin where accelerometer is being worn	☐ Yes: ☐ No
Part III – Delirious symptoms	
Note:	