Posture, Mobility, and 30-day Hospital Readmission

in Older Adults with Heart Failure

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved July 2015 by the
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August 2015

ABSTRACT

Background: Heart failure is the leading cause of hospitalization in older adults and has the highest 30-day readmission rate of all diagnoses. An estimated 30 to 60 percent of older adults lose some degree of physical function in the course of an acute hospital stay. Few studies have addressed the role of posture and mobility in contributing to, or improving, physical function in older hospitalized adults. No study to date that we are aware of has addressed this in the older heart failure population.

Purpose: To investigate the predictive value of mobility during a hospital stay and patterns of mobility during the month following discharge on hospital readmission and 30-day changes in functional status in older heart failure patients.

Methods: This was a prospective observational study of 21 older (ages 60+) patients admitted with a primary diagnosis of heart failure. Patients wore two inclinometric accelerometers (rib area and thigh) to record posture and an accelerometer placed at the ankle to record ambulatory activity. Patients wore all sensors continuously during hospitalization and the ankle accelerometer for 30 days after hospital discharge. Function was assessed in all patients the day after hospital discharge and again at 30 days post-discharge.

Results: Five patients (23.8%) were readmitted within the 30 day post-discharge period. None of the hospital or post-discharge mobility measures were associated with readmission after adjustment for covariates. Higher percent lying time in the hospital was associated with slower Timed Up and Go (TUG) time (b = .08, p = .01) and poorer hand grip strength (b = -13.94, p = .02) at 30 days post-discharge. Higher daily stepping activity during the 30 day post-discharge period was marginally associated with improvements in SPPB scores at 30 days (b = <.001, p = .06).

Conclusion: For older heart failure patients, increased time lying while hospitalized is associated with slower walking time and poor hand grip strength 30 days after discharge. Higher daily stepping after discharge may be associated with improvements in physical function at 30 days.

ACKNOWLEDGMENTS

This dissertation would have remained a dream for me had it not been for the many people at Arizona State University who stood behind and beside me. It is with immense gratitude that I acknowledge my committee chair and mentor, Dr. Matthew Buman, for encouraging me to pursue my interests and push myself to achieve the most that I could in this program. You gave me the freedom to explore areas I found interesting, while providing the support to refine and develop my ideas. Your passion to share your research knowledge is not matched by anyone else I know. Because of you I feel I am prepared to embark on a new career in research.

Each of my committee members has played an important role in helping me transform into a true scientific researcher. Dr. Steven Hooker, Dr. Cheryl DerAnanian, Dr. Jared Dickinson, and Dr. Marianne McCarthy, many thanks to each of you for helping me realize my passion for Gerontological research, support along the way with your sound advice, critique, and encouragement, and professional friendship.

My research was supported by the Hartford Center for Gerontological Nursing Excellence Scholarship Program. Thank you Dr. Nelma Shearer and Dr. Adrianna Perez for your encouragement to apply to the program. You both have supported my development into a budding Gerontological nursing scholar.

Erin Krzywicki, my research assistant and colleague, who has been with me through my dissertation research journey, thank you for your professional support, hard work, and humor. You kept us sane and I could not have done this with you. Cheryl Dodson, Serena Roberts, heart failure coordinators, and Dr. Sabbath and Dr. Birkholz

supported my research ideas and welcomed me into their hospital facilities to work with their patients. I am deeply thankful for your support and professional friendship.

I am indebted to my doctoral cohort colleagues, Alberto Florez, Jessica Knurick, Andrew Miller, Wesley Tucker, and Wenfei Zhu, who helped me through this journey providing both academic and research support and personal friendship.

Lastly, and most importantly, I want to acknowledge and thank my husband, Michael, for his tireless support, love, and willingness to be my punching bag when needed. And my children, Courtney and Thomas, who have been schooling side-by-side with me, for their love and support, and ability to slip in humorous breaks from schoolwork (mine, not theirs) when I needed it.

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DEFINITION OF TERMS

Mobility— the ability of an individual to purposively move about his or her environment (Rosso, Taylor, Tabb, & Michael, 2013).

Functional decline—the decrement in physical and/or cognitive functioning that occurs when a person is unable to engage in activities of daily living.

Functional independence—the ability to perform daily living activities safely and autonomously (Covinsky et al., 2003).

Length of stay—based on 24-hour clock, the number of days residing in the hospital, including day of admission and day of discharge.

Comorbidity—the simultaneous presence of 2+ morbid conditions or diseases in the same person (Segen, 2002).

Readmission—a subsequent unplanned hospital admission within 30 days following an original admission.

Heart failure class I, II, III, IV— the New York Heart Association Functional Classification System (NYHA) classifies heart failure patients according to three criteria: 1) limitations on physical activity, 2) symptoms (e.g. fatigue) and, 3) patient status at rest. Class I patients have cardiac disease present but suffer no symptoms during rest or physical activity. Class II patients have cardiac disease resulting in slight limitation of physical activity. They are comfortable at rest. Ordinary physical activity results in fatigue, palpitation, dyspnea or anginal pain. Class III patients have cardiac disease resulting in marked limitation of physical activity. They are comfortable at rest. Less than ordinary activity causes fatigue, palpitation, dyspnea or anginal pain. Class IV patients suffer symptoms of fatigue, dyspnea, or angina pain to a degree at rest and with any level of physical activity (Dolgin, 1994).

Ejection Fraction—a measurement of how much blood the left ventricle pumps out with each contraction (Huether & McCance, 2008). For example, an ejection fraction of 60 percent means that 60 percent of the total amount of blood in the left ventricle is pushed out to the systemic circulation with each heartbeat.

Brain-Type Natriuretic Peptide (BNP)—a blood marker for prognosis and risk stratification in heart failure. BNP levels are highly correlated with the severity of heart failure but does not provide a definitive diagnosis (Kim & Januzzi, 2011).

Hand-Held Dynamometry—portable device that can be used to obtain objective measures of upper extremity strength during manual muscle testing (Roberts et al., 2014).

CHAPTER 1

INTRODUCTION

Over the next two decades, the older adult population (ages 65+) in the United States will more than double from 30 million to 80 million and older elderly adults—those more than 75 years of age —will soon have the highest growth rate of any age group (U. S. Centers for Disease Control and Prevention, 2012). Aging is associated with a higher prevalence of chronic disease that can negatively affect the older adult's physical and functional abilities (Covinsky et al., 2003). An estimated 80 percent of older adults in the U. S. currently suffer from one or more chronic conditions (U. S. Centers for Disease Control and Prevention, 2011). Heart failure—a major chronic health condition of older age—greatly contributes to decline in the older adult's physical function level, thus affecting self-care abilities. As heart failure progresses older adults often experience frequent exacerbations from which they may not fully recover. This continued decline places the heart failure population at a high risk for dependence on others and is a catalyst to frequent hospitalization and long-term institutionalization. In spite of modern therapies, half of older adults diagnosed with heart failure will die within five years (Go et al., 2014) and quality of life deteriorates quickly in another one third of this population (Blecker, Paul, Taksler, Ogedegbe, & Katz, 2013).

Heart failure is the leading cause of hospitalization in older adults, accounting for more than one million U.S. hospitalizations annually and contributing to an additional two to three million admissions (Go et al., 2014; Blecker et al., 2013). In 2007, older adults with heart failure accounted for 14 percent of the Medicare population yet consumed 43 percent of the Medicare budget, with much of the cost burden attributed to hospitalization (Linden & Adler-Milstein, 2008). The current medical cost of caring for heart failure patients in the U. S. is $32 billion annually and with the explosive growth of the older population is predicted to be more than $77 billion by 2030 (Heidenreich et al., 2011).

The compounding of physiologic events related to heart failure often causes a greater loss of physical function for the patient and they may require hospitalization. However hospitalization, traditionally thought of as an event to assist the heart failure patient with recovery of health and function, may actually increase the dependence level of these susceptible older persons. Older adults in general are particularly vulnerable to loss of physical function during a hospital stay due to a decrease in physiological reserves related to age and lower health status (Covinsky et al., 2003). It is estimated that 30 to 60 percent of older adults lose some degree of physical function in the course of a hospital stay (Lafont et al., 2011). Older adults hospitalized with heart failure are especially vulnerable to further loss of function as cardiovascular and respiratory compromise, two conditions of heart failure, most often reduce the ability and desire of the older adult to move about in their environment. Further reduced mobility, especially when lying in bed, slows circulation, inhibits lung expansion and contributes to muscle wasting (Huether & McCance, 2008). While up to 50 percent of older adults may be admitted with at least one functional dependency during an exacerbation of heart failure, almost half of those hospitalized are discharged home with a higher functional dependency or increased mobility difficulty than their pre-hospital baseline (Rodriguez-Pascual et al., 2012). This clearly illustrates that although clinical symptoms may be improved through medical care, physical function often does not and may actually be made worse. Reduced physical function can lead to prolonged hospital stays, hospital readmission or the requirement for long term institutionalization, and is associated with poorer outcomes such as permanent disability and increased mortality (Covinsky et al., 2003).

Several factors have been identified as contributors to loss of physical function in older adults who are hospitalized. The age of the patient, the illness itself, comorbid conditions, altered nutritional status, and factors increasing fatigue (such as poor sleep patterns and the number of medications used) have been cited (Covinsky et al., 2003; Cunliffe et al., 2004; El Solh, Brewer, Okada, Bashir, & Gough, 2004). Covinsky et al. (2003) report an almost three times higher rate of functional decline from baseline to hospital discharge in adults over 90 years compared to those aged 70-74. Illness type and severity also contribute considerably to functional outcomes. Gill, Allore, Holford, & Guo (2004) identified that hospitalized older adults who had lower functional scores at discharge had twice the prevalence of chronic conditions such as heart failure, chronic lung disease and arthritis. Nutritional status often deteriorates during hospitalization and is a primary area of neglect by staff when patients require extensive care in other areas. Conditions such as orders for nothing by mouth and restrictive undesirable diets play a role in reduced nutrition as well as alterations in metabolism secondary to disease processes (Covinsky et al., 1999). Sleep deprivation can promote fatigue levels of patients and cause alterations in cognition, causing additional disability in the hospital. Compounding the sleep issue is the high use of sedative-hypnotic sleep aids in the older adult hospital population. Between 30 to 80 percent of patients are administered a medication ordered for sleep that may cause cognitive changes such as confusion and place them at higher risk for functional loss (Flaherty, 2008). Other medications prescribed in the hospital may cause adverse effects such as fatigue, nausea, and cognitive changes, all which place the patient at greater risk for mobility, nutrition and safety issues in the hospital (Inouye, 1998).

It is well known that physical activity such as walking greatly improves health in older adults (Gillison, Skevington, Sato, Standage, & Evangelidou, 2009; Kelley, Kelley, Hootman, & Jones, 2009). Moreover, physical activity can slow physiologic changes associated with aging and supports the management of chronic disease in older adults (Chou, Hwang, & Wu, 2012). Physical activity interventions in sedentary community-dwelling older adults have shown significant reductions in mobility disabilities that were sustained long term (>2 years) (Pahor et al., 2014). Even in newly disabled older persons, habitual physical activity was found to be a strong independent predictor of time to and duration of recovery of daily living activities (Hardy & Gill, 2005). The negative physical effects of low mobility and sedentary behavior in adults are also well documented (Booth, Roberts, & Laye, 2012; Thorp, Owen, Neuhaus, & Dunstan, 2011a). Of particular interest is identifying effects of very low mobility or bed rest on physical outcomes, as very low mobility is a consequence of progressing heart failure. (Kortebein et al., 2008) report on the impact of 10 days of bed rest in healthy middle age adults. They found a substantial loss of lower extremity strength and power in the subjects. These findings begin to illustrate the potential detrimental effects of very low mobility in the community population.

Only recently have investigators addressed hospital patient mobility (i. e. postural allocation and ambulatory activity) as a factor contributing to physical function level. Health care processes such as restraints and restrictive devices, physician orders for bed rest, use of sedative medications, and limited physical activity support have been identified as barriers to patient mobility and therefore may contribute to functional decline in older hospitalized adults (S. R. Fisher et al., 2011; Brown, Redden, Flood, & Allman, 2009a). In addition, low mobility level is cited as a contributor to poorer health status and is a risk factor for cardiovascular disease (Physical Activity Guidelines Advisory Committee, 2008) therefore, it may be that hospitalized elderly with heart failure and low mobility levels are at an even greater risk for lower physical function, subsequent readmission, and concomitant poorer health outcomes. Unfortunately, little is known regarding specific mobility assessment of hospitalized older adults and how low mobility may contribute to loss of physical function during the hospital stay. Further, there is even less information available to identify how patterns of patient activity over time may predict functional level at discharge or occurrence of hospital readmission, especially in older heart failure patients. In fact, functional variables are often overlooked in prediction models for hospital discharge prognosis and readmission.

This research will add strength to the small amount of evidence illustrating the negative association of mobility and patient outcomes. More importantly it is the first objective measure of mobility in older hospitalized heart failure patients and may provide valuable insight into the possible mobility needs of this special population.

The *purpose* of this study was to investigate the predictive value of mobility during a hospital stay and patterns of mobility following discharge on 30-day changes in functional status and hospital readmission status in older heart failure patients.

Aims and Hypotheses:

Aim 1

Purpose: To determine whether postural transitions and ambulatory activity during hospitalization are associated with incidence of readmission, lower-extremity physical function, and grip strength at 30 days post-discharge in older heart failure patients.

Hypotheses:

1A. Null hypothesis: There is no relationship between postural transitions during hospitalization and incidence of readmission, lower-extremity physical function, and grip strength at 30 days post-discharge.

1A. Alternative hypothesis: Fewer postural transitions (i.e., lying to sitting, sitting to standing) during hospitalization is associated with greater incidence of readmission, poorer lower-extremity physical function and grip strength at 30 days post-discharge.

1B. Null hypothesis: There is no relationship between ambulatory activity (i.e., steps) during hospitalization and incidence of readmission, lower-extremity physical function, and grip strength at 30 days post-discharge.

1B. Alternative hypothesis: Lower ambulatory activity level (i.e., fewer steps) during hospitalization is associated with greater incidence of readmission, poorer lower-extremity physical function and grip strength at 30 days post-discharge.

Aim 2

Purpose: To determine whether ambulatory activity (i.e., steps) during the first 30 days post-discharge is associated with incidence of readmission and change in lower-extremity physical function and grip strength at 30 days post-discharge in older heart failure patients.

Hypotheses:

2. Null Hypothesis: There is no relationship between ambulatory activity (i.e., steps) during the first 30 days post-discharge and incidence of readmission, and change in lower-extremity physical function and grip strength at 30 days post-discharge.

2. Alternative hypothesis: Lower ambulatory activity levels (i.e., fewer steps) during the first 30 days post-discharge is associated with greater incidence of readmission, and less improvement in lower-extremity physical function and grip strength at 30 days post-discharge.

CHAPTER 2

REVIEW OF LITERATURE

Normal Aging versus Chronic Illness

Aging is a biologic process of functional decline which is inevitable, variable and linear (Wilmoth, 2011). There is no way to characterize what “normal aging” is however there are normal biologic processes that occur as one gets older (Timiras, 2011). These changes may produce notable deficits in strength and balance, memory, vision and hearing, respiratory function, and cardiac function, for example (Spirduso, Francis, & MacRae, 2004). Chronic illness accelerates deficits or contributes to a greater deficit and increases mortality rates compared to the normal aging process. Chronic illnesses are “conditions that last a year or more and require continued medical care or limit activities of daily living” (Hwang, Weller, Ireyes, & Anderson, 2001, p 268). Many factors contribute to chronic illness however the increase in incidence of chronic illness in the United States is largely due to longer living. An estimated 88 percent of older adults have one or more chronic illnesses (U. S. Centers for Disease Control and Prevention, 2011). In comparison to normal aging, chronic illness follows a pathological pathway.

The normal aging process leads to a loss of skeletal muscle mass and quality (sarcopenia), and bone density loss that can result in about a 10 percent loss in strength in older adults (Goodpaster et al., 2006). This is the result of loss of type I and II muscle fibers and size reductions in type II fibers, infiltration of fatty tissue, and decreased blood flow to muscle cell fibers. Decreases in protein and calcium absorption due to normal aging processes can contribute to osteoporosis. This phenomenon is limited in healthy aging adults through good dietary intake and strength training which can attenuate bone loss through stimulating bone growth (Layne & Nelson, 1999). In comparison to normal aging changes, decreased strength and balance related to sarcopenia and bone loss is often accelerated in older adults with chronic poor nutritional intake (adequate protein is necessary for muscle repair and adequate bone formation), who are sedentary (muscle atrophy related to disuse), and who have poor vascular perfusion to the muscles (Evans, 2010; Lang et al., 2010). Additionally, sarcopenia is accelerated in chronic inflammation as a result of increased release of inflammatory cytokines. Older adults with poor health behaviors or chronic inflammatory conditions exhibit weaker strength, a higher need for mobility assistance, and higher fall rates (Goodpaster et al., 2006).

Older adults also decline in certain memory functions (e.g. age-related ‘forgetfulness’), though different memory components show wide variability to aging effects. Episodic memory is most affected—the “what”, “when”, and “where” required in explicit recollection. There are various postulates regarding memory loss such as reduced receptors on brain nerve cells limiting transmission and changes in chemical messengers (Brickman et al., 2009). Cognitive changes beyond memory loss are not normal aging conditions. Dementia (Alzheimer’s accounts for 60-80 percent) is a chronic disease of cognitive dysfunction (Alzheimer's Association, 2013). Dementia is a progressive disease that is associated with poor brain perfusion (acute episodes as well as chronic low perfusion), low physical activity levels, poor nutrition, excessive alcohol intake and smoking (Brickman et al., 2009). Neurologic deficits include difficulty with memory, communication and language, reasoning and judgment, and emotional control. Memory loss and cognitive deficits are severe enough to impair occupational, social, and (eventually) self-care functions. Alzheimer-dementia patients typically have less than a 10 year life expectancy after symptom onset (Alzheimer's Association, 2013).

Sensory decline is also associated with older age and some deficit is expected with normal aging. One half of adults over 75 years report hearing loss. This is generally due to a decrease in vestibular sensitivity (Meisami, Brown, & Emerle, 2011). By age 65, one in three has some form of vision reduction. Changes in lens structure, reduced lubrication, and decreased light sensitivity of retina can cause difficulty in focus (and require corrective glasses), dry eyes, and difficulty adjusting to and seeing in dim light (Kaido et al., 2011). Visual deficits manifest earlier in older adults with a history of diabetes or hypertension. These chronic illnesses cause microvascular changes affecting perfusion to the eyes causing severe deterioration of vision. Diabetes is the primary cause of blindness in adults over 24 years (Antonetti, Klein, & Gardner, 2012). Older adults with reduced vision are at higher risk to sustain falls and injury.

Pulmonary changes are not usually noticed before age 60. The most prevalent change due to natural aging is efficiency of gas exchange. Aging lungs often have reduced vital capacity, increased residual volume, loss of elasticity, and permanent hyperinflation of alveoli. Chemoreceptor function can be blunted centrally (CNS) or peripherally. Structural changes related to skeletal loss/remodeling (spine compression, thoracic cavity remodeling) and altered muscle strength can lead to improper ventilatory response and ineffective cough reflex (Huether & McCance, 2008). These normal changes may predispose the older adult to respiratory illnesses and/or the inability to respond adequately to changes in body oxygenation. The most profound pathologic condition associated with respiration in adults is chronic obstructive pulmonary disease

(COPD). It is the leading lung disorder in older adults, and is the fourth leading cause of death in the US, and is the only major disease process that is increasing in prevalence (American Lung Association, 2013). Smoking is the primary cause of COPD. Older adults experience significant negative changes in gas exchange due to hyperinflation of alveoli and excess sputum production and aging lung tissue does not compensate well. COPD severely affects adults over 65, who can suffer extreme activity limitations due to low oxygenation levels and shortness of breath (Huether & McCance, 2008).

Decreased cardiovascular function is the result of structural, electrical, and functional loss due to aging cells and long exposure to risk factors. With aging, the left ventricle wall can thicken by up to 50 percent, and arteries thicken and lose elasticity leading to peripheral resistance and decreased blood flow to organs. In the healthy older adult, these changes occur very slowly and usually do not present a problem for the heart to respond to everyday activities (Spirduso et al., 2004). Decreased cardiac output, increased blood pressure, and decreased aerobic capacity are outcomes of decreased cardiac function (Huether & McCance, 2008). Improved blood flow can prevent early aging-related cardiovascular changes. Difficulties usually become significant when there are added stressors. Atrial fibrillation is the most common electrical disturbance in older adults as damaged nerve and cardiac cells no longer send or respond appropriately to electrical impulses. Diseases of the heart are among the most prevalent chronic diseases among older adults. Over 50 percent of women and men over 65 years have hypertension. And approximately 38 percent of men and 27 percent of women have heart disease (U. S. Centers for Disease Control and Prevention, 2011). More adults in the United States die from cardiovascular disease than any other condition (Karavidas, Lazaros, Tsiachris, & Pyrgakis, 2010). Several factors contribute to heart disease including genetics and lifestyle behaviors such as smoking, high fat diet, high stress, and sedentary behavior. Cardiovascular deterioration most often results in heart failure which leads to reduced organ perfusion throughout the body.

It is important to emphasize that age-related biologic changes do not cause diseases of dysfunction, rather a modest reduced ability or limitation in some functions compared to earlier ages. Aging is influenced by many factors such as heredity, lifestyle behaviors, nutrition, physical diseases, environment, social support, and mental/ emotional coping abilities. It is often difficult to identify whether a deficiency in function in the older adult is related only to aging of cells or exposure to a pathogen or environmental hazard/risk factor, or a combination of both.

Heart Failure in an Aging Population

Many cardiovascular diseases (such as a heart attack or coronary artery disease) lead often to chronic heart failure. The abnormal clinical syndrome of heart failure results in inadequate pumping and/or filling of the heart that cannot meet the body's demands for oxygen and nutrients. This leads to fatigue, shortness of breath, weight gain from fluid retention, and swollen extremities (Hobbs, Doust, Mant, & Cowie, 2010). These physiologic processes negatively affect the older adult's ability to maintain their overall physical function. Adequate physical function is dependent on muscular strength, postural ability, flexibility, cognition and sensation (Saxon, Etten, & Perkins, 2010). Physical functioning is conceptualized as being supported by physical abilities such as standing (i.e., postural allocation), walking, reaching, and vision as well as cognitive abilities such as spatial orientation, short-term memory, and alertness (Tomey & Sowers, 2009). Heart failure, through reduced perfusion to the muscles, lungs, brain, and skin, for example can cause deficiencies in all areas of physical function. Adequate physical function is required for the older adult to care for themselves independently at home. Activity limitation—caused by one or more deficits in physical function—is a hallmark symptom of heart failure. With the exception of osteoarthritis, heart disease contributes most to reports of activity limitations in older adults (Rodriguez-Pascual et al., 2012). A major difference between heart failure and other chronic conditions is that an exacerbation of heart failure becomes an acute (and frequently critical) problem and most often requires hospitalization, intensive treatment and subsequent rehabilitation.

Older adults are acutely hospitalized often for medical care when they meet NYHA Functional Classification of Heart Disease Class II criteria and most always for Class III and Class IV criteria. During exacerbation of heart failure, hospital care may include administration of medications to aid removal of excess body fluid and support cardiac function, oxygen therapy, pain control, nutritional support, and rest. Critically ill patients may require intensive monitoring and treatments such as invasive cardiac monitoring in an intensive care setting and cardiac catheterization. As the heart failure patient becomes stable, diuretic and cardiac support medications and oxygen may be discontinued or weaned, and nutrition and increased activity encouraged (Lewis, Dirksen, Heitkemper, & Bucher, 2014). Cardiac rehabilitation may be prescribed post-hospitalization for heart failure patients requiring higher levels of support for recovery. Cardiac rehabilitation is a professionally supervised program including counseling, exercise training in an outpatient clinical setting, monitoring of blood pressure and weight at home, and possibly home visits for assessment and ongoing education by a professional health care worker (American Heart Association, 2015). Depending on the needs of the patient and health insurance limits, cardiac rehabilitation may last for six weeks to six months, with most programs completing in three months. Influences on recovery from heart failure exacerbation are highly variable. The patient's baseline clinical status, acute treatment plan, rehabilitation activity (American Heart Association, 2015; Lewis et al., 2014), and level of home support (Gallagher, Luttik, & Jaarsma, 2011) may affect the ability of the older adult to recover. However, older adults have a significantly lower recovery rate from heart failure exacerbation than their younger counterparts due to aging effects and the presence of comorbid conditions (Rodriguez-Pascual et al., 2012). In spite of modern therapies, 50 percent of heart failure patients will die within five years of diagnosis (Go et al., 2014). Furthermore, patients with heart failure are readmitted to the hospital within 30 days more than any other medical condition (Centers for Medicare & Medicaid Services, 2012; Chan & Tsuyuki, 2013).

Mobility decline in an aging population

Mobility is the ability to navigate and purposively move about in one's environment (in and outside the home) (Stavely, Owsley, Sloane, & Ball, 1999). Adequate physical function supports the individual's ability to be mobile. Mobility in the outside environment additionally includes environmental, social and financial influences (Webber, Porter, & Menec, 2010). Mobility is not just ambulating, but includes all levels of physical function and activity and is a complex interaction of many processes. In healthy adults, mobility is often addressed in terms of physical activity levels, however in older adults and those with chronic conditions, discussion of mobility should begin with basic physical function and may extend through physical activity and exercise endurance levels (Saxon et al., 2010).

Aging and pathological effects can interrupt mobility processes. A deficiency in one or more areas usually results in mobility impairment. In 2012, over 35 percent of adults 65 and older reported some type of mobility disability and it is projected that by 2030 over 60 percent of older adults will have at least one disability (Centers for Medicare & Medicaid Services, 2012; U. S. Census Bureau, 2012). Adults older than 80 years will have the greatest risk for mobility disability as medical advances have reduced acute death episodes so persons now experience longer life but with more chronic illness and increasing frailty (U. S. Census Bureau, 2012). Mobility impairment may be minor for some (such as slower walking), but for many older adults it will impact their ability to care for themselves. Caring for oneself requires adequate physical and mental function and encompasses the ability to complete basic activities of daily living (ADLs)— bathing, dressing, rising from bed or a chair, using the toilet, eating, walking across a room; and independent activities of daily living (IADLs)—shopping, cooking, performing chores, managing finances— needed to live independently without assistance (Covinsky, Pierluissi, & Johnston, 2011). Adequate physical function is also required to be productive and participate in leisure activities, and significantly reduces the need for long-term care. Older adults who have adequate physical function cite feelings of personal independence, social connectedness, security, and dignity (Maly, Costigan, & Olney, 2006). A deficit in performing one or more ADL or IADL's often requires the older adult to depend on others for completion of regular day-to-day activities. Heart failure can limit severely a person's mobility and self-care level and therefore inhibit the ability for older adults with this condition to remain living independently at home (Covinsky et al., 2011). The effects of heart failure often cause shortness of breath, fatigue, dizziness, and extremity swelling so the older adult may not have the energy or feel safe to ambulate outside their home, prepare meals for themselves, or even bathe, for example. Often, a smaller deficit in ADL ability will lead to further ADL deficits and older adults may often live for many years with disability and poor health. The effects of muscle loss/weakness, decreased respiratory capacity, and cognitive decline—associated with heart failure— place the older adult at risk for further de-conditioning as they become less active, eat less healthfully, and become a higher risk for illness and frailty (Chan & Tsuyuki, 2013). The loss of physical function most always creates negative consequences for the older adult.

Adequate physical function and mobility are also fundamental for interaction within the environment. Increased social engagement is associated with a greater quality of life, lower rates of depression and improved cognition (Rosso, Taylor, Tabb, & Michael, 2013). Older adults who live in residential care settings are often moderately to extremely functionally dependent. They often report feelings of loss of control over decisions in their lives and have reduced familial contact. These are risk factors for psychological issues such as depression. This may negatively impact their sense of identity. Older adults experiencing loss of physical function also report a loss of confidence in performance of day-to-day activities or self-care skills which can lower feelings of self-worth and promote social withdrawal (Maly et al., 2006). Social activity has shown a strong association with reduced risk of developing a disability in mobility, ADLs and IADLs in the older population (James, Boyle, Buchman, & Bennett, 2011).

Older adults participating in social activities spend about 20 percent of their time outside the home (Rosso et al., 2013). A loss of physical function often prevents older adults from attending social gatherings or even being able to leave their home to interact with peers. McLaughlin et al. (2012) and James et al. (2011) found a negative relationship between disability and social activity in community-dwelling older adults.

Economic consequences of declining physical function in older adults are shouldered at both the societal and individual level. Relatively little is known about the true costs of functional decline in older adults as disability is a highly dynamic process with wide variation. However, in 2001, the top 10 percent (high users) of Medicare beneficiaries consumed 62 percent of the Medicare budget while the bottom 50 percent (low users) spent only four percent (Agency for Healthcare Research and Quality, 2006). And according to the National Institute for Health Care Management (2012) (National Institute for Health Care Management, 2012), of the top five percent cost consumers in the U.S., almost 50 percent had at least one chronic condition with a functional limitation. At the state level, Medicaid support is available for older adults with low income, and many older adults use it. In 2010, over 30 percent of Medicaid spending was used to care for older adults who had functional and/or cognitive limitations (U.S. Department of Health and Human Services, 2014). These services are primarily found in skilled nursing and long-term care settings and additionally in adult day care and community services. Medicare and Medicaid costs are shared at the national and state level by taxpayers.

Acute care resources required to care for older adults with functional limitations have always been high and will increase exponentially with the graying of America. Over 50 percent of hospital patients are now over the age of 65, as opposed to 37 percent 20 years ago (Centers for Disease Control and Prevention, 2012) and the average hospital cost per stay for older adults is 25 percent higher than the younger population (<65 years) (Moore, Levit, & Elixhauser, 2014). Patients with a decline in physical function often require even longer hospitalization—an average 1.5 days longer—and up to 20 percent of older adults with a functional limitation will be discharged to a rehabilitation center or skilled nursing facility instead of going home (Gill, Allore et al., 2004). These significant costs of care will be shared by families and the community. Hospital and health care organizations spend twice as much (and bill for) on older Medicare beneficiaries with significant functional loss (Linden & Adler-Milstein, 2008). Currently, the health care delivery system does not consider mobility limitation an essential factor in its provider payments, thus hospitals that employ additional measures to support mobility of older adults often do not see reimbursement. This may minimize hospital-based initiatives that could support older adults to return to home after discharge. Many health plans are just beginning to expand functional prevention benefits to the older population.

Effect of Hospitalization on Physical Function and Mobility

Older adults are at greater risk for functional loss due to aging processes and higher prevalence of chronic diseases. Many older adults may become debilitated from an illness and require hospitalization for adequate recovery (Volpato et al., 2007). Unfortunately, in addition to the effect of the illness, the actual event of hospitalization may increase the level of functional loss of older patients (Covinsky et al., 2003). Older adults are particularly vulnerable in the hospital because of decreased physiological reserves and high comorbidities (Lafont et al., 2011). It is estimated that 30 to 60 percent of older adults lose some degree of physical function in the course of a hospital stay

(Barnes et al., 2012). Although the illness requiring hospitalization may be a primary cause of functional loss, it is likely that hospital processes play a role both in inhibiting recovery of physical function or in accelerating additional functional decline during hospitalization (Gill, Allore, & Guo, 2004). Functional decline can occur in as early as day two of hospitalization. In 30 percent of hospitalized older people, functional decline is unrelated to their primary diagnosis. At three months post discharge only 50 percent recover fully from functional decline (Boltz, Resnick, Capezuti, Shuluk, & Secic, 2012).

Several studies identify various predictors and pre-hospital processes contributing to functional decline in the hospital. Volpato et al. (2007) and others (Hardy & Gill, 2005; Lafont et al., 2011) identify older age, lower baseline cognitive and functional status, social situation, polypharmacy, comorbidities, and baseline nutrition as risk factors for functional decline during the hospital stay and after discharge. Processes within and under some control of the hospital may have as much impact on functional loss for these older adults. For example, nutritional status often deteriorates during hospitalization and is a primary area of neglect by staff when patients require extensive care in other areas. Several studies identify a close association between hospital nutrition status and prevalence of sarcopenia in older adults (Bonnefoy, Jauffret, & Jusot, 2007; Smoliner, Sieber, & Wirth, 2014). Conditions such as orders for nothing by mouth and restrictive or undesirable diets also play a role in reduced nutrition (Covinsky et al., 1999). Salvi et al. (2008) evaluated in-hospital nutritional status and albumin levels and found that almost half of the participants were at risk for malnutrition and those at risk stayed an average two days longer and had a higher rate of functional decline than participants without nutritional issues.

Sleep quality in the hospital also can affect patient outcomes. Multiple staff activity increases noise and has been shown to increase patient stress and interrupt sleep patterns at night (Christensen, 2005). Sleep deprivation can promote fatigue levels of patients and cause alterations in cognition, causing additional disability in the hospital. Additionally, the high use of sedative-hypnotic sleep aids in the older adult hospital population may contribute to reduced physical function. Between 30 to 80 percent of patients are administered a medication ordered for sleep that may cause cognitive changes such as confusion and place them at higher risk for falls (Flaherty, 2008). Polypharmacy or specific medications prescribed in the hospital may cause adverse effects such as fatigue, nausea, and cognitive changes, all which place the patient at greater risk for mobility and safety issues while hospitalized (Lenhart & Buysse, 2001).

Older adults with adequate cognitive status may be at risk for development of delirium while hospitalized. Delirium may be influenced by many hospital factors and is associated with poorer outcomes. De Castro et al. (2014) report the average length of stay for older surgical patients with delirium was significantly longer than patients without delirium, at 13 days versus seven days ($p = .02$), and was associated with the presence of a urinary catheter, infection, and cognitive decline at admission. Inouye et al. (1998) found in their study that 18 percent of elderly patients developed delirium during the hospital stay. They cite precipitating factors of physical restraint use, malnutrition, three or more medications prescribed in the previous day, and use of urinary catheter. Many of these risks are controlled by hospital and staff processes.

Finally, a majority of hospitalized older adults spend most of their day bed, with minimal activity outside the hospital room (Brown, Friedkin, & Inouye, 2004). High sedentary behavior contributes to muscle loss and weakness (S. R. Fisher et al., 2011). Kortebein et al. (2008) report on the harmful effects of bed rest in healthy older adults (average age 67 years). They found that 10 days of continuous bed rest resulted in significantly poorer lower extremity strength, power and aerobic capacity, and that voluntary physical activity was decreased after the bedrest period. This shows not only the effects of prolonged bedrest that may occur while hospitalized but also demonstrates the possible long-term effects of bedrest in the hospital after the patient has been discharged. Gill et al. (2004) evaluated the association between self-reported periods of bed rest and ADL function in healthy adults and found that episodes of bed rest were associated with a decline in IADLs, mobility, physical activity and social activity. The primary author further investigated functional decline in older hospitalized adults and found the hazard ratio for development of a functional disability was 61.8 (95% [CI], 49.0-78.0) within 30 days of hospitalization (Gill, Allore et al., 2004). S. R. Fisher et al. (2011) and Ostir et al. (2013) found negative associations in step activity and length of hospital stay in older adult subjects. Both report that lower stepping activity was also predictive of greater risk of death within 2 years after discharge (S. R. Fisher et al., 2012; Ostir et al., 2013). The most common barriers to mobility cited by older hospitalized patients were feelings of weakness, pain, fatigue, and having an intravenous line or urinary catheter in place. A lack of adaptive accommodations also was cited by both patients and staff as inhibiting mobility for older adults. Unfortunately, staff also perceived that patients were just not motivated to be more active, though this perception was not supported by patient statements (Brown, Williams, Woodby, Davis, & Allman, 2007).

Measurement of Physical Function and Physical Activity in Older Adults

Physical activity assessment of older adults should extend beyond purely physical performance and include function-based considerations so interventions are appropriately designed to meet the full functional needs of this special population. Physical function or functional status is conceptualized as “the ability to perform self-care, self-maintenance, and physical activities” (Leidy, 1994, p196) and is often measured by the ability to perform ADLs and IADLs (Saxon et al., 2010). Physical activity is defined as “any bodily movement produced by skeletal muscles resulting in energy expenditure” (Caspersen, Powell, & Christenson, 1985, p126), and often is discussed in terms of minutes and level performed. Physical function and physical activity are intimately related however tools for measurement of these two concepts are vastly different (see Figure 1). Assessment of function/physical activity in chronically ill older adults should be tailored to specific and appropriate outcomes. Measurement of physical activity only in older adults with chronic conditions is not appropriate as they often may not be able to perform or engage in traditional types of measured activities. Assessment of the older adult’s ability to complete ADLs or tests that use a battery of physical function measures may accurately assess more their physical function level (Leidy, 1994; Painter & Marcus, 2013).

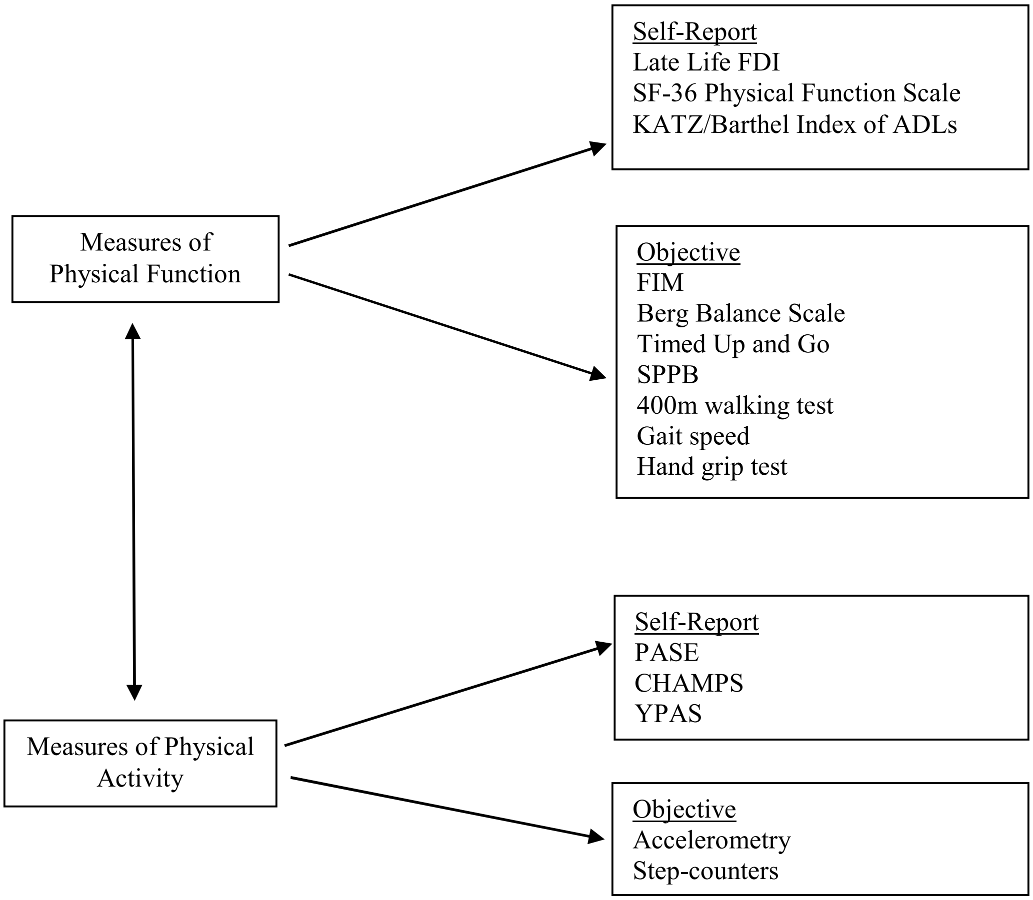


Figure 1. Measurement of Physical Function and Physical Activity in Older Adults

Self-report tools (e.g. self- and proxy-questionnaires, diaries) are practical to use and appropriate for many situations and economic for large studies. Surveys can be tailored to specific populations and generally place little burden on the researcher and general population to complete. The major limitation of self-report of physical activity and function is precision in measurement such as recall inaccuracies, misinterpretation, social desirability bias, and energy expenditure limitations (Prince, Adamo, Hamel, Hardt, Connor Gorber, & Tremblay, 2008b). Additionally, older adults more often have changes in health condition, cognitive and memory problems, fatigue, and may take medications that alter mood, all of which may affect accuracy of self-report questionnaires (Kriegsman, Penninx, van Eijk, Boeke, & Deeg, 1996). Additionally, wording in physical activity surveys may be confusing to older adults who may not engage in traditional exercise activities later in life or who do not perceive their activity level as light-moderate-vigorous or in terms of "minutes per day".

Objective measurement tools (e.g. direct observation, accelerometry) avoid the biases and inaccuracies of recall, providing more precise information. Accurate measurement is required to document patterns and changes in physical activity between and within individuals over time. Some objective measures may only involve minimal interference with participant's activities. Direct observation serves as the "gold standard" for validating other measures of physical activity. Limitations of objective measurement are the higher cost, especially for multi-unit sensors and direct observation, more time consuming, may be burdensome for both participant and researcher (Prince, Adamo, Hamel, Hardt, Connor-Gorber, & Tremblay, 2008a), and may alter the participant's activities therefore may not be representative of normal habits (Riki, 2000). Objective measurement also suffers from methodological inconsistencies (e.g. varying cut points) and is subject to researcher interpretation, which may limit comparability across studies. "Floor" and "ceiling" effects are also more commonly seen in measurement of physical activity and function in older adults as they are prone to more disability. Ceiling effects and floor effects both limit the range of data reported by the instrument, reducing variability in the gathered data (Van Ness et al., 2010). It is important to use objective measures that have been validated in the older population to minimize these types of effects.

Physical function measurement in older adults.

Self-report measures of physical function. The Late Life Function and Disability Instrument (Late Life FDI) is a self-report or interview-based measure of physical functioning and disability in community-dwelling older adults and has been used extensively for many years. It contains two questionnaires that assess functional capability and disability level through approximately 50 questions. It has demonstrated significant associations with performance-based measures of function (McAuley, Konopack, Motl, Rosengren, & Morris, 2005; Sayers et al., 2004). Test-retest reliability is high for both portions of the measure and has been cited as having minimal floor and ceiling effects and more precise measurement than other measures in both function and disability (McAuley et al., 2005). A limitation of the Late Life FDI is the burden of time to administer/complete the survey. Older adults and especially those with multiple morbidities may not have the endurance to complete an approximately 30 minute questionnaire. A shortened version of the Late Life FDI may be appropriate to lessen the time burden however may lose precision in assessment of function (McAuley et al., 2005).

The Physical Function Scale on form Short Form-36 (SF-36) is a multi-purpose recall survey assessing functional and physical health along with well-being and mental health through 36 questions. It is a generic measure that has been validated in the general population and special populations. SF-36 may be the most widely used health assessment form in the world and has been used to assess health in subjects with a wide variety of diseases, conditions, and functional limitations (Turner-Bowker et al., 2002). The questions in SF-36 cover eight health concepts most affected by disease and treatment. Strengths of the form are its generic nature allowing comparison across studies and populations, greater precision in scoring and reduced floor and ceiling effects (Jenkinson, Layte, & Lawrence, 1997). It can be self-administered, via computer, phone or in person in approximately 10 minutes for the general population. Systematic comparisons show that eight of the most frequently measured health concepts are included in the SF-36. Reliability studies consistently exceed .80 across various population groups (Bohannon & DePasquale, 2010; Kosinski, Keller, Hatoum, Kong, & Ware, 1999; Ware et al., 1993). Bohannon et al. (2010) investigated reliability and validity in the older adult population and found significant correlation to physical performance measures. Limitations may be the various versions of SF-36, including two shorter versions (SF-12 and SF-8) that may not be as accurate in assessing function. Their use in older persons with multiple comorbidities may lead to floor effects as the test does not discriminate at the lowest levels of function (Van Ness et al., 2010).

The Katz Index of ADLs (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963) and Barthel Index (Mahoney & Barthel, 1965) have been used extensively in functional assessment. Both tools measure the level of independence in completing basic ADLs and are predictive of future decline or improvement. Katz Index of ADLs measures limitations in a person’s ability to perform six basic self-care tasks: bathing, dressing, continence, toileting, feeding, and transferring. Its score range is zero to six, with higher numbers representing higher independence (Katzet al., 1963). Barthel Index was originally developed to measure disability level in individuals with a known physical disability (such as stroke effects). It measures 10 ADL items similar to Katz plus a few more specific measures of care and mobility. Barthel scores from zero to 100 with 100 representing total independence (Mahoney & Barthel, 1965). Both measures can be done by self-report but observation of the individual’s actual performance is most accurate. Both tests have been validated and show high reliability (Katz, 1983). A strength of both tools is support for a common language regarding patient function, and ease and quickness of administration. Studies show that Barthel is more sensitive to changes in subject condition, but that Katz is more predictive long-term (Hartigan, 2007). Limitations of both measures may be inability to notice variations in individual function and assessment of function in a one-time measure as it may not capture “normal” patterns of the individual (Hartigan, 2007; Kwon, Hartzema, Duncan, & Min-Lai, 2004). Additionally, small incremental changes may not be noticed in older adults with either tool. Both surveys assess basic ADL activity, with Barthel including a few more discriminatory measures, but neither assess more advanced activities of daily living. Other measures would need to be incorporated to capture the full breadth of the older adult’s ability to function at home independently. If functional deficit is determined using either measure, further geriatric assessment is suggested (Kwon et al., 2004). If cognitive impairment is present in participants, both the KATZ and Barthel should be administered by observation.

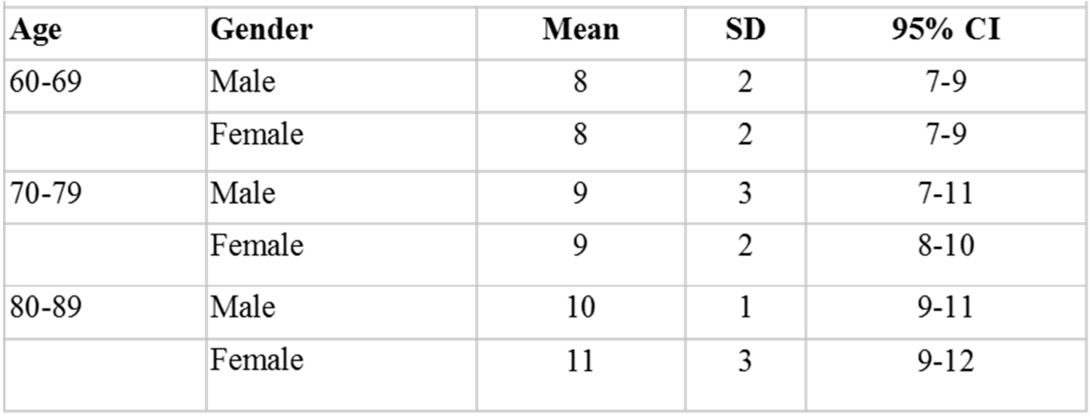
Objective measures of physical function. The Functional Independence Measure (FIM) is widely used and one of the most comprehensive functional assessment tools. It is administered by a trained clinician or researcher through observation (Ottenbacher, Hsu, Granger, & Fiedler, 1996). In response to mandates from Centers for Medicare and

Medicaid Services, the FIM is used in all rehabilitation settings as an outcome measurement for calculation of payment (Centers for Medicare & Medicaid Services, 2002). FIM more accurately measures the type and amount of assistance required by the disabled person to perform basic ADLs. The measure assesses six areas of function in two dimensions: motor and cognitive. Each activity within the functional areas is scored according to ability to perform the task. Scores for each area range from one for total assistance to seven, indicating complete independence (Cournan, 2011). A score of 126 is the highest independence. Previous studies report high interrater reliability when clinicians are well-trained. Kappa coefficients were between .69 to .84 for individual measures (Chau, Daler, Andre, & Patris, 1994; Hamilton, Laughlin, Fiedler, & Granger, 1994) and .91 for total FIM (95% CI, .82-1.0) (Chau et al., 1994). Granger et al. (1990) tested the FIM and found it to have high precision. Additionally, Dromerick, Edwards & Diringer (2003) found the FIM highly responsive to change in functional abilities in stroke patients. Limitations of the tool are certification for administration of FIM is required so it is not easily administered. Another limitation is possible administrator bias as the FIM is used for reimbursement of rehabilitation charges, thus the focus of the tool's use may not be patient-driven.

The Berg Balance Scale (BBS) is a 14-item scale designed to measure balance and risk of falling in older adults by assessing performance of functional tasks such as standing up from sitting position to standing on one foot. The test takes approximately 15 minutes to administer. The measure has good predictive and construct validity (Berg, Wood-Dauphinee, Williams, & Maki, 1992) and has been tested in stroke patients in various settings with high reliability (Blum & Korner-Bitensky, 2008). Downs et al.

(2013) reviewed several studies using the BBS across varied populations (N = 668) and found it correlated well with other laboratory measures. However floor and ceiling effects were noted in a few studies with older community-dwelling adults (Boulgarides, McGinty, Willett, & Barnes, 2003). Equipment is required (chair, stool, other items) and the test must be administered by a trained staff person. Other limitations are the BBS requires a trained therapist to administer, is limited to balance only, has no common interpretation of scores, requires a rather significant change in points (eight) to show a change in function among older adults with a loss of FI (with a well-trained therapist it may only require a four point change), and may not be appropriate in acute care settings as it takes 15-20 minutes to administer (Donoghue, & Stokes, 2009).

The Timed Up and Go Test (TUG) measures the time taken by an individual to rise from a standard arm chair, walk three meters at a normal pace, turn around and walk back to the chair and sit down. Assistive ambulation devices are allowed if normally used. The TUG is a measure of balance and functional status in older adults that can be used across different settings (Podsiadlo & Richardson, 1991). It is used frequently as part of a comprehensive fall risk assessment. There are age, gender and research-based normative values to compare results (see Table 1). Shumway-Cook, Brauer, & Woollacott (2000) investigated predictability of the test and found it to be a sensitive and specific indicator of falls in community-dwelling older adults (with and without history of falling) with a 90% prediction rate. They established a cut-off value for falls risk. Older adults who take longer than 14 seconds to complete the test are considered at a higher risk for falls. The TUG has also been used to identify associations between function and mortality, hospital length of stay (LOS), and readmission in older adults. In a sample of 147 adults admitted to an acute geriatric care unit, TUG time was significantly associated with hospital LOS ($p < .001$) (Wong & Miller, 2008). The risk of an adverse event occurring within six months of hospital discharge was also significantly associated with a longer TUG time (adjusted HR 1.28, 95% CI 1.03 to 1.59, $p = .03$ for 20 seconds longer). Despite its apparent simplicity, the TUG actually tests multiple components of balance and mobility. Even just the sit-to-stand component is a sequence of multiple tasks. Sit-to-stand requires forward movement of the center-of-mass while still seated (in preparation for standing), acceleration of the center-of-mass both in the anterior-posterior and vertical plane, push-off, and stabilization once standing is achieved (Shumway-Cook et al., 2000). In addition to these tasks, the TUG also demands appropriate initiation of stepping, acceleration and deceleration, and preparation to turn twice. The first turning sequence and the final turning around to sit down may be relatively challenging, even for healthy older adults above the age of 70, as it is for frail elderly with mild balance disorders thus supervision during the test may be required. Strengths of TUG are its ability to be used in testing older adults with cognitive impairment—but who can follow directions, and deconditioned older adults. Training is minimal and the test can be administered by staff and others in less than 5 minutes. Limitations of the TUG are it only provides information on a few aspects of balance, scores are not sensitive enough to discriminate between different types of impairment, and equipment is required (appropriate chair height). Also, it cannot be used in people unable to mobilize without assistance (Barry, Galvin, Keogh, Horgan, & Fahey, 2014).



Age	Gender	Mean	SD	95% CI
60-69	Male	8	2	7-9
	Female	8	2	7-9
70-79	Male	9	3	7-11
	Female	9	2	8-10
80-89	Male	10	1	9-11
	Female	11	3	9-12

Table 1. Normative values for Timed Up and Go test for older community-dwelling adults. Mean time in seconds for walking predetermined course (Steffen, Hacker, & Mollinger, 2002).

The Short Physical Performance Battery (SPPB) measures domains in strength, balance, and endurance and has been used extensively for assessment of physical performance and decline over time in older adults (Freire, Guerra, Alvarado, Guralnik, & Zunzunegui, 2012; Guralnik et al., 1994; Volpato et al., 2011). It is an observational test of three performance-based measures of 1) balance—testing side-by-side stands, semi-tandem, and tandem standing, 2) walking speed on an eight foot walking course and, 3) lower body strength—testing the ability to rise from a chair five times. Each performance measure is scored separately with a total summative scale. Scores range from zero to 12 (highest performance), with an accepted score cut-off of < 6 indicating functional dependence, 6 to 8 indicating some level of functional disability, and scores 9 to 12 indicating no disability. The three performance measures are significantly correlated, with Spearman coefficients between .39-.48 ($p < .001$) (Guralnik et al., 1994). SPPB scores have been consistently associated with statistically significant differences in self-perceptions of health and dependency in ADLs (Guralnik et al., 1994) and has high scores in reliability, validity, and responsiveness (Freiberger et al., 2012). Corsonello et al. (2012) tested SPPB in older adults recently discharged from the hospital (N = 506) and found scores were significantly associated with functional decline during the follow-up period (odds ratio [OR] = 0.80, 95% CI 0.69–0.88). The measure has also been tested safely in the hospital setting in older adults with no adverse events occurring (Fisher, Ottenbacher, Goodwin, Graham, & Ostir, 2009; Volpato et al., 2008). The SPPB has several strengths. It can easily be administered in a variety of settings, has been tested in diverse groups of older adults with a high prediction of disability and mortality, and is highly sensitive to changes in functional status (Studenski et al., 2011; Volpato et al., 2011). A few limitations of the SPPB are that it cannot be used in non-ambulatory patients, may suffer floor effects in the very frail using the community standard cut-points established by Guralnik et al. (1994) and physical demand of the test may be a burden in the hospital population.

The 400 meter walking test was developed for older adults and measures physical performance in walking. The individual is asked to walk a distance of 400 meters—divided into equal laps—at the fastest pace they can safely maintain. Instructions include allowance to stop and rest. Data collected include total time to complete task, individual lap times, and the need to stop and rest. For the trained observer, gait performance may also be measured. Inability to complete the walk and longer walking times are associated with higher mortality in community-dwelling older adults (Vestergaard, Patel, Bandinelli, Ferrucci, & Guralnik, 2009). However, there is limited evidence related to walk time and subsequent mobility disability. Simonsick et al. (2008) tested 3056 older community-dwelling men and women to identify deficits based on criteria of: stopping to rest during the walk and taking greater than seven minutes to complete the walk. They found 11 percent of men and 22 percent of women showed objective evidence of mobility deficit based on the established criteria. There were no studies found testing this measure in the hospital setting with older adults. Strengths of this measure are its value in prediction of mortality, ease of measurement, and use of only a stopwatch for equipment. Limitations include the small amount of evidence on validity of mobility limitation identification, the feasibility of use in various disabled or frail populations (many cannot ambulate 400 m), and testing locations are limited for a 400 meter course without obstacles.

Gait speed is also used as a physical performance tests for older adults. Gait speed is measured as the patient's usual walking pace over short distances (eight feet to six meters). A usual gait speed of < 0.6 m/sec is associated with poor outcomes in older individuals (Studenski et al., 2011). A strength is the ability to administer the shorter test to frail older adults or in a confined area such as a hospital unit or skilled nursing facility hallway. A limitation of gait speed measurement is the potential ceiling effects in healthier older adults, thus administration of the 400 meter walking test may be a more accurate measurement tool to assess gait speed.

Hand dynamometry is a measure of upper extremity strength. There are numerous hand dynamometers used in research, all which measure the force of muscular contraction in the hand. It has been used in older adults to evaluate physical health status and performance (Gale, Martyn, Cooper, & Sayer, 2007). Laukkanen, Heikkinen, & Kauppinen (1995) assessed grip strength in 463 community-dwelling adults 70 to 84 years and found their risk of death over two to four years was significantly associated with poor hand grip strength (OR = 1.86, CI=1.13-3.07). These findings are supported by Gale et al. (2007) who report similar findings in their longitudinal study over 24 years.

They found significant differences in grip strength between older adults with diagnosed disease compared with those who were healthy (57.4 vs 62.7 kg, $p < .001$). The authors cite poorer grip strength was associated with increased mortality from all-causes. Few studies compare grip strength with functional outcomes. However, Rantanen, Era, & Heikkinen (1994) tested mobility and muscle strength (including hand grip) in 287 men and women and found those who reported no mobility limitations and who performed better on the stair-climbing test exhibited greater hand grip strength. In their five-year follow-up to the study, the authors report those who were in the lowest tertile for hand grip strength had two to three times greater risk of ADL dependency than those in the highest tertile of strength (Rantanen, Avlund, Suominen, Schroll, Frandin, & Pertti, 2002b). The connection between strength and dependency lends support to the use of hand dynamometry for screening and evaluation in older adults. However, measurement of lower extremity strength is a stronger (and earlier) predictor of functional decline and should also be used (Shumway-Cook et al., 2000).

Physical activity measurement in older adults. Measurement of physical activity in older adults (> 65 years) poses challenges as many of the tools in existence were originally designed on factors related to younger populations. Frequency, intensity, type, and time questions designed for younger populations or the term “exercise” may be confusing to older adults who often do not engage in traditional or higher levels of physical activity. Questions related to their ability to complete every day functional tasks using words such as “gardening, household chores, grocery shopping” may be more appropriate to accurately capture physical activity in older adults (Eckert & Lange, 2015).

Self-report measures of physical activity. The Physical Activity Scale for the Elderly (PASE) (Washburn, Smith, Jette, & Janney, 1993) was developed for use in epidemiologic studies of older community-dwelling adults but has also been extensively tested in chronic populations such as stroke and osteoarthritis. The seven-day recall survey takes 10 minutes to complete and can be done by self-report, over the phone, or interview. Questions on PASE relate to type and frequency of leisure activities. Overall PASE scoring ranges from 0 to over 400. PASE shows excellent test-retest reliability over a three to seven week interval (ICC = 0.75) (Washburn et al., 1993), high correlations between the first and second interview total PASE scores (r = 0.91), and adequate correlations were found between objective monitoring with Actigraph accelerometer mean counts and first interview total PASE scores (r = 0.43) (Dinger, Oman, Taylor, Vesely, & Able, 2004).

The Yale Physical Activity Survey (YPAS) (Dipietro, Caspersen, Ostfeld, & Nadel, 1993) is administered by researcher interview. Completion time is approximately 20 minutes. Questions are specific to activities in later life and include a checklist of activities and questions with categorical responses to assess level of participation. Reports of weekly energy expenditure and time in activity were correlated with daily energy expenditure at baseline in a diverse group (r = 0.37 and 0.30 respectively, $p < 0.01$) (Young, Jee, & Appel, 2001). Moderate to vigorous intensity reporting correlated well with objective measures and comparison survey, the Stanford seven-day physical activity recall. Light-intensity activities did not correlate and the authors identify the need for further investigation. These findings are supported by Semanik et al. (2011) who found significant associations between the YPAS Activity Dimensions Summary index (computation from part two of the survey asking about time spent in the activity categories) of moderate to vigorous activity and objective accelerometry (r = 0.45) in a sample of older adults with arthritis. No significant associations were found with light activity reporting.

The Community Healthy Activities Model Program for Seniors (CHAMPS) Activities Questionnaire for Older Adults (Stewart et al., 2001) was developed for administration to community dwelling older adults participating in a large-scale physical activity intervention. CHAMPS questions are specific to capture physical activity changes in a sedentary population for outcome measurement. Completion time is less than 20 minutes and also asks for a seven day recall of activities performed. The measure shows overall good results. Harada et al. (2001) report the survey had good two-week test-retest reliability in a sample of 80 older adults (ICC 0.62), all measures were sensitive to change ($p < .01$). However the correlation of frequency per week of all activities and the 6-min walk was very low (r = .10) in the original intervention testing (Stewart et al., 2001) and the authors identified the need for further investigation.

The major strength of the three named surveys is their development specifically for use in the older adult population. The surveys provide good descriptive choices, in terms familiar to older adults to support accurate recall of performed activities (Harada, Chiu, King, & Stewart, 2001). Though the questions in these surveys are very measured, recall inconsistencies are still a limitation. Health condition of the older adult at the time of survey may also affect scores. However Harada et al. (2001) reviewed all three surveys simultaneously and found correlations with the six-minute walk test were moderate to high [r = .68 (PASE), .58 (YPAS), and .46 (CHAMPS), with $p<0.01$ for all]. Another limitation of these surveys is the inaccuracies associated with estimation of energy expenditure although this is a known limitation for all self-report survey measures. The PASE, YPAS, and CHAMPS specificity in assessment questions may minimize this limitation.

Objective measures of physical activity. Accelerometers and pedometers are frequently used in direct assessment of physical activity. Accelerometers contain a piezoelectric element and provide time-stamped estimates of activity volume or activity rates. Pedometers may be based on a horizontal spring-suspended lever arm with some newer models incorporating the piezoelectric elements similar to accelerometers. The choice of accelerometers or pedometers to measure activity in older adults is quite tremendous. This can be a challenging task though, as the literature shows movement (and its capture) in older adults can be much different than that of younger populations in which most accelerometry/pedometry has been validated (Bergman, Bassett, Muthukrishnan, & Klein, 2008; Cavanaugh, Coleman, Gaines, Laing, & Morey, 2007; de Bruin, Hartmann, Uebelhart, Murer, & Zijlstra, 2008; Lord et al., 2011). Additionally, further investigation into step-count and active-minute benchmarks for older adults with chronic illness is needed to establish normative values for comparison purpose, when planning interventions, and to interpret change (Tudor-Locke et al., 2011). Tudor-Locke et al. (2009) presented revised expected values in pedometers in adults living with chronic disease to range from 3500 to 5500 steps/day, compared to healthy adults who averaged 7000 to 13000 steps/day. One study was found that measured step-count via pedometer in heart failure patients with an average age of 69 years. Over a 14 day period, the sample mean step count was 4342 (Houghton, Harrison, Cowley, & Hampton, 2002).

Direct measurement via accelerometry in a group of healthy older adults (>70 years) found that only two-thirds averaged the same estimated physical activity energy expenditure of younger adults (Davis & Fox, 2007). These differences may be influenced by more sedentary time, but volume and intensity need to be taken into consideration for the older adult.

There are several strengths in using accelerometers and pedometers. Much of the equipment used in the community (not lab settings) is non-intrusive and can be worn and “forgotten” by the older adult. These tools can collect information about daily levels and patterns of activity which may be more useful in intervention development. The objective measurement removes the inconsistencies associated with self-report measures. Many accelerometers and pedometers have been tested extensively and validated in adult populations.

Two major limitations of accelerometers and pedometers include the higher cost for equipment and training requirements for collection and analysis, and the inability to describe the type of activity performed. Additionally, discrepancies using various cut-points for intensity level have been noted in measurement of older adults. Altered gait patterns, for example, may affect walking counts and the added metabolic cost of ambulation in functionally disabled older adults may be missed (Davis & Fox, 2007). Placement of accelerometers and pedometers must be a consideration also for older adults as they may experience changes in gait that affect sensing capabilities of the device or may use assistive devices that inhibit arm swing, thus affecting capture of movement (Freiberger et al., 2012; Lauritzen, Munoz, Luis Sevillano, & Civit, 2013; Ostrosky, VanSwearingen, Burdett, & Gee, 1994). Devices placed on upper extremities show poor accuracy in older adult populations with altered gaits or those using assistive devices (Floegel et al., 2015, unpublished data).

Functional and physical activity surveys of older adults in clinical settings

As the healthcare paradigm shifts from disease to health, well-being, and functioning, clinicians need reliable assessment tools to capture patient information. Whether assessing functional status or physical activity level, measurement methods must be accurate and quick for realistic use in the clinical setting. The KATZ ADL survey or Lawton Instrumental Activities of Daily Living Scale are reliable and valid instruments to use in the clinical setting to assess physical function and self-care levels in older adults (see Measures of function and physical activity section) (Katz, 1983; Lawton & Brody, 1969). The Rapid Assessment of Physical Activity (RAPA) and Patient-centered Assessment and Counseling for Exercise (PACE) surveys were developed to enable clinicians to quickly assess level of activity in older adult patients. These surveys were designed to complement the care provider health visit and provide an accurate assessment of the level of physical activity engagement of the patient. RAPA is a nine-item questionnaire regarding level of physical activity and strength and flexibility. The PACE questionnaire has eight items from which to select and is intended to identify the patient's activity level and stage of readiness to begin a physical activity program. PACE is meant to be incorporated into behavioral counseling. Both measures show good sensitivity and predictive value using the CHAMPS survey as criterion (Topolski et al., 2006). An advantage of RAPA over PACE is its inclusion of strength and flexibility questions though PACE assesses readiness to change which may aid the clinician to provide counseling accordingly (Calfas et al., 2002). Other survey measures such as KATZ are used when function only is the priority for assessment.

Mobility/function measurement in hospitalized older adults and associated outcomes

There is a paucity of objective measure studies of postural and ambulatory activity of older hospitalized patients using accelerometry, and no study, to date, measuring postural and ambulatory activity in older hospitalized heart failure patients. Studies using functional measures (e.g. Functional Independence Measure) in hospitalized older patients are slightly more frequent in the literature, but again, none focuses explicitly on the heart failure patient.

S. R. Fisher et al. (2011) used an ankle-mounted step count monitor to measure step activity of 239 hospitalized older adults (average age 76 years) with varying medical diagnoses and found that patients spent only 4.1 percent of their time ambulating. They further identified that patients who ambulated more had shorter hospital stays. Patients with a stay of three to four days averaged significantly more steps per day compared to stays greater than seven days (883 steps vs 360 steps, p=.03). They found that self-reported baseline functional status prior to hospitalization impacted ambulatory time in the hospital, as older patients who walked less than 500 steps daily for five days in the hospital reported a variety of preadmission limitations to ADLs. Of particular interest, the authors also report no significant differences in physician activity orders, admission diagnoses, and presence of restrictive equipment (e. g. indwelling catheters and intravenous lines) between the lowest level ambulators and higher level ambulators. In a subsequent study, S. R. Fisher et al. (2012) investigated patient characteristics and clinical variables and their relationship to daily steps in a patient subgroup (N=198). They report a median step count of 322 steps per day and found that mobility status prior to hospitalization was the strongest predictor of steps during hospitalization. Among patients who were functionally independent prior to hospitalization, diagnostic category (i.e. diagnosis and severity) was the strongest predictor of ambulatory activity. This predictive finding of diagnostic category was somewhat different from their first study, but mobility parameters for discharge status were very similar.

Hospital mobility has also been evaluated as a predictor of survival after discharge in older adults. Ostir et al. (2013) used ankle-mounted monitors to collect step counts from the first 24 hours and last 24 hours of hospitalization and compared them with two-year survival rates in 224 older adults with varying diagnoses. Investigators found a four times greater risk of death in older adults who had a decline in steps from the first 24 hours to the last day (HR = 4.21, 95% CI = 1.65–10.77). Furthermore, they identify that one-fourth of the study population declined in their step activity count over the course of the hospitalization. Small increases in steps (only 100 per day) were associated with a lower risk of death (Ostir et al., 2013).

Another objective measure of mobility status that can be effective to use in clinical settings is gait speed. The value of gait speed has been tested minimally in the hospitalized population however it has been proven to be an accurate predictor of functional ability in the older community population (Li et al., 2012; Cesari et al., 2005). Ostir et al. (2012) found an association between gait speed and activities of daily living with length of hospital stay and home discharge prognosis. In their prospective study of 322 older adults, those with slower walking speeds (< 0.40m/s) had an average 1.4 to 1.9

day longer hospital stay than those with higher speeds (> 0.60m/s). Additionally, the slower the walking speed the less likely the patients were to be discharged home. Patient's self- reported ADL levels were less discriminatory at predicting discharge prognosis, but support the findings of their gait speed tests. This study did not identify mechanisms such as disease severity, fatigue or mobility restrictions that may predict slower walking speeds.

Brown, Redden, Flood, & Allman (2009a) are of the few researchers to investigate postural allocation in hospitalized older patients. The authors measured sitting and standing time using a single accelerometer. Their study cohort of 45 males averaged 43 minutes per day (3.1 percent) of standing or walking activities in the hospital with a significant part of their hospital day (83.3 percent) spent lying in bed. The authors also report that after day four of hospitalization, ambulatory time declines further, however they did not measure any clinical outcomes related to activity time.

The existing research provides a strong argument for the continuing need to address low mobility in hospitalized older adults. Its strengths include the use of objective measurements of mobility and a combination of various accelerometry data supported by patient self-report on activity levels. Additionally, these studies identified relationships between mobility levels and patient outcomes. However, there are still several gaps in the literature regarding hospital mobility assessment and functional decline. Though the cited studies identify specific measures of mobility, many of the studies assume patient ambulation is the only form of mobility. To date, only one study addresses patient postural allocation as a form of mobility. In the hospitalized population, mobility events other than ambulation may be taking place such as frequent bed-to-chair transfer and chair-activities. These non-ambulatory activities may support functional improvement and should be captured in a mobility assessment. Further studies should distinguish between lying, sitting and standing positions as changes in posture are important aspects of mobility support for older adults.

Mobility/Functional Interventions for Acute Hospitalization and Rehabilitation

The benefits of planned exercise in healthy older adults such as walking are well documented and significant. Benefits include reduction in blood pressure, reduction in chronic diseases such as osteoporosis, cardiovascular disease, type II diabetes, and improved sleep and ability to perform ADLs, and general improved mood (Nelson et al., 2007; Singh, 2002). Most of the demonstrated benefits relate to walking and exercise programs of longer duration or greater intensity than what would be possible by an acutely ill older patient in the confines of an inpatient care setting. It may be possible, however, to achieve some of these benefits in smaller doses for this special population, in particular functional performance. There are limited studies detailing effects of in-hospital interventions aimed at improving/maintaining physical function. It may be as simple as earlier and more frequent ambulation. Several studies cite significant improvements in time to discharge and discharge destination related to increased walking in the hospital. In their STRIDE program, Hastings, Sloane, Morey, Pavon, & Hoenig, (2014) provided education and encouragement to increase walking activity, coupled with daily supervised walking for older hospitalized veterans. Participant's risk of being discharged to a skilled nursing facility was only eight percent compared to the usual care group at 26 percent ($p = .007$). Mundy, Leet, Darst, Schnitzler, & Dunagan (2003) found assisting older adults with pneumonia out of bed to ambulate within the first 24 hours reduced hospital length of stay by one full day. Tucker, Molsberger and Clark (2004) report increases in walking frequency throughout the hospital period improved regaining of ADL abilities and a shortened hospital stay by an average of 0.5 days. Daily or more ambulation prescription may be tolerable by most patients, but more importantly may be welcomed by all. One study of 102 hospitalized older adults showed a 100 percent patient satisfaction rate for their daily walking program (Tucker et al., 2004).

Exercise other than walking may also be incorporated in the hospital setting. Older hospitalized adults who performed daily isometric exercises, balance, and strength training exercises (personalized to patient ability level) had a quicker recovery and discharge to home 2.5 days sooner than control group (Opasich et al., 2010). In their systematic review of nine randomized controlled exercise interventions de Morten, Keating & Jeffs (2007) highlight significant reduced length of stay (> one day) and reduced hospital costs. The programs used varied exercise approaches, to include resistance training, passive and active range of motion exercise, flexibility training, and aerobic exercise.

Not all activity and exercise studies for hospitalized older adults show positive results. Killey and Watt (2006) found no significant improvement in regaining functional loss or shorter hospital stay in their cohort of older adults (N=55) who were more frequently ambulated than controls. Researchers also have found that the mere presence of a mobility plan does not improve functional decline at discharge or post hospital. However regardless of a written plan (or physician order), documentation of actual ambulatory episodes by hospital staff is associated with a shorter length of stay (Hastings et al., 2014). Engagement of patients to improve hospital mobility via technology has also shown mixed results. Laver, et al. (2012) used WII Fit in their feasibility study to promote mobility and balance in a small group of hospitalized older adults (N = 44). Participants in the randomized controlled pilot were assigned to standard physical therapy or interactive gaming physical therapy. There was only a marginal significant difference in TUG scores between groups (p = .048), and narrow overall gains for both groups, while other measures such as balance and functional measures were the same across groups. The authors note recruitment of older adults was difficult for this study as many refused participation with gaming devices.

There is less evidence related to physical activity and exercise in heart failure patients who are hospitalized. The majority of intervention research is related to outpatient cardiac rehabilitation for this population. However, most studies show positive results, some of which may be transferrable to the inpatient setting. Several randomized controlled studies show intervention participants with heart failure improved significantly in physical components such as walking faster (Pihl, Cider, Stromberg, Fridlund, & Martensson, 2011; Witham, Argo, Johnston, Struthers, & McMurdo, 2007; Witham et al., 2012) and improving upper and lower extremity muscle strength (McKelvie et al., 2002) compared to controls. Intervention measures included walking, group exercise, strength training, and resistance exercises. Even in older frail adults with heart failure, exercise interventions may improve functional outcomes. Witham et al. (2005) conducted a three month supervised plus three month home-based seated exercise program in a cohort of older adults with multiple comorbidities and found the intervention group was significantly more active throughout the day (measured over a seven-day period by accelerometry) compared to controls.

To date, there are no mobility intervention studies published involving only inpatients with a primary diagnosis of heart failure, however there are a few studies that may lend support for this population. Intensive care settings have employed early mobilization plans for even the critically ill older adult and some of these studies include patients with heart failure. Morris et al. (2011) and others (Bailey et al., 2007) found that early intensive care mobility protocols (such as beginning passive range of motion the day after admission, performing active range of motion, and assisting out of bed to chair frequently) improved odds of discharge to home, and resulted in shorter length of stay and fewer readmissions.

A critical area to consider when conducting mobility/physical activity interventions in heart failure patients is fatigability or the perception of fatigue. Shortness of breath is the most cited symptom in heart failure patients and may be a major deterrent to instituting a physical activity plan in the hospital. In the outpatient setting, perception of fatigue is associated with higher drop-out and reduced participation (Norberg, Boman, & Lofgren, 2010; Wall, Ballard, Troped, Njike, & Katz, 2010). Strategies to improve function and mobility may not involve physical activity yet still support functional improvement in patients with heart failure. Studies show that interventions such as a prescribed diet (Gariballa, Forster, Walters, & Powers, 2006), comprehensive education plan (Warden, Freels, Furuno, & Mackay, 2014), social-service consultation, and planning for an early discharge (Deschodt, Flamaing, Haentjens, Boonen, & Milisen, 2013) are associated with improved outcomes in older hospitalized adults. Detailed dietary assessment within first 24 hours in hospitalized older adults may identify malnourished patients more quickly and dietary interventions implemented sooner.

Holyday et al. (2012) found a significant reduction in length of stay in an intervention cohort identified as ‘malnourished’ in assessment phase and who received early nutritional support compared to controls who received usual care (19.5 ± 3 days v. 10.6 ± 1.6 days, p=0.013). Gariballa et al. (2006) conducted a double blind RCT comparing nutritional supplementation to standard hospital nutrition in older adults and reports a significant reduction in the number of readmissions over six months in intervention group. This may be related to nutritional improvements found such as higher protein levels.

Some hospitals have instituted geriatric inpatient unit programs such as the Acute Care for Elders model (ACE units). These function-focused models provide specialty comprehensive care to adults 65 and older and go well beyond usual acute medical care by working to prevent functional decline and related complications (Covinsky et al., 1998). ACE units include extra measures and equipment to support older adult’s healing, independence, and interaction by incorporating supportive environmental elements such as fewer restraints, extensive use of handrails around rooms and hallways, specialized therapies with music and art, central eating and visiting areas to encourage movement outside the room. A key element of the units is the use of interdisciplinary health care teams which include the physician(s) (including the primary care physician and a geriatrician), nursing, social work, nutrition, physical therapy, pastoral counselor, home care coordinator and others as needed (Panno et al., 2000). Fox et al. (2012) found in a large scale meta-analysis (N = 6,839) that ACE unit care was associated with approximately 50% fewer falls and episodes of delirium, reduced functional decline from prehospital baseline to discharge, shorter length of stay, lower costs, and more discharges of older adults back to their home compared to usual care medical units. The average age in these ACE units was 81 years. However in contrast, Palleschi et al. (2011) showed mixed results on geriatric care units. Their control cohort of older adults (N = 620) on a usual care medical improved at a faster rate than the comparison geriatric ward cohort (N = 428). These results need further review as the geriatric group was significantly older (82 years versus 78.4 years), more were widowed (53.4 percent vs 30.7 percent), living alone (25.4 percent vs 15.6 percent), scored lower on the Barthel index at baseline and had almost two more comorbid conditions, among other factors.

Further investigation into the mobility needs of older hospitalized adults should focus on specific diagnostic and illness categories, age groups, functional status, and living arrangements to identify interventions that may support positive outcomes. Thus, this observational study focusing on posture, mobility, and step activity in older adults with heart failure may provide more accurate information to support the appropriate adoption of mobility and functional care measures during hospitalization for this population.

CHAPTER 3

METHODS

Research Design

This was a prospective observational clinical trial of ambulatory older adults from two community hospitals from February 2015 to July 2015. The study was approved by the Scottsdale Healthcare (IRB #2014-082) and Arizona State University Institutional Review Boards (IRB #00001351). Study participation time was hospital length of stay plus 30 days following hospitalization. To date, no other study has addressed objective mobility measurement in older adults with heart failure therefore a pilot test was warranted. Given the preliminary nature of this study, 20 to 30 patients was deemed adequate in order to determine the feasibility of our approach for continuously monitoring behavior in this population both during and following hospitalization and to obtain meaningful effect sizes for larger investigations (Bowen et al., 2009). This sample size was in line with similar preliminary studies of mobility/activity in other clinical populations of older hospitalized adults (Brown, Redden, Flood, & Allman, 2009a; S. R. Fisher et al., 2012).

Participants

Patients were recruited from the inpatient medical units at John C. Lincoln Hospitals (JCL) — North Mountain and Deer Valley campuses.

Inclusion criteria with rationale were as follows:

- Admitted to general medical unit in hospital with primary diagnosis of heart failure as this population's mobility and activity status and outcomes have not been studied;

- Adults aged 60 years or older, given the rising demographic, intensive care required, and subsequent medical costs of this age group;
- Previously living independently prior to hospitalization with self-reported ability to walk without assistance of another person across a small room during the month prior to admission, as an aim of this study was to investigate if limited mobility/ambulation in hospital negatively affects functional ability at home;
- No medical contraindication (e.g., isolation orders, allergy or skin sensitivity, dressings covering areas of accelerometry placement) to wearing activity monitors with occlusive dressing on thigh/rib area and soft elastic ankle strap on ankle, as these objective measurement devices were required for the study and could not be substituted with observation;
- Ability to understand English, to assure full understanding of study procedures;
- Living in the greater Phoenix area, to ensure follow-up at the patient's home was possible.

Exclusion criteria with rationale were as follows:

- Active bilateral lower leg infection, for patient safety and infection control the areas for placement of postural and activity monitors must have been free from infection;
- Severe lower leg edema, for patient safety activity monitor should not be placed around severely edematous legs as this may have exacerbated circulatory problems;
- Cognitive impairment diagnosis indicated on admitting medical record, to ensure appropriate consent from the patient and understanding of monitor wear;

- Hospitalized for more than two days prior to initial consent, to ensure that postural transitions and ambulatory activity were adequately assessed during the hospital stay;
- Patients with an expected hospital stay of less than two days, as this would have limited the opportunity to recruit, consent, and capture data during the hospital stay;
- Any additional condition/event considered exclusionary by the attending physician, investigator, and/or hospital staff.

Recruitment

Study investigators reviewed admission information from JCL clinical coordinators and conducted an initial screen via medical chart review. Potentially eligible patients were approached within 48 hours of hospital admission by study staff and given a short description of the study and asked further eligibility-related questions. If the patient continued to meet eligibility criteria and if interest continued, the investigator provided a consent form approved by the hospital Institutional Review Board and the study protocol was explained in full. After consent was obtained, the Mini-Cog^{TM} Mental Status Assessment Tool was administered to ensure there was no cognitive impairment of the participant. It is a brief assessment tool designed to differentiate persons with dementia from those without and is used extensively in the clinical setting. Studies have shown the Mini-Cog^{TM} has a sensitivity of76-99 percent in identifying dementia and specificity of 89-93 percent for ruling out dementia (Borson, Scanlan, Chen, & Ganguli, 2003). Per hospital policy, the patient was provided a copy of the hospital’s Health

Information Portability and Protection Act (HIPPA) form and the investigator obtained the patient's signature of understanding.

Procedures

Study procedures are summarized in Figure 2. Following consent, Mini-Cog^{TM} assessment, and HIPPA, two activPAL3™ micro accelerometers (hereafter referred to as activPAL^{TM}) were each initialized and waterproofed with a latex-free finger cot and wrapped in clear occlusive tape. One was affixed to the right rib cage area approximately one inch below the nipple line. The other was placed midline on the right thigh midway between the hip and knee joint. Both were secured with cover-roll stretch tape. These devices were placed as described by Bassett et al. (2014) for accurate assessment of lying, sitting, standing and stepping. Next, the investigator placed the Tractivity® ankle sensor in the accompanying nylon band and affixed it to the participant's right ankle (Appendix A). Participants were instructed to continue wearing the sensors during their entire hospital stay and to alert nursing staff if the sensor became displaced. Investigators provided appropriate training on the placement of sensors and instructed nursing staff to contact study investigators if they had concerns during the study duration. Written and pictorial material was placed in the participant's room and also provided to staff upon request (Appendix B). While hospitalized, an investigator visited the participant daily to ensure device placement, assess the skin for irritation, download Tractivity® data, and answer questions from the participant and/or staff. Full records review was performed during the participant's hospital period to obtain the necessary demographic and clinical information. A majority of demographic information was obtained through records review to reduce participant burden. Participants were asked of their living arrangement, whether living alone, with family, or friends. When discharge was anticipated, investigators made arrangements with the participant to visit them at home on the day after discharge. During the first visit, the investigator removed the activPAL^{TM} sensors and administered the Katz survey on activities of daily living, and measures of lower-extremity physical function (TUG, SPPB, and hand grip strength). The investigator again reviewed the ankle-mounted Tractivity® monitor with the participant and instructed them to continue wearing it at home for 30 days. An information sheet with pictures of the monitor and its placement, and information on signs of skin irritation and instructions to contact investigators if needed, were left with the participant (Appendix C). At two weeks post-discharge, the investigator visited the participant again at home and administered brief surveys (described in covariates section) to obtain sleep and nutrition information from the patient, and download step data. They reviewed the Tractivity® monitor and assessed the participant's skin and answered any questions the patient had. At 30 days post-discharge, investigators made a final visit to the patient at home to re-administer the TUG, SPPB, and hand grip strength tests. During all of the visits participants were queried if they had any unplanned hospital admissions. Investigators also reviewed hospital records for confirmation of admission to the primary hospital used.

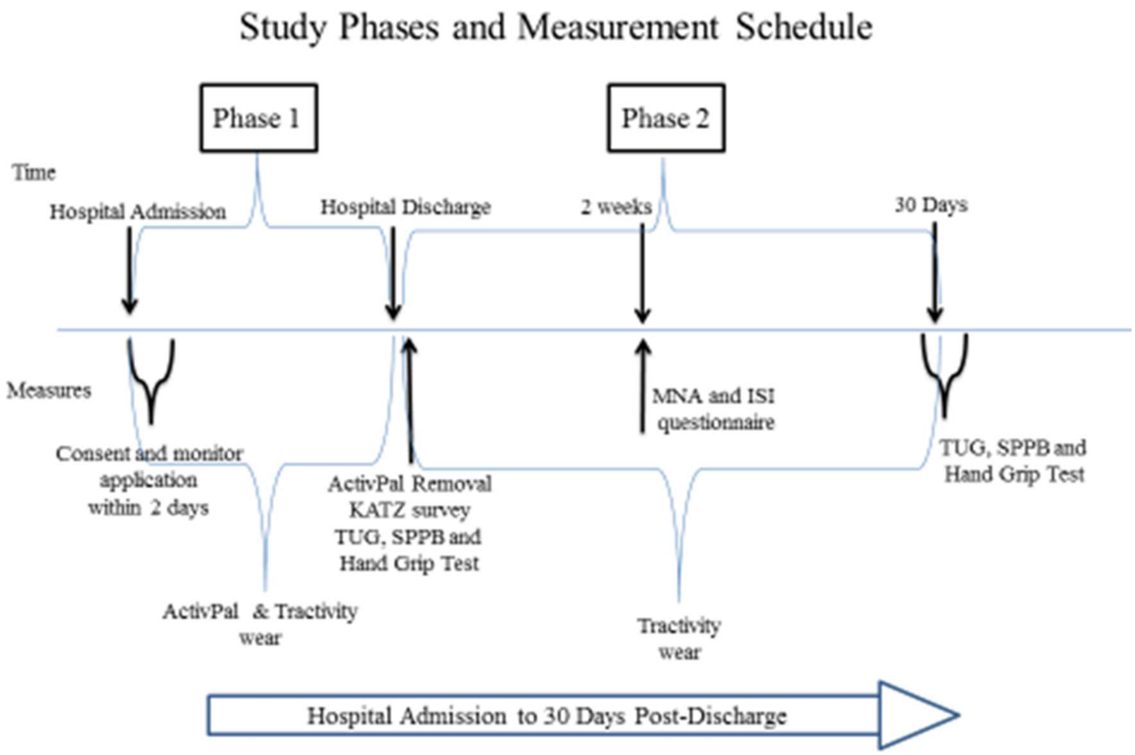


Figure 2. Study Timeline

Measures

Demographics. General demographics and specific health and hospital characteristics were obtained through participant interview and electronic medical record review. Age, gender, race, marital and living arrangement status, height/weight, and comorbid conditions were obtained at baseline. Medication use, use of restrictive devices, laboratory results, and hospital length of stay information were obtained during and at the end of the hospitalization period. Most participants did not have their heart failure severity documented by NYHA classification, therefore, criteria from AHA was used to classify as mild heart failure (EF $\geq$ 45) and moderate/severe heart failure (EF < 45) (AHA, 2015).

As measures of mobility, postural transitions (lying to sitting to standing) and postural time were assessed with activPAL^{TM}. Data collection began immediately after consent and continued until the patient was discharged from the hospital. Ambulatory activity began at the same time as posture and was assessed using step activity measurement during the hospital stay until 30 days post-discharge. Physical function was assessed the day after hospital discharge and again at 30 days post-discharge using objective measurement tools and tests.

Wearable Monitors

- Postural transitions and percent time in posture: Number of transitions per 24 hours from lie to sit, and from sit to stand. Percent of day spent in lying, sitting, standing posture. The activPAL™ monitors (Pal Technologies Limited, Glasgow, UK) were applied to the right thigh and rib area of patient after consent and worn until discharge from the hospital. The activPAL™ measures approximately four centimeters long by three centimeters wide and is less than one centimeter in thickness (0.7 cm). Using proprietary algorithms, this accelerometer samples posture >1 time/second. The activPAL™ is the most accurate (with 97% precision) free-living postural classifier of lying/sitting versus standing when the device is placed on the thigh (Kozey-Keadle et al, 2011). More recent data suggests that an additional activPAL™ sensor placed on the rib/torso can accurately (with close to 100% precision) distinguish between sitting and lying positions when data are merged with the device on the thigh (Bassett et al., 2014). No other device we are aware of is able to distinguish between these positions. The activPAL™ can be fully waterproofed and fixed discreetly to the thigh and torso using a transparent dressing and continuously record for 10 days.

- Ambulatory activity: Number of steps per 24 hours and percent active time were assessed for hospital stay. Daily steps during 30 day post-discharge period were also assessed and additional variables calculated. With proprietary algorithms, an active minute was identified whenever at least 10 steps were taken (Kineteks, unpublished data, 2014). The Tractivity® monitor (Kineteks Corp., Vancouver, B. C., Canada) was applied to the right ankle and worn during hospitalization and 30 days post-discharge. Tractivity® is a secure web-based activity monitor worn on the ankle. It measures approximately three centimeters by three centimeters. It is a newer electronic device on the market that utilizes tri-axial accelerometers and advanced signal-processing techniques to detect step count and time active and is designed to track ambulatory activities that involve taking steps. It uses a cloud-based data collection system. The choice of Tractivity® was for three reasons: 1) preliminary results show a high correlation of step counts and active minutes between Tractivity® and the known "gold standard" Stepwatch Activity Monitor (SAM) ($r^2 = 0.98$) (unpublished raw data, 2013). SAM has been extensively tested and validated in healthy older adults (Resnick, Nahm, Orwig, Zimmerman, & Magaziner, 2001) and older adults with impaired gait (Schmidt, Pennypacker, Thrush, Leiper, & Craik, 2011), 2) the use of a pliable, adjustable, soft nylon strap is most appropriate in this population who frequently suffer from swollen extremities (Hobbs et al., 2010) and, 3) location of a sensor on the ankle is less obtrusive in daily activities thus it is more likely the participant will continue to wear it for the 30 days post-hospital discharge. Tractivity® continually obtains activity data for up to one year on a battery and wirelessly transfers activity data via IOS Cloud systems or a Bluetooth® connection—included with the device—to a secure server for viewing by those with granted access. Investigators used tablet devices with internet capability (e.g. Smartphone, Ipad) to download ongoing step data. The Tractivity® is fully waterproof for shower use.

Independent Variables. Independent variables included 1) postural transitions during hospital stay (average number of transitions per each 24 hour period from lying to sitting and from sitting to standing), 2) percent time of each 24 hour period spent in the three postures, 3) ambulatory activity during hospital stay (average steps per each 24 hour period) and, 4) ambulatory activity 30-days post-discharge (average steps/day). Additional variables were calculated from these variables and tested for association with outcomes. The variables with description of metrics are found in Table 2 for hospital activity, and Table 3 for post-discharge activity.

Table 2. Hospital metrics

Device	Description	Computation
ActivPal		
Time lying (% 24h)	Percentage of observered period in a lying position (lying/sitting registered on both rib and thigh sensors)	(lying time/total time)*100
Time sitting (% 24h)	Percentage of day spent in a seated position (per rib sensor in standing and thigh sensor in lying position)	(sitting time/total time)*100
Time standing (% 24h)	Percentage of day spent in standing position (per rib and thigh sensor in standing position)	(standing time/total time)*100
Time stepping (% 24h)	Percentage of day stepping (per thigh sensor detecting stepping)	(stepping time/total time)*100
Lying to sitting transitions (per 24h)	Transitions from lying to sitting during the oberserved period (registered by rig sensor; normalized to 24h)	(lie to sit/Freq[a])*1440
Sitting to standing transitions (per 24h)	Daily average of transitions from sitting to standing	(sit to stand/Freq)*1440
Tractivity		
Active time[b] (% 24h)	Time spent in ambulation during the observed period	(Total active minutes/total time)*100
Steps (% 24h)	Steps registered during the observed period	(Total steps)/(Total hrs/24)

a. Frequency = number of minutes in each participant's hospital data set

b. Active time = any minute in which 10 or more steps were taken

Table 3. Post-discharge metrics

Device	Description	Computation
Tractivity		
Steps (per day)	Steps per day during the post-discharge 30 day oberservation period; Non-wear and partial wear days excluded (e.g., day of discharge, day of readmission)	Total steps/Total days
Initial 5d post-discharge change (% change)	Moving daily % change in steps over the first 5 days following discharge	AVG [(day 2 steps - day 1 steps)] [(day 3 steps - day 2 steps)]…
Daily excursions above the mean of post-discharge observation period (% days)	The number of days the individual ambulated 2 standard deviations above their post-discharge observation mean	(Days > 2SD/Total Days)*100
Change in steps (% change)	Change between initial 5d average and final 5d average of post-discharge observation period	[(last 5 days steps - 1st 5 days steps) /1st 5 days steps]*100

Outcome Variables

- Incidence of 30-day hospital readmission: This was self-reported by patient and adjudicated via medical chart review. Any unexpected hospital readmission to any inpatient facility for any reason within 30 days of discharge was viewed as a readmission. Planned procedures within the 30 day period were excluded as readmission.
- Lower extremity function and change in function: Physical function level was measured on the day after discharge and at 30 days post discharge with the TUG and SPPB test. To minimize fatigue and enable each participant to complete the tests to the best of their ability, only one measured performance was attempted for each test. Investigators explained fully, and demonstrated each test measure and answered any questions prior to the participant completing each measure. Both the TUG and SPPB have been used extensively to evaluate older adult's physical performance in various clinical settings (Volpato et al., 2008; Wong & Miller, 2008). The TUG focuses on lower extremity strength and function, which has been associated with mobility disability, hospitalization and mortality (Volpato et al., 2011). The activity requires the participant to rise from a chair, walk a short pre-determined distance (three meters for this version), turn around and walk back to the chair and sit down. There are age, gender and research-based normative values to compare results. Older adults who take longer than 13.5 seconds to complete the TUG are considered at a

higher risk for falls. TUG time is also significantly associated with hospital length of stay (p<.001) (Wong & Miller, 2008). The SPBB is a physical performance measure of balance, walking speed, and lower body strength with a summative scale. The tasks include assessments of standing balance in three positions (side-by-side, semi-tandem, and tandem), normal walking speed (over a three meter course), and up to 5 consecutive unassisted chair stands. SPPB scores have been consistently associated with significant differences in self-perceptions of health and dependency in ADLs (Guralnik et al., 1994). Scores are generally categorized as zero to four –very low physical function, five to eight—low to moderate physical function, and nine to 12—high physical function (Volpato et al., 2011). The SPPB can easily be administered in a variety of settings, has high test-retest reliability, high prediction of disability and mortality, and high sensitivity to changes in functional status (Guralnik et al., 2000). The battery has an excellent safety record. It has been administered to over 20,000 persons in various studies and no serious injuries are known to have occurred. These outcome variables were measured as continuous.

- Upper extremity function and change in function: Hand-grip test (measured by hand dynamometer) was administered the day after discharge and at 30-days post discharge. The hand grip measurement test has been shown to accurately predict ADL dependence in both healthy older adults and the chronically ill (Rantanen, Avlund, Suominen, Schroll, Frandin, & Pertti, 2002a). Poor hand-grip strength has been demonstrated to accelerate the older adult's dependency in physical function (Taekema, Gussekloo, Maier, Westendorp, & de Craen, 2010). Furthermore, poor hand-grip strength is associated with an increased risk of rehospitalization after discharge (Cawthon et al., 2009). Measuring hand-grip strength by dynamometry has high test-retest reliability (ICC > 0.9) and high correlation with results of the six-meter walking test in older adults (Reuter, Massy-Westropp, & Evans, 2011). This was a continuous variable.

Due to the small sample size, inclusion of all possible data was preferred. If a participant was not able to perform one or any of the functional assessments, a score was generated for them based on the highest (for TUG) or lowest (for SPPB and handgrip test) recorded score at the conclusion of the study. For each test not performed, a value of one was added or deducted from the highest or lowest score in the data for that test and assigned to the participant.

Study Covariates. Covariates included in this analysis have been selected due to their confounding effects on hospital readmission and physical function/activity. Covariates included age, marital/living status, heart failure severity based on diagnostic results, number of comorbid conditions, number of restrictive conditions, number of medications while hospitalized, general nutritional status, and reported sleep quality. All covariates were added to the model and eliminated only if p > 0.20 to protect against residual confounding (Budtz-Jorgensen, Keiding, Grandjean, & Weihe, 2007; Maldonado & Greenland, 1993).

- Demographic information—age, gender, height/weight, race, marital status. These variables influence health outcomes; the more aged adult has poorer outcomes in most health conditions; Age, height and weight will be measured as continuous variables; gender and marital status will be measured as dichotomous, and race will be categorical;
- Severity of diagnosis based on current ejection fraction (EF) and admission laboratory result of b-type natriuretic peptide (BNP); Illness severity influences care protocols and patient outcomes. These results were obtained through medical chart review. If participant did not have a documented EF, the attending cardiologist was queried for his/her expert medical opinion for approximate EF and this was recorded. Participants who did not have BNP level result (not obtained) were documented as "not done"; These were measured as continuous variables;
- Number of comorbid conditions—a higher number of comorbid conditions negatively affects physical function and recovery; These were grouped according to system for description and collapsed as a continuous variable for analysis;
- Nutritional status—inadequate nutritional status and nutrition during hospitalization contributes to loss of muscle strength and function (Salvi et al., 2008). This was measured at two weeks post-discharge via patient interview using the Mini Nutritional Screener (MNA) (Guigoz, Lauque, & Vellas, 2002). The MNA is a validated nutrition

screening and assessment tool that can identify adults age 65 and older who are malnourished or at risk of malnutrition. It correlates highly with clinical assessment and objective indicators of nutritional status (albumin level, BMI, energy intake, and vitamin status) (Guigoz et al., 2002). The indicator score is 24-30 points for normal nutrition intake; 17-23.5 points for at risk of malnutrition, and < 17 points for malnourished. This covariate was analyzed as a continuous variable;

- Number of medications prescribed in the hospital—five or more medications in older adults are associated with poorer functional outcomes while hospitalized; this was measured as a continuous variable;
- Reported sleep quality history—altered sleep patterns and lack of sleep are associated with alterations in cognition and increased fatigue in older adults (Flaherty, 2008). Sleep quality was measured two weeks following discharge via patient interview using the Insomnia Severity Index (ISI) questionnaire, a clinical screener for insomnia. The questionnaire has been tested in the clinical population with an internal consistency of 0.74 and is sensitive to detect changes in patient's perceptions of sleep (Bastien, Vallieres, & Morin, 2001). Sleep quality was measured continuously;
- Number of restrictive events/devices—the use of restrictive devices significantly alters mobility patterns in the hospital; if at any time during the hospital stay the patient was administered continuous

intravenous fluids, oxygen, a urinary catheter was used, a bed alarm was placed, or other similar equipment was used that may restrict movement, their record was marked with restrictive device. This variable was reported as continuous;

- Length of stay—length of stay in the hospital is negatively associated with mobility and functional outcomes in adult patients; length of stay was measured as continuous days and was obtained from medical record review after discharge and was reported as continuous and categorical for descriptive and analysis purposes.

Statistical Analysis

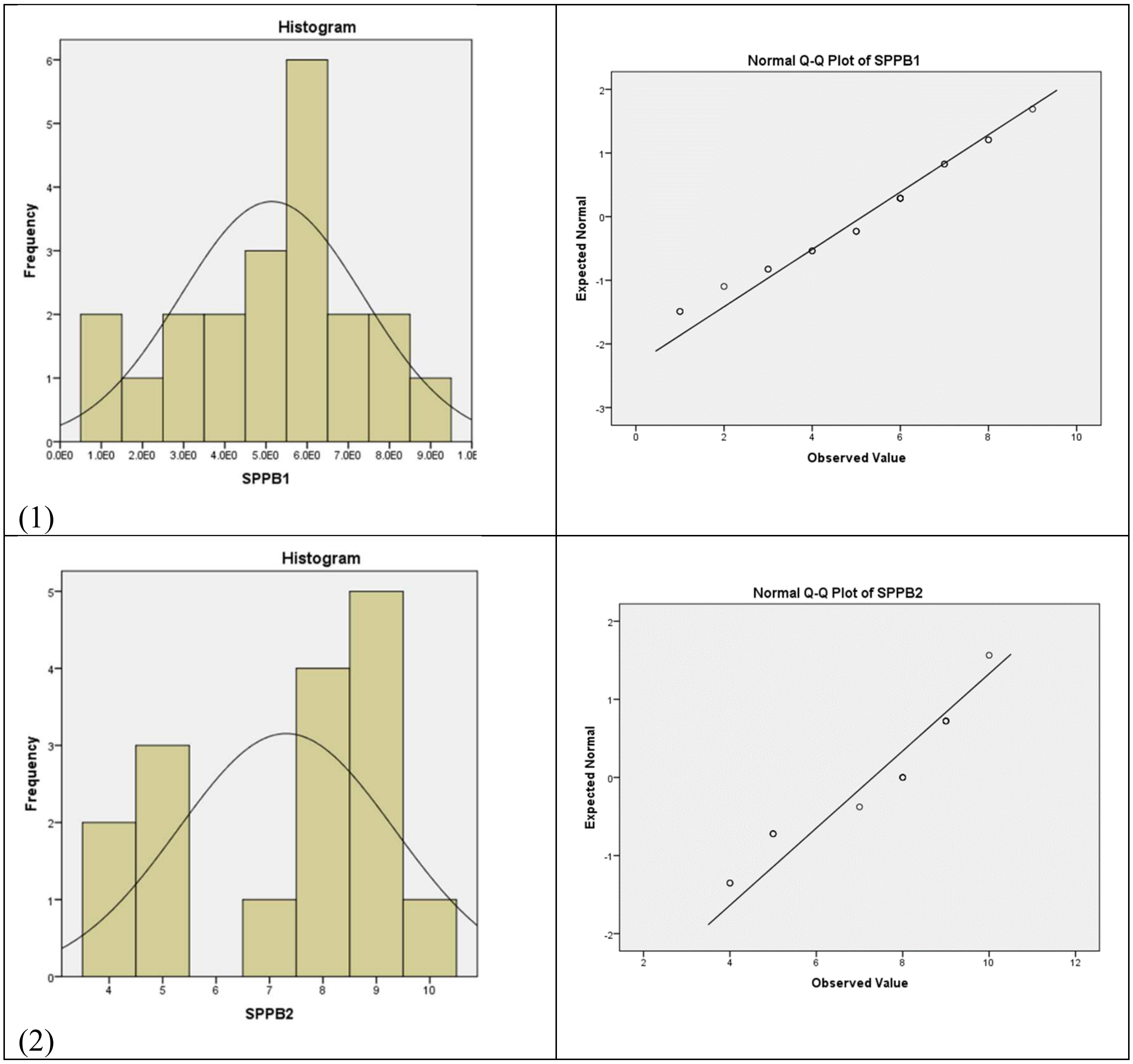
Descriptive statistics are reported as mean ± SD and with frequencies or percentages. Outcome variables were 30-day hospital readmission (dichotomous), lower physical function level (continuous), and grip strength (continuous). All continuous outcomes were tested for normal distribution and transformed if necessary (e.g., square root, natural log, or inverse transformation). All analyses were performed using SPSS statistical software version 21.0 (SPSS Inc., Chicago, IL) and SAS version 9.3 (SAS Institute, Cary, NC). Dichotomous outcomes were analyzed by logistic regression analyses to test the effect of each independent predictor after adjustment for all study covariates and were summarized with odds ratios and their 95% confidence intervals (CI). For continuous outcomes, multiple linear regression analyses were performed and were summarized with predictor-level metrics including beta coefficients and p-values and their 95% CI. Statistical significance was set at a two-tailed p value <.05.

Aim 1. Raw activPAL™ data from the manufacturer's software were exported to an Excel spreadsheet using 15-second epoch time recording. Using SAS software version 9.3 (SAS Institute, Cary, N. C.) data were then merged from the rib and thigh device for each participant based on timestamp and classified as the number of minutes per day and percentage of recorded time per day spent in each of the three postures: lying, sitting, and standing. Next, the number of transitions were calculated from each device: lying to sitting from activPAL on the rib, and sitting to standing from the activPAL on the thigh. Step data from Tractivity® were exported by the vendor and entered into each participant's Excel file. Hospital data included daily and hourly step counts. Steps per 24 hours were calculated for hospital ambulatory time.

Aim 2. Ambulatory activity (step data) were exported from Tractivity® by the vendor and entered into each participant's Excel file. Step data were then entered into logistic and linear regression models after adjusting for all study covariates (including baseline values of the functional outcome variables in order to model change in the outcome), postural transitions, and ambulatory activity measured during hospitalization.

Normality Testing

A Shapiro-Wilk's test (p >.05) and visual inspection of their histograms and Q-Q plots was performed for all outcome variables. SPPB scores for the first and 30-day post-discharge visit were normally distributed with a skewness of -0.38 (SE = 0.50) and kurtosis of -0.41 (SE = 0.97; p = .37) for first visit and skewness of -0.60 (SE = 0.56) and kurtosis of -1.21 (SE = 1.09; p = .10) for 30-day visit (Figure 3).



(1)

(2)

Figure 3. Histogram and Q-Q plot for untransformed data for SPPB scores, first day post-discharge visit (1) and day 30 visit (2).

Right handgrip strength for both first and 30-day visit were normally distributed with a skewness of -0.17 (SE = 0.50) and kurtosis of -1.13 (SE = 0.97; p = .33) for first visit and skewness of 0.06 (SE = 0.56) and kurtosis of -0.86 (SE = 1.09; p = .67) for 30-day visit (Figure 4).

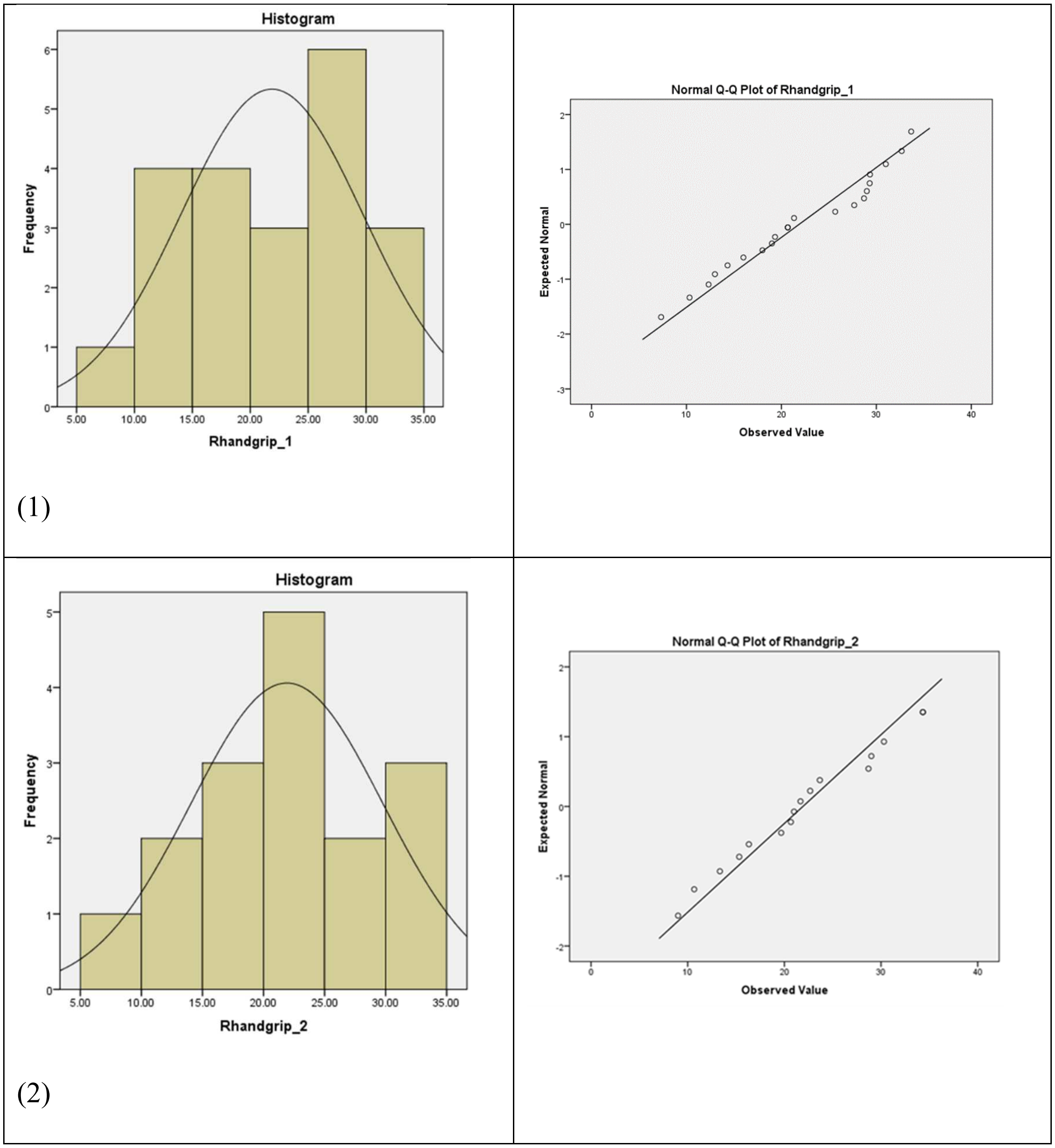


Figure 4. Histogram and Q-Q plot for untransformed data for right hand grip strength test, first day post-discharge visit (1) and day 30 visit (2).

TUG scores were non-normally distributed, thus transformation was necessary. Natural log, Log10, and square root functions were applied and normality did not improve. Inverse transformation was required to normalize the data (Figure 5). TUG first visit inverse transformation resulted in skewness 0.76 (SE = 0.50), kurtosis 0.81 (SE = 0.97; p = .13); and 30-day TUG skewness -0.52 (SE = 0.56), kurtosis 0.77 (SE = 1.09; p = .65; Figure 5).

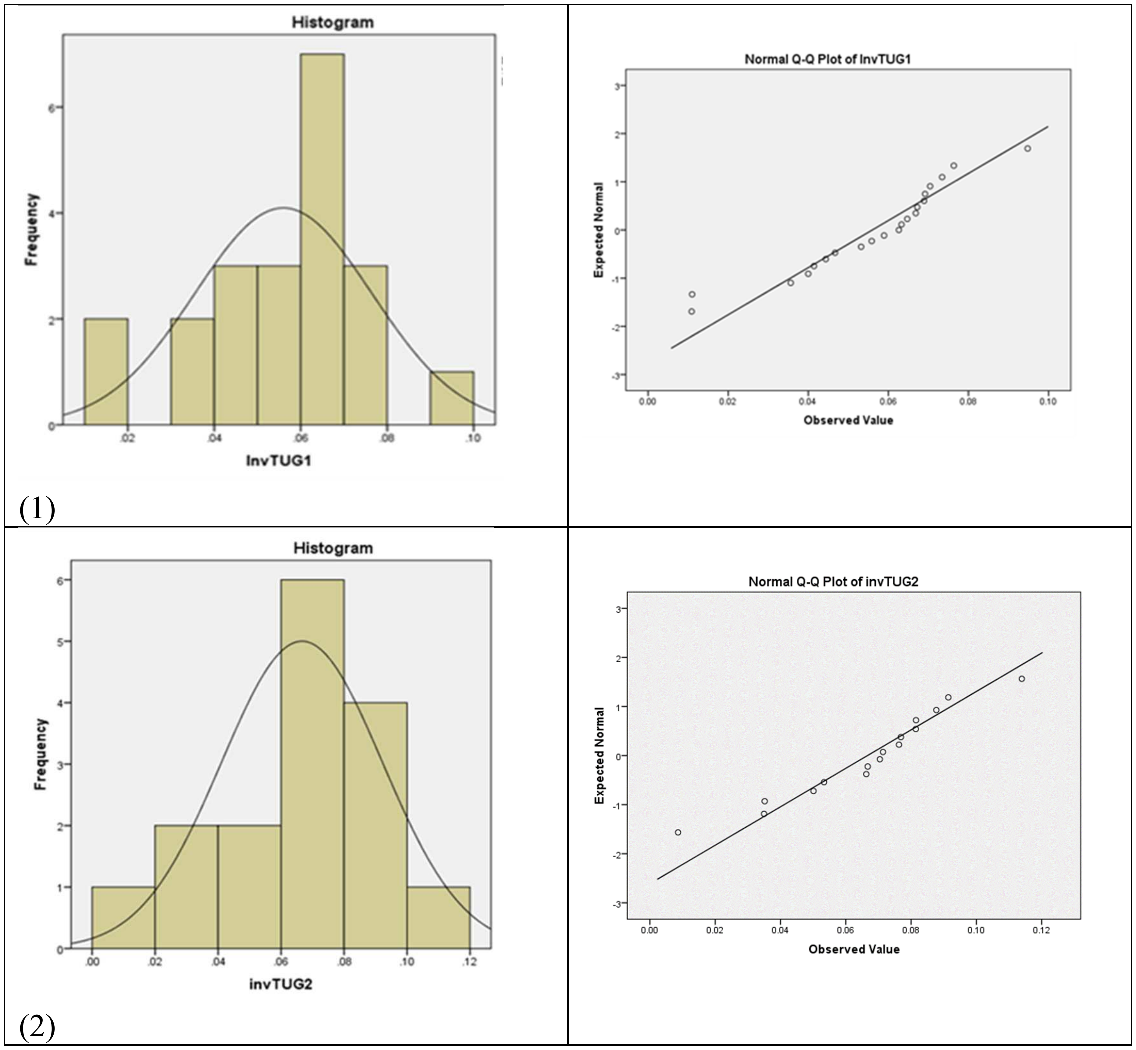


Figure 5. Histogram and Q-Q plots for TUG, first day post-discharge visit (1) and 30-day visit (2). Inverse transformation performed to normalize data.

Data Selection for Prediction Models

Independent variables. There were high correlations observed between some derived activity measures (Table 4). It is recommended that independent variables with a bivariate correlation more than .70 not be included in multiple regression analysis (Tabachnick & Fidell, 2001). Active time and steps per 24 hours were strongly correlated, therefore steps per 24 hour was selected for use in prediction models, as most of the literature reports this outcome. Percent time lying was highly correlated with percent time sitting. As the literature supports greater negative consequences of reduced mobility in older adults, and lying is the highest form of immobility, percent time lying was selected for inclusion in the models. Lastly, percent time sitting and number of lying to sitting transitions were also highly correlated. As Aim 1 investigates postural transitions, the postural transition lying to sitting was selected for inclusion in the models.

Table 4. Pearson correlation coefficients between hospital mobility/activy measures

	Active time per 24h	Steps per 24h	Time lying (% 24h)	Time sitting (% 24h)	Time standing (% 24h)	Time stepping (% 24h)	Lying to sitting transitions (per 24 h)	Sitting to standing transitions (per 24h)
Active time per 24h								
Steps per 24h	$.99^{**}$							
Time lying (% 24h)	-.29	-.28						
Time sitting (% 24h)	.08	.06	$-.89^{**}$					
Time standing (% 24h)	$.56^{**}$	$.56^{**}$	.04	-.09				
Time stepping (% 24h)	.25	.27	-.27	-.19	-.15			
Lying to sitting transitions (per 24h)	-.19	-.15	$.67^{**}$	$-.75^{**}$	.08	.14		
Sitting to standing transitions (per 24h)	.36	.36	-.17	.11	$.56^{**}$	-.05	.05	

$^{**}p < .01$.

Covariates. Ejection fraction (EF) percentage was highly correlated with b-type natriuretic (BNP) laboratory values (r = .72). Both measures are accurate clinical indicators of the severity of heart failure. Four participants were missing BNP values in the clinical record. EF was either assessed during the hospitalization with an echocardiogram or a recent (within six months) EF percentage was brought forward from a previous medical visit and supported by attending cardiologist opinion. EF was selected as the covariate to include in regression analysis as there were no missing values and also to eliminate redundancy.

All covariates were added to each model predicting readmission and functional outcomes. In order to reduce the number of covariates in a given model and to preserve statistical power, a p value criterion of $p < 0.2$ was established for inclusion of the covariate in the model. Tables 4 and 5 show the variables that were retained according to this criterion. This approach allows variables of importance to be investigated for associations with outcomes while reducing confounding effects and preserving power (Maldonado & Greenland, 1993).

Table 5. Covariates selected for Aim 1 (hospital) prediction models

Dependent Variables	Covariates[a]
Readmission	Number medications, nutrition status
Physical function at 30 days[b]	
TUG	Age, EF[c], marital status, number restrictive devices, sleep quality
SPPB	Age
Hand-grip strength	Gender, age, EF, nutrition status, living alone

a. Covariates selected based on p value < 0.2

b. Functional level measured by TUG, SPPB, and hand-grip strength

c. Ejection fraction

Table 6. Covariates selected for Aim 2 (post-discharge) prediction models

Dependent Variables	Covariates[a]
Readmission	Number medications, nutrition status
Change in physical function[b]	
TUG score	LOS[c]
SPPB score	None
Handgrip strength	None

a. Covariates selected based on p value < 0.2

b. Change in function from 1st visit to 30 day visit

c. Length of stay in hospital

CHAPTER 4

RESULTS

Sample

Participant flow is described in Figure 6. One hundred fifteen patient records were reviewed for eligibility. Fifty patients met initial screening criteria and were approached by the investigator for further screening. Forty-eight patients met full eligibility criteria and were invited to participate in the study. Twenty-two patients consented to participate in the study—18 patients admitted to North Mountain hospital and four admitted to Deer Valley hospital. Those who declined to participate were similar to the sample in age, race, and comorbid status. Of the 22 enrolled, one patient was discharged from the hospital to a skilled nursing facility therefore no longer met eligibility criteria. There was no drop out from the study. All participants discharged to home either completed the 30-day post-discharge period or were readmitted, which was the end point for their participation. Of the 21 patients discharged to home, five were readmitted (23.8 percent) within the 30 day post-discharge period—with one readmission occurring within 48 hours of discharge. Two participants had emergency department visits but were discharged home, and 14 had no readmission events.

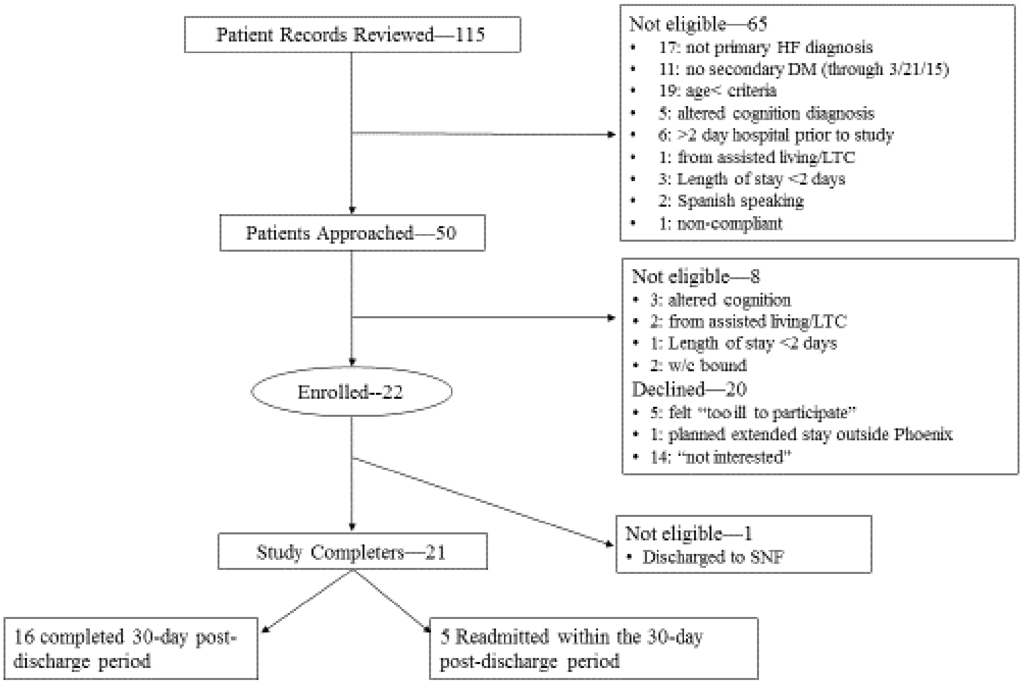


Figure 6. Flow Diagram of Participant Recruitment and Retention

Demographic Characteristics

Table 7 shows participant demographics and health history at admission to the hospital stratified by heart failure severity status. All participants were admitted through the emergency department. The sample was predominantly white with equal gender representation and an age range of 60 to 97 years. For descriptive purposes, heart failure category was categorized into 'mild' and 'moderate/severe' using ejection fraction criteria from the American Heart Association (AHA) (AHA, 2015). Those with lower EF values had more comorbidities. The five participants who were readmitted within the 30 day post-discharge period had similar demographics and health histories compared to the other participants. Three of the readmitted had moderate/severe heart failure, while two had mild heart failure. Two-thirds of participants lived with their spouse or family member(s) and one-third lived alone. Four of the readmitted participants lived alone while one lived with their spouse.

Table 7. Demographics and health history of heart failure participants (N = 21)

	Mild Heart Failure[a] (N = 11)	Moderate/Severe Heart Failure (N = 10)	Total
Characteristic	N (%)	N (%)	N (%)
Age, M ± SD	81.75 ±9.97	74.73 ± 10.05	78.00 ± 10.40
Younger (60-79yrs)	5 (45.5)	6 (60.0)	11 (52.4)
Older (80+ years)	6 (54.5)	4 (40.0)	10 (47.6)
BMI, M $\underline{+}$ SD	24.51 ± 4.59	28.38 ± 4.99	26.40 ± 5.07
Gender			
Male	2 (18.2)	7 (70.0)	9 (42.9)
Female	9 (81.8)	3 (30.0)	12 (57.1)
Race/Ethnicity			
Hispanic	0 (0.0)	2 (20.0)	2 (9.5)
African American	0 (0.0)	0 (0.0)	0 (0.0)
White	11 (100.0)	8 (80.0)	19 (90.5)
Marital status			
Married	3 (27.2)	4 (40.0)	7 (33.3)
Widowed	7 (63.6)	5 (50.0)	12 (57.1)
Single	0 (0.0)	0 (0.0)	0 (0.0)
Divorced	1 (0.09)	1 (10.0)	2 (9.5)
Living alone			
Yes	4 (36.4)	3 (30.0)	7 (33.3)
No	7 (63.6)	7 (70.0)	14 (66.7)
Comorbidities, M ± SD	4.73 ± 2.28	5.3 ± 2.50	5.00 ± 2.26
Hypertension	8 (72.7)	9 (90.0)	17 (81.0)
Atrial fibrillation	5 (45.5)	3 (30.0)	8 (38.1)
History of MI	0 (0.0)	1 (10.0)	1 (4.7)
Diabetes	2 (18.0)	5 (50.0)	7 (33.3)
Arthritis	4 (36.4)	0 (0.0)	4 (19.1)
Renal disease	2 (18.0)	3 (30.0)	5 (23.8)
COPD	3 (27.2)	3 (30.0)	6 (28.6)
Depression	2 (18.0)	0 (0.0)	2 (9.5)
Ejection Fraction[b] %, M ± SD	55.00 ± 5.00	27.50 ± 8.58	41.90 ± 15.61
<30 (severe HF)	0 (0.0)	5 (50.0)	5 (23.8)
30-40 (moderate HF)	0 (0.0)	5 (50.0)	5 (23.8)
45-55 (heart damage/mild HF)	7 (63.6)	0 (0.0)	7 (33.3)
>55 (normal)	4 (36.4)	0 (0.0)	4 (19.1)
BNP levels on admission, M ± SD	601.25 ± 259.06	1716.94 ± 1074.65	1191.90 ± 967.61
< 100 (normal)	0 (0.0)	0 (0.0)	0 (0)
101-300 (HF detected)	1 (9.1)	0 (0.0)	1 (4.7)
301-600 (mild HF)	3 (27.3)	2 (20.0)	5 (23.8)
601-900 (moderate HF)	3 (27.3)	0 (0.0)	3 (14.3)
> 900 (severe HF)	1 (0.0)	7 (70.0)	8 (38.1)
not performed	3 (27.3)	1 (10.0)	4 (19.1)

a. EF value ranges for mild heart failure > 40, moderate/severe heart failure 40 > (American Heart Association, 2015)

b. EF reported in percentage of volume

Table 8 shows characteristics for the participants while hospitalized. The average hospital length of stay was almost five days with a median stay of 3.9 days.

Table 8. Hospital characteristics of participants (N = 21)

	Mild Heart Failure[a] (N = 11)	Moderate/Severe Heart Failure (N = 10)	Total
Characteristic	N (%)	N (%)	N (%)
Length of Stay, days			
M ± SD	4.27 ± 2.57	5.74 ± 2.53	4.90 ± 3.84
Median	3.8	4.2	3.9
Range of days	2.2 - 10.6	2.5 - 19.0	2.2 - 19.0
Use of Restrictive Devices			
IV	9 (81.8)	7 (70.0)	16 (80.9)
Oxygen	5 (45.5)	5 (50.0)	10 (47.6)
Urinary catheter	1 (9.1)	2 (20.0)	3 (14.3)
Sequential Compression Device	1 (9.1)	1 (10.0)	2 (9.5)
Bed alarm	2 (18.2)	1 (10.0)	3 (14.3)
None	0 (0.0)	3 (30.0)	3 (14.3)
Medications			
Beta-blocker	10 (90.9)	8 (80.0)	18 (85.7)
ACE inhibitor	3 (27.3)	3 (30.0)	6 (28.6)
Calcium channel blocker	6 (54.6)	0 (0.0)	6 (28.6)
Diuretic	9 (81.8)	9 (90.0)	18 (85.7)
Antidepressant/anti-anxiety	2 (18.2)	1 (10.0)	3 (14.3)
Total # of Medications, M ± SD	7.73 ± 2.28	7.5 ± 1.51	7.62 ± 1.91
1 to 5	2 (18.2)	0 (0.0)	2 (9.5)
6 to 10	7 (63.3)	10 (100.0)	17 (80.9)
>10	2 (18.2)	0 (0.0)	2 (9.5)

a. EF value ranges for mild heart failure > 40, moderate/severe heart failure 40 > (American Heart Association, 2015)

Hospital Postural and Ambulatory Activity

ActivPAL^{TM} data for the entire hospital period (after consent) was obtained on 19 of the 21 participants. Two activPALs^{TM} were lost on two participants during the hospital stay. The devices were replaced and partial stay activity was captured for those participants and are included in analysis (resulted in 30% of possible total data collection for one participant and 67% for the second participant). Non-matched activPAL^{TM} data (based on merging of the two devices) were not analyzed. Hospital ambulatory activity captured by Tractivity® was obtained for all participants with no missing data.

Table 9 shows hospital activity data for the participants by heart failure diagnosis severity. Participants spent a great majority of their hospital time lying in bed. Those with mild heart failure recorded more lying time, however adults with moderate to severe heart failure often remain upright to aid in breathing and oxygenation. Ambulation time was low. Mean steps during hospitalization was higher for participants with moderate to severe heart failure; however, there were two more active individuals in this category and differences between groups were non-significant. Median step count was higher in participants with mild heart failure, despite their higher age. Several participants (N = 9) registered less than 100 steps for at least one 24 hour period of the hospital stay. One participant had three of their 10 hospital days with 100 percent time lying in bed. Steps in the hospital per 24 hour period were similar between those who were readmitted and those who were not.

Table 9. Percent of hospital day in the three postures, number of posture transitions, and steps per day

	Mild heart failure[a] (N = 11)	Moderate/Severe heart failure (N = 10)	Total
Posture (% per 24h), M ± SD			
Time lying	70.68 ± 17.45	55.74 ± 21.90	63.57 ± 20.65
Time sitting	21.25 ± 14.75	39.54 ± 21.54	29.96 ± 20.13
Time standing	4.01 ± 2.04	5.51 ± 3.81	4.79 ± 3.04
Time ambulating	4.29 ± 13.41	0.25 ± 0.16	0.47 ± 0.99
Number of posture transitions per 24h, M ± SD			
Lying to sitting	27.84 ± 14.66	19.72 ± 13.28	23.97 ± 14.28
Sitting to standing	18.14 ± 11.00	15.28 ± 9.78	18.58 ± 10.19
Number of steps per 24h, M ± SD	1027.45 ± 671.68	1526.70 ± 1403.12	1265.19 ± 1084.80
Median	965	917	965
Minimum	54	428	54
Maximum	2524	5024	524

a. EF value ranges for mild heart failure > 40, moderate/severe heart failure 40 > (American Heart Association, 2015)

Post-Discharge Activity

Participant results for the 30 day post-discharge period are shown in Table 10. Participants had high wear time of Tractivity® post-discharge (> 96%). Participants were queried if they wore the device for at least 10 hours each day. Any day with < 10 hours of observed Tractivity® wear was removed from analysis. One participant had 11 days of non-wear, one had three days, and another had two days of non-wear due to misplaced or lost devices. If the device was lost a new device was initialized and placed by the investigator. One participant had three days of undercounted steps due to technology error as the device was not situated in the appropriate band by the investigator. These days were removed from analysis. One individual completed study participation at 25 days due to a planned hospital admission and their full data are included in the analysis. Overall, mean step activity was just under 5000 steps. Although there was a wide step range overall between participants, there was low variability in daily stepping within participants. Participants in both heart failure categories increased their mean step count over the first five days post-discharge. Participants with mild heart failure had a larger step increase over the 30 day post-discharge period than those with moderate/severe heart failure, increasing their mean steps from the first five days to the last five days by 37 percent versus six percent, though the difference was non-significant due to small sample size. The four participants who were readmitted after being home for at least five days had similar percent change in steps the first five days with those who were not readmitted.

Table 10. 30 day post-discharge step activity

Measure	N[a]	Mild heart failure[b]	Moderate/Severe heart failure	Total
Steps during 30d post-discharge period[c], M ± SD	20	4888.71 ± 2869.21	4816.22 ± 1962.37	4856.09 ± 2440.40
(Median, Min, Max)		(4182, 2009, 11104)	(5300, 1472, 7736)	(4741, 1472, 11104)
Steps 1st five days post-discharge, M ± SD	20	3789.91 ± 1793.54	4500.44 ± 1828.21	4109.65 ± 1797.75
(Median, Min, Max)		(3263, 2097, 7954)	(4449, 1551, 7736)	(3627, 1551, 7954)
Steps last five days post discharge[d], M ± SD	16	5189.11 ± 3443.89	4941 ± 1415.13	5080.94 ± 2672.57
(Median, Min, Max)		(4966, 1255, 12177)	(5626, 3174, 6296)	(5296, 1255, 12177)
% change in steps over 1st five days, M ± SD	20	21.22 ± 16.94	15.27 ± 13.79	18.54 ± 15.51
(Median, Min, Max)		(16.94, -2.47, 60.10)	(13.25, -5.72, 38.64)	(14.99, -5.72, 60.10)
% change 1st week to last week[d], M ± SD	16	37.08 ± 61.43	6.19 ± 23.56	25.04 ± 46.79
(Median, Min, Max)		(32.05, -50.62, 148.20)	(5.82, -34.30, 34.17)	8.89. -50.62, 148.20)
% daily excursions 1SD above the 30 day mean[d], M ± SD	16	10.63 ± 3.21	13.69 ± 3.80	11.97 ± 3.70
(Median, Min, Max)		(10.00, 6.70, 15.80)	(13.80, 6.70, 17.90)	(11.30, 6.70, 17.90)
% daily excursions 2SD above the 30 day mean[d], M ± SD	16	0.73 ± 1.45	3.53 ± 2.99	1.96 ± 2.60
(Median, Min, Max)		(0.00, 0.00, 3.30)	(3.30, 0.00, 7.70)	(0.00, 0.00, 7.70)

a. N not equal across measures as participants were readmitted as early as two days post-discharge to 14 days post-discharge

b. EF value ranges for mild heart failure > 40, moderate/severe heart failure 40 > (American Heart Association, 2015)

c. Average steps for 30-day post discharge period or period prior to readmission if at least five days of post-discharge data

d. N = 16; does not include readmitted patients

Functional Outcomes

Functional outcomes for comparison of post-discharge day 1 and 30 days post-discharge were obtained on the 16 participants who completed the study period (Table 11). Overall, participants significantly decreased their walking time (TUG) ($p <.001$) and significantly increased their SPPB scores ($p < .001$) from post-discharge day 1 to day 30. Handgrip strength only slightly increased between time points. Percent improvements in all the functional outcomes over the 30 day period were similar between groups.

Table 11. Functional outcomes during post-discharge period (N = 16)

	Mild heart failure[a]	Moderate/Severe heart failure	Total
TUG (sec)			
Post dc day 1, M ± SD	35.33 ± 32.16	16.54 ± 4.15	27.11 ± 25.51
(Median, Min, Max)	(18.80, 14.20, 92.00)	(15.90, 10.55, 22.54)	(17.44, 10.55, 92.00)
Post dc day 30, M ± SD	28.84 ± 33.35	13.19 ± 3.21	21.99 ± 25.71
(Median, Min, Max)	(14.99, 11.40, 116.00)	(12.80, 8.78, 21.99)	(14.11, 8.78, 116.00)
% change	-17.07 ± 125.62	-19.68 ± 8.30	-17.89 ± 18.89
(Median, Min, Max)	(-17.44, -68.90, 27.47)	(-16.78, -33.05, 10.13)	(-17.32, -68.90, 27.47)
SPPB[b] Score			
Post dc day 1, M ± SD	4.11 ± 2.37	6.00 ± 1.29	4.94 ± 2.14
(Median, Min, Max)	(4, 1, 8)	(6, 4, 8)	(5.5, 1, 8)
Post dc day 30, M ±SD	6.89 ± 2.37	7.86 ± 1.46	7.31 ± 2.02
(Median, Min, Max)	(8, 4, 10)	(8, 5, 9)	(8, 4, 10)
% change	162.22 ± 267.82	33.45 ± 26.05	105.89 ± 207.07
(Median, Min, Max)	(33.33, 25.00, 800.00)	(33.33, 0.00, 800.00)	(33.33, 0.00, 800.00)
Hand-grip Strength (kg)			
Post dc day 1, M ± SD	17.37 ± 6.91	27.24 ± 5.70	21.69 ± 8.00
(Median, Min, Max)	(16.00, 7.33, 27.67)	(29.30, 18.00, 33.67)	(21.00, 7.33, 33.67)
Post dc day 30, M ± SD	17.74 ± 6.55	27.29 ± 6.13	21.92 ± 7.86
(Median, Min, Max)	(16.33, 9.00, 29.00)	(28.70, 20.67, 34.33)	(21.34, 9.00, 34.33)
% change	4.57 ± 13.68	-1.57 ± 15.43	1.89 ± 14.32
(Median, Min, Max)	(4.81, -23.00, 23.00)	(1.96, -33.00, 17.00)	(3.30, -33.00, 23.00)

a. EF value ranges for mild heart failure > 40, moderate/severe heart failure 40 > (American Heart Association, 2015)

b. SPPB score range from 0 to 12, with < 6 functional dependence, 6-8 some disability, 9-12 no disability (Guralnik et al., 1994)

Regression Models

Aim One. Logistic regression analyses were conducted, adjusting for covariates as necessary (Tables 5 and 6 in methods section), to evaluate the association between postural time/transition and ambulatory activity during hospitalization and 30-day hospital readmission (Table 12). Multiple regression analyses were conducted, adjusting for covariates as necessary, to evaluate these measures in predicting functional outcomes (Table 13).

There was no association between hospital posture transition, lying time, or ambulatory time and readmission. There was a small but significant association between percent lying time and TUG. Participants who had a higher percent of lying time ambulated slower on the TUG test at 30 days post-discharge. The prediction model is depicted in Figure 7. Percent lying time was also associated with handgrip strength at 30 days post-discharge. An increase in lying time was negatively associated with handgrip strength (Figure 8).

Table 12. Adjusted Associations and Odds Ratios between Hospital Mobility Metrics and Readmission (N = 21)

					95% CI	
	b	SE	p	OR	lower	upper
Readmission						
Mean steps per 24 hr	0.00	0.00	0.16	1.00	1.00	1.00
% time lying	-2.80	2.65	0.29	0.06	<-0.001	10.93
Lie to sit transitions	0.01	0.04	0.88	1.01	0.93	1.09
Sit to stand transitions	-0.03	0.06	0.59	0.97	0.87	1.08

*Model adjusted for number of medications and nutrition status

Table 13. Adjusted Associations Between Hospital Mobility Metrics and Function at 30 Days (N = 21)

				95% CI	
	b	SE	p	lower	upper
TUG					
Mean steps per 24 hr	<0.001	<0.001	0.47	<-0.001	<0.001
% time lying	0.08	0.02	0.01	0.03	0.14
Lie to sit transitions	0.00	<0.001	0.58	0.00	0.00
Sit to stand transitions	<0.001	0.00	0.46	<-.001	0.00
SPPB					
Mean steps per 24 hr	0.00	0.00	0.41	0.00	0.00
% time lying	0.41	1.63	0.81	-3.11	3.93
Lie to sit transitions	0.01	0.02	0.75	-0.04	0.05
Sit to stand transitions	0.02	0.08	0.62	-0.05	0.08
Hand grip strength					
Mean steps per 24 hr	0.00	0.00	0.53	-0.01	0.01
% time lying	-13.94	4.69	0.02	-24.59	-3.36
Lie to sit transitions	-0.10	0.09	0.32	-0.30	0.11
Sit to stand transitions	0.01	0.12	0.95	-0.26	0.27

*TUG models adjusted for age, EF, marital status, restrictive devices, and sleep quality; SPPB models adjusted for age; Hand grip strength models adjusted for gender, age, EF, living alone, and nutrition status

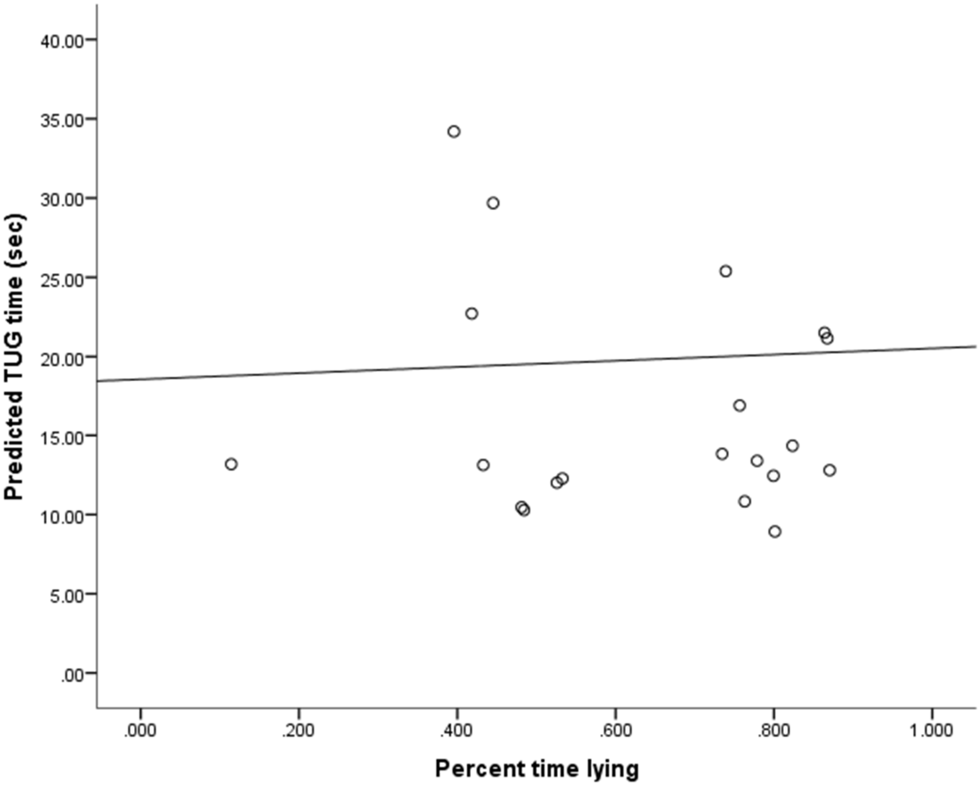


Figure 7 Association between time lying (%) and TUG scores 30 days post-discharge. TUG scores are model-based estimates. Model adjusted for age, EF, marital status, number of restrictive devices, and nutrition status.

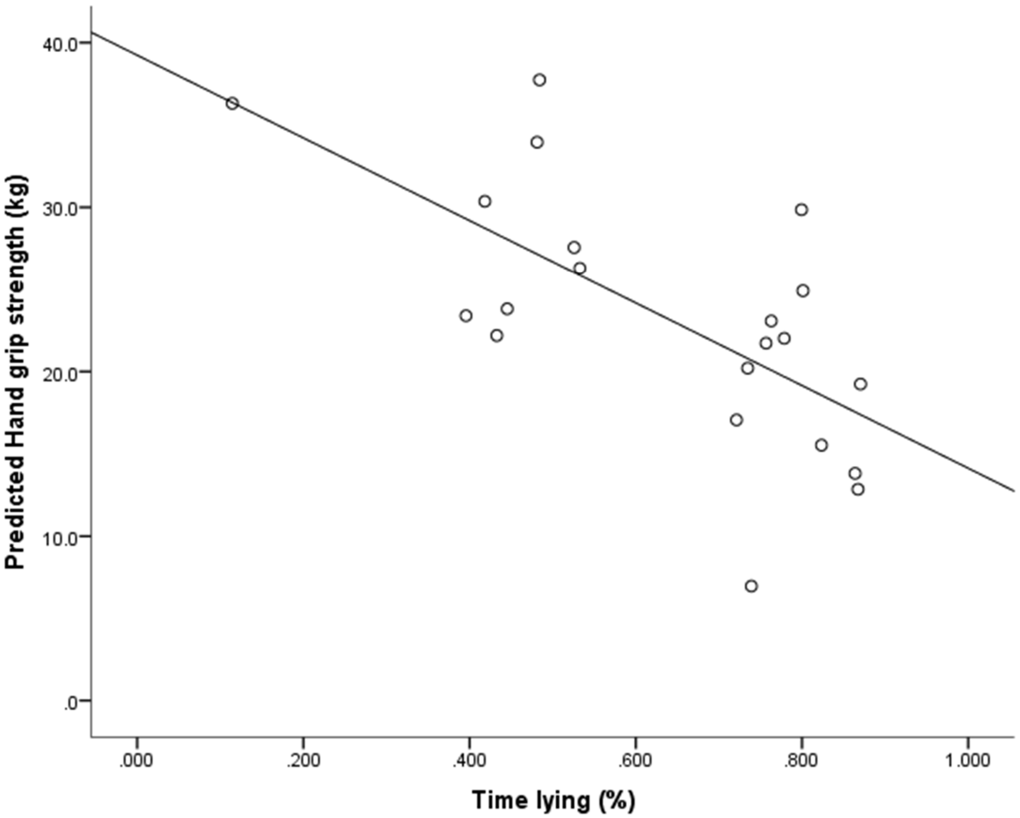


Figure 8. Association between time lying (%) and handgrip strength (kg) at 30 days post-discharge. Hand grip strength are model-based estimates. Model adjusted for gender, age, EF, nutrition status, and living alone.

Aim Two. Logistic regression was used to evaluate the association between post-discharge ambulation and 30-day hospital readmission after adjusting for covariates (Table 14). Multiple regression was used to evaluate the association between post-discharge ambulation and change in functional status after adjusting for covariates (Table 15). There were no associations between post-discharge ambulation and hospital readmission. None of the ambulatory measures showed statistical significance on functional outcomes; however, there appeared to be a trend toward association between daily number of steps for the 30 day period and change in SPPB scores (p = .06). Given the exploratory nature of this study, this warranted further investigation as it may have clinical relevance. Figure 9 shows the mean 30-day steps and comparison of groups by SPPB score increase (small increase 0-1, moderate 2-3, large 4-8) from post-discharge day 1 to day 30.

Table 14. Adjusted Associations and Odds Ratios between Selected Post-Discharge Mobility Metrics and Readmission (N = 20) [b]

					95% CI	
	b	SE	p	OR	lower	upper
Readmission						
Daily number of steps for 30 day period	<0.001	<0.001	0.67	1.00	-1.00	1.00
% change in steps 1st five days	-3.88	5.07	0.44	0.02	<-0.001	427.63
% change in steps from 1st five days to last five days[c]	—	—	—	—	—	—

*Readmission models adjusted for number of medications and nutrition status

a. Post-discharge period is 30 days or up to day of readmission or planned admission

b. One participant readmitted within 48 hours, not enough data to include

c. Readmission for the 5 participants occured within 14 days of discharge, therefore no "last 5 days" data available for analysis

Table 15. Adjusted Associations Between Change in Mobility and Function Metrics (immediately following discharge to 30-day post-discharge; N = 20) [a]

				95% CI	
	b	SE	p	lower	upper
TUG					
Daily number of steps for 30 day period	<0.001	<0.001	0.52	<-0.001	0.00
% change in steps 1st five days	-0.10	0.34	0.76	-0.83	0.62
% change in steps from 1st five days to last five days	-0.09	0.11	0.42	-0.05	0.01
Number of daily excursions 1SD above mean	0.94	1.32	0.49	-1.92	3.80
Number of daily excursions 2SD above mean	-3.01	1.73	0.11	-6.75	0.73
SPPB					
Daily number of steps for 30 day period	<0.001	<0.001	0.06	0.00	0.00
% change in steps 1st five days	0.17	3.62	0.96	-7.61	7.94
% change in steps from 1st five days to last five days	0.13	1.11	0.91	-2.25	2.51
Number of daily excursions 1SD above mean	-15.19	14.39	0.31	-46.04	15.67
Number of daily excursions 2SD above mean	-11.03	21.07	0.61	-56.23	34.17
Hand grip strength					
Daily number of steps for 30 day period	0.00	0.00	0.82	0.00	0.00
% change in steps 1st five days	0.34	0.23	0.17	-0.16	0.84
% change in steps from 1st five days to last five days	-0.01	0.08	0.92	-0.17	0.16
Number of daily excursions 1SD above mean	-0.64	1.02	0.54	-2.83	1.55
Number of daily excursions 2SD above mean	0.90	1.45	0.55	-2.22	4.01

*TUG models adjusted for Length of stay; No adjustment required for SBPB and Hand grip models

a. Participants who were readmitted were not reassessed, therefore not included in analyses.

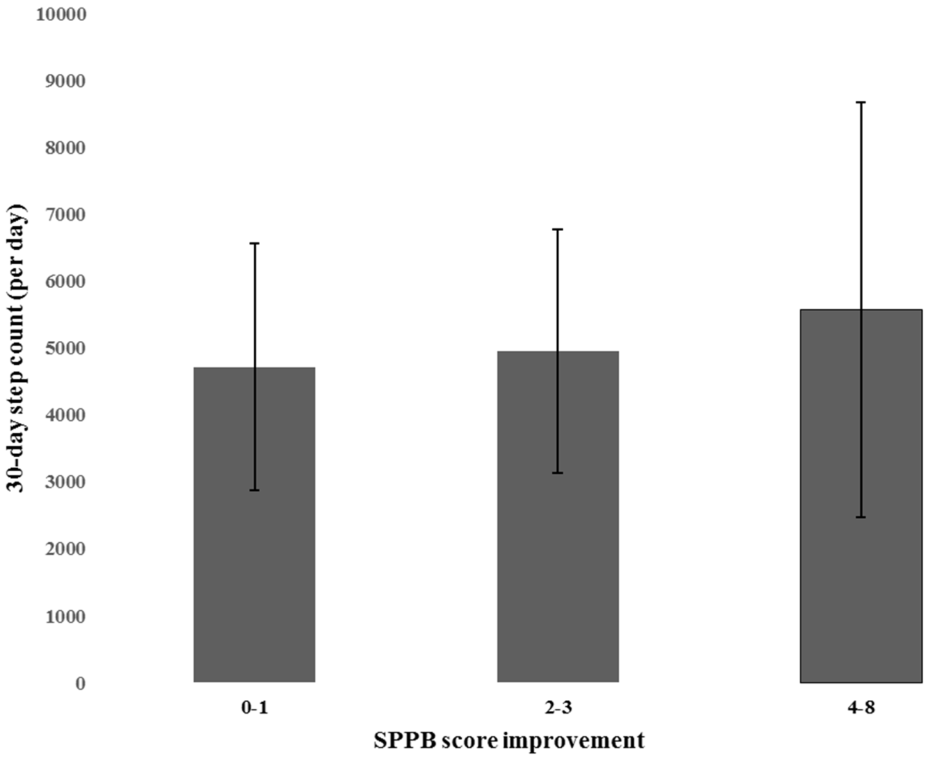


Figure 9. SPPB score improvement from post discharge day 1 to day 30 by 30-day step count. Error bars are standard deviations.

CHAPTER 5

DISCUSSION

The purpose of this study was to investigate the relationship between hospital posture and ambulation, and post-discharge ambulation, with readmission and functional outcomes at 30 days. The study findings suggest that in older patients admitted to the hospital for an exacerbation of heart failure, some mobility measures—both in the hospital and during the post-discharge period—may predict physical function or changes in physical function, but not readmission at 30 days.

Aim One – Hospital-based Results

Posture. This study shows that a sample of independent-living older adults with heart failure had very low mobility level while hospitalized, with almost 94 percent of their time in the hospital spent either lying (63.5 percent) or sitting (30 percent). The total combined lying and sitting time identified in this study is similar to other studies of older hospitalized medical patients. Brown, Redden, Flood, & Allman (2009b) were the first to use objective monitoring of activity in the hospital. They found their cohort of 45 previously independent older male veterans spent 83 percent of their time lying in bed and 13 percent sitting. Similarly, Pederson et al. (2013) found their older adult cohort hospitalized with medical illness registered 73 percent lying time and 22 percent sitting time. Though the current study cohort registered less lying time than subjects in the other studies, it may have been due to medical necessity—lying in a supine or near supine position aggravates the respiratory compromise seen in heart failure patients as increases in venous and capillary pressure cause interstitial pulmonary edema, reduced pulmonary compliance, increased airway resistance and dyspnea. Often, heart failure patients choose to remain in at least a reclined position to aid in oxygenation. This effect may be supported by the study data showing the moderate/severe heart failure group had a higher sitting time and registered 37 percent fewer lie to sit postural transitions per 24 hours than the mild heart failure group. Though the difference was non-significant, it may be an important clinical indicator of the special needs of the advancing heart failure patient. Additionally, it provides critical information about how little patients with moderate/severe heart failure may be moving. Postural transitions in the hospital for the entire study sample was very low, though none of the postural measures were significant in predicting outcomes. In particular, sit to stand transitions were lower than any other study found. In comparison, patients at a rehabilitation hospital performed an average 36 ± 17 sit to stand transitions per day, whereas healthy community-dwelling older adults registered 71 ± 25 transitions (Grant, Dall, & Kerr, 2011). Studies show that prolonged lying and sitting times are associated with a higher risk for many diseases and chronic conditions such as heart disease, diabetes, obesity, depression and cancer (Thorp, Owen, Neuhaus, & Dunstan, 2011b), and mortality (Katzmarzyk, Church, Craig, & Bouchard, 2009).

Ambulatory Activity. Step activity results from this study— a median step count of 965 steps per 24 hours—were comparable to results of other investigators using objective monitoring of ambulatory activity in hospitalized older adults. Sallis et al. (2015) report a median step count of only 968 steps in the 24 hours prior to discharge in a sample of 287 medical patients over 65 years. S. R. Fisher et al. (2011) reported an even lower median step count during hospitalization in their older medical patients, at 468 per day. Participants from this study spent less than one percent of their time in the hospital ambulating, similar to results from Pederson et al. (2013) who report 4 percent standing or ambulatory time in their cohort, and Brown et al. (2009b) who reported three percent in their study sample. No participant in this study had strict bedrest orders for any day of their hospitalization, however several registered less than 60 steps on some days. The presence of restrictive devices such as oxygen, and intraveneous lines—which are commonly used for heart failure patients—may have been factors impeding ambulation. Many participants stated they would have liked to get out of bed more often but were not able or were told not to get out of bed without assistance.

This study also confirms some of the findings from several studies showing the linear relationship between low mobility levels and lowered functional status at discharge in older adults who have been hospitalized (Brown et al., 2004; Covinsky et al., 2003; Zisberg et al., 2011). The high percent time lying in this study population showed a negative association with hand grip strength, an important measurement of upper extremity strength, and a small but significant association with increased time to complete the TUG. TUG has been widely used in clinical settings to show associations between function and mortality, LOS, and readmission in older adults (Wong & Miller, 2008). Four of the readmitted participants had baseline (one day after discharge) TUG times greater than 13.5 seconds. Several more participants took longer than 13.5 seconds to complete the test at 30 days post-discharge. Lowered functional status often precipitates the need for skilled care and prevents the older adult from returning to their home. It is also associated with higher readmission rates and mortality (Hoyer et al., 2014). Older heart failure patients already have lower activity tolerance and higher mortality rates due to their health condition (Blecker et al., 2013; Go et al., 2014). It is possible the additive effect of low mobility may accelerate these negative outcomes.

Changing posture more frequently and daily ambulation aids in circulation, return of excess fluid from extremities, and promotes oxygen transport, which support improved health during an exacerbation of heart failure. Increasing mobility level in the hospital also promotes physical strength—a vital component of physical function. Encouragement and more frequent assistance to get out of bed to chair and/or ambulate in the room or hallway is needed for older heart failure patients.

Aim Two – Post-hospitalization Results

Daily step counts for this cohort during the 30 day post-discharge period was similar to findings by Fisher et al. (2013) of older hospitalized adults. They also found no differences in stepping between those who were readmitted and those who were not. There is very little conclusive information on associations between post-discharge stepping and readmission. Tudor-Locke et al. (2011) investigated stepping activity across a range of community-dwelling older adults and found normative step counts in older adults with chronic illness of 3,500 to 5,000 steps per day, which are supported by the findings of this study. However, Cavenaugh et al. (2007) report an average 7,681 steps in their study using objective monitoring of older adults with functional limitations. Their study, using similar accelerometry, measured step activity for six consecutive days in a small group of older adults with functional limitations living independently. The limited evidence demands further investigation. The potential association with 30 day mean step count and level of function measured by the SPPB identified in this cohort may be of clinical importance. As this was identified in a small sample size, it should be investigated further.

Strengths

This study has several strengths. The use of continuous objective monitoring during hospitalization and continuing through 30 days post-discharge provided seamless data collection for accurate analysis of associations between mobility and function in the hospital and at home. The use of two activPALs^{TM} to investigate posture is a novel approach and has been reported in very few studies and has not been performed in the heart failure population until this study. Also, a majority of participants were fitted with monitors within 24 hours of admission, providing more in-depth hospital mobility data for analysis. Assessment of patient function at a consistent and immediate time (the day after discharge) for baseline data, and consistently at 30 days across the sample provides strength to the functional assessment results. Use of TUG and SPPB for functional assessment is another strength as these evaluation measures have been previously validated in similar groups, and they have been used a predictor of vulnerability in older populations. Lastly, there was equal representation of women, who are often overlooked or underrepresented in cardiovascular research.

Limitations

This study has a few limitations. The small sample size does not permit generalization. However, the primary purpose of this study was to demonstrate feasibility and to justify an investigation on a larger scale. Many of the observed results were unpowered. The majority of participants were white, which further reduces generalizability, however even in this small sample there were very similar findings in mobility to Fisher et al. (2012) who used a diverse older population. The large number of predictor variables requires a larger sample size than this study for meaningful variance. Reduction of covariates through statistically sound methods assisted in reducing this impact. Additionally, this study was a sample of convenience, however all heart failure patients were screened for eligibility and invited to participate. One patient in the study was transferred to a skilled nursing facility therefore no longer met eligibility criteria. As the sample size was very small and some patients that declined participation cited poor health, this may have resulted in biased conclusions. Using a larger sample size in future research will minimize this issue. Lastly, the use of the Katz questionnaire did not yield any relevant data as it was not sensitive enough to discriminate across the sample (some participants were somewhat dependent on family/others for cooking and cleaning) therefore no results were used. Future research should incorporate a more detailed activity assessment measure such as the Lawton Independent Activities of Daily Living Scale to better capture any dependency level at home (Graf, 2008). Lastly, as this was an observational study, causality cannot be inferred. Because of the potential for influence on outcomes from the many confounding factors that may be present in older adults with heart failure, the results should be interpreted with caution.

Feasibility of Hospital- and Community-based Objective Monitoring in Older Adults with Heart Failure

This study demonstrates the feasibility of using objective monitoring in older adults with heart failure-both while they are hospitalized for illness and as they are home recovering. Almost all of the participants—and hospital staff—felt the activity monitors were suitable to wear during care. The use of small, non-intrusive monitors, medical-grade tape/dressings, and soft, elasticized ankle bands minimizes the burden of wearing such devices. The Tractivity® monitor had very high wear time in this study. Ankle placement of accelerometers may improve wear compliance as they do not interfere with clothing at the waist or become a distraction on the wrist. This waterproof sensor can be affixed and “forgotten” by the wearer. The long-term data collection capability and usability of personal Smartphones for data download with Tractivity® or other similar accelerometers supports the use of these devices in the community without the requirement for frequent investigator follow-up.

A few activPAL™ monitors were lost during hospitalization. One participant was diaphoretic and changed positioning in bed or chair frequently that led to loosening of the tape over the device on the rib area. Another lost device from the thigh of a second participant was due to similar circumstances. A limitation of this device is the inability to download data until the device is removed from the participant, resulting in loss of data from lost devices.

There was some burden on hospital staff during this study. Investigators reviewed patient charts independently and only confirmed patient eligibility information with the primary nurse. Staff nurses made positive comments regarding the daily communication by investigators with the participants. To support our clinical partnership with the hospital organization, investigators made frequent contact with the heart failure coordinators to share progress and receive feedback.

Use of objective sensors for health monitoring may be well-accepted by older adults. Though recruitment was slower than anticipated, only a few more older adults declined to participate in the study than those who consented. This is encouraging to see that even as they are suffering an acute exacerbation of their condition, these older adults are willing to participate in research. Several cited their support for research, interest in “trying out the device”, and social connection through participation. Most of the participants stated they liked the idea of being able to share objectively obtained information about their health with their physician.

Several participants required frequent explanation of the sensors in the hospital such as the method of data collection, how to wear the devices, and care of the devices. At the study conclusion, four of 21 participants were interested in continuing with personal use of the accelerometer. One participant owned an iPad device and was able to interface with their sensor. One participant had the investigator download the software onto their computer and was able to interface. However two interested participants did not have the technology at home to interface with the accelerometer. Most participants did not wish to continue use of the accelerometer at the conclusion of the study. They cited lack of interest knowing their daily step count or activity level in the long-term, lack of knowledge or desire to manage the accelerometer by themselves, and inconvenience of wearing the device long-term. Difficulty or disinterest in engaging with digital devices by older adults is commonly cited in the literature (Callaria, Ciairanob, & Rea, 2012; Delello & McWhorter, 2015).

Future Directions

This study should be replicated in a larger sample size of older heart failure patients to confirm findings from this study and to identify other significant associations between posture, mobility, and readmission and functional outcomes. A longer follow-up period after discharge should also be incorporated to evaluate associations long-term. Additionally, the preliminary findings of this study indicate that those with moderate/severe heart failure may be more sedentary than mild heart failure. It may be prudent to investigate associations specifically in this group. Postural findings from this study indicate the need to investigate further the potential for interventions focusing on increasing movement in bed and out of it. For heart failure patients suffering an exacerbation, it is very possible they may not be able to ambulate much during a hospital stay due to their physiologic condition. Interventions to promote posture changes may support this population's mobility level until their health condition is improved. Wearable monitors may be used to aid nursing and other healthcare personnel to capture real-time data on time-in-posture or ambulatory status for their patients. This objective information could inform staff about appropriate times for repositioning, assisting out of bed or ambulation in the hallway, for example. Additionally, future research should focus on identifying key time points of ambulatory change in the transition to home that may indicate a decline in health status of the older adult. Heart failure patients experiencing an exacerbation may have notable changes in stepping activity due to fatigue. The ability to identify a decline prior to a critical emergency may reduce the need for hospital admission or promote faster recovery. Lastly, findings from this and similar studies should be used to inform interventions targeting patient care practices to improve mobility care and support of older adults hospitalized with medical illnesses such as heart failure.

CHAPTER 6

CONCLUSION

There have been only a few studies on objective monitoring in older hospitalized adults and none currently that we are aware of in older heart failure patients. This study used novel in-hospital variables such as percent time lying and number of postural transitions to investigate their value as predictors of readmission and function at 30 days. The primary results of this study were that some measures of mobility in hospitalized older adults with heart failure are associated with functional level 30 days after the patient is discharged. Mobility support in the hospital should be a modifiable and routine part of patient care to improve, maintain, or at least limit functional decline during an acute illness. Considering the implications of functional decline and increased use of health care resources—already high in the heart failure population—hospital organizations should begin to focus on function as another "vital sign" assessment while the patient is admitted. Patient care should include consistent promotion of various physical activities and utilize a multidisciplinary approach in planning discharge that takes into consideration the patient's functional needs.

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APPENDIX A

PHOTOS AND INFORMATION, PLACEMENT DIAGRAM OF MONITORS

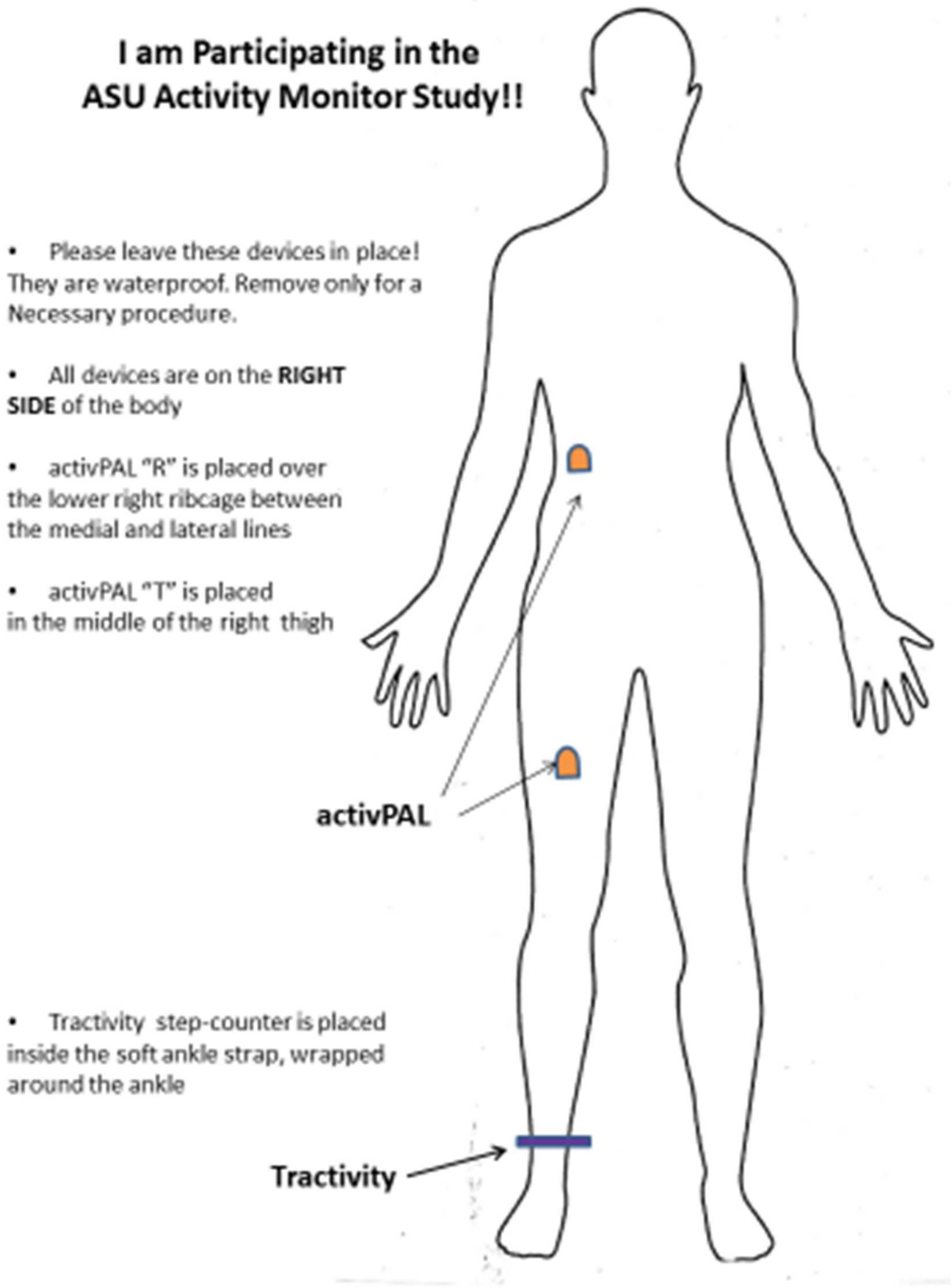
Some information on your activity monitors:

Both monitors are SAFE—they will not interfere with ANY other devices you have on/in your body. They run on a battery charge and do not emit any harmful material.

The activPAL is worn while you are in the hospital. They are secured with hospital tape to your body. Leave them on when you are discharged. The nurse researcher will visit you at home the next day to remove them.

The Tractivity step counter will stay on your ankle while you are in the hospital and for a while when you are at home. Leave this on your ankle. When the study is over, you get keep the step-counter for your personal use.

Call us any time if you have questions:
RN Researchers:
Theresa Floegel (480) 686-6807 or Erin Krzywicki (610) 212-4304



I am Participating in the ASU Activity Monitor Study!!

- Please leave these devices in place! They are waterproof. Remove only for a Necessary procedure.
- All devices are on the **RIGHT SIDE** of the body
- activPAL "R" is placed over the lower right ribcage between the medial and lateral lines
- activPAL "T" is placed in the middle of the right thigh
- Tractivity step-counter is placed inside the soft ankle strap, wrapped around the ankle

APPENDIX B

PATIENT AND STAFF INFORMATION

Testing Posture and Mobility
in Heart Failure Patients
Information for Patients and their Nurses

Arizona State University is partnering with John C. Lincoln to conduct a prospective observational study assessing mobility behaviors (i.e. posture, physical activity) and mobility status of older patients admitted with heart failure. Patients recruited into the study will wear an ankle sensor and posture monitors (2) placed on right thigh and right rib cage area.

Who will you see and how to reach them:

The RN researchers who will be coming to your unit to enroll patients in the study are

- Theresa Floegel (480) 686-6807
- Erin Krzywicki (610) 212-4304

Our study will be investigating:

- The relationship between hospital mobility behavior patterns (using objective metrics derived from continuously worn sensors) and physical function outcomes and hospital readmission within 30 days of discharge.
- The feasibility of using inpatient mobility monitoring from both patient (i.e. acceptability, preferences) and provider team (i.e. integration with clinical care) perspectives.

Notification and Recruitment of Potential Participants:

- Prior to approaching patients the RN researchers will approach the primary RN to confirm patient potential for the study. The RN researcher will then consult the patient record for demographics and diagnosis for the patient.
- The RN researcher will approach patients independently, we are not asking for assistance from the primary RN for this.

Education and Demonstration of Devices:

- ActivPAL- This consists of 2 small monitors for each participant. One is worn on the participant's abdomen and the other on the thigh. This device can distinguish changes in a patient's position, i.e. lying, sitting, or standing. These devices are secured with medical tape.
- Tractivity- This is a small device that counts the participants steps. It is secured to the participant's ankle with a soft, nylon strap.
- The devices are waterproof and can be worn in the shower, but they cannot be submerged.
- The RN researchers will initialize, prepare, and place the devices on the patient.

What we are asking of you:

- Please leave the activity monitors in place for the entire hospital stay—the patient will wear them home.

- Please check the patient's skin around the monitors with each shift assessment to assess for irritation. If signs of irritation occur, we rely on your clinical judgment if monitor should be removed immediately or if you can notify RN researcher.
- If the activPAL device falls off or needs to be removed for a procedure, please **call one of the RN researchers.** If you feel comfortable, you may replace the device following these instructions:
    - Replace the activPAL marked with an 'R' on the patient's rib area and the device marked with a 'T' on the patient's thigh. Place on RIGHT SIDE.
    - Place activPAL on the patient's right thigh—Place ½ way between hip and knee (as noted in picture) directly in line with knee cap, when placed correctly the rounded edge is on top and the arrow should be pointed up, secure with hypafix tape.
    - Place activPAL on patient's lower right rib cage—Place 2 inches below nipple line and 1 inch lateral, when placed correctly the rounded edge is on top and the arrow should be pointed up, secure with hypafix tape.
    - Tractivity ankle band—if removed place band back on RIGHT ankle.

APPENDIX C

TRACTIVITY INFORMATION FOR HOME MONITORING

Your Tractivity Step-Monitor at Home:

This monitor has a standard watch battery inside and does not emit any harmful material.

The Tractivity step counter will stay on your ankle while you are at home. Please keep it on at all times if possible. The band and the plastic sensor can get wet (e.g. in the shower). If you need to take it off, please put it back on as soon as possible. Check your skin every day around the band (a good time to look is after your shower or when you are putting your socks/shoes on). If the band irritates your skin, causes redness, or just bothers you, take it off and then call us and we will come visit you.

Call us any time if you have questions:

Theresa Floegel (480) 686-6807
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