Risk Factors for Falls in Community-Dwelling Older Adults with Heart Failure

by

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ABSTRACT

Community-dwelling older adults with heat failure (HF) appear to have a greater risk of falling related to their symptoms, comorbid diseases, and/or adverse effect of HF management. The complexity of HF conditions and the growing number of HF patients pose new challenges for developing innovative fall prevention programs. To be successful, it is essential first to examine the independent effect of HF on falls, and to describe fall risk factors in the HF population. However, little is known about the effect of HF on falls in the U.S. population, and known risk factors have not been fully examined specific to HF patients. This study had two aims. Aim 1 examined the independent effect of HF on the likelihood of falling among community-dwelling older adults. Aim 2 explored functional impairment (i.e., physical, cognitive, sensory, and urinary impairment) in explaining falls among community-dwelling older adults with HF.

This retrospective cohort study used data from Health and Retirement Study (HRS), a nationally-representative longitudinal study. The sample for Aim 1 included 17,712 community-dwelling older adults aged 65 or older, who participated in at least two consecutive HRS interview waves between 1998 and 2014. Among them, the sample for Aim 2 included 1,693 community-dwelling older adults with self-reported HF.

This study found that HF patients had a 14% higher likelihood of falling than those without HF, after controlling for socio-demographics, physical and psychological symptoms, health behaviors, functional factors, psychiatric medication use, and environmental factors (OR = 1.14, 95% CI: 1.04, 1.26). This study of the sample of HF patients found that while a decline in

sensory function was least associated with falls, three functional domains (declines in physical, cognitive, or urinary function) were associated with an approximately two-fold higher likelihood of falling, after controlling for socio-demographic factors (i.e., age, sex, race/ethnicity, and spouse/partner status).

This study provides empirical evidence for developing fall prevention interventions specific to community-dwelling older adults with HF. Future prospective studies are needed to extend this research to elucidate the causal mechanism among HF, functional factors and falls. Also, future work is needed to understand the indirect effect of behavioral/environmental factors, and/or person-environment interactions, which have not been fully tested on falls in HF patients. In order to develop and test fall prevention interventions for this population, more attention needs to be paid to HF patients' fall experiences in outpatient, primary or home care settings and their need for support from caregivers, health providers, and the social community.

CHAPTER 1

INTRODUCTION

Background

Falls are a serious problem among older adults. In the U.S., nearly 20 to 30% of community-dwelling older adults report falling each year (Bergen, Stevens, & Burns, 2016; Verma et al., 2016). Of those who fall, one in three report fall-related injuries that require medical treatment (Bergen, Stevens, & Burns, 2016; Verma et al., 2016). Although most falls do not result in serious injury or fatalities, in 2014 approximately 2.8 million older adults were treated in emergency department and among these 800,000 were hospitalized (Bergen, Stevens, & Burns, 2016). Even after discharge from the hospital, patients experience functional decline (e.g., difficulties in walking or climbing a flight of stairs) that persists and often requires assistances for routine daily activities. Functional decline increases the probability of long-term care admission and healthcare expenditures (Burns, Stevens, & Lee, 2016). The consequences of falls are a significant burden not only to older adults, but also to caregivers, taxpayers, and the federal government. Thus, there is a need for innovative fall prevention methods to identify high-risk populations who may benefit from specifically designed interventions rather than simply targeting non-specified older adults.

Multiple risk factors contribute to falls. Two systematic literature reviews have identified various risk factors for falls in community-dwelling older adults including socio-demographic, biological, cognitive, psychosocial, behavioral or environmental factors (Deandrea et al., 2010; Gillespie et al., 2012). Importantly, older adults with multiple chronic diseases are also known to have higher rates of falls compared to healthy older adults (Deandrea et al., 2010; Lord, Sherrington, Menz, & Close, 2007). Among chronic diseases, some evidence indicates that heart failure (HF) is an important risk factor for falls (Jansen, Kenny, de Rooij, & van der Velde, 2014; Stenhagen, Ekström, Nordell, & Elmståhl, 2013). Heart failure (HF) is a chronic condition in which an impaired heart is unable to adequately pump blood to the body. Impaired heart function produces various signs and symptoms, such as decreased exercise tolerance, impaired cognitive function, and postural hypotension that predisposes them to falls (Benjamin et al., 2017; Mosterd & Hoes, 2007; Murad & Kitzman, 2012). Some individuals suffering from HF also have physiologic impairments of the brain, especially in the area regulating motor function, which may alter gait and balance, placing them at higher risk for falling. In previous studies, the brain images of HF patients showed a loss of tissue integrity in gray matter and axons in the cerebellar cortices and deep nuclei of the brain, which are related to motor regulation alteration (Kumar et al., 2011; Woo et al., 2015). To alleviate their symptoms, HF patients often take medication such as diuretics, digoxin, or type IA anti-dysrhythmic, which are also recognized as high fall risk medications (Hartikainen, Lönnroos, & Louhivuori, 2007; Leipzig, Cumming, & Tinetti, 1999). Thus, HF patients can be seen as a high-risk population for falls.

As the population of older adults increases in size, HF is a growing public health problem in the U.S. The total number of HF patients in the U.S. has risen significantly and is expected to increase by 46% from 2012 to 2030, resulting in a total of more than 8 million adults with the disease (Benjamin et al., 2017). The rise in the number of people with HF poses new challenges for developing innovative fall prevention programs in the U.S. According to a systematic review (K. Lee, Pressler, & Titler, 2016), little attention has been paid to either the effect of HF on falls or possible fall risk factors among HF patients. To implement innovative fall prevention interventions in community-dwelling older adults with HF, it is essential to first examine the independent effects of HF on falls, and to describe fall risk factors in this population.

Problem Statement

The effect of HF on falls among community-dwelling older adults is understudied. To the best of my knowledge, there are only two studies, neither conducted in the U.S populations. Both the study conducted in Sweden and the study conducted in Ireland reported the association between HF and the higher likelihood of falling among community-dwelling older adults. In Sweden, a prospective cohort study among community-dwelling older adults found that people with HF have greater odds of falling (one or more falls vs. no falls), adjusted OR = 1.9, 95% CI: 1.2, 3.8 (Stenhagen et al., 2013). In Ireland, a cross-sectional study among community-dwelling older adults found that people with HF have greater odds of falling (two or more falls vs. no falls), adjusted OR = 1.9, 95% CI: 1.0, 3.4 (Jansen et al., 2014). No previous study has examined the effect of HF on the likelihood of falling among the U.S. community-dwelling older adults – thus, there is a need for empirical evidence to identify fall risk factors for this high-risk population in the U.S., where the healthcare system and its accessibility are different from Sweden or Ireland.

In addition, potential risk factors have not been fully examined among HF patients. In a systematic review (K. Lee et al., 2016), few studies addressed the effect of medication or poor gait/balance on falls among HF patients. A cross-sectional study reported that HF patients living in the community showed poor gait and balance which indicated a higher fall risk (Tymkew & Templin, 2011). A case-control study revealed that benzodiazepine and digoxin are significantly related to falls among hospitalized older adults (Gales & Menard, 1995). A cohort study reported that loop diuretics were not significantly associated with falls among postmenopausal women aged 50 to 79 years enrolled at the Women's Health Initiative clinical centers. However, little is known about other risk factors for falls in community-dwelling older adults with HF. Therefore, identifying the effect of HF on falls and describing multifaceted fall risk factors in specific patients (older adults with HF) and settings (U.S. community-dwelling) are the two most important first steps to testing fall prevention interventions in this population.

Purpose of Study

The purpose of this retrospective cohort study is to (1) examine the independent effect of HF on the likelihood of falling among community-dwelling older adults, and (2) explore functional impairment (i.e., physical, cognitive, sensory, and urinary impairment) in explaining falls among community-dwelling older adults with HF. The following specific aims and research questions guided the analyses for this dissertation. Table 1.1 presents detailed research questions and hypotheses for each specific aim. All analyses used longitudinal survey data from the Health and Retirement Study (HRS) from 1998 to 2014.

Specific aims and research questions are:

Aim 1 Among community-dwelling older adults, aged 65 and older, examine the independent effect of HF on the likelihood of falling overall and for each functional sub-group (i.e., those with and without physical, cognitive, sensory, and urinary impairment).

> **Research Question (RQ) 1.1** Do community-dwelling older adults with HF have a higher likelihood of falling than those without HF, after controlling for personal (socio-demographics, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication use) and environmental (physical and social environment) factors?

RQ 1.2 Does the effect of having HF on the likelihood of falling differ by each functional sub-group (i.e., those with and without physical, cognitive, sensory, and urinary impairment), after controlling for personal (socio-demographics, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication use) and environmental (physical and social environment) factors?

RQ 1.3 Is there an interaction effect of HF and functional impairment (i.e., physical, cognitive, sensory, and urinary impairment), after controlling for personal (socio-demographics, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication use) and environmental (physical and social environment) factors?

Aim 2 Among community-dwelling older adults (aged 65 and older) *with HF*, explore functional impairment (i.e., physical, cognitive, sensory and urinary impairment) in explaining falls.

RQ 2.1 Among community-dwelling older adults *with HF*, what is the independent effect of each functional impairment on the likelihood of falling, after controlling for age, sex, race/ethnicity, and spouse/partner status?

Table 1.1 Specific Research Questions and Null Hypotheses

Aim 1. Among community-dwelling older adults, aged 65 and older, examine the independent effect of heart failure (HF) on the likelihood of falling overall and for each functional sub-group (i.e., those with and without physical, cognitive, sensory, and urinary impairment).

RQ 1.1 Do community-dwelling older adults with HF have a higher likelihood of falling than those without HF, after controlling for personal and environmental factors?

- Study Population: Community-dwelling older adults, aged 65+
- Outcome variable: fall (yes/no)
- Independent variable: **HF (yes/no)**
- Covariates to be adjusted: All 32 covariates *

RQ 1.1 Null Hypothesis

Among community-dwelling older adults, there is no relationship between HF and falls.

RQ 1.2 Does the effect of having HF on the likelihood of falling differ by *each functional sub-group* (i.e., those with and without physical, cognitive, sensory, and urinary impairment) after controlling for personal and environmental factors?

- Study Population: Sub-group those with and without functional impairment
- Outcome variable: fall (yes/no)
- Independent variable: **HF (yes/no)**
- Covariates to be adjusted All 31 covariates excluding *one factor* examined below

RQ 1.2 Null Hypotheses

Physical	a.	The effect of having HF on falls does not differ by groups with and without *mobility difficulty*.
	b.	The effect of having HF on falls does not differ by groups with and without *large muscle difficulty*.
	c.	The effect of having HF on falls does not differ by groups with and without *ADL difficulty*.
Cognitive	d.	The effect of having HF on falls does not differ by groups with and without *cognitive impairment*.
	e.	The effect of having HF on falls does not differ by groups with and without *IADL difficulty*.
Sensory	f.	The effect of having HF on falls does not differ by groups with and without *poor vision/legally blind.*
	g.	The effect of having HF on falls does not differ by groups with and without *poor hearing*.
Urinary	h.	The effect of having HF on falls does not differ by groups with and without *urinary incontinence.*

RQ 1.3 Is there an interaction effect of HF and *functional impairment* (i.e., physical, cognitive, sensory and urinary impairment), after controlling for personal and environmental factors?

- Study Population: Community-dwelling older adults, aged 65+
- Outcome variable: fall (yes/no)
- Independent variable: **HF (yes/no)**
- Covariates to be adjusted: All 31 covariates excluding *one factor* examined below

RQ 1.3 Null Hypotheses

Physical	a.	There is no interaction effect between HF and *mobility difficulty*.
	b.	There is no interaction effect between HF and *large muscle difficulty*.
	c.	There is no interaction effect between HF and *ADL difficulty*.
Cognitive	d.	There is no interaction effect between HF and *cognitive impairment*.
	e.	There is no interaction effect between HF and *IADL difficulty*.
Sensory	f.	There is no interaction effect between HF and *poor vision/legally blind*.
	g.	There is no interaction effect between HF and *poor hearing*.
Urinary	h.	There is no interaction effect between HF and *urinary incontinence*.

Table continued on next page.

Table 1.1 Specific Research Questions and Null Hypotheses (continued)

Aim 2. Among community-dwelling older adults (aged 65 and older) *with HF*, explore functional impairment (i.e., physical, cognitive, sensory, and urinary impairment) in explaining falls.

RQ 2.1 Among community-dwelling older adults with HF, what is the independent effect of each *functional impairment* on the likelihood of falling, after controlling for age, sex, race/ethnicity, and spouse/partner status?

- Study Population: **HF patients**
- Outcome variable: fall (yes/no)
- Independent variable: **one factor examined below**
- Covariates to be adjusted: age, sex, race/ethnicity and spouse/partner status

RQ 2.1 Null Hypotheses

Physical	a. Among those with HF, there is no relationship between *mobility difficulty* and falls.
	b. Among those with HF, there is no relationship between *large muscle difficulty* and falls.
	c. Among those with HF, there is no relationship between *ADL difficulty* and falls.
Cognitive	d. Among those with HF, there is no relationship between *cognitive impairment* and falls.
	e. Among those with HF, there is no relationship between *IADL difficulty* and falls.
Sensory	f. Among those with HF, there is no relationship between *poor vision/legally blind* and falls.
	g. Among those with HF, there is no relationship between *poor hearing* and falls.
Urinary	h. Among those with HF, there is no relationship between *urinary incontinence* and falls.

Note.
* All 32 covariates include:
- Physical function: mobility difficulty, large muscle function difficulty, ADL difficulty
- Cognitive function: cognitive impairment(TICS/IQCODE), IADL difficulty
- Sensory function: poor vision, poor hearing/legally blind
- Urinary function: urinary incontinence
- Interview indicator
- Socio-demographics: age, sex, race/ethnicity, spouse/partner status
- General health: self-reported health, fall history, BMI, hypertension, diabetes, cancer, lung disease, stroke/TIA, arthritis
- Physical symptom: pain
- Psychological symptom: depressive symptom (CESD)
- Health-related behavior: vigorous activities, alcohol use, walking aid use
- Medication use: psychiatric medication use
- Physical environment: home safety features, neighborhood safety
- Social environment: getting together, getting an ADL help.

Abbreviations: BMI, Body Mass Index; TIA, Transient Ischemic Attack; ADL, Activities of Daily Living; TICS, Telephone Interview for Cognitive Status; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly; IADL, Instrumental Activities of Daily Living; CESD, Center for Epidemiologic Studies Depression scale.

CHAPTER 2

REVIEW OF THE LITERATURE

In this chapter, seven components of the scientific literature review are discussed as follows: (1) definitions of falls in community settings; (2) conceptual classification of risk factors for falls in community-dwelling older adults; (3) risk factors for falls in community-dwelling older adults; (4) fall prevention for community-dwelling older adults; (5) overview of HF; (6) falls in HF patients; and, (7) the conceptual framework guiding the dissertation study based on the review.

Definitions of Falls in Community Settings

Conceptual Definition of Falls in Community Settings

Various definitions of falls have been proposed by researchers in different settings and with different perspectives. Most fall definitions in community settings usually include three components: (a) antecedents, including reasons, location, and how falls occurred; (b) biomechanical consequences, including the change in body position, anatomical landing point, or injury; and, (c) behavioral components (e.g., intentional or not) (Hauer, Lamb, Jorstad, Todd, & Becker, 2006; Zecevic, Salmoni, Speechley, & Vandervoort, 2006). A systematic review reported that definitions from the Kellogg International Work Group and the Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) collaboration were most commonly cited; while some studies used original definitions, other studies modified the original or created their own definitions (Hauer et al., 2006). For example, the Kellogg group defined a fall as "an event which results in a person coming to rest inadvertently on the ground or some other lower level, and is not as a consequence of the following: sustaining a violent blow, loss of consciousness, sudden onset of paralysis, as in a stroke, or an epileptic seizure (Gibson, Andres, Issacs, Radebaugh, & Worm-Petersen, 1987, p.4).” Tinetti, Speechley, and Ginter (1998) modified the definition as “unintentionally coming to rest on the ground or at some other lower level, not as a result of a major intrinsic event (e.g., stroke or syncope) or overwhelming hazard (p. 1702).” Later, the FICSIT Collaboration group specified topographical factors of the definition as “unintentionally coming to rest on the ground, floor, or other lower level; [excluding] against furniture, wall, or other structures (Buchner et al., 1993, p. 300).” Carter et al. (2002) expanded the fall definition by including the state of consciousness as “… with or without loss of consciousness and other than as the consequence of sudden onset of paralysis, epileptic seizure, excess alcohol intake or overwhelming external force (p.999).” In addition, while most fall definitions include only unintentional events, Tideiksaar (2010) included intentional behavior in the fall definition as “…any event in which a person inadvertently or intentionally comes to rest on the ground or another low level such as a chair, toilet, or bed (p.13).” Definitions are summarized in Table 2.1.

Defining falls are important specifically in the HF population because cardiovascular-related risk factors for falling can be related to both syncopal and non-syncopal falls. Patients with cardiovascular disorders including HF have experienced some events, such as loss of consciousness, syncope, or fainting (Soteriades et al., 2002). However, many fall definitions often have excluded these particular health conditions from their contribution to falls. These exclusions may underestimate fall incidences in the HF population, and may create fewer opportunities to provide early interventions. Recent collaborative work for consensus by Prevention of Falls Network Europe (ProFaNE) recommended using a simpler definition, including falls occurring from all causes, which is “an unexpected event in which the participants come to rest on the ground, floor, or lower level” (Lamb et al., 2005). Menant, Wong, Trollor, Close and Lord (2016) also argued that unexplained falls, subsequent to syncopal or pre-syncopal episode (related to orthostatic hypotension and carotid sinus hypersensitivity), have been understudied in community settings, although estimated unexplained falls were 14% in community-dwelling older women (Lord, Ward, Williams, & Anstey, 1993), which cannot be negligible. Therefore, including falls from all causes in research can be beneficial to find potential risk factors for falls in the HF population, and to develop fall prevention interventions that target specified risk factors for this population. For the dissertation study, fall is defined as *an unexpected event in which the participants unintentionally come to rest on the ground, floor, or lower level, other than as a consequence of substantial external force (e.g., moving vehicle).*

Table 2.1 Fall Definitions in Community Settings

Author (Year)	Conceptual Definitions (attribution part) *	Exclusion
Gibson et al. (1987) Kellogg Group	…an event which results in a person coming to rest inadvertently on the ground or other lower level	· sustaining a violent blow · loss of consciousness · sudden paralysis · stroke · epileptic seizure
Tinetti et al. (1989)	…a subject's unintentionally coming to rest on the ground or at some other lower level	· stroke · syncope · overwhelming hazard
Nevitt et al. (1989)	…falling all the way down to the floor or ground, or falling and hitting an object like a chair or stair	· a controlled/intentional movement · a "near fall" – the participant caught himself or herself before falling · being knock down by a substantial external force (e.g., moving vehicle)
Buchner et al. (1993) Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT trials)	…unintentionally coming to rest on ground, floor, or other lower level	· coming to rest against furniture, wall, or other structure
Means et al. (1996)	…any involuntarily change from a position of bipedal support (standing, walking, bending, reaching, etc.) to position of no longer being support by both feet, accompanied, by (partial or full) contact with the ground or floor	not specified
Carter et al. (2002)	…inadvertently coming to rest on the ground or other lower level with or without loss of consciousness	· sudden onset of paralysis · epileptic seizure · excess alcohol intake · overwhelming external force
Cesari et al. (2002)	…a sudden loss of gait causing the hit of any part of the body to the floor	not specified
Lamb et al. (2005) Prevention of Falls Network Europe (ProFaNE)	…an unexpected event in which the participants come to rest on the ground, floor, or lower level	not specified
Tideiksaar (2010)	…any event in which a person inadvertently or intentionally comes to rest on the ground or another lower level such as a chair, toilet or bed	not specified
Menant, Wong, Troller, Close, & Lord (2016)	Unexplained fallers were those who reported falls due to a blackout, dizziness, feeling faint, or "found themselves suddenly on the ground," subsequent to a syncopal or pre-syncopal episode.	not specified

Note. * Directly excerpted from the studies.

Operational Definitions of Falls in Community Settings

In many studies among community-dwelling adults, fall ascertainment has relied on self-reported information because this method is the most feasible in community settings, unlike hospitals or nursing homes where health providers are able to report falls. Common, self-reported methods of fall ascertainment include using a fall diary/calendar or telephone/mail interviews. During a follow-up period, the following data can be obtained weekly, bi-monthly, or monthly: number of falls, number of faller/non-faller/frequent fallers, fall rate per person-year, and time to first fall. Fall rate can be calculated as follows: the total number of falls divided by designated unit of person and time that falls were monitored (e.g., falls per person-year, falls per 100 person-years, etc.). A questionnaire, for example, can ask, "In the past month, have you had any fall including a slip or trip in which you lost your balance and landed on the floor or ground or lower level (Lamb et al., 2005)?" However, even with frequent ascertainment, falls can be under-reported. Older adults sometimes deny their falls because of the discrepancy between participants' and researchers' fall definitions; for example, older adults tend to not report falls , such as tripped over an physical obstacle, or simply do not remember them (Cummings, Nevitt, & Kidd, 1988). To improve subjective fall reporting methodology, a recent study firstly employed wearable sensor to the prospective study in a community setting to evaluate future fall risk with a combination of telephone interviews after two years from baseline interview; the study found that using a method based on both sensor-based and clinical approach more accurately predicted falls than a clinical approach (Greene et al., 2012).

In community settings, weekly or monthly fall ascertainment of older adults is often not feasible for population-based complex survey studies. For this dissertation study, I used data on falls based on two-year fall recall question of the Health and Retirement Study. A previous study that examined the validity of 1-year fall recollection demonstrated a relatively high specificity (91-95%) and sensitivity (77-89%) (Ganz, Higashi, & Rubenstein, 2005; Sanders, Stuart, Scott, Kotowicz, & Nicholson, 2015). The sensitivity and specificity for the two-year fall recall question is unknown and may underrepresent a true fall occurrence among older adults, suggesting future studies are needed to examine the sensitivity & specificity of 2-year recollection of fall events.

Conceptual Classification of Fall Risk Factors for Community-Dwelling Older Adults

Fall risk factors are multifaceted. However, there are no consistent classifications for risk factors for falls. Traditionally, risk factors for falls are categorized as *intrinsic* and *extrinsic* factors. *Intrinsic* factors refer to within-person factors including age, chronic illnesses, muscle weakness, gait and balance impairments, and cognitive declines; *extrinsic* factors are not inherent, but are environmental factors such as environmental hazards and risky activities (Deandrea et al., 2010). Tinetti, Speechley, and Ginter (1988) categorized risk factors as follows: socio-demographic characteristics, environmental hazards, psychological functioning, health and functioning, medications and alcohol, physical symptoms or impairments. Sattin (1992) suggested that risk factors can be categorized as host, agent, and environment: (a) host elements includes age, sex, osteoporosis, chronic diseases, gait and balance, vision, mental status, medication use, and alcohol use; (b) agent elements includes mechanical energy, impact position, and impact location; and (c) environment includes lighting, stairs, rugs and flooring, bathtubs, shelving, footwear, street and walkways. Lord et al. (2007) specified the classification for analytic purposes: socio-demographic factors, balance and mobility factors, sensory and neuromuscular factors, psychological factors, medical factors, medication use, and environmental factors. Some epidemiologic studies often proposed that ADL/IADL limitation, history of falls, walking aid use, life style (alcohol consumption) are categorized in socio-demographic factors.

In this dissertation, I used the following conceptual domains to identify risk factors for falls in community-dwelling older adults with HF: personal factors (socio-demographic, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behaviors and medication) and environmental factors (physical environment and social environment). Socio-demographic factors refer to sociological and demographic characteristics including age, gender/sex, race/ethnicity, and living alone. General health refers to participants' overall health, including perceived health conditions, current co-existing medical conditions, or history of health events. Physical function refers to a person's ability to perform various activities, ranging from basic self-care to more vigorous activities that requires mobility, strength, or endurance. Cognitive function refers to a person's ability for the intellectual processes of acquiring and using knowledge. Sensory function refers to a person's ability to detect information though persons' sense including eyesight or hearing. Urinary function refers to a person's ability to be continent and to eliminate liquid waste from the body through the urinary tract. Physical symptoms refer to a person's subjective feeling or body responses related to the consequence of body impairment including dizziness, pain, or sleep problem. Psychological symptoms refer to a person's mental responses to the affected emotions or thoughts. Health behavior refers to activities influencing a person's health including alcohol use. Medication refers to number of medications or types of medications. Environmental factor refers to any situations external to the person and/or physical obstacles that influence falls.

Risk Factors for Falls among Community-Dwelling Older Adults

Introduction

Since Tinetti, Speechley, and Ginter (1988)'s study, more than 1,400 studies reported risk factors for falls in community-dwelling older adults. To synthesize risk factors for falls in community-dwelling older adults, Deandrea and colleagues (2010) conducted a systematic review and meta-analysis using data extracted from 74 prospective studies published from 1988 to 2008 (Deandrea et al., 2010). Thirty risk factors with pooled ORs were reported. To complement findings from the meta-analysis, scientific literature published from 2009 to 2016 was analyzed for risk factors for falls among community-dwelling older adults. The following section describes as follows: (a) methods for syntheses of the research of 2009 to 2016, and (b) reports findings from both meta-analysis and the 2009 to 2016 research.

Methods

A database from PubMed was used to identify publications from January 2009 to July 2016. Five search themes were combined using the Boolean operator "AND." The first theme, "falls," combined in title *fall*, *falls* or *falling*. The second theme, "risk", combined in title/abstract *risk* or *predict*. The third theme, "elderly", combined in title/abstract *older* or *elderly*. The fourth theme, "community", combined in title/abstract *community*, *home*, or *non-institutional*. The fifth theme, "prospective study", combined in all field *prospective* or *cohort*. After scanning titles and abstracts, 121 original studies, addressing risk factors for falls in community-dwelling older adults, were selected for further review. The following inclusion and exclusion criteria were applied to 121 publications. The inclusion criteria were: (a) participants with a mean/median age of 65 years or older; (b) prospective cohort study design; (c), sample size greater than 200 subjects; (d) participants living in the community (e.g., home or senior housing); (e) one or more falls as a study outcome; (f) reporting odds ratio (OR), hazard ratio (HR), incident rate ratio (IRR) or relative risk ratio (RR); and, (g) written in English. The exclusion criteria were (a) elderly in hospitals, skilled nursing facilities, or nursing homes, (b) studies only focusing on samples with specific disease or health conditions, (c) studies using a total score of multifactorial frailty index as an explanatory variable because the summation of multiple factors does not show which particular factor has the strong association with falls. Publications studied outside of the U.S. were also excluded except for a study (Mackenzie, Byles, & D'Este, 2009) because this study included environmental factors that U.S. publications have not addressed between 2009 and 2016. In addition, after reference tracking, a prospective study (Himes and Reynolds, 2012) was included because this study addressed a detailed relationship between obesity and falls in the U.S. population. Finally, the meta-analysis (Deandrea et al, 2010) was also included in the review because this study synthesized 74 publications from December 1988 to December 2008. Figure 2.1 provides a flow diagram of the review procedure.

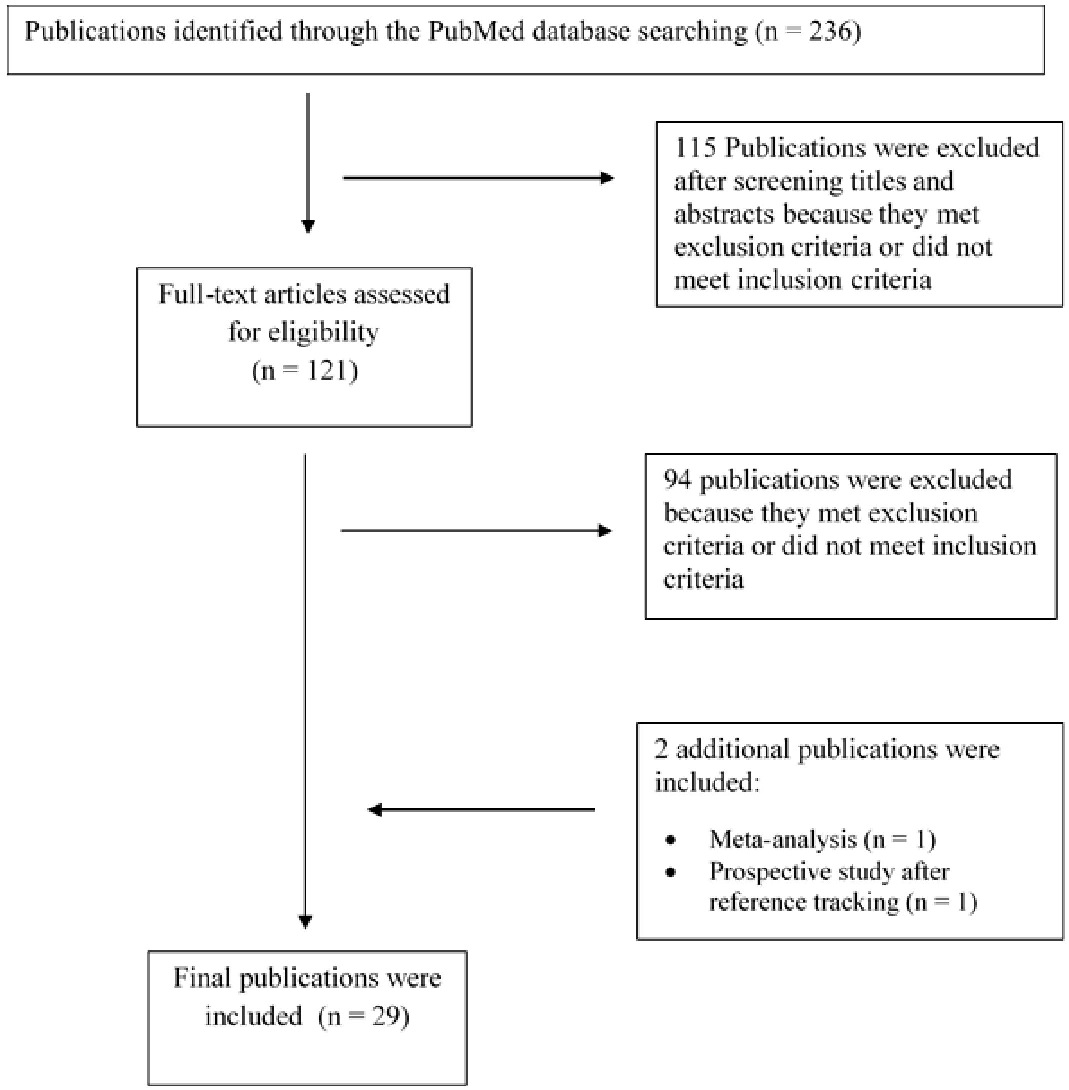

Figure 2.1 The flow diagram of the review procedure: risk factors for falls among community-dwelling older adults

Note. The final review included one meta-analysis (Deandrea et al, 2010) and 28 publications from 2009 to 2016.

Results

A total of 236 publications were initially identified. Twenty-six publications met the inclusion criteria, and full texts were retrieved (Figure 2.1). The following section will summarize risk factors among community-dwelling older adults. The summary includes data from a previous meta-analysis (Deandrea et al., 2010), recent 27 publications from 2009 to 2016, and a prospective study from reference tracking (Himes and Reynolds, 2012). Synthesis of the risk factors for falls are organized by the following categorization: (a) personal factors – socio-demographic, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication; and (b) environment factors – physical environment and social environment. The findings from the meta-analysis (Deandrea et al, 2010) and 28 prospective U.S. studies published from 2009 to 2016 are summarized in Table 2.2.

Table 2.2 Summary of 29 Selected Studies on Risk Factors for Falls in Community-Dwelling Older Adults

Author (year)	Primary risk factor (aim)	Sample Size	mean age	% female	Follow-up duration (month)	Follow-up frequency *	Falls (outcome)	Key findings
Berry et al. (2010)	Poor adherence to medications	654	78	62	22	High	All§	• Poor medication adherence, AIRR = 1.5, 95% CI: 1.2, 1.9
Chen et al. (2012)	Cognitive function (processing speed, executive function, psychomotor speed)	509	73	56	36	High	All/ recurrent	• Psychomotor speed AOR = 1.01, 95% CI: 1.00, 1.02 • After adjusting confounding factors, processing speed and executive function have no association with falls.
Diem et al. (2014)	Non-benzodiazepine sedative hypnotics	4450	71	0	12	Intermediate	All/ recurrent	• Non-benzodiazepine sedative hypnotic was associated both any falls and recurrent falls, ARR = 1.44, 95% CI: 1.15, 1.81, ARR = 1.51, 95% CI: 1.07, 2.14, respectively.
Duckham et al. (2013)	Sex difference in circumstances	743	78	63	35	High	All	• Women had lower rates of overall outdoor falls, snowy/icy road surfaces, during vigorous outdoor activity, and in recreational sites, UIRR = 0.72, 95% CI: 0.56, 0.92, UIRR = 0.55, 95% CI: 0.36, 0.86, UIRR = 0.38, 95% CI: 0.18, 0.81, UIRR = 0.34, 95% CI: 0.17, 0.70, respectively. • Women had higher fall rates in the kitchen and during household indoor activity, UIRR = 1.88, 95% CI: 0.56, 0.92, UIRR = 3.68, 95% CI: 1.50, 8.98, respectively. • No difference outdoor falls on sidewalks, streets, curb, and while walking

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Table 2.2 (continued)

Eggermont et al. (2012)	Depressive symptom, chronic pain	722	78	63	18	High	All	• Severe depressive symptom associated with higher fall rates, AIRR = 1.91, 95% CI: 1.39, 2.61. • Pain location and interference mediated the association between depressive symptom and falls.
Faulkner et al. (2009)	Multiple risk factors	8378	71	100	48	Intermediate	All/ recurrent	• Adjusted relative risk revealed that dizziness, fear of falling, poor self-rated health, fall history, Central Nerve System medications, IADL limitation, smoking history, and infrequent outdoor activity are associated with falls.
Fischer et al. (2014)	Cognition	245	79	77	12	Intermediate	All	• Declining cognition was associated with falls, ARR = 1.16, 95% CI: 1.03, 1.32 for each unit change in Short Portable Mental Status Questionnaire scores (a higher score, declining cognition).
Gangvati et al. (2011)	uncontrolled and controlled hypertension, orthostatic hypotension	722	78	64	6	High	All	• Slower gait (< 0.6 m/s) was associated with indoor falls, AIRR = 2.17, 95% CI: 1.33, 3.55.
Hanlon et al. (2009)	Central Nervous System (CNS) medications (benzodiazepine and opioid receptor agonists, antipsychotics, antidepressants)	3055	74	52	60	Low	Recurrent	• Multiple CNS medications was associated with falls, AOR = 1.95, 95% CI: 1.35, 2.8.1 • High dose of CNS medications was associated with falls, AOR = 2.89, 95% CI: 1.96, 4.25.

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Table 2.2 (continued)

Henry-Sanchez et al. (2012)	ADL status and needs for home accessibility	9250	76	60	12	Low	Once/ Recurrent	• Severe ADL limitation (level 3 vs. level 0) was associated with falls, ARR = 4.30, 95% CI: 3.29, 6.51. • Lacking home accessibility was associated with one-time fall and recurrent falls, ARR = 1.42, 95% CI: 1.07, 1.87, ARR = 1.95, 95% CI: 1.44, 2.36, respectively.
Himes et al. (2012)	Obesity	10,755	74	64	24	Low	All	• Obese Class 1 (BMI 30.0-34.9 kg/m2), obese Class 2 (BMI 35.0-39.9 kg/m2) and obese Class 3 (BMI ≥ 40.0 kg/m2) were associated with falls, AOR = 1.12, 95% CI: 1.01, 1.24, AOR = 1.26, 95% CI: 1.05, 1.51, AOR = 1.50, 95% CI: 1.21, 1.86, respectively.
Kelsey, Procter-Gray, Nguyen, Kiel, and Hannan (2010)	Footwear	765	75	63	28	High	All/ injurious falls	• Barefoot, wearing socks without shoes or wearing slippers was associated with only serious fall injuries, AOR = 2.27, 95% CI: 1.21, 4.24.
Kelsey, Berry,… Hannon (2010)	Multiple risk factors according to indoor and outdoor	765	78	64	24	Low	All	• Indoor falls: graduate-level education, most physical disability indicators, pain, multiple comorbidities, depression, psychotropic medication, fall history and fear of falls were associated with indoor falls, AIRR > 1.50. • Outdoor falls: white race, graduate-level education, having multiple stairs at home, high/moderate alcohol use, and having depression were associated with outdoor falls, AIRR > 1.50.

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Table 2.2 (continued)

Kelsey et al. (2012)	Multiple risk factors according to indoor and outdoor activity	765	NR	NR	52	High	All	• Indoor falls (while walking or not moving/transitioning): Poor balance, slow gait, unable to stand from a chair, ADL difficulty, psychotropic medication use, fear of falling, fair/poor self-rate health, low physical activity were associated with indoor falls, UIRR > 1.50 • Outdoor falls: Relatively healthy and active people had elevated UIRR. Fast gaits were associated with outdoor falls while walking UIRR = 2.83, 95% CI: 1.84, 4.33 or while performing vigorous activity UIRR = 7.36, 95% CI: 2.54, 21.28.
Kiely et al. (2015)	Race	666	78	64	34	High	All	• Whites (vs. African American) had more falls, URR = 1.77, 95% CI: 1.33, 2.36.
Leveille et al. (2009)	Pain (chronic musculoskeletal)	748	77	58	18	Low	All	• Two or more sites of joint pain, AIRR = 1.18, 95% CI: 1.13, 1.23 • Two or more pain sites, AIRR = 1.53, 95% CI: 1.17, 1.99 • Highest pain severity, AIRR = 1.53, 95% CI: 1.12, 2.08 • Pain limiting activities, AIRR = 1.53, 95% CI: 1.15, 2.05
Mackenzie et al., (2009)	Environmental factors	727	77	48	36	Intermediate	All	• Home hazard were significantly related to falls, AOR = 1.02, 95% CI: 1.0, 1.1
Marcum et al. (2015)	Antihypertensive	2948	74	52	12	Low	Recurrent	• Overall antihypertensive use: no association • Only loop diuretic, AOR = 1.50, 95% CI: 1.11-2.03

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Table 2.2 (continued)

Marcum, Perera, …Hanlon (2016)	Antidepressant	2821	74	52	72	Low	Recurrent	• Antidepressant use, AOR = 1.48, 95% CI: 1.12, 1.96 • SSRIs, AOR = 1.62, 95% CI: 1.15, 2.28 • Short duration use, AOR = 1.47, 95% CI: 1.04, 2.00 • Moderate dosages, AOR = 1.59, 95% CI: 1.15, 2.18
Marcum, Wirtz, … Gray (2016)	Anticholinergic	61451	69	100	18	Low	Recurrent	• Anticholinergic medication use, AOR = 1.51, 95% CI: 1.43, 1.60 • Multiple anticholinergic medications, AOR = 2.00, 95% CI: 1.73, 2.32
Marshall et al. (2016)	Pain (back)	6841	73	100	12	Intermediate	All/ recurrent	• Any back pain was associated with recurrent falls, ARR = 1.5, 95% CI: 1.3, 1.8
Munch et al. (2015)	Pain (hip, knee, and elsewhere)	5993	74	0	39	Intermediate	All/ recurrent	• Any falls: Pain at the following site was associated with any falls. Hip, knee, and elsewhere, UOR = 1.48, 95% CI: 1.30, 1.69, UOR = 1.62, 95% CI: 1.43, 1.83, UOR = 2.02, 95% CI: 1.76, 2.31, respectively. • Recurrent falls: Pain at the following site was associated with recurrent falls. Hip, knee, and elsewhere, UOR = 1.72, 95% CI: 1.45, 2.03, UOR = 2.00, 95% CI: 1.71, 2.35, UOR = 2.75, 95% CI: 2.17, 3.04, respectively.

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Table 2.2 (continued)

Parsons et al., (2009)	Lower urinary tract symptoms (LUTS)	5872	74	0	12	Intermediate	All/ recurrent	• Any falls: Moderate and severe LUTS was associated with at least one falls, ARR = 1.11, 95% CI: 1.01, 1.22, ARR = 1.33, 95% CI: 1.15, 1.53, respectively. • Recurrent falls: Moderate and severe LUTS was associated with recurrent falls, ARR = 1.21, 95% CI: 1.05, 1.40, ARR = 1.63, 95% CI: 1.31, 2.02, respectively
Quach et al. (2011)	Gait speed	763	78	64	18	High	All	• Slower gait (< 0.6 m/s) was associated with indoor falls, AIRR = 2.17, 95% CI: 1.33, 3.55. • Faster gait was associated with outdoor falls, AIRR = 2.11, 95% CI: 1.40, 3.16.
Quach et al. (2013)	Depression Antidepressant	763	78	64	28	High	All	• Depression, AIRR = 1.67, 95% CI: 1.28, 2.18. • Antidepressant, AIRR = 1.50, 95% CI: 1.11, 2.03.
Spoelstra et al. (2013)	Cancer	9481	NR	68	2-3	High	All	• Having cancer history, AOR = 1.16, 95% CI: 1.02, 1.33.
Stone et al. (2014)	Sleep disturbance	3101	76	0	12	Intermediate	Recurrent	• Excessive daytime sleepiness, AOR = 1.52, 95% CI: 1.14, 2.03.
Vaughan et al. (2010)	Nocturia	692	76	48	36	Intermediate	All	• Nocuria was associated with falls, ARR = 1.28, 95% CI: 1.02, 1.59.

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Table 2.2 (continued)

Deandrea et al. (2010)	Multiple risk factors	This is a meta-analysis including 74 publications from 1998 to 2008. 31 risk factors were considered. Among them, risk factors strongest associated with falls were: • fall history, OR_{pooled} = 2.8 all fallers; OR_{pooled} = 3.5 recurrent fallers • gait problems, OR_{pooled} = 2.1; 2.2 • walking aid use, OR_{pooled} = 2.2; 3.1 • vertigo, OR_{pooled} = 1.8; 2.3 • Parkinson disease, OR_{pooled} = 2.7; 2.8 • Antiepileptic drug use, OR_{pooled} = 1.9; 2.7

Note. Publications are listed in alphabetical order by author. The meta-analysis study is listed in the last.

* Follow-up frequency: High (< every 3 months), Intermediate (every 3 month – every 6 month), Low (> every 6 months).

§ All, one or more falls vs no falls; Recurrent, two or more falls vs. no or one falls.

Abbreviations: AIRR, adjusted incidence rate ratio; AOR, adjusted odds ratio; ARR, adjusted relative risk ratio; UIRR, unadjusted incidence rate ratio; IADL, instrumental activities of daily living, ADL, activities of daily living; UOR, unadjusted odd ratio; OR_{pooled}, pooled odds ratio.

Personal Factors

Personal factors refer to within-person factors that influence the likelihood of falling. Personal factors consist of socio-demographic factors, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication.

Socio-demographic factors. Socio-demographic factors refer to a group defined by sociological and demographic characteristics, such as age, gender/sex, race/ethnicity, marital status, and so on. According to the meta-analysis, a higher likelihood of falling in community settings was reported in older adults with advanced age and in females, OR_{pooled} = 1.12, 95% CI: 1.07, 1.17 and OR_{pooled} = 1.30, 95% CI: 1.18, 1.42, respectively (Deandrea et al., 2010). A study of 666 white and African American older adults found that whites are more likely to fall than African Americans, RR = 1.77, 95% CI: 1.33, 2.36 (Kiely et al., 2015). A meta-analysis found that community-dwelling older adults who are living alone have a higher incidence of any falls, OR_{pooled} = 1.33, 95% CI: 1.21, 1.45 (Deandrea et al, 2010).

General health. General health is defined as participants' overall health status, including perceived health condition, current co-existing medical conditions, or history of health events. Meta-analysis revealed that fall history was the strongest risk factors for any falls among general health condition factors, OR_{pooled} = 2.77, 95% CI: 2.37, 3.25; other contributing factors include: poor self-perceived health status and comorbidity, OR_{pooled} = 1.50, 95% CI: 1.15, 1.96 and OR_{pooled} = 1.23, 95% CI: 1.16, 1.30, respectively (Deandrea et al., 2010). In addition, a population-based study showed that obesity was associated with falls; specifically, in a full model controlling for confounding factors, obese Class 1 (BMI 30.0-34.9 kg/m^2), obese Class 2 (BMI 35.0-39.9 kg/m^2) and obese Class 3 (BMI $\geq$ 40.0 kg/m^2) were associated with falls, OR =

1.12, 95% CI: 1.01, 1.24, OR = 1.26, 95% CI: 1.05, 1.51, and OR = 1.50, 95% CI: 1.21, 1.86, respectively (Himes and Reynolds, 2012).

In the meta-analysis, it was found that older adults with the following medical diagnoses had a higher risk of falling: Parkinson's disease, stroke history, rheumatic diseases and diabetes, OR_{pooled} = 2.71, 95% CI: 1.08, 6.84, OR_{pooled} = 1.61, 95% CI: 1.39, 2.33, OR_{pooled} = 1.47, 95% CI: 1.28, 1.70, and OR_{pooled} = 1.19, 95% CI: 1.08, 1.31, respectively (Deandrea et al., 2010). From prospective studies in a large sample (n = 9,481), it was found that falls were more frequently found in people having cancer, adjusted OR = 1.16, 95% CI: 1.02, 1.33 (Spoelstra et al., 2013). These medical diagnoses are found as risk factors for falls in the previous studies.

Physical function. Physical function is defined as a person's ability to perform various activities, ranging from basic self-care to more vigorous activities requiring mobility, strength, or endurance (Resnick et al, 2015). In order to investigate the association between falls and mobility or muscular strength, studies have used various methods, from self-reported data to laboratory measures, including sit-to-stand/transfer ability, gait speed or step length. According to the meta-analysis, gait impairment was strongly associated with any fall, OR_{pooled} = 2.06, 95% CI: 1.82, 2.33 (Deandrea et al., 2010). In a study on indoor falls, poor balance, inability to stand from a chair, and difficulty in ADLs were significantly associated with falls (Kelsey et al, 2012).

Cognitive function. Cognitive function refers to a person's ability for the intellectual processes of acquiring knowledge. This includes reasoning, memory, attention, perception and language. Meta-analysis reported that cognitive impairment is associated with falls, OR_{pooled} = 1.36, 95% CI: 1.12, 1.65 (Deandrea et al., 2010). Specifically, impaired psychomotor speed was associated with falls after controlling for confounding factors, OR = 1.01, 95% CI: 1.00, 1.02 (Chen, Peronto, & Edwards, 2012). In addition, studies found that declined cognition, measured by Short Portable Mental Status Questionnaire, was associated with falls, RR = 1.16, 95% CI: 1.03, 1.32 (Fischer et al., 2014). Instrumental Activities of Daily Living (IADL), such as managing money and paying bills, following complex medical regiments, or planning sequences of activities, is often used as a complement measure of cognition because to perform these complex activities, adequate cognitive function is required. Meta-analysis reported that IADL limitation was associated with falls, OR_{pooled} = 1.46, 95% CI: 1.20, 1.77 (Deandrea et al., 2010).

Sensory function. Sensory function refers to a person's ability to detect information through person's sense such as touch, eyesight, smell, hearing, and taste. Meta-analysis found that vision impairment and hearing impairment are associated with falls, OR_{pooled} = 1.35, 95% CI: 1.18, 1.54 and OR_{pooled} = 1.21, 95% CI: 1.05, 1.39, respectively (Deandrea et al., 2010).

Urinary function. Urinary function refers to a person's ability to be continent and to eliminate liquid waste from the body through the urinary tract. Older adults with urinary incontinence have a higher risk of falling, OR_{pooled} = 1.40, 95% CI: 1.26, 1.57 (Deandrea et al., 2010). In addition, moderate and severe lower urinary tract symptoms (e.g., urinary urgency, difficulty initiating urination and nocturia) were associated with falls, RR = 1.11, 95% CI: 1.01, 1.22, and RR = 1.33, 95% CI: 1.15, 1.53, respectively (Parsons et al, 2009).

Physical symptoms. Physical symptoms refer to a person's subjective feeling or body responses related to the consequence of body impairment. Meta-analysis revealed that pain and dizziness/vertigo are associated with falls, OR_{pooled} = 1.39, 95% CI: 1.19, 1.62 and OR_{pooled} = 1.80, 95% CI: 1.39, 2.33, respectively (Deandrea et al., 2010). Additionally, recent prospective studies found that falls were more frequently found in people who have any one of the following conditions: pain (two more site or severity) and excessive daytime sleepiness were associated with falls (Leveille et al., 2009; Marshall et al., 2016; Munch et al., 2015; Stone et al., 2014).

Orthostatic hypotension with uncontrolled hypertension are strongly associated with falls, HR = 2.5, 95% CI: 1.3, 5.0; however, orthostatic hypotension without uncontrolled hypertension was not associated with falls (Gangavati et al., 2011).

Psychological symptoms. Psychological symptoms refer to a person's mental responses to the affected emotions or thoughts. Many studies have shown that psychological factors were associated with falls. Meta-analysis reported that depression and fear of falling were associated with falls, OR_{pooled} = 1.63, 95% CI: 1.36, 1.94 and OR_{pooled} = 1.55, 95% CI: 1.14, 2.09, respectively (Deandrea et al., 2010). Recent prospective studies also found that depression was associated with falls among community-dwelling older adults (Eggermont et al., 2012; Quach et al., 2013). In addition, older adults with fear of falling reported higher indoor and outdoor fall rates while not moving/transitioning, and higher indoor fall rates during walking, unadjusted RR = 2.42, 95% CI: 1.55, 3.78, unadjusted RR = 2.37, 95% CI: 1.06, 5.31, and unadjusted RR = 1.85, 95% CI: 1.19, 2.90, respectively (Kelsey et al., 2012).

Health behavior. Health behavior is activities influencing a person's health. Traditionally, decreased physical activity was known as a fall risk factor because inactivity can reduce muscle strength, balance, and functional capabilities in the elderly. This, in turn, can place them at higher risk of falling. Meta-analysis showed that limited physical activities and walking aid use can predict more falls, OR_{pooled} = 1.2, 95% CI: 1.04, 1.38 and OR_{pooled} = 2.2, 95% CI: 1.79, 2.65 (Deandrea et al., 2010). Faulkner et al. (2009) also found that active people, going outdoors at least twice per week but no more than once daily, reported fewer falls than twice daily among 8,378 community-dwelling women. In addition, other health behavioral factors, associated with more falls or injurious falls include: increased alcohol use, and inappropriate shoe fit and use (Kelsey, Berry, et al., 2010; Kelsey, Procter-Gray, et al., 2010).

Medication (Types and number). In community settings, falls were associated with an increased number of medications (OR_{pooled} = 1.06, 95% CI: 1.04, 1.08), and the use of following types of medications: sedatives, anti-hypertensives, anti-epileptics according to the meta-analysis, OR_{pooled} = 1.38, 95% CI: 1.15, 1.66, OR_{pooled} = 1.25, 95% CI: 1.06, 1.48, and OR_{pooled} = 1.88, 95% CI: 1.02, 3.49, respectively (Deandrea et al., 2010). A prospective cohort study among 2,948 older adults found that after controlling for confounding factors, anti-hypertensive medications were not associated with falls (Marcum et al., 2015), which is an inconsistent result from the meta-analysis (Deandrea et al., 2010). Additionally, recent prospective studies in large sample found that anti-depressants, anti-cholinergics, loop diuretics, benzodiazepines, anti-arrhythmics, polypharmacy (> 4) were significantly associated with falls (Diem et al., 2014; Hanlon et al., 2009; Kelsey et al., 2012; Marcum et al., 2015; Marcum, Perera, et al., 2016; Marcum, Wirtz, et al., 2016; Quach et al., 2013).

In summary, from the literature review, multiple personal factors were found to be risk factors for falls in community-dwelling older adults. Socio-demographic fall risk factors include advanced age, female gender, white race (vs. African American) and living alone. General health risk factors include poor self-perceived health status, having multiple diseases, and obesity. Functional fall risk factors include poor physical function (e.g. poor balance, difficulty in ADLs), cognitive impairment (e.g., impaired psychomotor speed, difficulty in IADLs), poor hearing/vision, and urinary incontinence. In addition, other personal fall risk factors, such as physical symptoms (e.g., pain, dizziness/vertigo), depressive symptoms, inactivity, excessive alcohol use, inappropriate shoes, use of psychotic medications and polypharmacy, were associated with falls.

Environmental Factors

Environmental factors refer to any situations external to the person and/or physical obstacles that influence falls. Environmental factors consist of the physical environment and social environment. Physical environment includes (a) living environment/home, (b) outdoor/neighborhood environment, and (c) public environment. Social environment includes (a) social participation and (b) social support.

Physical environment. The physical environment includes physical objects in the home or place of resident and physical objects or structures in the neighborhood or outdoors. We have long known that physical structures in the home, such as loose rugs, cord across walkways, unstable furniture, lack of grab rails of shower/bathtub/toilet, uneven/broken steps, and so on, contribute to falls; additionally, objects in the outdoors that are part of the home property can contribute to falls, such as obstructed pathways and stairways, or unsafe garbage bin use (Lord et al, 2007). A recent prospective study among 727 community-dwelling older adults in Australia found that falls were associated with unsafe living/home environmental hazards (measured by the HOME FAST tool at baseline), OR = 1.02, 95% CI: 1.00, 1.10 (Mackenzie, Byles, & D'Este, 2009). In the study, most prevalent home hazards were loose mats (56.4%), no non-slip bathmats (53.2%), and no bathroom rails (49.7%). It is important to note that most indoor falls among community-dwelling older adults occur in the home. A recent prospect cohort study among 765 community-dwelling older adults in the U.S. found that 53.3% of falls occurred indoors, and 77% of indoor falls occurred inside the home (Kelsey et al., 2010). The outdoor/neighborhood environment is defined as objects in the neighborhood that people may encounter such as cracked/uneven side sidewalks, holes in streets, or poor street lighting. A case-control study (Li et al., 2006) found that older adults experienced outdoor falls in the garden/patio/porch/deck

(25.8% in men, 35.8% in women) or sidewalk/curb/street (48.4% in men, 30.8% in women); and most of falls occurred while walking (48.4% in men, 45% in women). Public place environment includes indoor physical structure and outdoor environment in public places (e.g., schools, churches, grocery stores), such as a poor building design including slippery surfaces, poor lighting, uneven stairs/sidewalk, lengthy distances to sitting areas/public restrooms, and other features that interfere with mobility of for older adults or busy street junctions (Fothergill et al., 1995; Gallagher & Scott, 1996; Poh-Chin et al., 2009).

Social environnent. Social environnent includes (a) social participation and (b) social support. The lack of social participation is associated with isolation and depression, and this increases fear of falling, and vice versa. In addition, social support includes living with someone, checking in on older adults regularly, or encouraging them to participate in social events. A cross-sectional study, among 1,000 community-dwelling older adults in the U.S., found that both social participation (social contact) and social support were not associated with falls among community-dwelling older adults after controlling for socio-demographic and other personal factors (Durbin et al., 2016). On the other hand, a prospect cohort study, among 6,391 community-dwelling older adults in Japan, found that social participation (participation in sport organization) at least one per week was associated with the less likelihood of falling after controlling socio-demographic, medical history, physical function, depression, physical activity and physical environmental factors, OR = 0.82, 95% CI: 0.72, 0.95 (Hayashi et al., 2014). A recent longitudinal study, among a middle-aged and elderly European sample (n = 16,583), found that the long-term effect of falls was negatively associated with social participation (OR = 0.73, $p < .001$) and social support (OR = 2.20, $p < .001$) after confounding factors (Pin and Spini, 2016). Prospective cohort studies investigating social environment have not been published in the U.S.; however, social environment could be important factor interacting between fear of falling and falls (Meulen, Zijlstra, Ambergen, & Kempen, 2014).

Person-environment interaction. The interaction between the person and the environment is also important. According to the World Health Organization (WHO) report in 2007, "environmental factors encapsulate the interplay of individuals' physical conditions and the surrounding environment…, [and environmental factors] are not by themselves cause of falls – rather, the interaction between other factors and their exposure to environmental ones (p. 5)." Lord et al. (2006) reported that previous prospective cohort studies found that household hazards themselves were not associated with fall in primary analyses (Tinetti et.al 1988; Nevitt et al., 1990; Campbell et al, 1990; Teno et al., 1990; Gill et al, 2000); however, secondary analyses found that among vigorous older adults, more environmental hazards were associated with the likelihood of falling (Northridge et al, 1995; Speechley & Tinetti, 1991). In addition, some studies reported the effect of environmental factors differs with varying personal factors, such as gender, gait speed, or health status. First, a prospective study among 743 community-dwelling older adults found that women had lower rates of overall outdoor falls compared to men, RR = 0.72, 95% CI: 0.56, 0.92; however, women had higher rates of indoor falls, such as during household indoor activity compared to men, RR = 3.68, 95% CI: 1.50, 8.98, respectively (Duckham et al., 2013). Second, interesting findings of a nonlinear, U-shaped relationship between gait speed and falls was reported. People having faster or slower gait speed are at higher risk of falls compared to people having normal gait speed, IRR = 2.12, 95% CI: 1.48, 3.04 and IRR = 1.60, and 95% CI: 1.06, 2.42, respectively; to be specific, people walking fast had higher risk of outdoor falls, and people walking slowly had higher risk of indoor falls (Quach et al., 2011). Third, a study found that older adults with poor health status reported higher indoor fall rates during not moving, transitioning, or transferring; however, healthy older adults with fast gait speed reported higher outdoor fall rates during vigorous activity (Kelsey, Procter-Gray, Hannan, & Li, 2012).

Fall Prevention for Community-Dwelling Older Adults

Fall prevention interventions for community-dwelling older adults are summarized in this section. American Geriatrics Society and British Geriatrics Society (Kenny et al., 2011) and Cochrane systematic review by Gillespie et al. (2012) proposed effective fall prevention interventions including assessment and modification of risk factors. Among risk factors, evaluating feet and footwear, functional status (activity of daily living skills, use of adaptive equipment and mobility aids), fear of falling, and environment are important to assess risk of falls. In addition, the following direct interventions are effective to reduce fall rates or the number of fallers. First, a large body of evidence showed that both group and home-based, multiple-component exercise including balance and muscle strength training, and Tai Chi have significant effects in reducing risk of falling. Environmental modification including home safety, and feet and footwear management including using anti-slip shoe can reduce falls. Medication management including psychotropic medication reduction or adjustment reduced falls. While Vitamin D supplementation (800 IU daily) is not effective overall in general older adults, it may be effective in people with lower Vitamin D levels to decrease injuries from falls. In addition, management of postural hypotension, cardiac abnormality, and visual deficit can reduce falls.

While the above interventions are significantly effective in reducing falls among community-dwelling older adults, small number of trials showed that other single interventions such as fluid/nutrition therapy, psychological intervention, and/or knowledge/education intervention did not significantly reduce risk of falling (Gillespie et al., 2012). A recent Cochran review reported that using hip protection has little or no effect on reducing hip fracture risk in the community (Santesso, Carrasco-Labra, & Brignardello-Petersen, 2014); exercise interventions have small to moderate effects on reducing fear of falls (Kumar et al., 2016).

For unexplained recurrent falls, dual-chamber cardiac pacing is recommended for older adults with bradyarrhythmias including cardioinhibitory carotid sinus hypersensitivity (Kenny et al., 2011; Gillespie et al., 2012). Underlying mechanisms of falls related to cardiac disorder are carotid sinus hypersensitivity, vasovagal syndrome, bradyarrythmias, and tachyarrhtymias: specifically, these conditions result in two main episodes: (a) transient hypotension causing loss of balance, or (b) loss of consciousness with no recollection (Kenny et al., 2011). There have not been any other customized interventions specifically for HF patients living in the community.

Overview of Heart Failure

Heart failure (HF) is defined as "a complex clinical syndrome that can result from any structural or functional cardiac disorder that impairs the ability of the ventricle to fill or eject blood" (Yancy et al., 2013, p. 1814). Heart failure is a culmination of prolonged pathological process (Agarwal et al, 2012) and can be seen as a progressive disorder that is usually initiated after at least one of the following three types of index events: (1) an abrupt onset, such as a myocardial infarction, (2) a gradual or insidious onset, such as hemodynamic pressure or volume overloading, or (3) a heredity, such as genetic cardiomyopathies (Mann, Zipes, Libby, Bonow, & Braunwald, 2015). After these initial index events, cardiovascular function can return to normal function resulting in the patient being asymptomatic (i.e., compensatory mechanism). However, if these index events increase in frequency over time, it leads to secondary organ damages within the ventricle of the heart, which make HF patients experience HF symptoms (Mann et al., 2015; Yancy et al., 2013). Clinical warning signs and symptoms include shortness of breath, persistent coughing and wheezing, swelling in the lower legs or abdomen, fatigue or lightheadness, difficulties with everyday activities, poor appetite, cognitive impairment or increased heart rate (American Heart Association, 2015). Other signs or symptoms of HF include depression, sleep problems, or urinary incontinence related to the use of diuretics (Moraska et al., 2013; Hwang et al., 2013).

When HF is suspected, various laboratory testing and imaging can provide further evaluation to establish the presence of HF. Routine evaluation is based on chest radiology, electrocardiogram, laboratory panel and biomarkers (Mann et al., 2015). Left ventricle ejection fraction (LVEF) is an important parameter to further define HF as preserved LVEF (having normal left ventricular function; LVEF $\geq$ 50%) and reduced LVEF ($\leq$ 40%). This categorization is critical because treatment strategies are determined based on these two categories (Mann et al., 2015; Yancy et al., 2013).

To communicate information about the severity and prognosis of HF, the American College of Cardiology Foundation/American Heart Association Stages of HF (ACCF/AHA Stage of HF) includes four stages based on structural changes (Hunt et al., 2009): Stage A is high risk for developing HF, Stage B is asymptomatic HF, Stage C is symptomatic HF, and Stage D is refractory end-stage HF. Although the first two stages (A and B) do not have HF symptoms, patients in Stage A and B are at risk for developing HF. For example, in Stage A, patients have coronary artery disease, hypertension, or diabetes mellitus, but they do not have structural heart diseases (e.g., left ventricular (LV) function impairment, hypertrophy etc.). In Stage B, however, they have structural heart disease including LV function impairment and/or hypertrophy without HF symptoms. If their structural heart diseases are sustained and HF symptoms occur, then the severity of HF is classified as Stage C. If patients' HF symptoms worsen, which may need an advanced medical care, such as mechanical circulatory support, cardiac transplantation, or end-of-life care, they are viewed as in Stage D.

At Stage C and D, HF patients have various levels of functional limitations. The New York Heart Association (NYHA) functional classification (The Criteria Committee of the NYHA, 1994) provides useful information about the severity of HF based on a patient's exercise capacity and clinical symptoms. Patients with Stage C have various functional limitations ranging from no limitation of physical activity without symptoms (NYHA Class I) to severe functional limitation, where they are unable to carry on any physical activity and have symptoms even at rest (NYHA Class IV). Patents with Stage D are considered to have NYHA Class IV (Yancy et al., 2013).

As above, assessing severity of HF seems straightforward, however, it is challenging to isolate the independent effect of HF on falls because of the complex inter-relationships among comorbid conditions and HF. Studies have found that 86% of HF patients had 2 or more co-existing diseases, and nearly 40% of HF patients had more than five comorbid diseases (Triposkiadis et al. 2016; Braunstein et al., 2003). A recent review illustrated the complexity of comorbid disease associated with HF (Triposkiadis et al., 2016). One example of the complex mechanism of interactions among comorbidities that influences developing HF is as follows: hypertension can lead to several conditions that are risk factors for developing HF (e.g., LV hypotrophy, coronary artery disease). Coronary artery disease often leads to myocardial infarction. Adverse outcomes of HF may develop into other diseases, such as chronic kidney disease or atrial fibrillation. Diabetes and obesity are known risk factors for HF, but HF can lead to diabetes (cardiogenic diabetes). Anemia and chronic obstructive pulmonary disease may be inter-related with HF. These complex relationships among comorbid conditions and HF patients suggest that it is critical to include possible comorbid diseases in the model examining the independent effect of HF on falls.

Falls in HF Patients

Introduction

The purpose of this section is to identify state-of-the science knowledge regarding falls in people with HF. As mentioned in Chapter 1, many HF patients show fall-related signs/symptoms including postural hypotension, cerebellar injury, and cognitive impairments. The associations between symptoms, comorbid disease, and treatment-related effects and fall risks have been widely recognized in non-specific heterogenous older population. However, risk factors for falls in the HF patients have been understudied. Thus, a systematic review was conducted to identify fall rates, fall injuries, and fall risk factors among adult patients with HF. Specific research questions that guided the review were: (a) Are fall rates in adults with HF higher than the general adult population? (b) What is known about types of fall-related injuries in adults with HF? and, (c) What fall risk factors are prominent in adults with HF? Methodology and results of this section are a portion of a previous systematic review (K. Lee et al., 2016).

Methods

A systematic literature review used MEDLINE, CINAHL, PubMed, PsycINFO, and Cochrane Library to identify publications from August 1973 to June 2013. Keywords were accidental falls, heart failure, fall rates, fall injuries, and fall risk. Inclusion criteria were publications that were primary data-based, included heart failure sample, had falls/fall risk as study variables, and written in English language. Exclusion criteria were quality improvement/evaluation, case reports/studies, news, opinions, narrative reviews, meeting reports, reflections, and letters to editors. Data were abstracted using a standardized data collection form.

To update and complement findings from a previous systematic review (K. Lee et al., 2016), a recent PubMed search of scientific literature published from June 2013 to October 2016 was performed by using the same keywords. The following section describes findings from both a systematic review (K. Lee et al., 2016) and current publications from June 2013 to October 2016.

Results

Search results. In this systematic review, a total of 241 publications were identified: Medline (n = 35), CINAHL (n = 47), PubMed (n = 152), PsycINFO (n = 5), and Cochrane Library (n = 2). After excluding 64 duplicate publications (n = 64), 177 publications remained. In the process of screening titles and abstracts, 143 publications were excluded because they did not meet the inclusion criteria (i.e., inclusion criteria: publications that were primary data-based, included heart failure sample, had falls/fall risk as study variables, and written in English language). In the full-text assessment, 30 additional publications were excluded for the following reasons: did not include HF sample (n = 26), case report (n = 1), case study (n = 2), and overview of the literature (n = 1). Reference lists of included publications were reviewed, and no additional publications were identified in a hand-search of the reference lists. Four publications met the inclusion criteria (i.e., inclusion criteria: publications that were primary data-based, included heart failure sample, had falls/fall risk as study variables, and written in English language), had no exclusion criteria (i.e., exclusion criteria: quality improvement/evaluation, case reports/studies, news, opinions, narrative reviews, meeting reports, reflections, and letters to editors). In a PubMed search from 2013 to 2016, three publications met the inclusion criteria. Four publications from the systematic review and three publications from the additional recent search were critiqued for synthesis. Figure 2.2 provides a flow diagram of the review procedure.

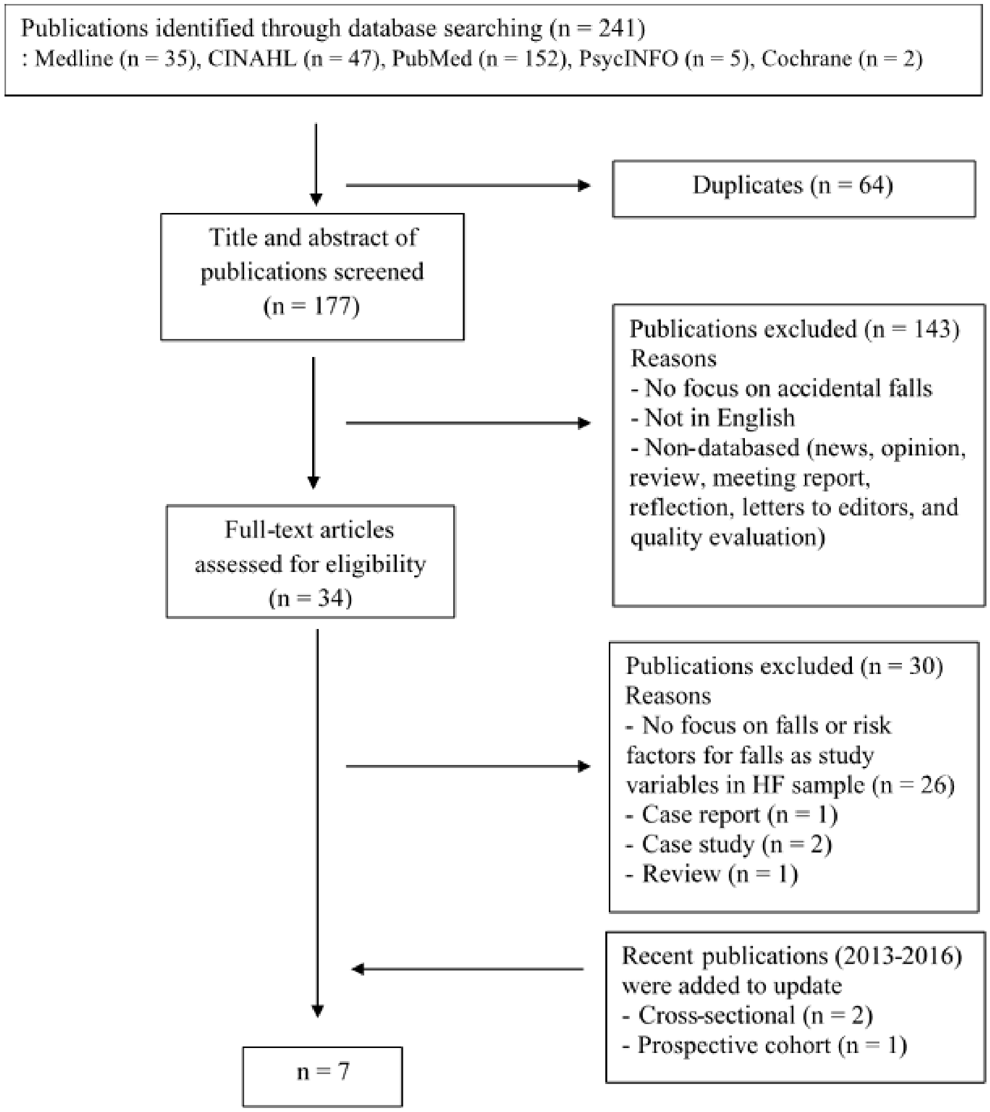

Figure 2.2 The modified flow diagram of the review procedure (falls in heart failure)

Note. The original figure appears in Lee, K., Pressler, S. J., & Titler, M. (2016). Falls in Patients with Heart Failure: A Systematic Review. Journal of Cardiovascular Nursing. doi: 10.1097/jcn.0000000000000292

Study characteristics. The seven publications included four descriptive studies with cross-sectional data collection (Lee, Cigolle, & Blaum, 2009; Tymkew & Templin, 2011), one retrospective case-control study (Gales & Menard, 1995), and one prospective cohort study (Carbone et al., 2009). The number of study participants with HF was 55 patients (Tymkew & Templin, 2011), 61 patients (Gales & Menard, 1995), 533 patients (P. G. Lee et al., 2009), 3,820 patients (Carbone et al., 2009), 91 patients (Stenhagen et al., 2013), 62 patients (Jansen et al., 2014), and 1,393 patients (Vetano et al., 2015). Study settings were acute care hospitals (Gales & Menard, 1995), long-term care facilities and community (P. G. Lee et al., 2009), home health services (Tymkew et al., 2011), and clinical centers (Carbone et al., 2009). Falls were measured in six publications (Carbone et al., 2009; Gales & Menard, 1995; P. G. Lee et al., 2009), and fall risk factors among HF patients were measured in one publication (Tymkew et al., 2011). Five publications were classified as high quality, and one publication was classified as moderate quality based on the Stanford critical appraisal form (Hanon et al., 2013) check lists. One of the four selected publications was unable to be classified because it contained only an abstract and not a full-text article (Table 2.3).

Fall rates and types of fall-related injuries in heart failure. To answer Research Question 1 - is the fall rate in HF higher than in the general adult population - one publication was found. The study (P. G. Lee et al., 2009) using a cross-sectional design reported data from the Health and Retirement Study (HRS). The purpose of the study was to describe the co-occurrence of five index conditions including falls, heart failure, coronary artery disease, diabetes, and urinary incontinence. In the study, 533 (4.8%) of 11,113 respondents aged 65 and older had HF, and among these HF patients, 43% had experienced two or more falls in the past two years (P. G. Lee et al., 2009). With this information, assumed that roughly 22% of community-dwelling older adults with HF had experience recurrent falls (two or more falls) in a year, the proportion of recurrent falls among HF patients is higher than that of recurrent falls (12.1%) in a year among general older adults living in the community (Tromp et al., 2001). In the study, among the 1,767 patients with coronary artery diseases, 17% had HF and 34% reported falls; among the 2,156 patients with diabetes mellitus, 9% had HF and 28% reported falls; and, among the 2,778 patients with urinary incontinence, 7% had HF and 36.6% reported falls (P. G. Lee et al., 2009). Another cross-sectional study (Vetano et al, 2015) used a similar approach to identify co-occurrence conditions between chronic disease and geriatric syndrome among Canadian and European community-dwelling older adults. Among 1,393 HF patients, 29% reported falls. In addition to estimating the prevalence of falls, one prospective cohort study (Stenhagen et al, 2013) and one cross-sectional study (Jansen et al, 2014) examined the association between HF and falls among general community-dwelling older adults, adjusted OR = 1.88, 95% CI: 1.17, 3.84 and adjusted OR = 1.89, 95% CI: 1.04, 3.44. No publications were found that addressed Research Question 2 - what are the types of fall-related injuries among adults with HF.

Risk factors for falls in HF To answer the Research Question 3 - what are the fall risk factors among adults with HF - three publications were found (Carbone et al., 2009; Gales & Menard, 1995; Tymkew & Templin, 2011). Two publications reported an association between HF and increased fall risk (Gales & Menard, 1995; Tymkew & Templin, 2011). Results of one case-control study (Gales & Menard, 1995) demonstrated that HF was significantly more prevalent in the fall group (n = 100) than the non-fall group (n = 100) (37% vs. 24%; $p = 0.046$), and patients with HF had 1.86 times greater odds of falling than people without HF, OR = 1.86, 95% CI: 1.01, 3.43. According to the cross-sectional study (Tymkew & Templin, 2011), among the total 75 participants with HF or COPD (COPD n = 20, HF n = 55), 94.7% were identified as being at risk for falls based on the results of the following tests: Dynamic Gait Index, Tinetti Test, Berg Balance Test, Timed Up and Go Test, 2 Minute Walk Test, and gait speed. The study (Tymkew & Templin, 2011) reported fall risk measured by the state of the patient's gait and balance, but did not test the association between risk factors and fall incidence or report HF fall risk rates exclusively.

Two publications focused on the relationship between medications and falls (Carbone et al., 2009; Gales & Menard, 1995). One cohort study (Carbone et al., 2009) reported that the use of loop diuretics was not significantly associated with falls after controlling for confounding factors, HR = 1.01, 95% CI: 0.96 , 1.08. While the full model above did not find a significant association between loop diuretics and falls, the reduced model, adjusted for age, ethnicity, and BMI, showed the loop diuretics was significantly associated with falls, HR = 1.37, 95% CI: 1.30, 1.45 (Carbone et al., 2009). One case-control study found that more frequent benzodiazepine use was associated with falls, OR = 2.67, 95% CI: 1.42, 5.02 (Gales & Menard, 1995). Additionally, more digoxin therapy was associated with falls, OR = 1.91, 95% CI: 1.02, 3.57 (Gales & Menard, 1995). The association between other medications (antihypertensives, antipsychotics, other sedatives, narcotics, and nitrates) and falls were not statistically significant (Gales & Menard, 1995). Studies are summarized in Table 2.3.

Table 2.3 Selected 7 Publications Examining Falls in Heart Failure (1995 – 2015)

Topic	Author (year)	Aim	Sample (medical condition, number, age, gender) and setting	Study design	Measures	Key findings	Overall study quality and limitation
Fall occurrence in HF	P.G. Lee et al. (2009)	To examine the co-occurrence of coronary artery disease, HF, diabetes mellitus, urinary incontinence, and falls.	HF is a sub-sample (n = 533) Total sample (n = 11,113) Age 65 + Female (58%) Community and long-term care facilities. U.S.A.	Cross-sectional	DV: falls Falls: self-reported information (two or more falls or any injurious fall requiring medical attention in the previous 2 years).	In 533 HF patients, 43% have recurrent falls (two or more falls) in 2 years.	HQS HF data were collected from a patients' or a proxy's self-report in the past 2 years.
Fall occurrence in HF	Vetrano et al. (2015)	To examine the association betweeen chronic diseases and geriatric syndromes.	HF is a sub-sample (n = 1393) Total sample (n = 6803) Mean age 82 Female (69%) Community (home care) Canada and Europe	Cross-sectional	DV: falls IV: Having HF	The prevalence of any falls in 3 months was 29% among 1393 HF patients.	HQS The subjects were recruited from home care services. Therefore, this population may not be generalized to other older population. The association between HF and falls was not examined.

Table continued on next page.

Table 2.3 (continued)

Association between HF and Falls	Stenhagen et al. (2013)	To identify risk factors predicing falls in general population	HF is a sub-sample (n = 91) Total sample (n = 1763) Mean age 78 Female (54%) Community Sweden	Prospective cohort study	DV: falls IV: HF with symptoms	Having HF has greater odds of falling (age-and sex- adjusted OR = 1.88, 95% CI: 1.17, 3.84)	HQS Selection bias may occur. Lower fall incidence (13.3% to 19.1%) in the general population was reported. Relatively healthy subjects were included in the overall study population, and this may lead to underrepresentation of older adults.
Association between HF and Falls	Jansen et al. (2014)	To examine the association between cardiovascular condition and recurrent falls.	HF is a sub-sample (n = 62) Total sample (n = 8,173) Mean age 64 Female (54%) Community Ireland	Cross-sectional	DV: recurrent falls IV: Having HF	Having HF has greater odds of recurrent falls (fully adjusted OR = 1.9, 95% CI: 1.0, 3.4)	HQS Most variables are based on self-reports. Fall reports were lower than previous studies that may be due to underreports. Cross-sectional study have limit estimate the causal relationship between HF and falls.
Fall prevalence in HF	P. G.Lee et al. (2009)	To examine the co-occurrence of coronary artery disease, HF, diabetes mellitus, urinary incontinence, and falls.	HF is a sub-sample (n = 533) Total sample (n = 11,113) Age 65 + Female (58%) Community & long-term care facilities. U.S.A.	Cross-sectional	DV: falls Falls: self-reported information (two or more falls or any injurious fall requiring medical attention in the previous 2 years).	In 533 HF patients, 43% have falls.	HQS HF data were collected from a patients' or a proxy's self-report in the past 2 years.

Table continued on next page.

Table 2.3 (continued)

Proportion of fall risk (poor gait and balance) in HF	Tymkew et al. (2011)	To examine whether patients with a primary diagnosis of COPD or HF are related to an increased fall risk.	HF is a sub-sample (n = 55) Mean age 81.3 Female (65%) Home health services U.S.A.	Cross-sectional	DV: overall fall risk – Dynamic Gait Index – Tinetti – Berg balance test – Timed Up and Go test – 2 Minute Walk Test – Gait speed. IV: CHF diagnosis	94.7% of participants with HF or COPD were identified as being at risk for falls (poor gait and balance).	Published abstract only. Not applicable to assess methodological quality. Small sample size. Limited description of measurements. Limited statistical analysis report. No comparison of results between COPD or HF groups.
Fall risk factors: medication	Gales et al. (1995)	To examine the relationship between the use of selected medications and falls in hospitalized older adults.	HF is a sub-sample (n = 61) Fall group: case n = 100 Non-fall group: control n = 100 Mean age: 77.8 Female (50.5%) Acute care hospital. U.S.A.	Case-control	DV: falls IV1: disease state IV2: selected medications (antidepressants, antihypertensives, antipsychotics, benzodiazepines, diuretics, digoxin, other sedatives, narcotics, and nitrates) 48 hours prior to the falls or reference day.	Having HF was associated with a 1.86 times greater risk of falling (OR = 1.86, 95% CI: 1.01, 3.43; p = 0.046). More frequent benzodiazepine use was associated with a greater risk of falling (OR = 2.67, 95% CI: 1.42, 5.02; p = 0.002). More frequent digoxin use was associated with a greater risk of falling (OR = 1.91, 95% CI: 1.02, 3.57, p = 0.042).	MQS The association between falls and specific combinations of diseases was not examined. Except for benzodiazepine, the effects of other medication dosages, duration of therapy, the association between medication use time and fall incidence time was not examined.

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Table 2.3 (continued)

Fall risk factors: medication	Carbone et al. (2009)	To investigate whether loop diuretics would be a risk factor in the loss of bone mineral density (BMD), falls, and fractures in women.	HF is a sub-sample (n = 3,820) Total sample for testing the association between loop diuretics and falls (n = 38,722) Mean age 67.5 Female (100%) 40 clinical centers U.S.A Mean follow-up: semiannual, for 7.7 years (falls)	Prospective cohort	DV: falls IV: Loop diuretics	Adjusted models (age, ethnicity, and BMI): Loop diuretics usage was significantly associated with falls (HR = 1.37, 95% CI: 1.30, 1.45). Fully adjusted models: Loop diuretics usage was not significantly associated with falls. (HR = 1.01; 95% CI: 0.96, 1.08, p = 0.620).	HQS In the analysis about the association between loop diuretics and falls among the entire women (n = 38,722), there is no report about the number of HF patients and non-HF patients.

Note. This data partially appears in Lee, K., Pressler, S. J., & Titler, M. (2015). Falls in Patients With Heart Failure: A Systematic Review. Journal of Cardiovascular Nursing. doi: 10.1097/jcn.0000000000000292.
Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; DV, dependent variable; HF, heart failure; HQS, high quality study; HR, hazard ratio; IV, independent variable; MQS, moderate quality study; OR, odds ratio
Publications are listed in order by topic.

Conceptual Framework

For this study, a fall is defined as *an unexpected event in which the participants unintentionally come to rest on the ground, floor, or lower level, other than as a consequence of substantial external force (e.g., moving vehicle)*. The previous review found a noteworthy gap in the research on risk factors for falls specific to community-dwelling older adults with HF patients. Only physical function (poor gait and balance) and medications (digoxin and benzodiazepine) were investigated, and to date other potential risk factors for falls have not been fully examined in community-dwelling older adults with HF patients. As the first step to develop and test optimized fall prevention interventions, this study examines risk factors for falls in community-dwelling older adults with HF.

Because there is no specific conceptual model addressing the mechanism of falls among community-dwelling older adults with HF, I first identified personal and environmental factors to explain falls via an extensive literature review using prospective studies on community-dwelling older adults. Following the literature review, I further categorized risk factors for falls into one of the two broad areas: (a) personal factors – socio-demographic, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication; and (b) environmental factors - physical environment and social environment. Table 2.4 summarizes fall risk factors identified from literature review and presents variables to be included in the dissertation study that is available in the HRS dataset. Table 2.5 summarizes conceptual and operational definitions of variables used in the study.

Table 2.4 Summary of Fall Risk Factors Identified in Literature Review and Available in the Health and Retirement Study (HRS)

Literature Review			**Available in the HRS (Dissertation)**			
Risk Factors for Falls known in community-dwelling older adults		Examined in HF patients	HRS availability	Aim 1 RQ1.1	Aim 1 RQ1.2-3	Aim 2
Pathology	HF		available	IV	IV	
Socio-demographic	age		available	cv	cv	cv
	gender/sex		available	cv	cv	cv
	race/ethnicity		available	cv	cv	cv
	spouse/partner status		available	cv	cv	cv
	living alone		available	ns	ns	
General health	self-rated health		available	cv	cv	
	fall history		available	cv	cv	
	multiple comorbidity		available	cv	cv	
	obesity (BMI)		available	cv	cv	
	Parkinson's disease		not available			
	stroke		available	cv	cv	
	arthritis/rheumatism		available	cv	cv	
	diabetes		available	cv	cv	
	cardiovascular disease		available	cv	cv	
	cancer		available	cv	cv	
Physical function	mobility (such as walking)		included	cv	IV	IV
	muscle strength	V	included	cv	IV	IV
	ADL difficulty		included	cv	IV	IV
	balance	V	only half of the sample			
Cognitive function	memory		available	cv	IV	IV
	processing speed		available			
	psychomotor speed		not available			
	IADL difficulty		available	cv	IV	IV

Table continued on next page.

Table 2.4 (Continued)

Sensory function	hearing impairment		available	cv	IV	IV
	visual impairment		available	cv	IV	IV
Urinary function	urinary incontinence		available	cv	IV	IV
Physical symptom	pain		available	cv	cv	
	dizziness/vertigo		alternative wave			
	sleep problem		inconsistent			
	orthostatic hypotension		not available			
Psychological symptom	depression		available	cv	cv	
	fear of falling		not available			
Health behavior	physical activity		available	cv	cv	
	increased alcohol use		available	cv	cv	
	walking aid use		available	cv	cv	
	inappropriate footwear use		not available			
Medication (number and types of)	polypharmacy (> 4 meds.)		not available			
	sedatives	V	available	cv	cv	
	anti-depressants	V				
	antihypertensive		not available	ns	ns	
	antiepileptic		not available			
	anti-cholinergic		not available			
	antiarrhythmic	V	not available			
Physical environment	living environment/ home		available	cv	cv	
	neighborhood environment		available	cv	cv	
	public environment		not available			
Social environment	social participation		available	cv	cv	
	social support		proxy variables	cv	cv	

Note. Abbreviations: V, variable used in the study; cv, covariates; IV, independent variable;, ns, not selected from the variable selection process

Table 2.5 Conceptual Definitions and Operational Definitions for Conceptual Factors Used in the Study

Concept	Conceptual Definition	Sub-concept	Operational Definition/Measurement
Socio-demographic	Sociological and demographic characteristics	Age	Age in years at the interview · Range: 65 – Actual number
		Gender/sex	Gender/sex · 0 = male · 1 = female
		Race/ ethnicity	Self-defined race/ethnicity · 1 = non-Hispanic White · 2 = non-Hispanic Black · 3 = Hispanic · 4 = other
		Marital/ partnered status	Marital/partnered status · 0 = married/partnered · 1 = does not have spouse or partner
		Living alone	Living alone, measured by asking the number of people in the household. · 0 = living with one or more · 1 = living alone
General health	Participants' overall health	Self-reported health	Self-reported general health status was measured in five categories, then dichotomized. · 0 = excellent, very good or good · 1 = fair or poor
		Fall history	Fall history in the past two years (yes/no) · 0 = No falls · 1 = falls in the past two years
		Co-existing medical conditions	For each, the following chronic diseases were coded as dummy variables and included in the model separately. (1) hypertension; (2) diabetes; (3) cancer/a malignant tumor of any kind except skin cancer; (4) lung disease except asthma, such as chronic bronchitis or emphysema; (5) stroke or transient ischemic attach; and, (6) arthritis or rheumatism.

Table continued on next page.

Table 2.5 (Continued)

		BMI	Body Mass Index (BMI) = kg/m2 (weight divided by the square height). · 1 = normal (18.5 – 24.9) – reference category · 2 = underweight (<18.5) · 3 = overweight (25.0 – 29.9) · 4 = obese (≥ 30.0)
Physical symptom	Person's subjective feeling or body responses related to the consequence of body impairment	Pain	Self-reported pain, assessed by asking whether a participant is often troubled with pain. · 0 = no · 1 = often troubled with pain
Psychological symptom	Person's mental responses to the affected emotions or thoughts.	Depression	Total score on the 8-item Center for Epidemiologic Studies Depression (CESD) scales: 6 negative indicators (yes/no): (1) depression, (2) everything is an effort, (3) sleep is restless, (4) felt alone, (5) felt sad, and (6) could not get going. 2 positive indicators (yes/no): (1) felt happy and (2) enjoyed life all or most of the time. A total score (ranging 0 – 8) was calculated by summing the number of "yes" answers of six negative indicators and summing the number of "no" answers of two positive indicators. Then, the variable was dichotomized based on the cutoff score of 4 or more, indicating depressive symptom. · 0 = CESD score 0 – 3 · 1 = CESD score 4 - 8, depressive symptom
Health Behavior	Activities influencing a person's health.	Physical activity	Physical activity was measured by asking whether a participant has participated in vigorous activity/exercise more than once a week in the last year, such as like sports, heavy housework, or a job involves physical labor. · 0 = at least one of vigorous activities more than once a week · 1 = less than a week or none of vigorous activities

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Table 2.5 (Continued)

		High-risk alcohol use	Alcohol use was measured by asking whether a participant has any alcohol to drink in the last three months. If a participant has any alcohol to drink, the subsequent question was asked how many drinks per day. · 1 = non-drinker (reference category; 0 drinks/day) · 2 = moderate (1-3 drinks/day for women, 1-4 drinks/day for men) · 3 = high-risk drink (≥ 4 drinks/day for women or ≥ 5 drinks for men)
		Walking aid use	Walking aid use was measured by asking whether a participant uses a walking aid while they are walking: · 0 = no walking difficulty or no walking aid use · 1 = walking aid use
Medication	Types of medications	Psychiatric medication use	Psychiatric medication use was measured by asking whether a participant takes any of the following medications: tranquilizers, antidepressants, or pills for nerves? · 0 = none of them · 1 = use at least one of them
		Anti-hypertensive medication use	Antihypertensive medication use was measured by asking whether a participant takes in order to lower blood pressure: · 0 = no use · 1 = use
Physical function	Person's ability to perform various activities, ranging from basic self-care to more vigorous activities requiring mobility, strength, or endurance.	ADL difficulty	ADL difficulty was measured by a 3-item questionnaire asking whether or not a participant has difficulties in performing each of the following basic tasks: bathing/showering, eating, and getting in/out of bed A total score was summarized by counting 'yes=1' answers. · 0 = No difficulty in any of ADL tasks · 1 = one or more difficulties in ADL tasks

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Table 2.5 (Continued)

		Mobility difficulty	Mobility difficulty is measured by a 5-item questionnaire asking whether or not a participant has difficulties in performing each of the following tasks: walking on block, walking several blocks, walking across a room, climbing one flight of stairs, and climbing several flights of stairs. A total score was summarized by counting 'yes=1' answers · 0 = No difficulty in any of mobility tasks · 1 = one or more difficulties in mobility tasks
		Large Muscle Move difficulty	Large Muscle weakness is measured by a 4-item questionnaire asking whether a participant has difficulties in performing each of the following tasks: (1) sitting for two hours, (2) getting up from a chair, (3) stooping, kneeling, or crouching, and (4) pushing or pulling large objects. A total score was summarized by counting 'yes=1' answers · 0 = No difficulty in any of large muscle function · 1 = one or more difficulties
Cognitive function	Person's ability for the intellectual processes of acquiring and using knowledge.	Cognitive impairment	Used both self-respondents and proxy interview. For self-respondent, imputed scores were used, measured by the m-TICS. Summary scores range from 0 to 35. Then, it was dichotomized based on the cutoff score of 8 or less out of 35. For proxy interview, the short form of Jorm IQCODE was used. Summary scores ranges from 1 to 5. Then, it was dichotomized based on the cutoff score of 3.44 or more out of 5. · 0 = no · 1 = cognitive impairment
		IADL difficulty	IADL is measured by a 5-item questionnaire asking whether a participant has difficulties in performing each of the following IADL tasks: using the phone, managing money, taking medication, shopping for groceries and preparing hot meals. A total score was summarized by counting 'yes=1' answers: · 0 = No difficulty in any of IADL tasks · 1 = one or more difficulties

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Table 2.5 (Continued)

Sensory function	Person's ability to detect information though persons' sense including eyesight or hearing.	Hearing	Self-rating hearing condition, using hearing aids as usual, was measured in five categories. Then, it was dichotomized. · 0 = excellent, very good, good or fair · 1 = poor
		Vision	Self-rating eyesight, using glasses or corrective lenses as usual, was measured in six categories. Then, it was dichotomized. · 0 = excellent, very good, good or fair · 1 = poor or legally blind
Urinary function	Person's ability to eliminate liquid waste from the blood through the urinary tract.	Urinary incontinence	Urinary incontinence measured by asking whether a participant has an experience losing any amount of urine beyond the control during the last 12 months. · 0 = no · 1 = yes (urinary incontinence)
Physical environment	Physical objects or structures in the home, place of residence, neighborhood, or outdoor.	Living environment (Home safety feature)	Living environment/home was measured by asking whether presence or absence of features to help older or disabled persons get around, such as a ramp, railings, or modifications for a wheelchair at home/apartment. Or, no special features to safeguard older or disabled persons, such as grab bars, a shower seat, or a call device or another system to get help when needed at home/apartment. · 0 = presence of home safety features · 1 = absence of home safety features
		Neighborhood environment (Neighborhood safety)	As a proxy variable for outdoor/neighborhood environment, the 'neighborhood safety' variable was used, assessed by rating the safety of participants' neighborhood. Then, it was dichotomized. · 0 = excellent, very good, or good · 1 = fair or poor

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Table 2.5 (Continued)

Social environment	Social dimension of a person's life including social participation and social support.	Social participation	Social participation was assessed by asking how often participants got together with any of their neighbors to chat or for a social visit. If participants answered 'never' or 'almost never', the variable was coded as '1'. Otherwise, it was coded as '0'. · 0 = getting together with neighbors · 1 = never or almost never
		Relatives in neighborhood	As a proxy variable for social support, the variable, assessed by asking whether participants had relatives in their neighborhood. · 0 = have relatives in neighborhood · 1 = none
		Good friends in neighborhood	As a proxy variable for social support, the variable, assessed by asking whether participants had good friends in their neighborhood. · 0 = have good friends in neighborhood · 1 = none
		Getting a ADL help	As a proxy variable for social support, the variables assessed by asking whether participants have ever had a help when they have difficulties in any of the following ADL tasks: dressing, walking, bathing, eating, getting in/out of bed, or toileting. · 0 = no difficulty or no help · 1 = ever had a help

Abbreviations: ADL, Activities of Daily Living; m-TICS, the Modified Telephone Interview for Cognitive Status; IQCODE, the Informant Questionnaire on Cognitive Decline in the Elderly; IADL, Instrumental Activities of Daily Living.

Understanding Conceptual Mechanism of Falls Resulting from Heart Failure

In order to lay groundwork for the conceptual model used in this study, it is useful to first discuss the Disablement Process Model (DPM; Verbrugge & Jette, 1994), one widely used in health science. The DPM helps us understand the mechanism of falls resulting from HF and distinguish the terminology of key components of the process. Four major parts of the disablement process is as follows (Verbrugge & Jette, 1994, p.4) – Pathology, Impairment, Functional Limitations, and Disability. A disease (Pathology) leads to “dysfunctions and structural abnormalities in specific body systems, such as musculoskeletal, cardiovascular, neurological etc. (Impairment)”. Impairment contributes to “restrictions in basic physical and mental actions, such as ambulate, reach, stoop, climb stairs, produce intelligible speech, see standard print etc. (Functional Limitations)”, which eventually leads to “difficulty doing activities of daily life, such as job, household management, personal care, hobbies, active recreation, clubs, socializing with friends and kin, childcare, errands, sleep, strips etc. (Disability).” However, the direction is neither always linear nor unidirectional. Feedback loops can also occur among frail or chronically disabled individuals (Verbrugge & Jette, 1994).

The information about the causal pathway of the DPM is beneficial to understand the falling process. For example, HF (Pathology) leads to the dysfunction and structural changes in specific body systems such as cardiovascular, musculoskeletal or neurological system (Impairment). This impaired body systems leads to restrictions in physical function (e.g., poor gait and balance) or cognitive function (e.g., declined psychomotor speed), which contribute to falls. Some falls lead to injuries, which contribute to difficulties in performing activities of daily life (Disability). However, this pathway is not unidirectional, and backward loops can be possible.

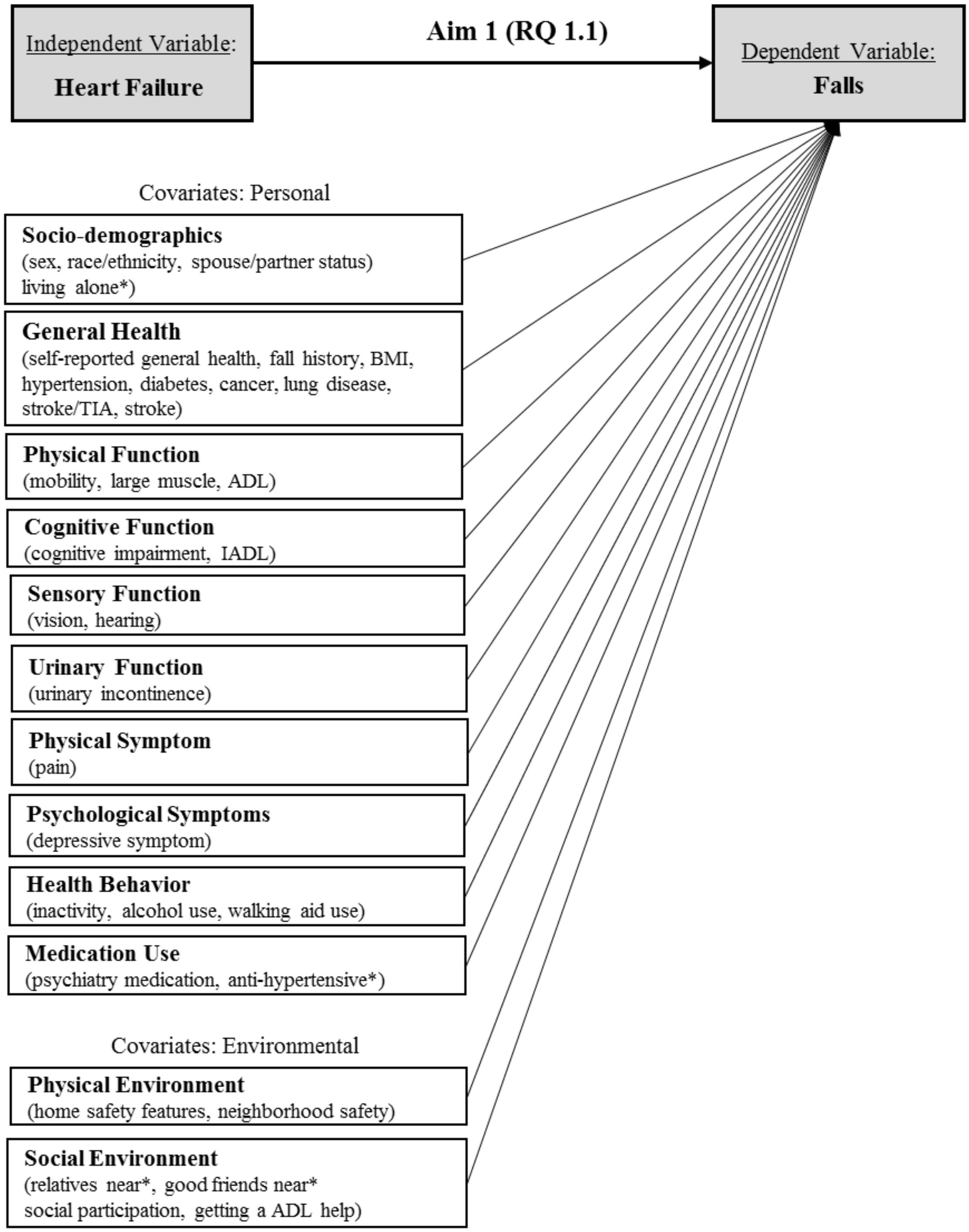
While understanding conceptual mechanism of falls explaining indirect effects of HF may be useful, the main interest of this study is which of these four key components independently explain falls and how they are interact with each other because knowing independent effects of each risk factor and their interactions are important to inform the nursing science to test fall prevention interventions for community-dwelling older adults with HF. This study focuses on the moderating effect of these functional parts (impairment, functional limitation and disability) between HF and falls rather than the mediating effect of them (causal pathway). Although this study does not focus on the causal pathway of the disablement process, discussing DPM also is useful because it distinguishes the terminology of Functional Limitation and Disability, which many researchers often used interchangeably. These terms are frequently confused in the literature and yet it is beneficial to inform the healthcare providers and researchers to have clear understanding of how Functional Limitation and Disability might differ.

According to the DPM, Functional Limitation refers to restrictions in individual generic capabilities to perform physical and mental (cognitive) actions, unrelated to a specific situation. For example, Functional Limitations in physical actions include difficulties in walking one block, stooping, or pushing large objects. Functional Limitations in cognitive actions include includes difficulties in performing memory test such as recalling 10 words or the Serial 7's subtraction test. On the other hand, Disability defines a pattern of behavior related to a specific situation resulting from Functional Limitation (Nagi, 1965; Verbrugge & Jette, 1994). Specifically, Disability includes difficulties in Activities of Daily Living (ADL; e.g., bathing) and Instrumental Activities of Daily Living (IADL; e.g., grocery shopping), in which these activities are essential daily activities for individuals as members of society.

Because this study mainly focuses on examining the independent effects of HF (Pathology) on falls (Aim 1) , and identifying how the independent effect of HF on the likelihood of falling varies depending on the functional status (i.e., testing moderating effect of each functional factor pertaining to physical, cognitive, sensory and urinary), the new conceptual model guiding this study categorized these three components (Impairment, Functional Limitation, and Disability) into one of the four major functions: Physical, Cognitive, Sensory, and Urinary that related to falls. I also incorporated other personal and environmental factors into my model based on the previous literature review on risk factors for falls among community-dwelling older adults.

Conceptual Model for Aim 1

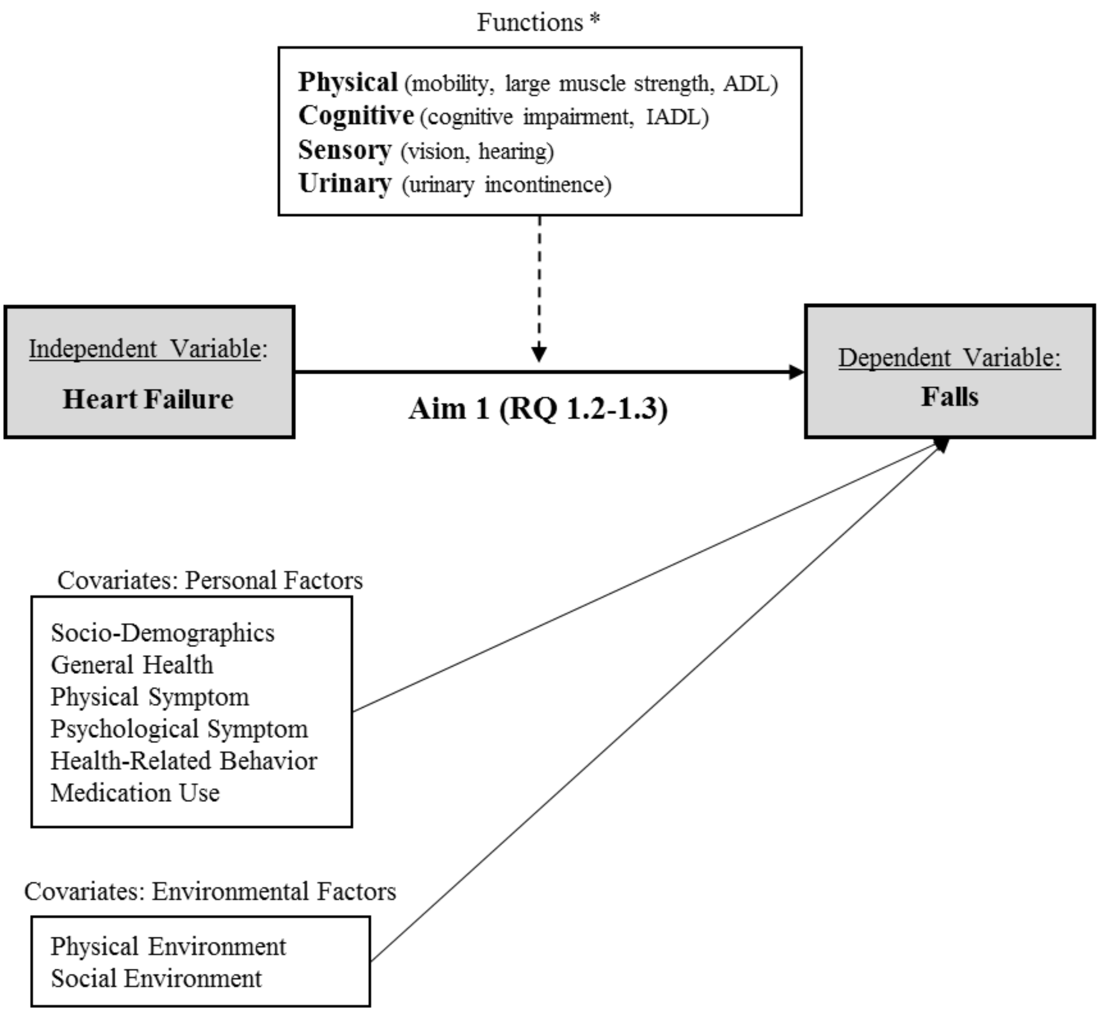
Aim 1 of the study is to examine the independent effect of HF on the likelihood of falling among community-dwelling older adults. In particular, Research Question 1.1 examines the null hypothesis that there is no relationship between HF and falls after controlling for personal (socio-demographics, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication use) and environmental (physical and social environment) factors (Figure 2.3).



Note. * 4 variables (living alone, anti-hypertensive medication, relatives near, good friends near) were not selected in the final model through the variable selection process.
Abbreviations: BMI, Body Mass Index; TIA, Transient Ischemic Attack; ADL Activities of Daily Living; IADL, Instrumental Activities of Daily Living

Figure 2.3 Conceptual model for Aim 1 (Research Question 1.1)

Research Questions 1.2 and 1.3 examine the differential effect of HF on falls moderated with and without functional impairment (i.e., physical, cognitive, sensory, and urinary impairment), after controlling for personal and environmental factors (Figure 2.4). To investigate the differential effect of HF on falls, this study used two approaches. The first approach (Research Question 1.2) is obtaining odds ratio for HF for each functional sub-group (i.e., those with and without physical, cognitive, sensory, and urinary impairment). The second approach (Research Question 1.3) is testing the ratio of odds ratio comparing the differential effect of HF on falls depending on those with and without functional impairment and obtaining the p-value for the difference. Table 1.1 presents detailed research questions and null hypotheses according to specific aims (see page 6 for Aim 1).



Note.
* For Aim 1 (RQ 1.2-1.3), each functional factor was examined one at a time, and other functional factors were used for adjustment.
Abbreviations: ADL Activities of Daily Living; IADL, Instrumental Activities of Daily Living

Figure 2.4 Conceptual model for Aim 1 (Research Questions 1.2 – 1.3) testing for interaction effect.

Conceptual Model for Aim 2

Aim 2 is restricted to the HF sample and examines the independent relationship between each functional impairment (i.e., physical, cognitive, sensory, and urinary impairment) and the likelihood of falling among community-dwelling older adults with HF. Specifically, I examine the null hypothesis that among those with HF, there is no relationship between each functional impairment (i.e., physical, cognitive, sensory and impairment) and the likelihood of falling after controlling for age, sex, race/ethnicity, and spouse/partner status. Table 1.1 presents detailed research questions and null hypotheses according to specific aims (see page 7 for Aim 2). Figure 2.5 shows a schematic presentation of the conceptual model guiding the study for Aim 2.

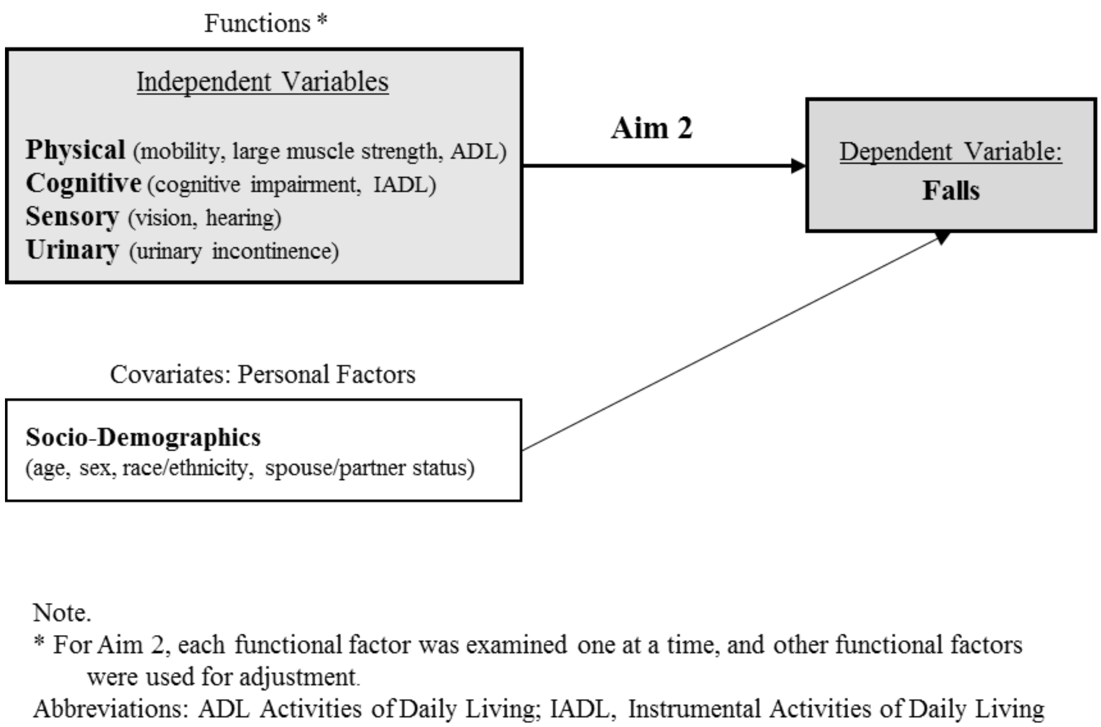


Figure 2.5 Conceptual model for Aim 2.

CHAPTER 3

METHODS

Overview of Research Strategy

This dissertation study addresses the gaps in the science about falls in community-dwelling older adults with HF. More specifically, for Aim 1, I estimated the independent effect of HF on the likelihood of falling among community-dwelling older adults aged 65 and older after controlling for personal (socio-demographic, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior and medication) and environmental (physical environment and social environment) factors. To achieve Aim 2, I explored functional impairment (i.e., physical, cognitive, sensory and urinary impairment) in explaining falls among community-dwelling older adults who have HF aged 65 and older. The study design of this dissertation is a retrospective cohort study using data from the HRS from 1998 to 2014. The HRS is a nationally representative US data source on older adults in the community (Servais, 2010) and is well suited to achieve the aims of this dissertation to examine the relationship between HF and falls among community-dwelling older adults.

Data Source: The Health and Retirement Study

The Health and Retirement Study (HRS) is a nationally representative longitudinal study of approximately 38,000 older adults in the U.S. that started in 1992 (Servais, 2010). The HRS participants are interviewed every two years. The HRS is sponsored by the National Institute of Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan. HRS participants are strategically sampled to represent the older US population using complex sample design methods. The HRS uses the core surveys of telephone interviews to obtain information on self-reported health conditions, health services, labor force, economic status, family structure, and expectations. HRS participants are selected to represent distinct birth cohorts moving through time together. In 1992, the initial HRS cohort consisted of participants born 1931 to 1941, who were aged 51 to 61 at the time. In 1993, the second study included another cohort born before 1921, who were 70 or older at the time (the Asset and Health Dynamics Among the Oldest Old, or AHEAD). In 1998, the original HRS and the AHEAD cohorts were merged, and two new birth cohorts were added to the study in order to fill the age gaps of the study. Since then, the HRS has added a new cohort every six years (aged 51 and older).

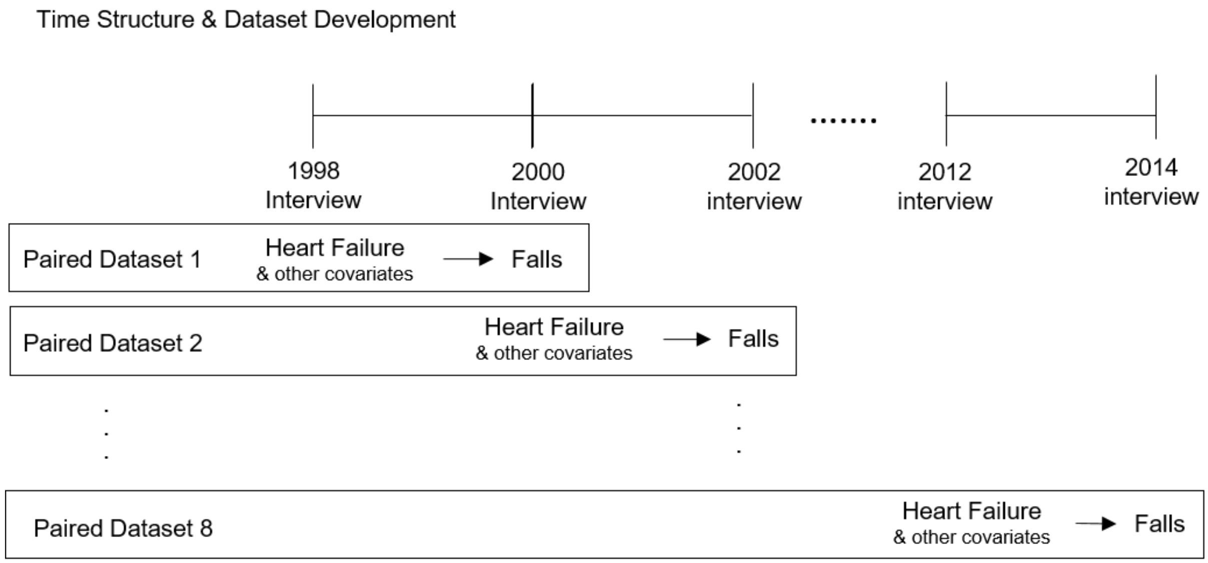
Because HRS data in 1998 and subsequent years have no age gap, this dissertation study used the HRS core interview data from 1998 (Wave 4), 2000 (Wave 5), 2002 (Wave 6), 2004 (Wave 7), 2006 (Wave 8), 2008 (Wave 9), 2010 (Wave 10), 2012 (Wave 11), and 2014 (Wave 12). Unlike the entire HRS study, which included people aged 51 or older, a subset of the participants aged 65 or older was used; therefore, a new age-eligible cohort for the dissertation is added every two years. The Institutional Review Board (IRB) at the University of Michigan determined that this dissertation study is exempt from IRB review because this dissertation used publicly available and de-identified human subject data, (IRB not regulated status; HUM00126099; See Appendix A).

Methods for Aim 1

Study Participants for Aim 1

For Aim 1, inclusion criteria of the HRS participants were the following: they had to be (1) 65 years of age or older at the time of the interview; (2) participated in at least two consecutive waves (Figure 3.1); (3) responsive to a question about having HF or not (yes/no) in HRS between 1998 and 2012 (HRS interview Waves 4 to 11); (4) responsive to a 2-year follow-up question whether they experienced falls or not (yes/no) between 2000 and 2014 (HRS interview Waves 5 to 12); and, (5) residing in the community at baseline of the study. I excluded HRS participants who were institutionalized at baseline, including nursing home or other types of institutions, such as in prison, jails, long-term or dependent care facilities, at baseline of the study. The initial sample included 33,314 unique individuals (157,531 observations[1]) in the HRS study from 1998 to 2012. Among them, a total of 17,712 unique individuals (70,888 observations) met the inclusion criteria for Aim 1. Figure 3.2 presents the flow diagram of the selection process of the study sample for Aim 1.

[1] Repeated observations with a subject over HRS study waves



For constructing the long-formatted dataset, 8 paired datasets were stacked.

On average, each unique individual was participated in a 2-year interval paired-interviews about four times (ranges 1 – 8).

Figure 3.1 Time structure and dataset development for Aim 1

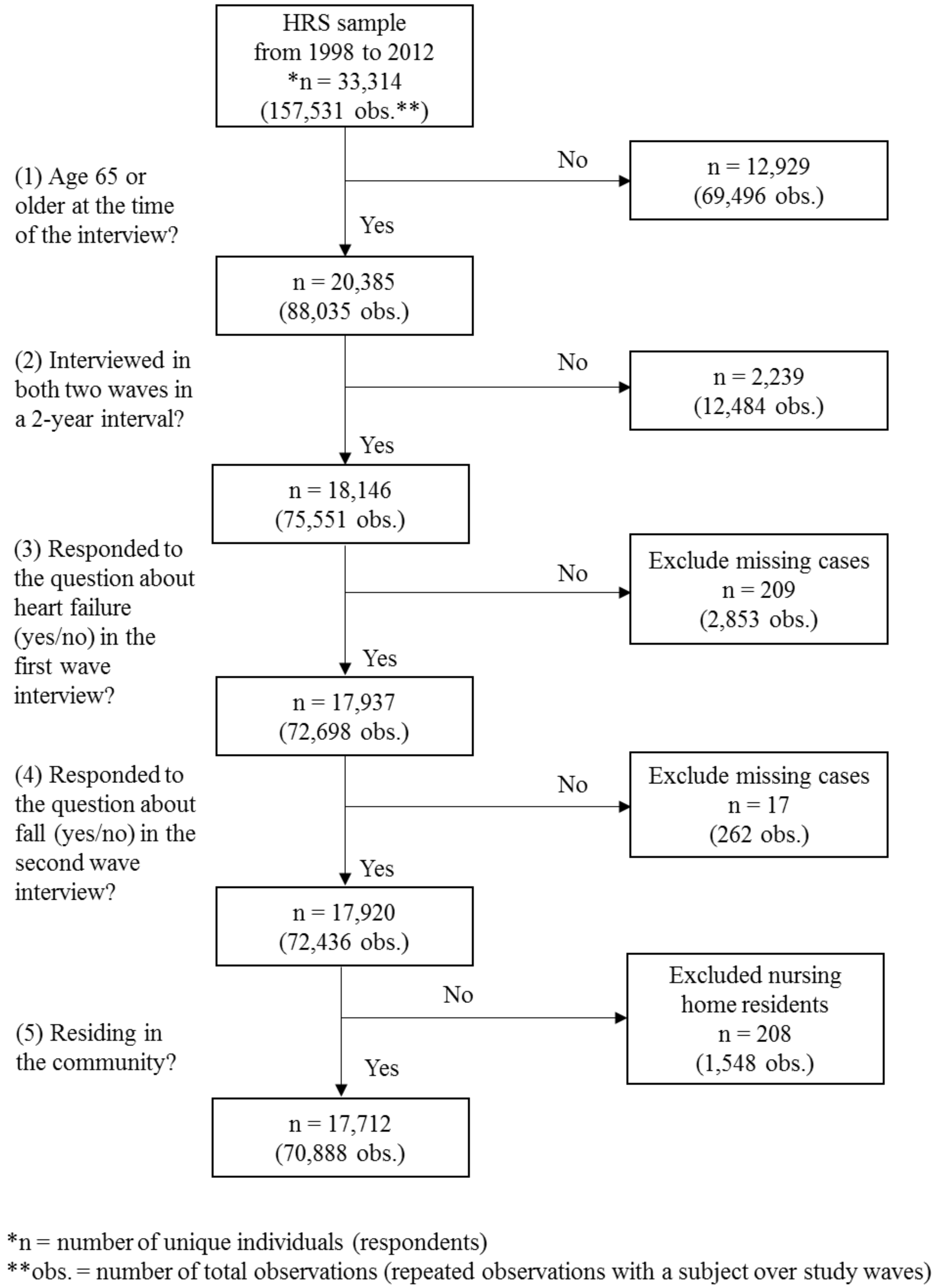


Figure 3.2 Flow diagram of the selection process of the study sample for Aim 1

Data Files and Dataset Construction: Aim 1

For Aim 1, I used two types of data files: (1) the RAND HRS Data file version P and (2) RAND Enhanced HRS Fat files (from 1998 to 2014). Table 3.1 summarizes variables by data sources used in this study. The RAND HRS Data file is an easy to use longitudinal data set based on the HRS data. It was developed at RAND with funding from the National Institute on Aging and the Social Security Administration. The RAND HRS Data file version P already cleaned/processed version for longitudinal analysis (each row represents a unique individual, and has several variables, such as mobility1998, mobility2000 etc.), derived from all waves of the HRS and cross-wave data from the 1992 data (Wave 1) to the most recent year of data (early release 2014; Wave 12). In the RAND HRS Data file version P ('the RAND version P file' thereafter), the available variables for this dissertation were as follows: demographics, chronic conditions, general health and summaries of physical/cognitive function.
However, the RAND version P file only includes a subset of HRS data. Unlike the RAND version P file, the RAND Enhanced HRS Fat files ('Fat files' thereafter) contain most of the HRS raw variables; a single file includes data for each interview year. In order to include other variables, such as falls, heart failure, medication etc., which are not in the RAND version P file, I used Fat files in addition to the RAND version P file. The benefit of using the Fat files is that household-level data were processed to the respondent level; in other words, each row represents a unique individual. In addition, the Fat file can be easily merged with the RAND version P file by using a respondent-level unique identification variable (`rahhidpn`). For this dissertation, I used nine Fat files (1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014; noted bottom of the Table 3.1 for detailed name and release year of the data product). Table 3.2 presents steps for developing dataset for Aim 1.

Table 3.1 Summary of Variables by Data Sources for Aim 1

Data Source	Conceptual Categories	Available Variables in HRS
RAND Version P file[1]	Socio-Demographics	· age · sex/gender · race/ethnicity · married/partnered
	General Health	· self-reported general health · Body Mass Index (BMI) · high blood pressure, diabetes, cancer, lung disease, stroke, arthritis
	Physical Function	· Activities of Daily Living (ADL) · mobility · large muscle
	Cognitive Function	· Telephone Interview for Cognitive Status (TICS) · Instrumental Activity of Daily Living (IADL)
	Psychological Symptoms	· Center for Epidemiologic Studies Depression scales (CESD)
	Health Behavior	· walking aid use
Fat Files[2] 1998-2012	**Independent Variable**	· **Heart failure (yes/no) in the past two years***
	Socio-Demographics	· living alone
	General Health	· fall history
	Cognitive Function	· Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE)
	Sensory Function	· vision · hearing
	Urinary Function	· urinary incontinence
	Physical Symptom	· pain
	Health Behavior	· vigorous activity · alcohol use
	Medication	· psychiatric medication · hypertension medication
	Physical Environment	· home safety features · neighborhood safety
	Social Environment	· relatives living in neighborhood · good friends in neighborhood · almost never get together with others · getting a help for ADL difficulty
Fat Files 2000-2014	**Dependent Variable**	· **Fall (yes/no) in the past two years***

Note continued in the next page

Data Source:

[1. RAND Version P File]

- RAND HRS DATA, Version P. Produced by the RAND Center for the Study of Aging, with funding from the National Institute on Aging and the Social Security Administration. Santa Monica, CA (August 2016).

[2. Fat Files]

- Health and Retirement Study, (RAND Fat File For HRS 1998, Wave 4) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (January 2014).

- Health and Retirement Study, (RAND Fat File For HRS 2000, Wave 5) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (June 2006).

- Health and Retirement Study, (RAND Fat File For HRS 2002, Wave 6, Version 2) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (March 2011).

- Health and Retirement Study, (RAND Fat File For HRS 2004, Wave 7) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (March 2007).

- Health and Retirement Study, (RAND Fat File For HRS 2006, Wave 8) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (March 2011).

- Health and Retirement Study, (RAND Fat File For HRS 2008, Wave 9) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (January 2014).

- Health and Retirement Study, (RAND Fat File For HRS 2010 Final Release, Wave 10) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (June 2014).

- Health and Retirement Study, (RAND Fat File For HRS 2012 Final Release, Wave 11) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (September 2015).

- Health and Retirement Study, (RAND Fat File For HRS 2014 Early Release, Wave 12) public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI, (July 2016).

Note. * Independent variable (heart failure) and dependent variable (falls) are in boldface.

Table 3.2 Steps for Developing Dataset for Aim 1

Steps		Aims and Tasks
Step 1	Aim:	Keep the HF indicator variable and other covariates for each interview year (1998-2012). · 1:1 Merge by unique identifiers (`rahhidpn`) using (1) RAND HRS Data File Version P and (2) a [1998*] RAND Enhanced HRS Fat file. · Keep cases applicable to [1998*]. · Keep HF variable and other covariates. · Drop cases if age < 65 · Follow the same process for each interview year (note: [year*] is placed with 2000, 2002, 2004, 2006, 2008, 2010 or 2012) to generate a total of 8 files.
Step 2	Aim:	Keep the fall indicator variable for each interview year (2000-2014) · Use a [2000**] RAND Enhance HRS Fat file. · Keep fall variable. · Drop cases if age < 65 · Follow the same process for each interview year (note: [year**] is replaced with 2002, 2004, 2006, 2008, 2010, 2012 or 2014) to generate a total of 8 files.
Step 3	Aim:	Generate 8 paired files · 1:1 Merge using (1) a Step 1 file and (2) a Step 2 file For example, Paired file 1: 1998 (HF & other variables) and 2000 (fall variable). Paired file 2: 2000 (HF & other variables) and 2002 (fall variable). · Keep cases with HF (yes/no) and 2-year follow-up fall (yes/no) data. · Follow the same process for each pair to generate 8 paired files.
Step 4	Aim:	Make a long format file · Append all paired files into a single, long format file.
Step 5	Aim:	With the long format dataset, recode the HF variable with a rule of 'once HF, always HF.' Otherwise the original 'no HF' or missing value remains as it is. · Because HF is a progressive disorder, the original HF variable was recoded to follow the decision, 'once HF, always HF' (note for the original HF variable: the question was whether the respondent has been told by a physician that he/she has HF in the last 2 years)
Step 6	Aim:	Make a complete dataset on HF (yes/no) and fall (yes/no) with no missing value · Drop cases non-responsive to the question about HF status · Drop cases non-responsive to the question about fall status
Step 7	Aim:	Exclude nursing home resident at the baseline interview. · Drop cases if a respondent lives a nursing at the baseline interview.

Note. [year*] is placed with 2000, 2002, 2004, 2006, 2008, 2010 or 2012
[year**] is replaced with 2002, 2004, 2006, 2008, 2010, 2012 or 2014

Dependent Variable (Outcome) for Aim 1: Falls

A fall is defined as an unexpected event in which the participant unintentionally comes to rest on the ground, floor, or lower level, and other than as a consequence of substantial external force (e.g., moving vehicle). After the baseline interview of Time 1, the fall data were asked at Time 2 (two years later). Operationally, the HRS inquires about falls by asking participants "Have you fallen down in the last two years since the last interview/in the last two years?" Participants, who answered "Yes", are coded as "1" and participants who answered "No", were coded as "0". Previous studies revealed that 1-year fall recollection has high specificity (91-95%) and acceptable sensitivity (77-89%) (Ganz Higashi, & Rubenstein, 2005; Sanders, Stuart, Scott, Kotowicz, & Nicholson, 2015).

Independent Variable for Aim 1: Heart Failure Status

For the independent variable for Aim 1, the HF variable included either 'yes' or 'no' answers to the question whether participants were diagnosed as having HF. Data were ascertained retrospectively during the observation years. To identify people who had HF between 1998 and 2012, participants were first asked questions about their general heart condition: (Q1) "Has a doctor ever told you that you had a heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems? If the participant answered "Yes", the follow-up question (Q2) was asked: "Has a doctor told you that you have congestive heart failure in the past two years (since the last interview)?" If the respondents answered "Yes" to Q2, they were then identified as HF patients. If the respondents answered "No" to Q1, then no further follow-up questions were asked. Those who answered "No" to Q1 were identified as people who did not have HF between 1998 and 2012 (Figure 3.3). Table 3.3 summarizes independent variable (HF) for Aim 1 and measures.

The criterion validity of a self-reported HF measurement was examined by comparing it to a HF diagnosis in the Medicare claims data. Gure and colleagues (2012) studied how much self-reported HF in HRS dataset in 2004 corresponded to the Medicare claims data between 2002 and 2004. Gure and colleagues (2012) found that among those who self-reported HF (aged ≥ 67), the agreements between self-report of HF and the Medicare claims was 87% ($\kappa = 0.34$). Among people without HF diagnosis codes in the claims-linked file, 99.2% also reported that they did not have HF.

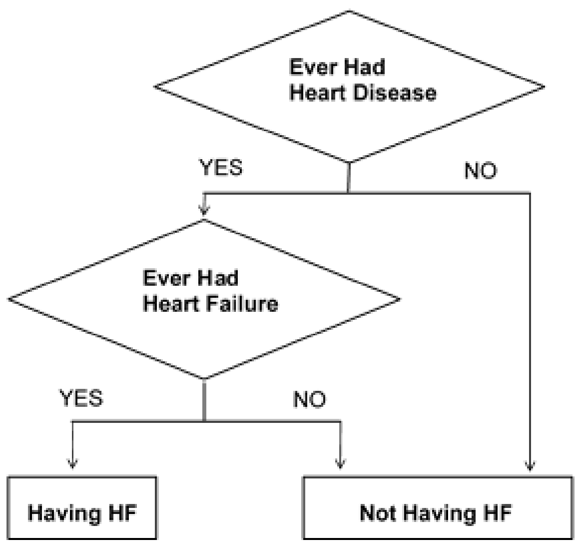


Figure 3.3 Algorithm of identifying heart failure.

Table 3.3 Summary of Independent Variables (Aim 1) and Measurement

Concept	Conceptual Definition	Sub-concept	Operational Definition/ Measurement	Variable Type	Possible Value
Heart Failure (HF)	a complex clinical syndrome that can result from any structural or functional cardiac disorder that impairs the ability of the ventricle to fill or eject blood	HF	Doctor-diagnosed congestive heart failure in the past two years	Nominal	0 = no 1 = yes

Covariates Used for Adjustment for Aim 1

For Aim 1, I examined the independent effect of HF on the likelihood of falling, after controlling for other variables selected from conceptual categories including socio-demographics, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior, medication, physical environment and social environment (see Figure 2.3). In this methods section, all variables, available in the HRS dataset across years between 1998 and 2012, were described. Some of them were ultimately selected for inclusion into the final model via the variable selection process (see the statistical method section later in this chapter). Table 3.4 presents conceptual and operational definition of factors associated with falls and is categorized by the personal concepts of socio-demographic factors, general health, physical function, cognitive function, sensory function, urinary function, physical symptoms, psychological symptoms, health behavior, medication, and environmental factors of physical environment and social environment.

Table 3.4 Summary of Covariates: Conceptual and Operation Definition (Measurements)

Concept	Conceptual Definition	Sub-concept	Operational Definition/Measurement	Variable Type
Socio-demographic	Sociological and demographic characteristics	Age	Age in years at the interview · Range: 65 – Actual number	Ratio
		Gender/sex	Gender/sex · 0 = male · 1 = female	Nominal (Dichotomous)
		Race/ ethnicity	Self-defined race/ethnicity · 1 = non-Hispanic White · 2 = non-Hispanic Black · 3 = Hispanic · 4 = other	Nominal
		Marital/ partnered status	Marital/partnered status · 0 = married/partnered · 1 = does not have spouse or partner	Nominal (Dichotomous)
		Living alone	Living alone, measured by asking the number of people in the household. · 0 = living with one or more · 1 = living alone	Nominal (Dichotomous)
General health	Participants' overall health	Self-reported health	Self-reported general health status was measured in five categories, then dichotomized. · 0 = excellent, very good or good · 1 = fair or poor	Nominal (Dichotomous)
		Fall history	Fall history in the past two years (yes/no) · 0 = No falls · 1 = falls in the past two years	Nominal (Dichotomous)
		Co-existing medical conditions	For each, the following chronic diseases were coded as dummy variables and included in the model separately. (1) hypertension; (2) diabetes; (3) cancer/a malignant tumor of any kind except skin cancer; (4) lung disease except asthma, such as chronic bronchitis or emphysema; (5) stroke or transient ischemic attach; and, (6) arthritis or rheumatism.	Nominal (Dichotomous)

		BMI	Body Mass Index (BMI) = kg/m2 (weight divided by the square height). · 1 = normal (18.5 – 24.9) – reference category · 2 = underweight (<18.5) · 3 = overweight (25.0 – 29.9) · 4 = obese (≥ 30.0)	Nominal
Physical symptom	Person's subjective feeling or body responses related to the consequence of body impairment	Pain	Self-reported pain, assessed by asking whether a participant is often troubled with pain. · 0 = no · 1 = often troubled with pain	Nominal (Dichotomous)
Psychological symptom	Person's mental responses to the affected emotions or thoughts.	Depression	Total score on the 8-item Center for Epidemiologic Studies Depression (CESD) scales: 6 negative indicators (yes/no): (1) depression, (2) everything is an effort, (3) sleep is restless, (4) felt alone, (5) felt sad, and (6) could not get going. 2 positive indicators (yes/no): (1) felt happy and (2) enjoyed life all or most of the time. A total score (ranging 0 – 8) was calculated by summing the number of "yes" answers of six negative indicators and summing the number of "no" answers of two positive indicators. Then, the variable was dichotomized based on the cutoff score of 4 or more, indicating depressive symptom. · 0 = CESD score 0 – 3 · 1 = CESD score 4 - 8, depressive symptom	Nominal (Dichotomous)
Health Behavior	Activities influencing a person's health.	Physical activity	Physical activity was measured by asking whether a participant has participated in vigorous activity/exercise more than once a week in the last year, such as like sports, heavy housework, or a job involves physical labor. · 0 = at least one of vigorous activities more than once a week · 1 = less than a week or none of vigorous activities	Nominal (Dichotomous)
		High-risk alcohol use	Alcohol use was measured by asking whether a participant has any alcohol to drink in the last three months. If a participant has any alcohol to drink, the subsequent question was asked how many drinks per day. · 1 = non-drinker (reference category; 0 drinks/day) · 2 = moderate (1-3 drinks/day for women, 1-4 drinks/day for men) · 3 = high-risk drink (≥ 4 drinks/day for women or ≥ 5 drinks for men)	Ordinal

		Walking aid use	Walking aid use was measured by asking whether a participant uses a walking aid while they are walking: · 0 = no walking difficulty or no walking aid use · 1 = walking aid use	Nominal (Dichotomous)
Medication	Types of medications	Psychiatric medication use	Psychiatric medication use was measured by asking whether a participant takes any of the following medications: tranquilizers, antidepressants, or pills for nerves? · 0 = none of them · 1 = use at least one of them	Nominal (Dichotomous)
		Anti-hypertensive medication use	Antihypertensive medication use was measured by asking whether a participant takes in order to lower blood pressure: · 0 = no use · 1 = use	Nominal (Dichotomous)
Physical function	Person's ability to perform various activities, ranging from basic self-care to more vigorous activities requiring mobility, strength, or endurance.	ADL difficulty	ADL difficulty was measured by a 3-item questionnaire asking whether or not a participant has difficulties in performing each of the following basic tasks: bathing/showering, eating, and getting in/out of bed A total score was summarized by counting 'yes=1' answers. · 0 = No difficulty in any of ADL tasks · 1 = one or more difficulties in ADL tasks	Nominal (Dichotomous)
		Mobility difficulty	Mobility difficulty is measured by a 5-item questionnaire asking whether or not a participant has difficulties in performing each of the following tasks: walking on block, walking several blocks, walking across a room, climbing one flight of stairs, and climbing several flights of stairs. A total score was summarized by counting 'yes=1' answers · 0 = No difficulty in any of mobility tasks · 1 = one or more difficulties in mobility tasks	Nominal (Dichotomous)
		Large Muscle Move difficulty	Large Muscle weakness is measured by a 4-item questionnaire asking whether a participant has difficulties in performing each of the following tasks: (1) sitting for two hours, (2) getting up from a chair, (3) stooping, kneeling, or crouching, and (4) pushing or pulling large objects. A total score was summarized by counting 'yes=1' answers · 0 = No difficulty in any of large muscle movements · 1 = one or more difficulties	Nominal (Dichotomous)

Cognitive function	Person's ability for the intellectual processes of acquiring and using knowledge.	Cognitive impairment	Used both self-respondents and proxy interview. For self-respondent, imputed scores were used, measured by the TICS. Summary scores range from 0 to 35. Then, it was dichotomized based on the cutoff score of 8 or less out of 35. For proxy interview, the short form of Jorm IQCODE was used. Summary scores ranges from 1 to 5. Then, it was dichotomized based on the cutoff score of 3.44 or more out of 5. · 0 = no · 1 = cognitive impairment	Nominal (Dichotomous)
		IADL difficulty	IADL is measured by a 5-item questionnaire asking whether a participant has difficulties in performing each of the following IADL tasks: using the phone, managing money, taking medication, shopping for groceries and preparing hot meals. A total score was summarized by counting 'yes=1' answers: · 0 = No difficulty in any of IADL tasks · 1 = one or more difficulties	Nominal (Dichotomous)
Sensory function	Person's ability to detect information though persons' sense including eyesight or hearing.	Hearing	Self-rating hearing condition, using hearing aids as usual, was measured in five categories. Then, it was dichotomized. · 0 = excellent, very good, good or fair · 1 = poor	Nominal (Dichotomous)
		Vision	Self-rating eyesight, using glasses or corrective lenses as usual, was measured in six categories. Then, it was dichotomized. · 0 = excellent, very good, good or fair · 1 = poor or legally blind	Nominal (Dichotomous)
Urinary function	Person's ability to be continent and to eliminate liquid waste from the body through the urinary tract.	Urinary incontinence	Urinary incontinence measured by asking whether a participant has an experience losing any amount of urine beyond the control during the last 12 months. · 0 = no · 1 = yes (urinary incontinence)	Nominal (Dichotomous)
Physical environment	Physical objects or structures in the home, place of residence, neighborhood, or outdoor.	Living environment (Home safety feature)	Living environment/home was measured by asking whether presence or absence of features to help older or disabled persons get around, such as a ramp, railings, or modifications for a wheelchair at home/apartment. Or, no special features to safeguard older or disabled persons, such as grab bars, a shower seat, or a call device or another system to get help when needed at home/apartment. · 0 = presence of home safety features · 1 = absence of home safety features	Nominal (Dichotomous)

		Neighborhood environment (Neighborhood safety)	As a proxy variable for outdoor/neighborhood environment, the 'neighborhood safety' variable was used, assessed by rating the safety of participants' neighborhood. Then, it was dichotomized. · 0 = excellent, very good, or good · 1 = fair or poor	Nominal (Dichotomous)
Social environment	Social dimension of a person's life including social participation and social support.	Social participation	Social participation was assessed by asking how often participants got together with any of their neighbors to chat or for a social visit. If participants answered 'never' or 'almost never', the variable was coded as '1'. Otherwise, it was coded as '0'. · 0 = getting together with neighbors · 1 = never or almost never	Nominal (Dichotomous)
		Relatives in neighborhood	As a proxy variable for social support, the variable, assessed by asking whether participants had relatives in their neighborhood. · 0 = have relatives in neighborhood · 1 = none	Nominal (Dichotomous)
		Good friends in neighborhood	As a proxy variable for social support, the variable, assessed by asking whether participants had good friends in their neighborhood. · 0 = have good friends in neighborhood · 1 = none	Nominal (Dichotomous)
		Getting a ADL help	As a proxy variable for social support, the variables assessed by asking whether participants have ever had a help when they have difficulties in any of the following ADL tasks: dressing, walking, bathing, eating, getting in/out of bed, or toileting. · 0 = no difficulty or no help · 1 = ever had a help	Nominal (Dichotomous)

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Abbreviations: ADL, Activities of Daily Living; TICS, the Telephone Interview for Cognitive Status; IQCODE, the Informant Questionnaire on Cognitive Decline in the Elderly; IADL, Instrumental Activities of Daily Living.

Demographic factors refer to sociological and demographic characteristics, which include age, gender/sex, race/ethnicity, martial/partnered status and living alone status, are risk factors for falls. In this study, 'age in years' was measured at the time of the interview. Gender/sex was defined as male or female. Race/ethnicity was categorized as non-Hispanic White, non-Hispanic Black, Hispanic and other. Marital/partnered status was dichotomized as with or without spouse/partner. In order to identify whether or not participants lived alone, I created another variable using the data responded to the interview question about the number of people in the household because the 'marital/partnered status' may not be congruent to 'living alone.' I dichotomized the number of people in the household (0 = living with one person or more, 1 = living alone).

General health refers to participants' overall health, including perceived health condition, current co-existing medical condition, or history of health events. The current study included self-reported health, Body Mass Index (BMI), fall history (yes/no), and co-existing medical conditions. For the 'self-reported health' variable, ordinal five-rating scores were categorized into two: (1) excellent to good and (2) fair/poor because the difference between 'excellent' and 'very good' may not the same magnitude between 'very good' and 'good'. Therefore, I collapsed these variables into dichotomous variables as good side or poor side. Likewise, the continuous value of BMI was categorized into four: (1) underweight, BMI 18.4 or less kg/m^2; (2) normal, BMI 18.5-2.49 kg/m^2; (3) overweight, BMI 25.0-29.9 kg/m^2; and (4) obese, BMI 30.0 or more kg/m^2. This is because categorization based on the conventional cut-point is more easily interpretable in clinical settings. For example, 'for obese people, the odds of falling is greater than that of people with normal weight (normal vs. obese)' is more understandable rather than 'for a unit increase in BMI, the odds of falling increases.' For the co-existing medical conditions, I used six indicator variables of the following six health conditions: hypertension (yes/no), diabetes (yes/no), cancer (yes/no), lung disease (yes/no), stroke (yes/no), and arthritis (yes/no). Note that Parkinson's disease was not included in the HRS.

Physical symptoms refer to a person's subjective feeling or body responses related to the consequence of body impairment. In this study, only pain was assessed by asking whether a participant is often troubled with pain. This variable was dichotomized as yes or no.

Psychological symptoms refer to a person's mental responses to the affected emotions or thoughts. In this study, only the depressive symptom was measured among psychological symptoms. To measure depressive symptom, the HRS used the simplified 8-item of the Center for Epidemiological Studies Depression Scale (CESD) instead of using the full 11-item CESD measurement (note: scores of 8-item CESD ranges 0–8; scores of the full 11-item CESD ranges 0–60). The 8-item scale consists of six negative feelings (self-reported depression, everything is an effort, sleep is restless, felt alone, felt sad, and could not get going) and two positive feelings (felt happy and enjoyed life). A summary score is constructed by summing the number of "yes" answers of negative feelings and by summing the number of "no" answers of two positive feelings. This 8-item summary score can be viewed as an ordinal variable because the difference between the 8 and 7 may not be the same magnitude between 7 and 6 of the score. Therefore, instead of using the 8 scoring value, I collapsed this value into a binary value (yes/no) based on the cut-off point of 4, indicating the likelihood of clinical depression. The HRS documentation reported that a score of 4 or more on the 8-item CESD corresponds to the traditional cut-off score of 16 or more on the full CESD, which indicates a clinically-relevant depressive symptom (Steffick et al., 2000; Radloff, 1977).

Health behavior refers to activities influencing a person's health. In this study, health behavior includes vigorous physical activity, alcohol use, and walking aid use. Vigorous physical activity was measured by asking whether a participant participated in vigorous physical activity/exercise, such as sports, heavy housework, or a job that involves physical labor, more than once a week in the last 12 months (yes/no). Note that the interview question about vigorous physical activity slightly changed since the interview Wave 7 as follows: (1) in Waves 4 to 6, the question was whether participants performed vigorous activity three time a week (a 'yes/no' question); and (2) in Waves 7 to 11, the question was how often participants participated in vigorous activity (every day, more than once a week, once a week, 1-3 times a month, or never). To be consistent, I dichotomized the answers of interview Waves 7 to 11 as follows: if the respondents has participated in vigorous activity 'every day' or 'more than once a week', then it is considered as 'yes, vigorous activity' otherwise, it is considered as 'no'.

Alcohol use was assessed by asking a series of questions: (Q1) whether a participant has had any alcohol to drink in the last three months; and, (Q2) for those who had, how many drinks per day when they drink. For this study, the 'alcohol use' variable was categorized into three: non-drinking, moderate and high-risk drinking based on the definition of 'high-risk drinking' in the 2015-2020 Dietary Guidelines for American (US Department of Health and Human Services and US Department of Agriculture, 2015). According to the guidelines, "high-risk drinking is the consumption of 4 or more drinks on any day, or 8 or more drinks per week for women, and 5 or more drinks on any day, or 15 or more drinks per week for men" (p.101). In the HRS data, only the number of drinks per day was used. Walking aid use was measured by asking a series of questions (Q1) whether a participant had walking difficulties and (Q2) whether a participant used a walking aid while walking (yes/no).

Medications are important risk factors for falls. In the study, two types of medications were considered: the use of antihypertensive medication and the use of psychiatric medication. Antihypertensive medication data were obtained by simply asking whether the participants are now taking any medication to lower blood pressure (yes = use at least one of blood pressure medications/ no = none of them). There was no information whether medications are diuretics, beta-blockers, ACE inhibitors, or others. The use of psychiatric medication was assessed by asking whether a participant takes any of the following medications: tranquilizers, antidepressants, or pill for nerves (yes = use at least one of psychiatric medications/ no = none of them).

Physical function refers to a person's ability to perform various physical activities, ranging from basic self-care to more vigorous activities requiring mobility, strength, or endurance. Physical function was assessed by three measurements: Activities of Daily Living (ADLs), mobility, and large muscle weakness. A basic ADL difficulty was measured by a 3-item questionnaire regarding whether a participant has some difficulties in performing each of the following ADLs: bathing/showering, eating, and getting in/out of bed (Wallace & Herzog, 1995). A total score was the summation of counting 'yes=1' answers. In this study, this summary score was collapsed into dichotomous values (0 = no difficulty, 1 = 1 or more difficulties in any tasks). This is because the summary score of ADL difficulty (0-3) are constructed by simply summing the number of difficulties in binary indicating tasks (e.g., three ADL tasks: bathing/showering, eating, and getting in/out of bed) and the difference score of 3 and 2 may not the same magnitude between 2 and 1. Therefore, for a more understandable interpretation, these variables were dichotomized. Mobility difficulty was measured by a 5-item questionnaire that asked whether a participant has difficulties in performing each of the following tasks: walking one block, walking several blocks, walking across a room, climbing one flight of stairs, and climbing several flights of stairs. A total score was the summation of counting ‘yes=1’ answers. If the summary score of 1 or more out of 5, the variable was coded as 1; otherwise it was coded as 0 for the same reason as noted above. Large muscle weakness was measured by a 4-item questionnaire asking whether a participant has difficulties in performing each of the following tasks: sitting for 2 hours, getting up from a chair, stooping/kneeling/crouching, and pushing/pulling large objects. A total score was the summation of counting ‘yes = 1’ answers. If the summary score of 1 or more out of 5, the variable was coded as 1; otherwise it was coded as 0 for the same reason as noted above. Reliability of physical measures is well-documented by Cronbach’s alpha, ranging from .87 to .84 in HRS documents using 1998 and 2000 dataset; physical functioning measures of HRS have moderate to high construct validity (Fonda and Herzog, 2004). Note that data obtained by other enhanced face-to-face physical test, such as timed walking and balance test was not be used in the full model because only half of the core sample starting from 2006 included these face-to-face physical measures in alternative waves.

Cognitive function refers to a person’s ability for the intellectual processes of acquiring and using knowledge. In this study, cognitive function was assessed with two parts of measurements: (1) cognitive status (impaired/not impaired) and (2) Instrumental Activities of Daily Living (IADL). For the first part, I used two different types of cognitive scores: one is for self-respondents (92% of participants); and the other is for proxy-interview (8% of participants) in order to minimize attrition bias on cognitive scores. For self-respondents, the Modified Telephone Interview for Cognitive Status (TICS) was used. Because the TICS was designed for only self-respondents, for proxy-interview, the short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE; Jorm, 1994; Jorm and Jacom, 1989) were used.

Then, in order to combine these two different scoring systems into one variable, TICS and IQCODE scores were dichotomized (cognitively impaired/not impaired) based on the cut-off points. The cut-off points for considering cognitive impairment are: (1) a score of 8 or less out of 35 of the TICS (Herzog and Wallace, 1997) and (2) a score of 3.44 or more out of 5 of the IQCODE (Jorm, 2004).

The TICS mentioned above is a 35-point scale with high sensitivity and specificity for cognitive impairment and dementia in community-dwelling older adults (de Jager, Budge, & Clarke, 2003; Plassman, Newman, & Welsh, 1994; Welsh, 1993). The TICS measures memory, working memory, processing speed, language and orientation. For assessing memory, immediate and delayed recall tests were used. The immediate recall test counts of the number of words from a 10-word list that were recalled correctly. After a delay of about 5 minutes spent answering other survey questions, the delayed recall test counts the number of words from a 10-word immediate recall list that were recalled correctly. For assessing working memory, the Serial 7's subtraction test was used. The serial 7s test asks the participants to subtract 7 from the prior number, beginning with 100 for five trials. For assessing processing speed, the backward counting test was used. The backward counting test asks the participants to count backwards for 10 continuous numbers beginning with the number 20. For assessing language, an object naming test was used. For assessing orientation, recall of the date and president and vice-president were used. Summery scores using all items range from 0 to 35. The short form IQCODE is a 5-point scale with high sensitivity and specificity for cognitive impairment and dementia in community-dwelling older adults (Jorm, 1994; Jorm and Jacom, 1989). The IQCODE was designed for participants who were unable to respond to the direct cognitive testing, such as the TICS. The IQCODE includes 16 items, which a proxy can answer to questions about a participant's present performance comparing to the performance 10 years ago. Performance includes memory functions, knowing how to work familiar machines, learning new things, decision making, handling money/financial matters, or using their intelligence/reasoning. A copy of the short-form questionnaire is available at the website (http://crahw.anu.edu.au/files/English_short.pdf).

Another measure, Instrument Activities of Daily Living (IADL) was used to assess cognitive function because cognitive functioning was required to perform IADL, such as managing money or following complex medical instruction (Fillenbaum et al., 1988). IADL was measured by a 5-item questionnaire asking whether a participant has difficulties in performing each of the following the IADL (yes/no): using the phone, managing money, taking medication, shopping for groceries and preparing hot meals. For the study, a total summary score will be used (score ranging 0–5) by the summation of counting 'yes = 1' answers. If the summary score of 1 or more out of 5, the variable was coded as 1, otherwise it was coded as 0. This is because the difference score of 5 and 4 may not the same magnitude between 4 and 3, so for a more understandable interpretation, this variable was dichotomized.

Sensory function refers to a person's ability to detect information through person's sense such as touch, eyesight, smell, hearing, and taste. Variables for sensory function included hearing and vision impairment. Hearing condition was assessed by a self-report whether the participant's hearing was excellent, very good, good, fair or poor with/without hearing aid as usual. Vision condition was assessed by a self-report whether the participant's eyesight was excellent, very good, good, fair or poor with/without glasses or corrective lenses, or legally blind. In this study, both variables were dichotomized as dummy variables: '1' indicating having poor vision/legally blind and fair/poor hearing respectively.

Urinary function refers to a person's ability to eliminate liquid waste from the blood through the urinary tract. Urinary function included urinary incontinence assessed by a question, "In the last 12 months, have you lost any amount of urine beyond your control." The response was yes or no.

Physical environment refers to any physical obstacles or structures in the home, place of residence, neighborhood, or outdoor, that influence falls. Physical environment includes (a) living environment/home, (b) outdoor/neighborhood environment, and (c) public environment. For the purpose of the study, only living environment/home and outdoor/neighborhood environment were used, because they are available in HRS 1998 to 2012. Living environment/home is defined as physical structures that could be obstacles inside the home, such as loose rugs, cord across walkways, unstable furniture, lack of grab rails of shower/bathtub/toilet and so on. In the study, the variable, including the information about home modification for special features to help an older or disabled person, was used as a proxy variable of living environment/home. Participants were asked whether their home environment included items such as a ramp, railing, or modifications for a wheelchair, grab bars, a shower seat, or a call device or other systems used to get help when needed. If there was at least one of the above special features in the participant's house/living place, then the data are defined as 'yes' (if none of them, defined as 'no'). Outdoor/neighborhood environment is defined as objects in the neighborhood that people may encounter such as cracked/uneven sidewalks, holes in streets, or poor street lighting. The current study used the 'neighborhood safety' variable of the HRS. It was assessed by asking participants to rate the safety of their neighborhood. The variable was re-coded as a dummy variable: '1' indicates fair/poor neighborhood safety. Otherwise, it was coded as 0, indicating excellent to good neighborhood safety.

Social environment refers to the social dimensions of a persons' life including social participation and social support. Social participation includes the frequency of attending social meetings, clubs, sports, organizations, or religious services. In this study, the variable, assessed by asking how often they got together with any of their neighbors to chat or for a social visit, was used. If participants answered 'never' or 'almost never', the variable was coded as '1'. Otherwise, it was coded as '0'. In addition, social support includes living with someone, checking in on older adults regularly, encouraging them to participate in social events, or rating supports of their family members or friends. In this study, two proxy variables were used separately, which assessed whether or not participants had relatives or good friends in their neighborhood respectively. Also, as a proxy variable of social support, the variable, assessed by asking whether participants ever have had help when they had difficulties in any of the following ADL tasks: dressing, walking, bathing, eating, getting in/out of bed, or toileting. If the participants answered 'yes, got help', the variable coded as '1'. Otherwise, it was coded as '0'.

As mentioned above, continuous variables except for age were categorized (e.g., BMI) or dichotomized (e.g., ADL or IADL) for this study. Table 3.5 summarizes means, standard deviations, and ranges for continuous variables, to check their data distributions of the original data before categorization or dichotomization.

Table 3.5 Means, SDs and Actual Ranges for Continuous Variables at Baseline

	All			No-Heart Failure			Heart Failure		
Continuous Variables	N	Mean (*SD*)	Range	n	Mean (*SD*)	Range	n	Mean (*SD*)	Range
Socio-demographic									
Age in years	17,712	70.4 (6.6)	65–105	16,019	70.4 (6.6)	65–105	1,693	71.3 (6.7)	65–100
General Health									
Body Mass Index	17,468	27.3 (5.3)	12.1–82.7	15,797	27.1 (5.2)	12.1–82.7	1,671	28.7 (6.2)	15.2–59.1
Psychological Symptoms									
CESD (0–8)	16,338	1.5 (1.9)	0–8	14,794	1.4 (1.8)	0–8	1,544	2.0 (2.2)	0–8
Physical Function									
ADL difficulty (0–3)	17,699	0.2 (0.5)	0–3	16,008	0.2 (0.5)	0–3	1,691	0.3 (0.7)	0–3
Mobility difficulty (0–5)	17,698	1.0 (1.4)	0–5	16,007	0.9 (1.3)	0–5	1,691	1.7 (1.6)	0–5
Large muscle difficulty (0–4)	17,695	1.2 (1.3)	0–4	16,005	1.2 (1.3)	0–4	1,690	1.7 (1.4)	0–4
Cognitive Function									
TICS (0–35) for self *	16,192	22.5 (5.1)	1–35	14,661	22.6 (5.1)	1–35	1,531	21.5 (5.2)	2–35
IQCODE (1–5) for proxy *	1,187	3.2 (0.5)	1–5	1,058	3.2 (0.5)	1–5	129	3.2 (0.5)	1.8–5
IADL difficulty (0–5)	17,697	0.2 (0.8)	0–5	16,007	0.2 (0.7)	0–5	1,690	0.4 (0.9)	0–5

Data source: Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, Wave 4 to 11) public use dataset; RAND HRS Data Version P.

Note. *For the cognitive impairment measures, TICS was used for self-respondent (cutoff score of 8 or less) and IQCODE was used for proxy-interview (cutoff score of 3.44 or more). In this study, both TICS and IQCODE were dichotomized based on the cut-off scores, and then they were combined into one variable.

Abbreviations: N, the number of participants; n, the number of sub-group participants; SD, standard deviation; CESD, Center for Epidemiologic Studies Depression Scale; ADL, Activities of Daily Living; TICS, the Telephone Interview for Cognitive Status; IQCODE, the Informant Questionnaire on Cognitive Decline in the Elderly; IADL, Instrumental Activities of Daily Living.

Statistical Analysis for Aim 1

The primary analysis for Aim 1 was to examine the relationship between having HF and the likelihood of falling, among community-dwelling older adults. Descriptive statistics was presented as means for continuous variables and frequencies for categorical variables in order to describe the baseline characteristics. I examined which variables were different between those who have HF and those who do not, using a two-sample t-test for continuous variables and chi-square test for categorical variables.

Before reporting the association between HF and falls using adjusted odds ratios (OR), I estimated the relative risk ratio (RR) and attributable risk (AR). As noted above, HRS participants are surveyed every two years. Therefore, I calculated the number of individuals who fell per 100 person-years of follow-up. It is important to note that we did not have data on the number of falls – thus, estimating the rate of older adults who fell is an approximation. While RR is an estimate of how strongly HF is associated with falling, AR expresses the absolute difference in the number of older adults who fell. The definitions are as follows:

1) Risk of falling (cases per 100 person-years):

(a) Risk of falling among older adults with HF

(b) Risk of falling among older adults without HF

2) Attributable risk (AR) = (a) – (b)

3) Relative risk ratio (RR) = (a) / (b)

For the longitudinal analysis for Aim 1, the mixed-effects logistic regression model with a person-specific random intercept was used. This is because the classic linear regression assumes that observations are independent from each other, but in this longitudinal study, several observations were nested within subjects, which were repeatedly measured over time. These observations nested in the same subject are often dependent; in other words, they tend to be correlated within subjects. Therefore, using the mixed-effects logistic regression model is more beneficial because it provides a more accurate estimation by taking into account correlated observations within subjects (Fitzmaurice, Laird, & Ware, 2012). To express the association between HF and falls in a 2-years period as an OR, the coefficients were exponentiated after controlling for other covariates.

Variable Selection. Before the main multivariate analysis to estimate the effect of HF on falls for Aim 1, I used the Purposeful Variable Selection method informed by Bursac et al. (2008) and Hosmer and Lemeshow (2013) in order to minimize an over-fitting issue and to make a more parsimonious model. To keep the conceptual model, the Purposeful Variable Selection was performed for each conceptual category. The first step of the variable selection was to perform a univariate analysis of each explanatory variable with the mixed-effects logistic regression to estimate the crude effect of each explanatory variable on falls (see Table 3.6). From the univariate analysis, if p-values were less than 0.25, the variables remained for the multivariate analysis in Step 2 because using traditional significant level, such as 0.05, often fails to include important explanatory variables at the initial stage of model development (Hosmer et al, 2013). Then, the fit was checked again whether the estimation of the effect of HF on falls was significantly changed by the removed variable. If the estimation of the effect of HF on falls is significantly changed (more than 10% change-in-OR for HF), then the removed variable would be added back in the model. The second step was to conduct a multivariate analysis within the same conceptual category using the retained variables from Step 1. After fitting the multivariate mixed-effects logistic model within the same category, if p-values were < 0.05, the variables were retained for use in the final model. If p-value were ≥ 0.05, the variable was assessed through the post-estimation of Wald statistic one at a time. If the Wald statistic revealed that there was no difference between the larger model and the smaller model, the smaller model was selected. In other words, the variable ($p \geq 0.05$) was removed from the model. Step 3 examined whether the removed variables in Step 2 were considered as confounders with a 10% change-in-estimate method (Walter and Tiemer, 2009). If the removed variable had more than 10% change-in-OR for HF, the estimation of the effect of HF on falls could be significantly changed by the variable. That means it needs to be added back in the model.

In Step 1 (univariate analysis), all variables were retained ($p < 0.25$). In Step 2 (multivariate within the category and a Wald-test), most variables were retained because their p-value < 0.05, except for three variables, '*living alone*', '*having relatives near their neighborhood*', and '*having good friends near their neighborhood*.' In Step 3 these variables were not added back to the model because their effects were minimal to change the estimation of the association between heart failure and falls (< 10%). The results of the variable selection are presented in Table 3.6.

Multicollineary. The next step was to check the multi-collinearity among explanatory variables. In this procedure, a three-step diagnostic test was performed by checking the following items: (1) the Spearman correlation matrix, (2) condition indexes and variance-decomposition proportion, and (3) Variance Inflation Factors (VIFs). First, from the Spearman correlation matrix, the high correlation coefficients ($r > .80$) indicated a concern for multi-collinearity (Midi, Sarkar, & Rana, 2013). Then, from the Stata multi-collinearity diagnostic package (`coldiag2`), if a large condition index (> 15) is associated two or more variables with a large variance proportion (> 50%), then these variables can be considered as multi-collinearity causing variables (Belsley, 1991; Midi et al., 2013). For the solution, the collinear variables were removed from the model. With the revised model, VIFs of explanatory variables were also checked. Usually, if the values of VIFs were more than 10, they have been considered an indicator of multi-collinearity. However, in this study, the more conservative criterion (VIF > 2.5) was used because in the case of logistic regression, values more than 2.5 may be a cause for concern (Midi et al., 2013). In this process, one variable (*Anti-hypertensive medication*) was removed from the model because VIF > 2.5. In the final model, 32 covariates were selected. The VIF results are presented in Table 3.6.

Table 3.6 Variable Selection Process

Explanatory Variable	Step 1	Step 2		Step 3	Step 4	
	Univariate p-value†	Multivariate within category p-value†	Wald test if p <.05	Change-in-estimate of heart failure‡, %	VIF[1]	VIF[2]
Heart failure	< .001	n/a		0.0	1.08	1.08
Interview Year[a]	< .001	n/a		4.8	1.05	1.05
Socio-demographic						
Age in years	< .001	< .001		28.4*	1.29	1.28
Female	< .001	< .001		-0.5	1.28	1.28
Race/ethnicity			< .001	-0.1		
Non-Hispanic Black	< .001	< .001			1.18	1.18
Hispanic	0.06	0.53			1.10	1.10
Other	< .001	< .001			1.01	1.01
No spouse/partner	< .001	< .001		3.7	1.24	1.24
Living alone	< .001	0.18	0.184	0.9	ns	ns
General Health						
Fair/poor general health	< .001	< .001		20.5*	1.45	1.45
Fall history in 2 years	< .001	< .001		28.1*	1.10	1.10
Body Mass Index[b]			< .001	1.0		
Underweight	< .001	0.108			1.04	1.04
Overweight	< .001	< .001			1.40	1.40
Obese	0.001	0.423			1.58	1.58
High blood pressure	< .001	< .001		4.9	**5.43**	1.12
Diabetes	< .001	< .001		7.0	1.14	1.14
Cancer[c]	< .001	< .001		1.4	1.03	1.03
Lung disease	< .001	< .001		7.0	1.09	1.09
Stroke/TIA	< .001	< .001		8.8	1.07	1.07
Arthritis	< .001	< .001		6.6	1.22	1.22
Physical Function						
ADL difficulty	< .001	< .001		15.5*	1.79	1.79
Mobility difficulty	< .001	< .001		22.2*	1.53	1.53
Large muscle difficulty	< .001	< .001		14.4*	1.43	1.43
Cognitive Function						
Cognitive impairment	< .001	< .001		1.3	1.05	1.05
IADL difficulty	< .001	< .001		20.2*	1.46	1.46
Sensory Function						
Poor vision/Legally blind	< .001	< .001		5.1	1.12	1.12
Poor hearing	< .001	< .001		3.0	1.05	1.05
Urinary Function						
Urinary incontinence	< .001	n/a		7.5	1.13	1.13
Physical Symptoms						
Pain, often troubled	< .001	n/a		9.6	1.32	1.32

Psychological Symptoms						
CESD score (4-8)	< .001	n/a		3.7	1.21	1.21
Health-Related Behavior						
Vigorous activities[d]	< .001	< .001		7.1	1.13	1.13
Alcohol use				2.1		
Moderate	< .001	0.001			1.11	1.11
High-risk	0.001	0.028			1.02	1.02
Walking aid use	< .001	< .001		24.8 *	1.53	1.53
Medication Use						
Psychiatric medications	< .001	< .001		6.6	1.12	1.12
Anti-hypertensives	< .001	< .001		4.5	**5.42**	ns
Physical Environment						
No home safety features	< .001	< .001		3.4	1.04	1.04
Fair/poor neighborhood safety	< .001	< .001		0.3	1.10	1.10
Social Participation						
Getting together	< .001	< .001		0.3	1.03	1.03
Relatives near	0.155	0.151	0.169	-0.6	ns	ns
Not good friend near	0.002	0.691	0.772	-0.7	ns	ns
Getting a ADL help	<.001	< .001		13.1*	1.70	1.70

Note.
Data were analyzed using 70,888 observations (17,712 unique individuals).
† p-value from the Wald statistic.
‡ Change-in-estimate (OR) of heart failure when adjusting for each covariate.
* indicates 10% or greater.
1. The regression model includes all selected variables from Step 3; VIF > 2.5 is presented in bold.
2. The regression model includes all selected variables from Step 3 except for the anti-hypertensive use.
a. Time variable was tested because a series of question on heart failure was slightly changed since 2010.
b. Body Mass Index was categorized into four: underweight (18.4 or less kg/m2), normal (18.5-2.49 kg/m2), overweight (25.0-29.9 kg/m2) and obese (30.0 or more kg/m2).
c. Cancer of a malignant tumor of any kind except skin cancer
d. Vigorous activities includes sports, heavy housework, or a job that involves physical labor.
Abbreviations: OR, odds ratio; CI, confidence interval; TIA, Transient Ischemic Attack; CESD, Center for Epidemiologic Studies Depression Scale; n/a, not applicable; ns, not selected

After checking for multi-collinearity, mixed-effects logistic regression (‘`melogit`’ command in Stata version 14.2) was used for the primary analysis to examine the relationship between having HF and the likelihood of falling, after controlling for all selected co-variables (Research Question 1.1). Then, two post-hoc analyses were performed. First, I examined the fully adjusted relationship between HF and falls in 16 different sub-groups that include people who have or do not have (1) difficulties in ADL, (2) difficulties in mobility, (3) difficulties in large muscle movement, (4) cognitive impairment, (5) difficulties in IADL, (6) poor vision/legally blind, (7) poor hearing, or (8) urinary incontinence (Research Question 1.2). Next, in order to test the potential interaction between HF and the above functional factors, I added one interaction term to the full model one at a time (Research Question 1.3). Table 3.7 summarizes study variables (dependent variable, independent variable, and covariates) by research questions for Aim 1. A Wald test was used to examine the statistical significance for the interaction term. All analyses were conducted using Stata SE 14.2 (StataCorp, 2015). The 95% confidence intervals (CIs) were presented to estimate statistical significance.

Table 3.7 Study Variables by Research Questions for Aim 1

	RQ[§] 1.1	RQ 1.2a	RQ 1.2b	RQ 1.2c	RQ 1.2d	RQ 1.2e	RQ 1.2f	RQ 1.2g	RQ 1.2h
Sample	ALL*	Subgroup by mobility difficulty (yes/no)	Subgroup by large muscle difficulty (yes/no)	Subgroup by ADL difficulty (yes/no)	Subgroup by cognitive impairment (yes/no)	Subgroup by IADL difficulty (yes/no)	Subgroup by poor vison (yes/no)	Subgroup by poor hearing (yes/no)	Subgroup by urinary incontinence (yes/no)
Fall (y/n)	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**
HF (y/n)	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**
Mobility	cv	n/a	cv	cv	cv	cv	cv	cv	cv
Large muscle	cv	cv	n/a	cv	cv	cv	cv	cv	cv
ADL	cv	cv	cv	n/a	cv	cv	cv	cv	cv
Cognitive impairment	cv	cv	cv	cv	n/a	cv	cv	cv	cv
IADL	cv	cv	cv	cv	cv	n/a	cv	cv	cv
Vision	cv	cv	cv	cv	cv	cv	n/a	cv	cv
Hearing	cv	cv	cv	cv	cv	cv	cv	n/a	cv
Urinary incontinence	cv	cv	cv	cv	cv	cv	cv	cv	n/a
Socio-demographics[1]	cv	cv	cv	cv	cv	cv	cv	cv	cv
General health[2]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Physical symptom[3]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Psychological symptom[4]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Health-related behavior[5]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Medication use[6]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Physical environment[7]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Social environment[8]	cv	cv	cv	cv	cv	cv	cv	cv	cv
Interview indicator[9]	cv	cv	cv	cv	cv	cv	cv	cv	cv

Table continued on next page.

Table 3.7 Study Variables by Research Questions (Continued)

	RQ[§] 1.3a	RQ 1.3b	RQ 1.3c	RQ 1.3d	RQ 1.3e	RQ 1.3f	RQ 1.3g	RQ 1.3h
Sample	ALL*	ALL	ALL	ALL	ALL	ALL	ALL	ALL
Fall (y/n)	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**
HF (y/n)	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**	**IV**
HF x Mobility	**IV**	n/a	n/a	n/a	n/a	n/a	n/a	n/a
HF x Large muscle	n/a	**IV**	n/a	n/a	n/a	n/a	n/a	n/a
HF x ADL	n/a	n/a	**IV**	n/a	n/a	n/a	n/a	n/a
HF x Cognitive impairment	n/a	n/a	n/a	**IV**	n/a	n/a	n/a	n/a
HF x IADL	n/a	n/a	n/a	n/a	**IV**	n/a	n/a	n/a
HF x Vision	n/a	n/a	n/a	n/a	n/a	**IV**	n/a	n/a
HF x Hearing	n/a	n/a	n/a	n/a	n/a	n/a	**IV**	n/a
HF x Urinary	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**IV**
Mobility	**IV**	cv	cv	cv	cv	cv	cv	cv
Large Muscle	cv	**IV**	cv	cv	cv	cv	cv	cv
ADL	cv	cv	**IV**	cv	cv	cv	cv	cv
Cognitive impairment	cv	cv	cv	**IV**	cv	cv	cv	cv
IADL	cv	cv	cv	cv	**IV**	cv	cv	cv
Vision	cv	cv	cv	cv	cv	**IV**	cv	cv
Hearing	cv	cv	cv	cv	cv	cv	**IV**	cv
Urinary	cv	cv	cv	cv	cv	cv	cv	**IV**
Socio-demographics[1]	cv	cv	cv	cv	cv	cv	cv	cv
General health[2]	cv	cv	cv	cv	cv	cv	cv	cv
Physical symptom[3]	cv	cv	cv	cv	cv	cv	cv	cv
Psychological symptom[4]	cv	cv	cv	cv	cv	cv	cv	cv
Health-related behavior[5]	cv	cv	cv	cv	cv	cv	cv	cv
Medication use[6]	cv	cv	cv	cv	cv	cv	cv	cv
Physical environment[7]	cv	cv	cv	cv	cv	cv	cv	cv
Social environment[8]	cv	cv	cv	cv	cv	cv	cv	cv
Interview indicator[9]	cv	cv	cv	cv	cv	cv	cv	cv

Note continued in the next page.

Note.
§ Research Questions (RQ)

RQ 1.1 Do community-dwelling older adults with HF have a higher likelihood of falling than those without HF?
RQ 1.2a. Does the effect of HF on the likelihood of falling differ by groups with and without *mobility difficulty*?
RQ 1.2b. Does the effect of HF on the likelihood of falling differ by groups with and without *large muscle movement difficulty*?
RQ 1.2c. Does the effect of HF on the likelihood of falling differ by groups with and without *ADL difficulty*?
RQ 1.2d. Does the effect of HF on the likelihood of falling differ by groups with and without *cognitive impairment*?
RQ 1.2e. Does the effect of HF on the likelihood of falling differ by groups with and without *IADL difficulty*?
RQ 1.2f. Does the effect of HF on the likelihood of falling differ by groups with and without *poor vision/legally blind*?
RQ 1.2g. Does the effect of HF on the likelihood of falling differ by groups with and without *poor hearing*?
RQ 1.2h. Does the effect of HF on the likelihood of falling differ by groups with and without *urinary incontinence*?

RQ 1.3a. Is there an interaction effect of HF and *mobility difficulty*?
RQ 1.3b. Is there an interaction effect of HF and *large muscle movement difficulty*?
RQ 1.3c. Is there an interaction effect of HF and *ADL difficulty*?
RQ 1.3d. Is there an interaction effect of HF and *cognitive impairment*?
RQ 1.3e. Is there an interaction effect of HF and *IADL difficulty*?
RQ 1.3f. Is there an interaction effect of HF and *poor vision/legally blind*?
RQ 1.3g. Is there an interaction effect of HF and *poor hearing*?
RQ 1.3h. Is there an interaction effect of HF and *urinary incontinence*?

*Sample for Aim 1: Community-dwelling older adults in the U.S.

DV, dependent variable; IV, independent variable; CV, covariate; n/a, not applicable

All 32 covariates include:

1. Socio-demographics: age, sex, race/ethnicity, marital status
2. General health: self-reported health, fall history, BMI, hypertension, diabetes, cancer, lung disease, stroke/TIA, arthritis
3. Physical symptom: pain
4. Psychological symptom: depressive symptom (CESD)
5. Health-related behavior: vigorous activities, alcohol use, walking aid use
6. Medication use: psychiatric medication use
7. Physical environment: home safety features, neighborhood safety
8. Social environment: getting together, getting an ADL help.
9. Interview indicator: participating in the interview at Wave 10 or 11

Abbreviations: BMI, Body Mass Index; TIA, Transient Ischemic Attack; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; CESD, Center for Epidemiologic Studies Depression scale.

Methods for Aim 2

Study Participants for Aim 2

For Question 2.1, the sample was restricted to people who have HF (1,693 unique individuals; 4,021 observations) to test the independent effect of each functional impairment (i.e., physical, cognitive, sensory, and urinary impairment) on the likelihood of falling after controlling for socio-demographic factors (age, sex, race/ethnicity, and marital status).

Dependent Variable (Outcome) for Aim 2: Falls

Falls (yes/no) is the outcome of interest. For the operational definition of falls, see the section of the Methods for Aim (See page 73).

Independent Variables for Aim 2

Question 2.1 examined the independent effect of each of the following functional impairment on falls: (1) ADL difficulties, (2) mobility difficulties, (3) large muscle difficulties, (4) cognitive impairment (measured by TICS/IQCODE), (5) IADL difficulties, (6) poor vision/legally blind, (7) poor hearing, or (8) urinary incontinence. The previous section of 'Methods for Aim 1' presents more information about these independent variables (See pages 84-88).

Covariates Used for Adjustment for Aim 2

Socio-demographic factors (age, sex, race/ethnicity, and marital status) were used for adjustment. These adjusters are selected to be parsimonious in the analysis.

Statistical Analysis for Aim 2

For Question 2.1, I restricted the sample to those who have HF, and constructed the base model which only included socio-demographic factors and falls. Then, I added functional impairment variable one at a time to the base model. In other words, I constructed eight separate models to test the effect of each functional impairment on the likelihood of falling, after controlling for age, sex, race/ethnicity, and marital status. Table 3.8 summarizes study variables by research question for Aim 2. To demonstrate odds ratios, I used mixed-effects logistic regression (‘`melogit`’ command in Stata version 14.2) for all analyses for Aim 2.

Table 3.8 Study Variables by Research Questions for Aim 2

	RQ§ 2a	RQ 2b	RQ 2c	RQ 2d	RQ 2e	RQ 2f	RQ 2g	RQ 2h
Sample*	HF patients	HF patients	HF patients	HF patients	HF patients	HF patients	HF patients	HF patients
Fall (y/n)	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**	**DV**
Mobility difficulty	**IV**	cv	cv	cv	cv	cv	cv	cv
Large Muscle difficulty	cv	**IV**	cv	cv	cv	cv	cv	cv
ADL difficulty	cv	cv	**IV**	cv	cv	cv	cv	cv
Cognitive impairment	cv	cv	cv	**IV**	cv	cv	cv	cv
IADL difficulty	cv	cv	cv	cv	**IV**	cv	cv	cv
Poor vision/legally blind	cv	cv	cv	cv	cv	**IV**	cv	cv
Poor hearing	cv	cv	cv	cv	cv	cv	**IV**	cv
Urinary incontinence	cv	cv	cv	cv	cv	cv	cv	**IV**
age	cv	cv	cv	cv	cv	cv	cv	cv
sex	cv	cv	cv	cv	cv	cv	cv	cv
race/ethnicity	cv	cv	cv	cv	cv	cv	cv	cv
spouse/partner status	cv	cv	cv	cv	cv	cv	cv	cv
interview indicator	cv	cv	cv	cv	cv	cv	cv	cv

Note.
§ Research Questions (RQ)

RQ 2a. Among those with HF, what is the independent effect of *mobility difficulty* on the likelihood of falls?
RQ 2b. Among those with HF, what is the independent effect of *large muscle movement difficulty* on the likelihood of falls?
RQ 2c. Among those with HF, what is the independent effect of *ADL difficulty* on the likelihood of falls?
RQ 2d. Among those with HF, what is the independent effect of *cognitive impairment* on the likelihood of falls?
RQ 2e. Among those with HF, what is the independent effect of *IADL difficulty* on the likelihood of falls?
RQ 2f. Among those with HF, what is the independent effect of *poor vision/legally blind* on the likelihood of falls?
RQ 2g. Among those with HF, what is the independent effect of *poor hearing* on the likelihood of falls?
RQ 2h. Among those with HF, what is the independent effect of *urinary incontinence* on the likelihood of falls?

*Sample for Aim 2: Community-dwelling older adults with heart failure.

DV, dependent variable; IV, independent variable; CV, covariate
Abbreviations: ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; CESD, Center for Epidemiologic Studies Depression scale.

CHAPTER 4

RESULTS

Results for Aim 1

Aim 1 estimated the effect of HF on the likelihood of falling among community-dwelling older adults, aged 65 and older after controlling for personal (socio-demographic, general health, physical function, cognitive function, sensory function, urinary function, physical symptom, psychological symptom, health behavior and medication) and environmental (physical environment and social environment) factors.

Baseline Characteristics of Community-Dwelling Older Adults with HF and without HF

For Aim 1, a total of 17,712 unique individuals (70,888 observations) met the inclusion criteria (Figure 3.2). On average, they were interviewed 3.8 times (ranges 1-8 times) between 1998 and 2014. Of the 17,712 unique individual participants, 46.9% had been interviewed since 1998 (HRS Wave 4) and 1,693 participants experienced HF.

Baseline characteristics of personal factors (i.e., socio-demographics, general health, physical and psychological symptoms, health-related behavior, and medication use) are summarized in Table 4.1. At baseline, the mean age overall was 70.4 years (SD 6.6), 57% were female, and 76% were non-Hispanic White. Nearly one-third of participants rated their health as fair or poor (29.2%), reported a fall history in the past 2 years (27.3%) and had general pain (29.6%). More than half of participants reported that they had high blood pressure (56.2%) and arthritis (61.7%). About 14% reported depressive symptoms, and about 8% were taking psychiatric medications. In comparison to older adults with no HF, a higher proportion of HF patients had fair/poor general health, a fall history, obesity, pain and depressive symptoms. Notably, HF patients had significantly a higher proportion of comorbid disease and related medication use: high blood pressure (HF, 70.5% vs. non-HF, 54.7%, $p = < .001$), diabetes (30.2% vs. 17.2%, $p = < .001$), lung disease (20.5% vs. 8.8%, $p = < .001$), stroke/TIA (14.3% vs. 6.3%, $p = < .001$), psychiatric medications (12.7% vs. 7.6%, $p = < .001$), and anti-hypertensive medication (63.7% vs. 48.3%, $p = < .001$). HF patients also had a higher proportion of musculoskeletal problems compared to older adults without HF, such as arthritis (71.3% vs. 60.7%, $p = < .001$) and walking aid use (19.9% vs. 9.4%, $p = < .001$).

Table 4.2 presents a description about baseline characteristics of environmental factors. Nearly 90% of participants reported that their neighborhood environment was safe. Approximately 85% reported that they did not have home safety features in their home, such as a ramp, railing, grab bars and so on. In comparison with the older adults without HF, a higher proportion of HF patients had home safety features (HF 18.0% vs. 15.1%, $p = .002$), poor neighborhood safety (11.6% vs. 9.4%, $p = .003$), and received an ADL help (11.2% vs. 5.4%, $p = < .001$). With respect to other social environmental factors, there were no significant differences except that a lower proportion of HF patients had relatives near their neighborhood.

Overall, HF patients were more likely to have functional difficulties, and the differences between the HF group and the non-HF group were statistically significant, $p < .001$ (Figure 4.1). For example, 68.5% of HF patients had mobility difficulties, while only 44.9% of non-HF participants had mobility difficulties, $p < .001$. On the other hand, the difference between two groups regarding cognitive impairment was not statistically significant, $p = .110$: 2.8% of HF patients had cognitive impairment and 2.2% of non-HF participants had cognitive impairment.

Table 4.1 Characteristics of Community-Dwelling Older Adults, Enrolled in the Health and Retirement Study by Heart Failure (HF) Status at Baseline: Personal Factors

Characteristics	All N = 17,712*	HF Status† No-HF n = 16,019	HF Status† HF n = 1,693	P Value§
Socio-demographic				
Age in years, mean (SD)	70.4 (6.6)	70.4 (6.6)	71.3 (6.7)	< .001
Sex, n (%)				.023
Male	7,626 (43.1)	6,853 (42.8)	733 (45.7)	
Female	10,086 (56.9)	9,166 (57.2)	920 (54.3)	
Race/ethnicity, n (%)				.007
Non-Hispanic White	13,470 (76.1)	12,143 (75.8)	1,327 (78.4)	
Non-Hispanic Black	2,430 (13.7)	2,196 (13.7)	234 (13.8)	
Hispanic	1,450 (8.2)	1,347 (8.4)	103 (6.1)	
Other	355 (2.0)	326 (2.0)	29 (1.7)	
Marital status, n (%)				.001
Married/partnered	11,698 (66.1)	10,641 (66.5)	1,057 (62.5)	
No spouse/partner	6,003 (33.9)	5,369 (33.5)	634 (37.5)	
Living alone				.277
No	13,528 (76.4)	12,253 (76.5)	1,275 (75.3)	
Yes	4,184 (23.6)	3,766 (23.5)	418 (24.7)	
General Health				
Self-report general health, n (%)				< .001
Excellent to Good	12,533 (70.8)	11,731 (73.3)	802 (47.4)	
Fair or Poor	5,173 (29.2)	4,284 (26.7)	889 (52.6)	
Fall history in 2 years, n (%)				< .001
No	12,700 (72.7)	11,606 (73.4)	1,094 (65.4)	
Yes	4,779 (27.3)	4,200 (26.6)	579 (34.6)	
Body Mass Index [a], n (%)				< .001
Underweight	302 (1.7)	288 (1.8)	14 (0.8)	
Normal	5,806 (33.2)	5,361 (33.9)	445 (26.6)	
Overweight	6,947 (39.8)	6,316 (40.0)	631 (37.8)	
Obese	4,413 (25.3)	3,832 (24.3)	581 (34.8)	
High BP, n (%)				< .001
No	7,651 (43.8)	7,160 (45.3)	491 (29.5)	
Yes	9,816 (56.2)	8,643 (54.7)	1,173 (70.5)	
Diabetes, n (%)				< .001
No	14,369 (81.5)	13,195 (82.8)	1,174 (69.8)	
Yes	3,258 (18.5)	2,750 (17.2)	508 (30.2)	
Cancer [b], n (%)				.086
No	15,314 (86.8)	13,877 (86.9)	1,437 (85.4)	
Yes	2,332 (13.2)	2,087 (13.1)	245 (14.6)	
Lung disease, n (%)				< .001
No	15,830 (90.1)	14,502 (91.2)	1,328 (79.5)	
Yes	1,735 (9.9)	1,393 (8.8)	342 (20.5)	
Stroke/TIA, n (%)				< .001
No	16,364 (92.6)	14,920 (93.3)	1,444 (85.7)	

Yes	1,314 (7.4)	1,074 (6.3)	240 (14.3)	
Arthritis, n (%)				< .001
No	6,682 (38.3)	6,200 (39.3)	482 (28.7)	
Yes	10,768 (61.7)	9,573 (60.7)	1,195 (71.3)	
Physical Symptoms				
Pain, often troubled, n (%)				< .001
No	12,460 (70.4)	11,474 (71.7)	986 (58.2)	
Yes	5,236 (29.6)	4,529 (28.3)	707 (41.8)	
Psychological Symptoms				
Depressive, n (%)				< .001
No (CESD 0-3)	14,031 (85.9)	12,826 (86.7)	1,205 (78.0)	
Yes (CESD 4-8)	2,307 (14.1)	1,968 (13.3)	339 (22.0)	
Health-Related Behavior				
Vigorous activities [c], n (%)				< .001
Yes (> 1/week)	6,372 (36.0)	5,881 (36.7)	491 (29.0)	
No	11,331 (64.0)	10,130 (63.3)	1,201 (71.0)	
Excessive drinking				<.001
Non-drinker	12,355 (69.9)	11,055 (69.2)	1,300 (77.0)	
Moderate	5,038 (28.5)	4,667 (29.2)	371 (22.0)	
Excessive	277 (1.6)	260 (1.6)	17 (1.0)	
Walking aid use				< .001
No	15,855 (89.6)	14,500 (90.6)	1,355 (80.1)	
Yes	1,844 (10.4)	1,508 (9.4)	336 (19.9)	
Medication Use				
Psychiatry medications				< .001
No	16,081 (91.9)	14,627 (92.4)	1,454 (87.3)	
Yes	1,412 (8.1)	1,200 (7.6)	212 (12.7)	
Anti-hypertensives				< .001
No	8,767 (50.2)	8,163 (51.7)	604 (36.3)	
Yes	8,696 (49.8)	7,636 (48.3)	1,060 (63.7)	

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
* Characteristics above apply to the individual level, which includes 17,712 unique individuals.
† In this table, HF group was defined as having HF at any point of interview waves.
§ P-value (HF vs. non-HF) based on the chi-square test used for categorical variables or on the independent t-test used for continuous variables.
a. Body Mass Index: underweight (18.4 or less kg/m^2), normal (18.5-2.49 kg/m^2), overweight (25.0-29.9 kg/m^2) and obese (30.0 or more kg/m^2).
b. Cancer of a malignant tumor of any kind except skin cancer
c. Vigorous activities includes sports, heavy housework, or a job that involves physical labor.
Abbreviations: HF, heart failure; SD, standard deviation; BMI, Body Mass Index; BP, blood pressure; TIA, Transient Ischemic Attack; CESD, Center for Epidemiologic Studies Depression Scale.

Table 4.2 Baseline Characteristics of Community-Dwelling Older Adults, Enrolled in the Health and Retirement Study by Heart Failure (HF) Status at Baseline: Environmental Factors

Characteristics	All N = 17,712*	HF Status† No-HF n = 16,019	 HF n = 1,693	P Value§
Physical Environment				
Home safety features[a], n (%)				.002
Presence	2,635 (15.3)	2,341 (15.1)	294 (18.0)	
Absence	14,540 (84.7)	13,167 (84.9)	1,343 (82.0)	
Neighborhood safety, n (%)				.003
Excellent to Good	15,892 (90.4)	14,405 (90.6)	1,487 (88.4)	
Fair or Poor	1,682 (9.6)	1,487 (9.4)	195 (11.6)	
Social Participation				
Getting together, n (%)				.197
Yes	13,018 (75.1)	11,798 (75.2)	1,220 (73.8)	
Almost Never	4,324 (24.9)	3,890 (24.8)	434 (26.2)	
Social Support				
Relatives near, n (%)				< .001
Yes	5,245 (29.9)	4,664 (29.4)	581 (34.7)	
No	12,282 (70.1)	11,190 (70.6)	1,092 (65.3)	
Good friends near, n (%)				.065
Yes	12,290 (70.1)	11,083 (69.9)	1,207 (72.1)	
No	5,233 (29.9)	4,766 (30.1)	467 (27.9)	
Getting a ADL help, n (%)				< .001
No	16,653 (94.1)	15,152 (94.7)	1,501 (88.8)	
Yes	1,046 (5.9)	856 (5.4)	190 (11.2)	

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
† In this descriptive table, HF group was defined as having HF at any point of interview waves.
* Characteristics above apply to the individual level, which includes 17,712 unique individuals.
§ P-value (HF vs. non-HF) based on the Chi-square test used for categorical variables.
a. Home safety features such as a ramp, railings, modifications for a wheelchair, grab bars, a shower seat, or a call device to get help when needed.
Abbreviations: HF, heart failure; ADL, Activities of Daily Living

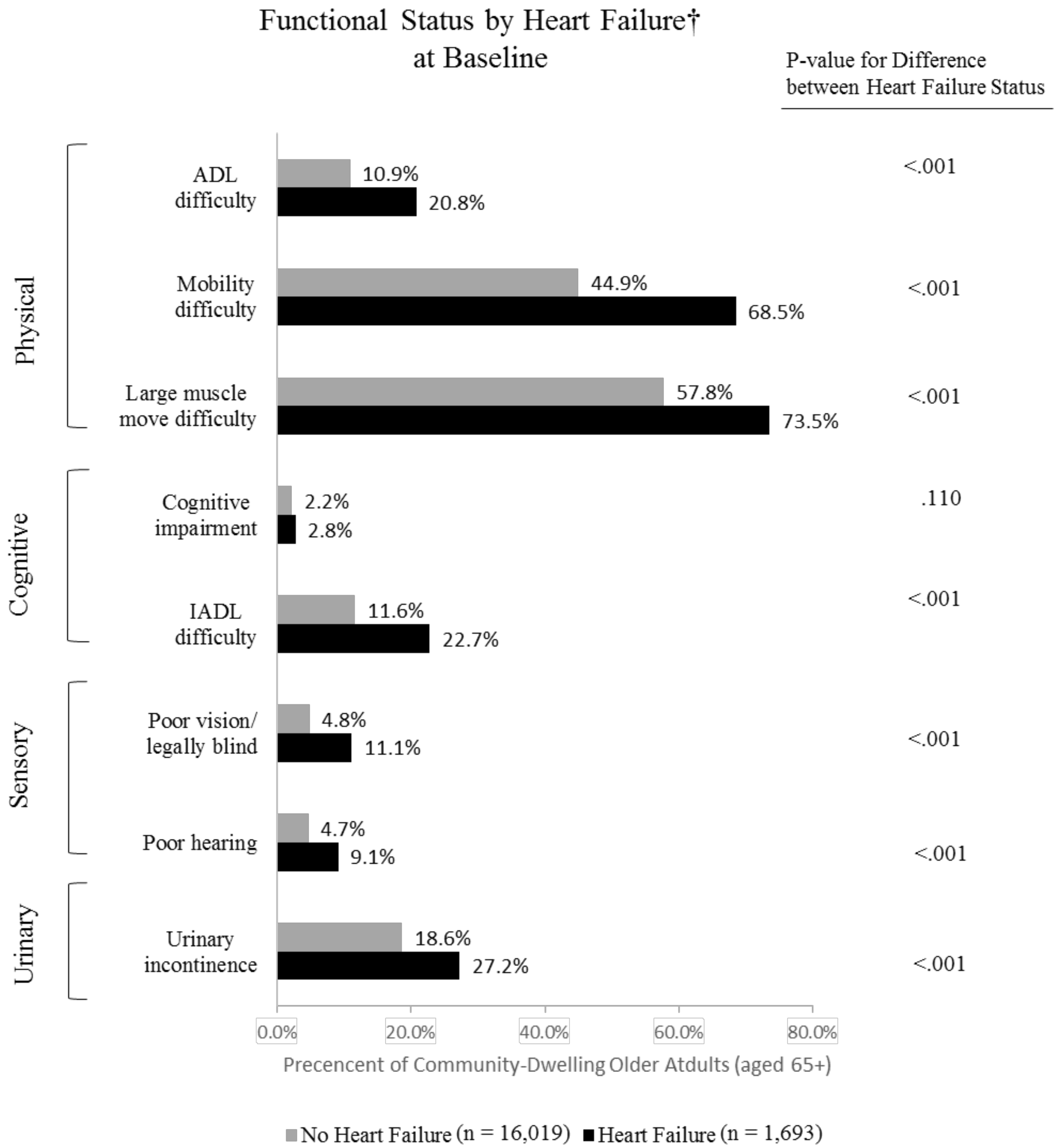


Figure 4.1 Functional status of community-dwelling older adults, enrolled in the Health and Retirement Study (HRS) by heart failure at baseline.

Data source: Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note. The characteristics above apply to the individual level, which includes 17,712 unique individuals. P-value (HF vs. non-HF) based on the chi-square test used for categorical variables.
† In the baseline descriptive table, HF group was defined as having heat failure at any point of interview waves. Cognitive impairment was recognized by TICS score 8 or less for self-respondents and by Jorm IQCODE 3.44 +.

Abbreviations: ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living.

RQ 1.1 Association Between HF and Falls Among Community-Dwelling Older Adults

As Table 4.3 shows, older adults with HF were at higher risk for falling compared to those without HF. Among older adults with HF, there were 25.1 adults who fell per 100 person-years; where as the fall rate among older adults without HF was lower (16.8 per 100 person-years). Exposure to HF was attributed to approximately 8 falls per 100 person-years over the observation period. HF was strongly associated with the risk of falling, unadjusted RR = 1.50, 95% CI: 1.44, 1.56.

Table 4.3 Risk of Falling Per 100 Person-Years, Attributable Risk and Unadjusted Relative Risk of Falling Associated with Heart Failure (HF) Among Community-Dwelling Older Adults (age 65+)

	HF	non-HF
Number of older adults who fell	2,021	22,457
Total person-years of follow-up	8,042	133,734
Risk of falling per 100 person-years	25.1	16.8
Attributable Risk (cases attributed to HF)	8.3 per 100 person-years (95% CI: 7.4, 9.3)	
Relative Risk	1.50 (95% CI: 1.44, 1.56)	

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Abbreviation: HF, heart failure; CI, confidence interval

Before conducting multivariate analysis using the mixed-effects logistic regression, univariate analyses were performed. Results from both unadjusted and adjusted association between HF and falls are presented in Table 4.4. As Table 4.4 shows, the unadjusted odds of falls in HF patients were approximately 2.4 times greater than in the non-HF participants, OR = 2.36, 95% CI: 2.14, 2.60. After controlling for covariates (socio-demographics, general health, physical function, cognitive function, sensory function, urinary function, physical symptom, psychological symptom, health-related behavior, medication use, physical and social environment; noted bottom of Table 4.4 –see conceptual model Figure 2.1), the association between HF status and falls persisted yet was attenuated – the adjusted odds of falling among those with HF were 14% greater than among those without HF, OR = 1.14, 95% CI: 1.04, 1.26.

Table 4.4 Unadjusted and Adjusted Odds Ratios of Falling Associated with Heart Failure (HF) Among Community-Dwelling Older Adults (age 65+)

Characteristics	No. of participants	Odds Ratio† (95% CI)
All, Unadjusted	17,712	**2.36 (2.14, 2.60)***
All, Adjusted	16,685	**1.14 (1.04, 1.26)***

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
†Odds ratios are adjusted for 32 covariates:
All 32 covariates include:
- Interview indicator
- Socio-demographics: age, sex, race/ethnicity, marital status
- General health: self-reported health, fall history, BMI, hypertension, diabetes, cancer, lung disease, stroke/TIA, arthritis
- Physical function/disability: mobility difficulty, large muscle difficulty, ADL disability
- Cognitive function/disability: cognitive impairment(TICS/IQCODE), IADL disability
- Sensory function: poor vision, poor hearing/legally blind
- Urinary function: urinary incontinence
- Physical symptom: pain
- Psychological symptom: depressive symptom (CESD)
- Health-related behavior: vigorous activities, alcohol use, walking aid use
- Medication use: psychiatric medication use
- Physical environment: home safety features, neighborhood safety
- Social environment: getting together, getting an ADL help.

*Significant ORs are presented in bold.
Abbreviation: CI, confidence interval; BMI, Body Mass Index; TIA, Transient Ischemic Attack; ADL, Activities of Daily Living; TICS, Telephone Interview for Cognitive Status; IQCODE, Informant Questionnaire on Cognitive Decline in the Elderly; IADL, Instrumental Activities of Daily Living; CESD, Center for Epidemiologic Studies Depression scale.

Table 4.5 presents the unique contribution of HF to falls as well as the association between each covariate and falls, after controlling for other variables in the table. For example, the adjusted odds of falling among those with fair to poor self-rated health were 16% greater than among those with excellent to good self-rated health after controlling for socio-demographics, physical function, cognitive function, sensory function, urinary function, physical symptom, psychological symptom, health-related behavior, medication use, physical and social environment, OR = 1.16, 95% CI: 1.10, 1.22.

Table 4.5 Unadjusted and Adjusted Odds Ratios for Association Between Risk Factors and Falls Among Community-Dwelling Older Adults (aged 65+)

Independent variable	Participant Who Fell, No. of Obs.[§] (%)	Odds Ratio (95% CI)†	
		Unadjusted	Adjusted‡
Heart Failure			
No	22,457 (33.6)	1.00 (reference)	1.00 (reference)
Yes	2,021 (50.3)	**2.36 (2.14, 2.60)***	**1.14 (1.04, 1.26)***
Interview Wave 10 or 11			
No	17,945 (33.9)	1.00 (reference)	1.00 (reference)
Yes	6,533 (36.6)	1.35 (1.29, 1.42)	0.95 (0.91, 1.01)
Socio-demographic			
Age in years[a]		**1.08 (1.08, 1.08)***	**1.04 (1.03, 1.04)***
Sex			
Male	9,562 (32.0)	1.00 (reference)	1.00 (reference)
Female	14,916 (36.4)	**1.32 (1.24, 1.40)***	0.97 (0.92, 1.02)
Race/ethnicity			
Non-Hispanic White	19,538 (35.6)	1.00 (reference)	1.00 (reference)
Non-Hispanic Black	2,666 (29.5)	**0.69 (0.63, 0.75)***	**0.67 (0.62, 0.72)***
Hispanic	1,915 (34.3)	0.91 (0.81, 1.01)	**0.83 (0.76, 0.91)***
Other	351 (27.0)	**0.57 (0.46, 0.71)***	**0.69 (0.58, 0.84)***
Marital/partner status			
Married/partnered	13,880 (32.1)	1.00 (reference)	1.00 (reference)
No spouse/partner	10,588 (38.3)	**1.56 (1.49, 1.65)**	1.03 (0.98, 1.09)
General Health			
Self-reported health			
Excellent to Good	15,318 (30.3)	1.00 (reference)	1.00 (reference)
Fair to Poor	9,146 (45.2)	**1.94 (1.85, 2.03)***	**1.16 (1.10, 1.22)***
Fall history in 2 years			
No	11,777 (24.2)	1.00 (reference)	1.00 (reference)
Yes	12,591 (57.6)	**3.14 (3.00, 3.28)***	**2.50 (2.38, 2.64)***
Body Mass Index[b]			
Normal	501 (39.1)	1.00 (reference)	1.00 (reference)
Underweight	8,067 (34.0)	**1.34 (1.14, 1.57)***	0.99 (0.84, 1.17)
Overweight	9,025 (32.7)	**0.89 (0.85, 0.95)***	0.97 (0.92, 1.02)
Obese	6,570 (34.5)	**1.12 (1.05, 1.20)***	**1.09 (1.02, 1.16)***
High blood pressure			
No	8,211 (31.3)	1.00 (reference)	1.00 (reference)
Yes	15,906 (36.4)	**1.42 (1.35, 1.49)***	1.01 (0.96, 1.06)
Diabetes			
No	18,273 (32.8)	1.00 (reference)	1.00 (reference)
Yes	6,038 (41.0)	**1.62 (1.52, 1.72)***	**1.23 (1.16, 1.30)***
Cancer			
No	19,788 (33.8)	1.00 (reference)	1.00 (reference)
Yes	4,579 (38.1)	**1.40 (1.31, 1.50)***	1.04 (0.98, 1.10)

Lung Disease			
No	21,074 (33.5)	1.00 (reference)	1.00 (reference)
Yes	3,460 (42.3)	**1.64 (1.52, 1.78)***	1.06 (0.99, 1.14)
Stroke/TIA			
No	21,528 (33.2)	1.00 (reference)	1.00 (reference)
Yes	2,878 (48.3)	**2.13 (1.96, 2.31)***	**1.26 (1.17, 1.37)***
Arthritis			
No	5,845 (26.1)	1.00 (reference)	1.00 (reference)
Yes	18,216 (38.5)	**1.94 (1.84, 2.04)***	**1.22 (1.15, 1.28)***
Physical Function			
ADL difficulty			
No	19,453 (31.7)	1.00 (reference)	1.00 (reference)
Yes	5,014 (53.1)	**2.35 (2.21, 2.50)***	1.08 (0.99, 1.17)
Mobility difficulty			
No	8,800 (26.1)	1.00 (reference)	1.00 (reference)
Yes	15,663 (42.2)	**2.12 (2.03, 2.22)***	**1.16 (1.11, 1.22)***
Large muscle difficulty			
No	6,185 (24.1)	1.00 (reference)	1.00 (reference)
Yes	18,278 (40.5)	**2.09 (2.00, 2.19)***	**1.21 (1.15, 1.28)***
Cognitive Function			
Cognitive impairment			
No	23,093 (33.9)	1.00 (reference)	1.00 (reference)
Yes	844 (52.8)	**2.57 (2.24, 2.94)***	**1.33 (1.10, 1.60)***
IADL difficulty			
No	18,956 (31.4)	1.00 (reference)	1.00 (reference)
Yes	5,509 (52.1)	**2.46 (2.32, 2.60)***	**1.12 (1.05, 1.21)***
Sensory Function			
Vision			
Excellent to Fair	22,209 (33.5)	1.00 (reference)	1.00 (reference)
Poor to Legally blind	2,222 (49.7)	**1.97 (1.81, 2.14)***	**1.13 (1.03, 1.24)***
Hearing			
Excellent to Fair	22,380 (33.8)	1.00 (reference)	1.00 (reference)
Poor	2,076 (45.5)	**1.66 (1.53, 1.81)***	1.04 (0.95, 1.14)
Urinary Function			
Urinary incontinence			
No	16,675 (30.9)	1.00 (reference)	1.00 (reference)
Yes	7,744 (46.0)	**1.88 (1.79, 1.98)***	**1.29 (1.22, 1.36)***
Physical Symptoms			
Pain, often troubled			
No	14,528 (29.8)	1.00 (reference)	1.00 (reference)
Yes	9,912 (44.8)	**1.82 (1.74, 1.91)***	**1.18 (1.12, 1.24)***
Psychological Symptoms			
Depressive			
No (CESD score 0-3)	18,598 (32.4)	1.00 (reference)	1.00 (reference)
Yes (CESD score 4-8)	4,188 (46.8)	**1.75 (1.64, 1.86)***	**1.12 (1.05, 1.20)***

Health-Related Behavior			
Vigorous activities			
Yes (> 1/week)	5,717 (28.2)	1.00 (reference)	1.00 (reference)
No	18,720 (37.0)	**1.61 (1.54, 1.69)***	1.05 (0.998, 1.10)
Alcohol use			
Non-drinker	17,838 (35.9)	1.00 (reference)	1.00 (reference)
Moderate	6,362 (31.3)	0.81 (0.77, 0.85)	1.02 (0.97, 1.07)
High-risk	235 (29.6)	**0.70 (0.57, 0.87)***	1.07 (0.87, 1.31)
Walking aid use			
No	18,939 (31.0)	1.00 (reference)	1.00 (reference)
Yes	5,525 (56.2)	**2.89 (2.72, 3.07)***	**1.19 (1.11, 1.28)***
Medication Use			
Psychiatry medications			
No	21,057 (32.8)	1.00 (reference)	1.00 (reference)
Yes	3,081 (52.2)	**2.37 (2.19, 2.56)***	**1.51 (1.40, 1.64)***
Physical Environment			
Home safety features			
Presence	5,451 (41.1)	1.00 (reference)	1.00 (reference)
Absence	18,777 (33.1)	**0.74 (0.70, 0.78)***	0.96 (0.91, 1.01)
Neighborhood safety			
Excellent to Good	21,963 (34.2)	1.00 (reference)	1.00 (reference)
Fair to Poor	2,346 (38.0)	**1.18 (1.09, 1.27)***	1.01 (0.94, 1.10)
Social Environment			
Getting together			
Yes	17,471 (33.5)	1.00 (reference)	1.00 (reference)
Almost Never	6,431 (37.5)	**1.18 (1.12, 1.24)***	0.99 (0.94, 1.04)
Getting a ADL help			
No	21,605 (32.8)	1.00 (reference)	1.00 (reference)
Yes	2,862 (57.0)	**2.67 (2.46, 2.89)***	1.11 (0.99, 1.24)

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
Data were analyzed using 70,888 observations (17,712 community-dwelling older adults).
§ Number of observations and row percentages are presented.
† ORs were obtained using mixed-effects logistic regression with a person-specific random intercept.
‡ Adjusted for all other variables in the table (59,264 observations, 16,358 unique individuals).
a. Mean age: 75.75 (SD 7.34).
b. Body Mass Index was categorized into four: underweight (18.4 or less kg/m2),
normal (18.5-2.49 kg/m2), overweight (25.0-29.9 kg/m2) and obese (30.0 or more kg/m2).
*Significant ORs are presented in bold.
Abbreviations: no, number of observations; CI, Confidence Interval; OR, Odds Ratio; TIA, Transient Ischemic Attack; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; CESD, Center for Epidemiologic Studies Depression Scale.

RQ 1.2 The Effects of HF on Falls for Each Functional Sub-Group

Table 4.6 presents odds ratios for the associations between HF status and the likelihood of falling for each functional sub-group (i.e., those with and without physical, cognitive, sensory, or urinary impairment). Across most functional sub-groups, the association between HF status and the likelihood of falling was similar to that in the entire population (OR ~ 1.14). However, the association was slightly stronger among those with an IADL difficulty (OR = 1.19, 95% CI: 1.00, 1.40) and those with urinary incontinence (OR = 1.23, 95% CI: 1.05, 1.44).

Table 4.6 Adjusted Odds Ratios For Association Between Heart Failure (HF) and Falls For Each Functional Sub-group Among Community-Dwelling Older Adults (age 65+)

Functional Sub-group	No. of Participants	Adjusted Odds Ratio† (95% CI) for Association with HF
Physical Function		
ADL difficulty		
No	15,283	**1.14 (1.02, 1.28)***
Yes	4,040	1.15 (0.97, 1.36)
Mobility difficulty		
No	10,594	1.16 (0.95, 1.42)
Yes	11,518	**1.14 (1.02, 1.26)***
Large muscle difficulty		
No	8,931	1.13 (0.90, 1.41)
Yes	13,132	**1.14 (1.03, 1.27)***
Cognitive Function		
Cognitive impairment		
No	16,207	**1.16 (1.05, 1.27)***
Yes	561	0.72 (0.38, 1.33)
IADL difficulty		
No	15,188	**1.13 (1.01, 1.26)***
Yes	4,335	**1.19 (1.00, 1.40)***
Sensory Function		
Vision		
Excellent to Fair	15,870	**1.16 (1.05, 1.29)***
Poor to Legally blind	2,036	1.01 (0.78, 1.30)
Hearing		
Excellent to Fair	16,009	**1.13 (1.03, 1.25)***
Poor	1,951	1.19 (0.90, 1.58)
Urinary Function		
Urinary incontinence		
No	14,422	1.09 (0.97, 1.22)
Yes	6,191	**1.23 (1.05, 1.44)***

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
For each functional sub-group, ORs for HF are presented.
†ORs are adjusted for all other factors in the table including interview year indicator, age, sex, race/ethnicity, self-reported general health, fall history in 2 years, Body Mass Index, high blood pressure, diabetes, cancer, lung disease, stroke/TIA, arthritis, pain, depressive symptom, vigorous activities, alcohol use, walking aid use, psychiatry medication use, home safety features, neighborhood safety, social participation, getting a ADL help.
*Significant ORs are presented in bold ($p < 0.05$).
Abbreviation: CI, confidence interval; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; TIA, Transient Ischemic Attack.

RQ 1.3 Interaction Between HF and Functional Impairment

Research Question 1.3 examined the differential effects of HF on falls depending on those with and without functional impairment (i.e., physical, cognitive, sensory, and urinary impairment). Using a Wald test to examine the null hypothesis that there is no interaction between HF and functional impairment, there was no statistical difference across functional sub-groups with the exception of cognitive function (measured by TICS/IQCODE). The effect of HF on the likelihood of falling among those without cognitive impairment (TICS/IQCODE) statistically differs ($p = 0.03$) from the effect of HF on the likelihood of falling among those with cognitive impairment (TICS/IQCODE).

Results for Aim 2

Aim 2 explored functional impairment (i.e., physical, cognitive, sensory and urinary impairment) in explaining falls among community-dwelling older adults with HF. Question 2.1 was restricted to the HF sample (n = 1,693), and examined each functional impairment. (See Conceptual Model Figure 2.5)

RQ 2.1 Association Between Each Functional Impairment and Falls Among Community-Dwelling Older Adults with HF

In older adults with HF, unadjusted analysis revealed that most associations between each functional impairment and the likelihood of falls were statistically significant. The strongest association between functional impairment and falls was a difficulty in large muscle function, unadjusted OR = 2.25, 95% CI: 1.74, 2.92. Among functional impairment factors, the least association with falls was poor hearing, unadjusted OR = 1.37, 95% CI: 1.04, 1.81. Notably, in cognitive function, while the IADL difficulty was associated with falls (unadjusted OR = 2.08, 95% CI: 1.71, 2.53), the association between cognitive impairment (TICS/IQCODE) and falls was not statistically significant (Table 4.7).

After adjusting for age, sex, race/ethnicity, and spouse/partner status, most functional impairment were still associated with higher odds of falling. Adjusted for socio-demographic differences, difficulty in muscle function was shown as the strongest factor to be associated with falls, adjusted OR = 2.21, 95% CI: 1.70, 2.88. Other difficulties in physical function, cognitive function (IADL), and urinary function were associated with nearly 2-fold higher odds of falling ranging from 1.86 to 2.00. Among functional impairment factors, poor vision/legally blind status appeared the least strong factor in explaining falls, adjusted OR 1.43, 95% CI: 1.10, 1.86. The adjusted analysis also revealed that known risk factors of cognitive impairment (TICS/IQCODE) and poor hearing were statistically insignificant in older adults with HF.

Table 4.7 Unadjusted and Adjusted Odds Ratios for Association Between Functional Impairment and Falls Among Community-Dwelling Older Adults with Heart Failure

Functional Risk Factors (Independent Variables)	Participant Who Fell, No. of Obs.§ (%)	Odds Ratio (95% CI)†	
		Unadjusted	Adjusted‡
Physical Function			
ADL difficulty			
No	1,267 (45.3)	1.00 (reference)	1.00 (reference)
Yes	751 (61.6)	**1.94 (1.59, 2.38)***	**1.86 (1.51, 2.29)***
Mobility difficulty			
No	256 (36.2)	1.00 (reference)	1.00 (reference)
Yes	1,762 (53.3)	**1.96 (1.53, 2.52)***	**1.86 (1.45, 2.40)***
Large muscle difficulty			
No	224 (34.6)	1.00 (reference)	1.00 (reference)
Yes	1,793 (53.2)	**2.25 (1.74, 2.92)***	**2.21 (1.70, 2.88)***
Cognitive Function			
Cognitive impairment			
No	1,852 (49.9)	1.00 (reference)	1.00 (reference)
Yes	96 (57.5)	1.53 (0.96, 2.44)	1.36 (0.84, 2.20)
IADL difficulty			
No	1,142 (44.3)	1.00 (reference)	1.00 (reference)
Yes	876 (60.8)	**2.08 (1.71, 2.53)***	**2.00 (1.63, 2.45)***
Sensory Function			
Vision			
Excellent to Fair	1,652 (48.7)	1.00 (reference)	1.00 (reference)
Poor to Legally blind	365 (58.8)	**1.52 (1.17, 1.98)***	**1.43 (1.10, 1.86)***
Hearing			
Excellent to Fair	1,716 (49.2)	1.00 (reference)	1.00 (reference)
Poor	301 (57.2)	**1.37 (1.04, 1.81)***	1.26 (0.95, 1.67)
Urinary Function			
Urinary incontinence			
No	1,146 (44.6)	1.00 (reference)	1.00 (reference)
Yes	871 (60.4)	**2.08 (1.71, 2.54)***	**1.96 (1.59, 2.40)***

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
Data were analyzed using 4,021 observations (1,693 community-dwelling older adults with HF).
§ Number of observations and row percentages are presented.
† ORs were obtained using mixed-effects logistic regression with a person-specific random intercept.
‡ Adjusted for age, sex, race/ethnicity, and spouse/partner status.
*Significant ORs are presented in bold.
Abbreviations: CI, Confidence Interval; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living.

Table 4.8 displays the association between each functional impairment and falls as well as the association between covariates (age, sex, race/ethnicity, and spouse/partner status) and falls. For each functional impairment (i.e., physical, cognitive, sensory, and urinary impairment), the base-model only includes socio-demographic factors, and the full model includes one functional impairment variable in addition to the base-model. For example, for Model 1 (testing ADL difficulty), HF patients with ADL difficulty had 86% higher likelihood of falling while adjusting for interview waves, age, sex, race/ethnicity, and spouse/partner status, adjusted OR = 1.86, 95% CI: 1.51, 2.29. In the same model, HF patients without spouse/partner had 32% higher likelihood of falling while adjusted for interview waves, age, sex, race/ethnicity, and ADL difficulty, adjusted OR = 1.32, 95% CI: 1.07, 1.68.

Table 4.8 Adjusted Odds Ratios for Falling for Various Risk Factors Among Community-Dwelling Older Adults with Heart Failure (Study Population Based on the HRS; N = 1,693)

Models	Risk Factors (Independent Variables and Covariates)	Participant Who No. of Obs.§ (%)	Adjusted Odds Ratio (95% CI)† Multivariate analysis for Base-model‡	Adjusted Odds Ratio (95% CI)† Multivariate analysis for Base-model + Function
	Physical Function			
Model 1	**ADL difficulty**			
	No	1,267 (45.3)		1.00 (reference)
	Yes	751 (61.6)		**1.86 (1.51, 2.29)***
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.09 (0.90, 1.32)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.01, 1.04)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.10 (0.86, 1.40)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.57 (0.41, 0.80)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.79 (0.19, 1.27)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.01 (1.22, 7.43)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.32 (1.07, 1.68)***
Model 2	**Mobility difficulty**			
	No	256 (36.2)		1.00 (reference)
	Yes	1,762 (53.3)		**1.86 (1.45, 2.40)***
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.08 (0.89, 1.30)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.01, 1.05)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.09 (0.85, 1.40)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.60 (0.43, 0.85)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.89 (0.56, 1.44)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.10 (1.25, 7.72)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.35 (1.06, 1.72)***

Model 3	**Large muscle difficulty**			
	No	224 (34.6)		1.00 (reference)
	Yes	1,793 (53.2)		**2.21 (1.70, 2.88)***
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.06 (0.88, 1.28)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.01, 1.05)**
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.07 (0.83, 1.37)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.60 (0.43, 0.84)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.91 (0.56, 1.46)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.23 (1.31, 8.00)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.37 (1.08, 1.74)***
		Cognitive Function		
Model 4	**Cognitive impairment**			
	No	1,852 (49.9)		1.00 (reference)
	Yes	96 (57.5)		1.36 (0.84, 2.20)
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.08 (0.89, 1.31)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.02, 1.05)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.17 (0.90, 1.52)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.57 (0.40, 0.81)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.97 (0.58, 1.61)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.45 (1.31, 9.04)***
	Spouse /partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.37 (1.07, 1.75)***
Model 5	**IADL difficulty**			
	No	1,142 (44.3)		1.00 (reference)
	Yes	876 (60.8)		**2.00 (1.63, 2.45)***
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.10 (0.91, 1.33)

	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.02 (1.01, 1.04)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.07 (0.89, 1.37)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.54 (0.39, 0.76)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.81 (0.50, 1.30)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.09 (1.25, 7.61)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.34 (1.06, 1.71)***
	Sensory Function			
Model 6	**Vision**			
	Excellent to Fair	1,652 (48.7)		1.00 (reference)
	Poor to Legally blind	365 (58.8)		**1.43 (1.10, 1.86)***
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.08 (0.89, 1.31)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.01, 1.05)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.12 (0.87, 1.45)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.59 (0.42, 0.84)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.89 (0.55, 1.45)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.20 (1.27, 8.08)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.38 (1.08, 1.76)***
Model 7	**Hearing**			
	Excellent to Fair	1,716 (49.2)		1.00 (reference)
	Poor	301 (57.2)		1.26 (0.95, 1.67)
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.08 (0.89, 1.31)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.01, 1.05)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	1.16 (0.90, 1.50)

	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.62 (0.44, 0.87)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.89 (0.55, 1.45)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.23 (1.27, 8.17)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.39 (1.09, 1.78)***
		Urinary Function		
Model 8	**Urinary incontinence**			
	No	1,146 (44.6)		1.00 (reference)
	Yes	871 (60.4)		**1.96 (1.59, 2.40)***
	Interview Wave 10 or 11			
	No	1,341 (50.2)	1.00 (reference)	1.00 (reference)
	Yes	680 (50.3)	1.08 (0.89, 1.31)	1.05 (0.86, 1.26)
	Age in years[1]	2,021	**1.03 (1.02, 1.05)***	**1.03 (1.01, 1.04)***
	Sex			
	Male	857 (47.3)	1.00 (reference)	1.00 (reference)
	Female	1,164 (52.7)	1.14 (0.88, 1.47)	0.99 (0.77, 1.28)
	Race/ethnicity			
	Non-Hispanic White	1,612 (51.1)	1.00 (reference)	1.00 (reference)
	Non-Hispanic Black	236 (42.8)	**0.61 (0.43, 0.86)***	**0.64 (0.46, 0.91)***
	Hispanic	122 (50.0)	0.91 (0.56, 1.48)	0.96 (0.60, 1.54)
	Other	51 (73.9)	**3.26 (1.29, 8.29)***	**3.25 (1.31, 8.09)***
	Spouse/partner status			
	Married/partnered	1,008 (47.0)	1.00 (reference)	1.00 (reference)
	No spouse/partner	1,011 (54.0)	**1.39 (1.08, 1.78)***	**1.37 (1.08, 1.75)***

Data source:
Health and Retirement Study (RAND Fat Files For HRS 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012 and 2014 Early Release, Wave 4 to 12) public use dataset; RAND HRS Data Version P.

Note.
Data were analyzed using 4,021 observations (1,693 community-dwelling older adults with HF).
§ Number of observations and row percentage are presented.
1. Mean age: Overall (n = 4,021), 75.75 (SD 7.34); Fell,
† ORs were obtained using mixed-effects logistic regression with a person-specific random intercept.
‡ The base-model includes interview wave indicator, age, sex, race/ethnicity, and marital status.
Mean age: 75.75 (SD 7.34).
*Significant ORs are presented in bold.
Abbreviations: CI, Confidence Interval; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living.

CHAPTER 5

DISCUSSION

Community-dwelling older adults with HF appear to be at a greater risk of falling related to their symptoms, comorbid diseases, and/or adverse effects of HF management (Benjamin et al., 2017; Mosterd et al., 2007; Murad et al., 2012). The complexity of HF conditions and the growing number of people with HF in the U.S. poses new challenges for developing innovative fall prevention programs. To implement innovative fall prevention interventions in community-dwelling older adults with HF, empirical evidence that identifies risk factors for falls in HF patients is required. However, little is known about the independent effect of HF on falls and possible fall risk factors among community-dwelling older adults with HF (K. Lee et al., 2016). To fill the gaps in the science, this dissertation addressed the following two specific aims in the U.S population: (1) Among community-dwelling older adults, aged 65 and older, examine the independent effect of HF on the likelihood of falling overall and for each functional sub-group (i.e., those with and without physical, cognitive, sensory, and urinary impairment); and, (2) among community-dwelling older adults with HF, explore each functional impairment (i.e., physical, cognitive, sensory, and urinary impairment) in explaining falls. This chapter includes a discussion of key findings, research strengths and limitations, directions for the future research, and implications for nursing practice.

Discussion of Key Findings

The Effect of HF on Falls Among Community-Dwelling Older Adults in the U.S. (Aim 1)

In this study, among community-dwelling older adults in the U.S., the presence of HF was associated with a 14% higher likelihood of falling compared to the absence of HF, after controlling for personal and environmental fall risk factors. This result aligns with two previous studies of large samples of community-dwelling older adults, in Sweden (Stenhagen et al., 2013) and in Ireland (Jansen et al., 2014). The adjusted HF effect on falls in the current study, however, was less than that of other two studies (adjusted OR: U.S., 1.14 vs. Sweden, 1.88 or Ireland[2], 1.38). This difference may be attributed to the different covariates used for adjustment. The Swedish study used age and sex for adjustment (Stenhagen et al., 2013). The Irish study used depressive symptoms, any ADL disability, arthritis, impaired vision, cognitive measures and the use of psychiatric medication (Jansen et al., 2014). The present study used more extensive covariates for adjustement, such as sociodemographics, general health, functional difficulties (i.e., physical, cognitive, sensory and urianry function), psychological and physical symptoms, health behavior, psychitric medication use, and phsycial and social environment. Despite the difference in covariates, the present study found that the effect of HF on the likelihood of falling was still statistically significant after removing the shared effects between HF and covariates in explaining falls. This result suggests that even after controlling for other personal and environmental fall risk factors, some effects of having HF contribute to falls in community-dwelling older adults such as unique symptoms of HF and side effects of HF management. Thus, this result supports the conceptual model addressing the independent effect of HF on falls

[2] Note that the Irish study reported two types of fall outcome: 'any falls' (one or more falls vs. no falls) and 'recurrent falls' (two or more falls vs. no falls). For the comparison of the association between HF and falls, I used the 'any fall' outcome in this discussion section.

(Figure 2.5). The presence of HF is independently associated with falls among community-dwelling older adults.

Building on Research Question 1.1 (i.e., the independent effect of HF on falls among community-dwelling older adults), using two approaches, this study further examined whether the effects of having HF on the likelihood of falling differ according to functional sub-groups. One approach (Research Question 1.2) examined the effect of HF on the likelihood of falling for each functional sub-group, those with and without physical, cognitive, sensory, and urinary impairment (i.e., obtaining odds ratio for HF for each functional sub-group). Overall, this study revealed that the effects of HF on the likelihood of falling were quite consistent over most functional sub-groups (an approximately 14% higher likelihood of falling), after controlling for other personal (e.g., age, general health, psychiatric medication use) and environmental factors (e.g., physical and social environment). However, the effect of HF was slightly stronger among the following two sub-groups. Among those with decreased cognitive function (IADL difficulty), having HF was associated with a 19% higher likelihood of falling. Among those with decreased urinary function (urinary incontinence), having HF was associated with 23% higher likelihood of falling. These results suggest that having HF independently plays an important role in predicting falls, particularly in older adults with decreased cognitive function (IADL difficulty) or urinary function (urinary incontinence).

The second approach (Research Question 1.3) examined statistical differences between those with and without functional impairment according to physical, cognitive, sensory, and urinary function (i.e., testing the ratio of odds ratio for the differential effect of HF on falls comparing between those with and without each functional impairment, and obtaining the p-value for the difference). In terms of testing the differential of HF effect on falls comparing between those with and without functional impairment, there was no difference across functional sub-groups with the exception of cognitive function (measured by TICS/IQCODE). *The effect of HF* on the likelihood of falling among those *without* cognitive impairment (measured by TICS/IQCODE) was statistically different and greater than the *the effect of HF* on the likelihood of falling among those *with* cognitive impairment (p = 0.03) (See Table 4.6). This is a counterintuitive result. This differential effect of HF suggests other influences may be at play among HF patients with and without cognitive impairment, and further studies are needed to validate this result. One possible influence may be measurement effects. This study used two different variables for cognitive functioning using different types of measurements (IADL and TICS/IQCODE). While the IADL measurement focuses on cognitive function related to situational/social aspects by measuring daily activities (e.g., medication management), the TICS[3] (or IQCODE) measurement focuses on cognitive function related to generic cognitive ability by measuring specific tasks (e.g., memory or backward counting) that are situation-free (Verbrugge & Jette, 1994). While there was no interaction effect between HF and IADL difficulty, there was a statistically significant interaction effect between HF and cognitive impairment measured by TICS/IQCODE although the effect was minimal (p = 0.03). This counterintuitive result in the same conceptual domain suggests that when cognitive function is measured, the choice of measurement is important to assess the risk of falling, and using the two types of measurements together may help evaluate the full scope of cognitive function.

In conclusion, among community-dwelling older adults, the presence of HF was independently associated with a higher likelihood of falling even after controlling for personal and environmental fall risk factors. With the exception of cognitive impairment measured by

[3] The cognitive impairment was measured using TICS for self-respondents (92 % of participants), and IQCODE for proxy-respondents (8 % of participants).

TICS/IQCODE, having HF was associated with a higher likelihood of falling regardless of whether the patients experienced functional impairment or not. From a clinical standpoint, the functional sub-groups were largely similar in terms of the effects of HF on falling. This implies researchers or clinicians need to pay attention to the risk of falls in those with HF and test nursing interventions to prevent falls in this population.

The Effect of Functional Impairment on Falls among Community-Dwelling Older Adults with HF (Aim 2)

The study sample for Aim 2 was restricted to HF patients. This study examined the independent relationship between functional impairment (physical, cognitive, sensory, and urinary impairment) and falls after controlling for socio-demographic factors (i.e., age, sex, race/ethnicity and spouse/partner status). The study identified that while sensory impairment was least associated with falls, three functional domains (physical, cognitive, and urinary impairment) were associated with an approximately 2-fold higher likelihood of falling in community-dwelling older adults with HF. In terms of the association between other functional impairments (physical, cognitive and urinary impairment) and falls, the findings of the present study are consistent with a meta-analysis reporting positive associations between falls and difficulties in physical, cognitive and urinary function in the general population of community-dwelling older adults (Deandrea et al., 2010). Specifically, in this study, difficulty in large muscle function (e.g., sitting for 2 hours, getting up from a chair, stooping/kneeling/crouching, or pushing/pulling large objects) was the strongest predictor of falls among functional factors. A previous study (Tymkew et al., 2011) showed that the HF patients had decreased physical function (i.e., poor gait and balance) indicating a higher fall risk. The present study further provided a statistically significant association between physical function and falls among HF patients with an analytic approach.

The higher likelihood of falling among HF patients with impaired cognitive function (IADL difficulty) can be explained in terms of difficulties in specific tasks of IADL, such as difficulty taking medication (Alosco et al., 2014). When HF patients have a cognitive impairment, they may have difficulty following the instructions on their medication, which can further exacerbate their HF symptoms. For instance, deteriorating HF symptoms (e.g. breathing difficulty) lead to limited physical function or require more aggressive therapies (e.g., increasing dose of a medication or adding multiple medications), and this further predisposes them to side-effects. This scenario suggests that future studies examining the feedback-looping relationship among cognitive impairment, self-care ability, HF symptom and falls may be beneficial to develop innovative fall prevention interventions.

One of the factor that explains the higher likelihood of falling among HF patients with urinary incontinence may be the frequent or urgent visits to the toilet. (Deandrea et al., 2010; Hwang, Chuan, Peters, & Kuys, 2013; P. G Lee et al., 2009; Lindeman, Li, & Palmer, 2012). The frequent or urgent visits to the toilet may be attributed to the side effects of pharmacotherapy (e.g., diuretics). HF patients often use diuretics in order to alleviate their HF symptoms such as pulmonary or peripheral edema (Yancy et al., 2017), which increases the volume of urine and sodium excretion. These HF treatments, however, often yield adverse events, such as hyponatremia, which is prevalent in 8% to 28% of HF patients (Albabtain et al., 2016). A recent growing body of literature has found that hyponatremia contributes to impaired cognitive function (attention) and muscle function, which in turn leads to falls (Albabtain et al., 2016; McGreal, Budhiraja, Jain, & Yu, 2016; Rittenhouse et al., 2015). These possible factors related to urinary incontinence suggests a need for further studies to address the mechanistic link between side effects of HF medications, urinary incontinence and falls, which may provide key evidence to develop fall prevention interventions specific to community-dwelling older adults with HF patients.

Specifically, for sensory function, this study examined visual and hearing functions. The results showed that the association between visual problems and falls was statistically significant (having 43% higher odds of falling). This finding aligns with that of a meta-analysis study that addressed the positive association between visual problems and falls among community-dwelling older adults (Deandrea et al., 2010). However, the present study found that the association between hearing problems and falls was statistically insignificant. This result differs from two other meta-analyses reporting a positive association between hearing problems and falls among community-dwelling older adults (Deandrea et al., 2010; Jiam, Li, & Agrawal, 2016). This inconsistent result may be attributed to the difficulty of distinguishing between hearing loss and other fundamental ear problems such as impairment of semicircular canals of the ear, which is related to vestibular dysfunction. Although the manifestation of vestibular dysfunction varies depending on its severity and its site, it often presents as hearing loss with vertigo and dizziness, which leads to instability of posture and poor gait (Lord et al., 2007). Further studies, including clinical data on vestibular function, are needed to examine which competing factors are significantly associated with falls in the community-dwelling older adults with HF.

In conclusion, this study found decreased physical, cognitive, sensory, and urinary functions were associated with falls and provides new evidence specific to HF patients, which aligns with previous systematic review and meta-analysis findings among community-dwelling older adults (Deandrea et al., 2010). These results also support the conceptual model addressing the independent effect of each functional impairment (physical, cognitive, sensory and urinary) on falls. These findings are not necessarily generalizable to other populations of institutionalized older adults because this sample represents community-dwelling older adults in the U.S. However, these results can be applied to what is already known about functional risk factors in older adults with HF for developing fall prevention interventions in the community settings. For example, evaluating functional status (e.g., activity of daily living skills, vision problem, and urinary incontinence) is important to assess risk of falls, and clinicians should provide routine fall risk assessment to this HF population when discharged from the hospital to home to prevent falls or when following-up during outpatient and/or primary care visits.

Based on the known fall prevention interventions that have been developed for community-dwelling older adults, findings from this study could guide developing and testing of fall prevention interventions for community-dwelling older adults with HF, specifically targeting those with specific functional impairments. American Geriatrics Society and British Geriatrics Society (Kenny et al., 2011) and the Cochrane systematic review (Gillespie et al., 2012) recommended evident-based fall prevention interventions for community-dwelling older adults. For those with physical impairment, exercise interventions for improving muscle strength, balance, gait and coordination (e.g., tai chi or physical therapy) is effective in preventing falls. However, caution needs to be taken when providing exercise training for those unable to perform physical activity, and customized exercise programs should be provided (e.g., individual vs. group, or single component vs. multi-component). For people with visual impairment, treatment and management of vision problems are recommended. Especially, for older adults with the indication of cataract surgery, expedited surgery is effective to prevent falls. For those with cognitive impairment, there is a lack of evidence or recommendation targeting cognitive impairment to prevent falls. In regards to urinary incontinence, screening and assessment of history of urinary incontinence is recommended but there is no specific intervention addressed in the review. This fall prevention interventions might be tailored to HF patients having the above functional impairments.

This study among community-dwelling older adults with HF showed that having functional impairment was associated with higher odds of falling compared to those without functional impairment. In particular, impaired physical function, cognitive function (IADL), and urinary function were associated with nearly 2-fold higher odds of falling, and poor vision/legally blind status was associated with approximately 40% higher odds of falling. These findings suggest that the fall prevention interventions for community-dwelling older adults may be compatible with those with HF and used for developing and testing fall prevention interventions.

Strengths and Limitations

To the best of my knowledge, this research is the first to examine the independent effect of HF on the likelihood of falling among community-dwelling older adults in the U.S using the HRS data. This study added new evidence to the previous cross-sectional study that described the prevalence of falls among U.S. community-dwelling older adults with HF (P.G. Lee et. al., 2009). The strength of using the HRS data is that the study sample, which is based on a multi-stage selection process for the sampling design, reflects the heterogeneous nature of community-dwelling older adults in the U.S. In the construction of the model to examine the independent effect of HF on the likelihood of falling, this study took multifaceted important risk factors for falls into consideration, which allowed the independent association of HF on falls to be isolated. This study also extensively explored known functional fall risk factors among community-dwelling older adults by first examining the independent effects of physical, cognitive, sensory, and urinary function on the likelihood of falling among HF patients after controlling for socio-demographic factors. These findings provide new empirical evidence that can inform the development of optimal fall prevention interventions targeting community-dwelling older adults with HF in the U.S. Another strength of this study is that it used longitudinal data from 1998 to 2014, which allow us to understand the relationship between HF and falls using repeated observations over study waves. To analyze the longitudinal data, the study used the mixed-effects logistic regression. This method is beneficial because it provides accurate estimation by taking into account repeated (correlated) observations within subjects over time (Fitzmaurice, Laird, & Ware, 2012).

Despite these strengths, several limitations must be noted. First, HF was ascertained through pre-existing self-reported data. Self-reported data tends to show higher specificity, but a lower level of reporting their HF condition when compared to the HF diagnosis code in the Medicare claims-linked file (Gure et al., 2012). Self-reported data can underestimate the true proportion of HF status in the general older population. In the current study, though, the obtained HF status is accurately aligned with the Medicare claims-linked file, according to a previous study (Gure et al., 2012). A second limitation is that fall data ascertainment relied on participants' 2-year interval recollection, which could be less reliable. One-year fall recollection might have been more accurate, as suggested by previous work that reported high specificity (91-95%) and acceptable sensitivity (77-89%) (Ganz et al., 2005; Sanders et al., 2015). Because older adults are likely to under-report their fall incidences, under-reporting may have influenced the outcomes of this study. Another limitation is that some potential risk factors, such as the presence of Parkinson's disease, fear of falling, or detailed information about medications (e.g.

types or dose), were not included in the analysis because they are not available in the HRS dataset. Some variables, such as objective physical measures (walking tests or balance tests) were only available for half of the sample and were inconsistent throughout the study period between 1998 and 2014, thus they were not included in the analysis. Other socio-economic status factors (e.g., education or financial status), time-related variables (e.g., the time of HF diagnosis), long-term care utilization, or mortality were not included as covariates. The fact that excluding these factors may lead to the possibility of unmeasured confounding effects. Therefore, future studies need to take these limitations into account when designing the study protocol.

Directions for Future Research

In light of the study's key findings and limitations, several areas have emerged for future research. First, this study found that having HF independently plays an important role in predicting falls among community-dwelling older adults. This study also found known risk factors (i.e., physical, cognitive, sensory, and urinary impairment) were strongly associated with falls among HF patients. Thus, a priority for future research is to develop and test fall prevention interventions specifically for community-dwelling older adults with HF. The fall prevention interventions should include (1) education about fall prevention in senior or community centers, (2) routine assessment of fall risk (e.g., functional impairment) when HF patients visit a primary or outpatient setting, (3) customized interventions guided by specific fall risk factors, and (4) special attention to this population when discharged from the hospital to home to prevent falls.

Second, this study found that across most functional sub-groups, the effect of HF is quite similar. In terms of the differential effect of HF on those with and without functional impairment, there was no difference across functional sub-groups with the exception of cognitive impairment (TICS/ICQCODE). These results suggest that other indirect effects may be at play among HF patients with cognitive impairment. Because determining the causal mechanism addressing mediating effects of functional impairments on falls was beyond the scope of this study, future study would be to elucidate the mechanism underlying a pre-established causal pathway among HF (Pathology), damages in cerebellum of the brain (Impairment), poor gait and balance (Functional Limitation), ADL difficulty (Disability), and falls based on the DPM model.

Third, although this study focused on exploring functional impairment for falls among HF patients, other risk factors, such as psychological, behavioral, social and environmental factors, still need to be examined in HF patients. For example, the indirect effect of behavioral (e.g., self-care management skills including medications or life-style changes etc.) and environmental factors (e.g., limited social participation due to HF symptoms or societal impediment – social stigma on HF patients or unsafe built environment for physical activity etc.), and/or person-environment interactions have not been fully tested on the likelihood of falls, although this study included some of these aspects as covariates in the model to test the effect of HF and falls. In particular, to study the person-environmental interaction is important because it allows us to identify specific situational factors related to falls. Thus, future studies are recommended to yield empirical evidence to build fall prevention interventions in collaboration with HF patients, health providers, and community.

Fourth, in this study, a long-term HF trajectory were not included because this study focused on identifying the independent effect of having HF on falls over 2 years in order to ensure an adequate HF sample size to adjust for multiple covariates. To make the longitudinal analysis more dynamic, future research for the longitudinal analysis needs to consider how the HF trajectory influences the likelihood of falling over a long period time by including other competing variables such as HF patients' mortality, admission to the long-term care, the time of the HF diagnosis, or severity of HF.

Implications for Nursing Practice

This study also has clinically important implications. Having HF is significantly associated with a higher likelihood of falling among community-dwelling older adults. HF patients should receive fall prevention interventions and be educated regarding their fall risk. In particular, clinicians should pay attention to the population with both HF and cognitive impairment to prevent falls, because these patients have shown worse health outcomes, such as mortality and readmission (Dodson, Truong, Towle, Kerins, & Chaudhry, 2013), implying that their health conditions are more complex and need more sophisticated nursing interventions (e.g., frequent monitoring) dealing with their functional status and risk of falls.

Older adults with HF have unique symptom profiles (e.g., exercise intolerance) and receive complex treatments for managing other comorbid conditions. They may receive fall risk information from their healthcare providers; however, receiving more information may not always be helpful to prevent falls. Ineffective fall education, when added to their HF management, could cause older adults to feel overwhelmed. Thus, simple but effective fall prevention interventions for this population are needed. Patients and healthcare providers may consider that HF-related symptoms and mortality are more serious problems than fall-related injuries and its mortality, which may explain why discussing fall risks in the HF population is often ignored in the community settings. Although there are many general fall prevention strategies for older adults, individualized fall interventions can be more effective to prevent falls specifically in community-dwelling older adults with HF patients. For example, for HF patients who have poor gait and balance with dyspnea, customized fall prevention interventions could include single or multiple components of exercise to improve muscle strength, balance, gait and coordination in order to minimize the risk of falling while performing physical activity. To develop simple but effective fall prevention interventions for this population, more attention is needed in the outpatient, primary, or home care setting or when discharging from hospital to home to discuss HF patients’ fall experiences or concerns (e.g., when, where, accompanied symptoms or situations) and their needs for support from caregivers, health providers, and the social community.

APPENDIX

A Letter of The Institutional Board Review (IRB)

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Health Sciences and Behavioral Sciences Institutional Review Board (IRB-HSBS) • 2800 Plymouth Rd., Building 520, Room 1170, Ann Arbor, MI 48109-2800 • phone (734) 936-0933 • fax (734) 998-9171 • irbhsbs@umich.edu

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To: Kayoung Lee

From:
Thad Polk

Cc:
Kayoung Lee
Matthew Davis

Subject: Notice of Determination of "Not Regulated" Status for [HUM00126099]

SUBMISSION INFORMATION:
Title: Falls in Community-Dwelling Older Adults with Heart Failure
Full Study Title (if applicable):
Study eResearch ID: HUM00126099
Date of this Notification from IRB: 1/26/2017
Date of IRB Not Regulated Determination: 1/26/2017

IRB NOT REGULATED STATUS:

Category	Outcome Letter Text
Research Using Publicly Available Data Sets	Based on the information provided, the proposed study falls under the University of Michigan's policy for research using publicly available data sets (http://hrpp.umich.edu/initiative/datasets.html). Under this policy and in accordance with federal regulations for human subjects research (45 CFR Part 46) IRB approval is not required as the data cannot be tracked to a human subject.

Thad A. Polk

Thad Polk
Chair, IRB HSBS

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