The Association of Significant Depressive Symptoms on the Risk of Falls: A Prospective Cohort Study from the Health and Retirement Study

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ABSTRACT

Falls are one of the leading causes of injury-related morbidity and mortality among the older adult population. Medical costs attributable to falls is projected to increase as the population grows over the next decades. Depression is one of the most common neurological disorders experienced among older adults. Utilizing data from the Health and Retirement Study, this study investigated the association between significant depressive symptoms (SDS) on the risk of falls among individuals aged 65 and up. After adjusting for potential confounders, individuals with SDS had a 25% increased risk for incident falls when compared to individuals without SDS (risk ratio [RR] 1.25, 95% confidence interval [CI] 1.22, 1.27). Both sex and BMI were found to be effect modifiers in the association of SDS on fall risk. This study suggests that depressive symptoms is a risk factor for falls, consistent with previous literature.

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CHAPTER 1. INTRODUCTION

1.1 Falls in Older Adult Populations

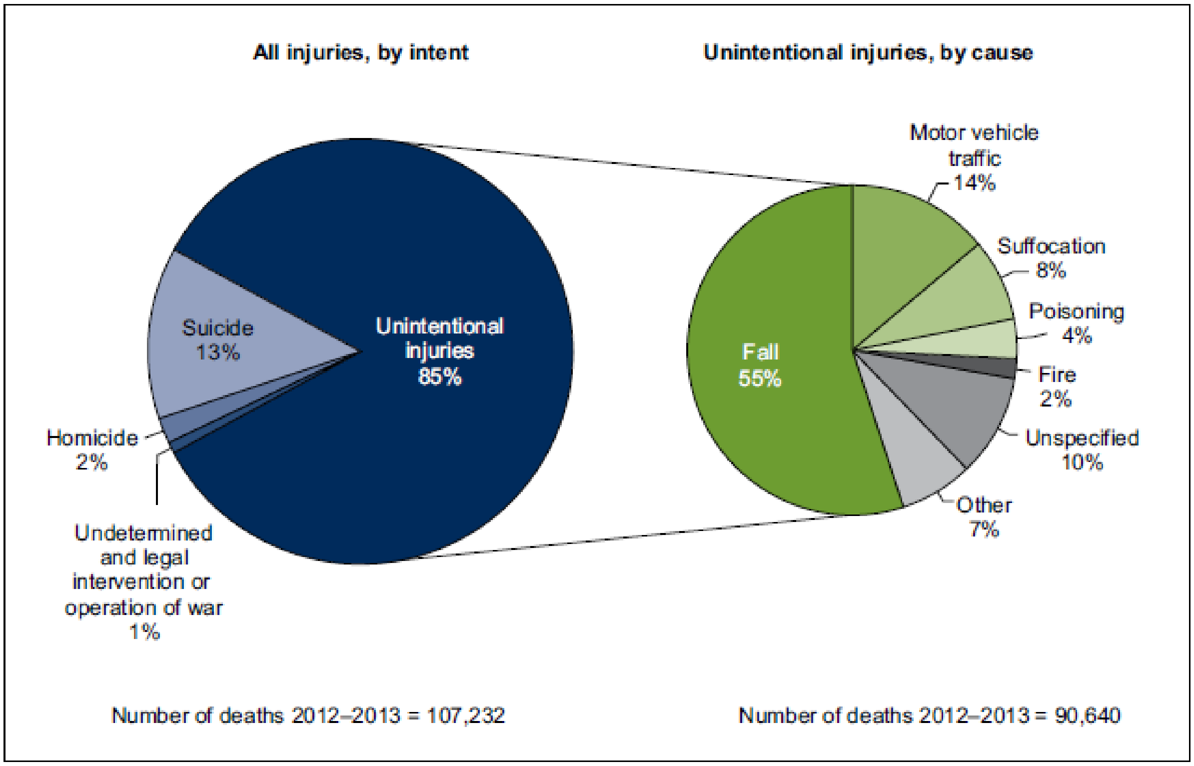
One of the leading causes of injury-related morbidity and mortality among older adults (aged 65 years and older) is falls. A fall is defined as "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects" from the World Health Organization (WHO) report on falls prevention.[1] Falls have substantial economic and financial burdens in the United States (U.S.). Every year, 1 out of 3 older adults fall, resulting in over 3 million emergency department (ED) visits and 800,000 hospitalizations.[2] According to federal data from 2015, direct medical care costs, including Medicare and Medicaid, related to non-fatal and fatal falls were estimated to be upwards of $31.3 billion.[3] Some factors contributing to costs for non-fatal falls include transportation to a medical facility, ED visits, hospitalization, office and outpatient visits, rehabilitation, and nursing home.[3] Costs for fatal falls are very similar, with additional factors such as hospice care and the cost for a coroner or medical examiner.[3] Although several studies have observed the cost of falls, results varied due to different time periods that the data was analyzed and the inclusion of treatment settings (e.g. inpatient vs. outpatient).[3]

The steady rise of non-fatal and fatal falls over the last few decades can be attributable to the increasing number of older adults as well as increased awareness plus surveillance of incident falls and fall-related injuries across all age groups. The older adult population is estimated to grow from 617 million in 2014 to over two billion by 2050 globally, and from 46.3 million in 2014 to over 98 million by 2060 in the U.S.[4] Goals for falls prevention were not implemented until about two decades ago – reducing fall fatality and hip fractures among the elderly was added as part of the U.S. Department of Health and Human Services' *Healthy People 2010* objectives.[5] Additionally, an objective to expand surveillance systems across the nation was included. The *Healthy People 2020* continue to focus on falls prevention through objective IVP-23: "Prevent an increase in fall-related deaths among all persons" and "[…] adults aged 65 and older."[6] National efforts have further focused on improving the quality of life and health of elderly, adding the "Older Adults" section.[7]

As a part of surveillance efforts, data collection for falls and related injuries were implemented in the International Classification of Diseases (ICD). The ICD is a system for physicians and healthcare providers to classify and code all disease diagnoses and symptoms.

Specific codes are entered through claims and a registry system via the Physician Quality Reporting System, or PQRS. In the ICD-9, a category for accidental falls was available, however it did not include a code for repeated falls, which is a known risk factor for subsequent falls.[4] It was not until the most recent revision, or the ICD-10-CM that was implemented on October 2015, where “repeated falls” was added as a diagnostic code.[4] Furthermore, there are predisposing factors that lead to falls and related injuries. However, identifying and determining these factors have been challenging. One example noted in the report by the Injury Surveillance Workgroup was a person with osteoporosis who experiences a hip fracture – “[…] the order of precipitating events may be that bone fractured under some change intension or position leading to the fall rather than the reverse.”[4] Such complex mechanism make it difficult for physicians and healthcare providers to code sufficient and adequate information.

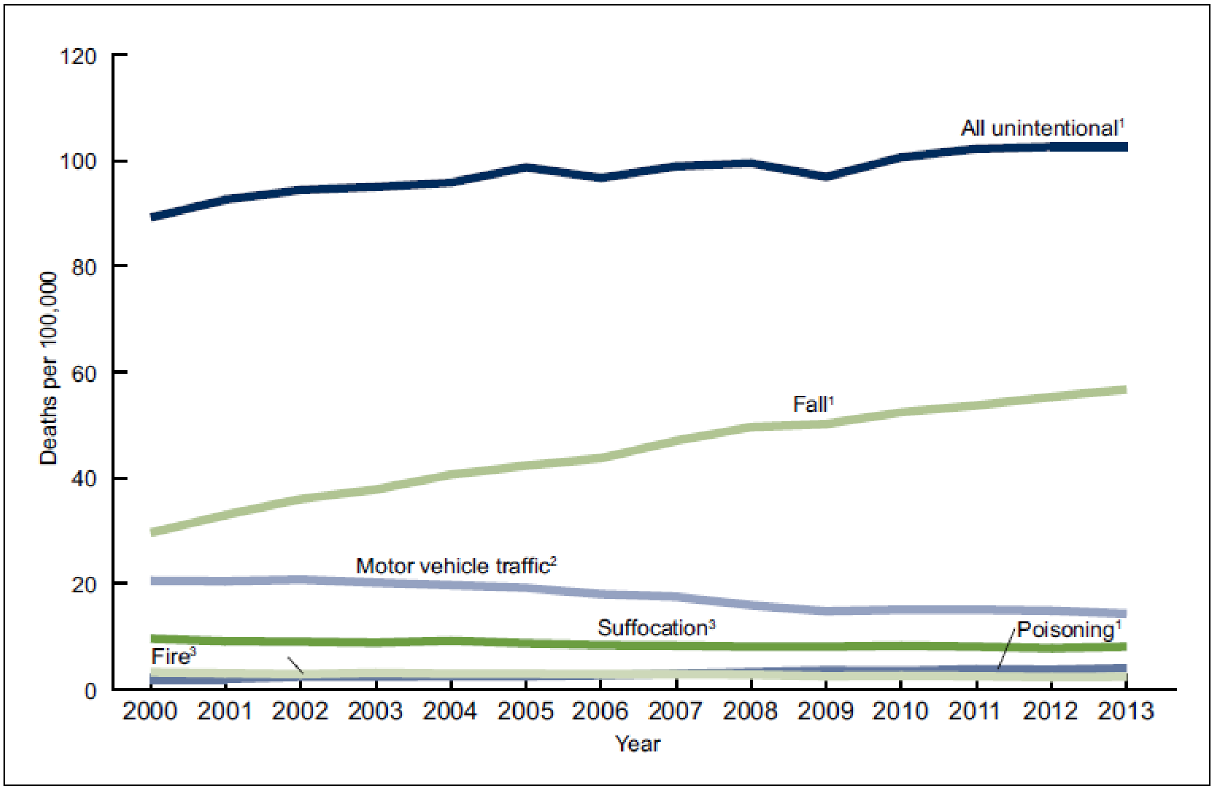
Unintentional injuries were the seventh leading cause of death among U.S. adults aged 65 and over in 2016.[8-9] Among all deaths due to unintentional injuries, such as motor vehicle traffic injury or suffocation, falls accounted for 55% among older adults in 2012 to 2013 (Figure 1.1).[9] While death rates may differ according to year, it is inevitable that the proportion of falls cases will increase with the growing number of older adults. While all age groups are susceptible to falling, older adults have experienced the highest increase in death rate: between 2000 to 2013 the death rate doubled from 29.6 per 100,000 to 56.7 per 100,000 persons (Figure 1.2).[9] With such evidence, costs related to falls have been increasing, and it is important to focus on methods to prevent injuries and fatalities due to falls as the older adult population grows in the U.S.



NOTE: Percents may not total 100% due to rounding.

Source: CDC/NCHS, National Vital Statistics System, Mortality
Kramarow E, Chen LH, Hedegaard H, Warner M.[9]

Figure 1.1: Percent distribution of deaths from all and unintentional injuries among adults aged 65 and over in the United States in 2012-2013



[1]Significant positive linear trend ($p < 0.05$).
[2]Significant negative linear trend from 2000 to 2009 ($p < 0.05$).
[3]Significant negative linear trend ($p < 0.05$).

Source: CDC/NCHS, National Vital Statistics System, Mortality
Kramarow E, Chen LH, Hedegaard H, Warner M.[9]

Figure 1.2: Comparison of age-adjusted death rates by cause of death among adults aged 65 and over in the United States in 2000-2013

1.2 Depressive Symptomatology as a Risk Factor for Falls

Several risk factors are associated with falls including biological (age, sex, cognitive impairment, mobility and gait reduction), environmental (uneven and slippery floors, lighting, time of day, location), socioeconomic (marital status, education, insurance type), and behavioral factors (alcohol and drug use, fear of falls, depression).[1,10-13] Depression is one of the most common neurological disorders experienced among the older adult population, with a global prevalence of 10.3%.[13] The first 3 waves of the Health and Retirement Study (HRS) showed similar prevalence rates of depressive symptoms based on an 8-Item Center for Epidemiologic Studies Depression scale (CESD 8) score of at least 4.[14] Symptoms of depression can have detrimental effects on many aspects of life.

While depressive symptoms often involve somatic symptoms, it does not necessarily indicate having clinical depression. Nonetheless, a number of studies have shown that questionnaires screening for depressive symptoms can be a valid tool to detect clinical depression.[15-16] Depressive symptoms include, but are not limited to: fatigue, little to no interest in hobbies or relationships, difficulty concentrating, sleep disturbances, significant weight changes or change in appetite, memory problems, neglect in personal care, feeling hopeless or helpless, and unexplained aches and pains.[17] Such symptoms can contribute to lower adherence to medications, decreased physical activity, and impaired motor function, which can lead to increased risk for falls.[17-18] In a prospective cohort study conducted by Kvelde et al.[18], results showed that older adults with depressive symptoms had a 1.5 times higher risk for falls than those without depressive symptoms (risk ratio [RR] 1.50; 95% confidence interval [CI] 1.06, 2.11).

Previous studies have also shown that depression may be a confounder between chronic disease conditions and falls (i.e., depression may exacerbate chronic disease symptoms and increase the risk for falls).[19-20] For example, Karakus and Patton[19] found that older adults with depression reported chronic disease conditions more often than those without depression. Specifically, depressed individuals were "1.50 times more likely to report arthritis, 1.69 times more likely to report heart problems, and 1.50 times more likely to report diabetes".[19] Similarly, individuals with both osteoarthritis and debilitating psychological symptoms are less likely to be physically active and experience increased pain levels than those without psychological distress.[20]

There are significant differences in depression scores across various demographic factors. The burden of depression disproportionately affects more women than men and more older adults than younger adults, especially in terms of levels of depressive symptoms.[13, 21-22] These results may be explained by socioeconomic and psychological factors. For example, older adults have a higher prevalence of multiple chronic conditions than younger adults due to increased physical inactivity and other mobility-limiting factors. Additionally, women are more likely than men to experience income inequality, have higher rates of violence and harassment, have more sleep problems, and express sadness with more intensity.[21,23] Other studies have also shown that depression is more frequent among individuals with low to medium socioeconomic status (SES), multiple chronic diseases, and higher disability.[24]

1.3 Pathways of Depressive Symptomatology and Falls

Several studies have observed significant associations between depressive symptoms and falls, yet the directionality of the causal association has been inconsistent.[25-27] There are three different ways in which these variables are related: 1) depressive symptoms and depression increase the risk for falls, 2) falls increase incidence of depressive symptoms, and 3) both depressive symptoms and falls occur jointly as a result of other factors.

In support of the first pathway, studies have shown that greater depressive symptoms are associated with increased falls risk.[25-26] Factors resulting from depressive symptoms and depression, such as fatigue, distractedness, and poor nutritional status, can be debilitating to individuals' lives and lead to falls.[25-26] Furthermore, depression is associated with cognitive impairment especially in terms of attention and executive functioning. Decreased executive functioning could impact an individual's ability to multitask, process information, and perform activities of daily living (e.g., walking and talking at the same time).[26] A study by Hausdorff, Rios, and Eelberg[28] found that older adults who have depressive symptoms generally walk slowly with shorter stride length, have longer standing phases, and have increased gait variability, all of which are associated with falling.

The second pathway focuses on the event of falls and how it triggers depressive symptoms. Studies have observed this association among various populations, especially in terms of injuries caused by falls, fear of falling, anxiety, and frailty.[27,29-30] Disabling medical events, such as hip fractures, are prevalent in more than six million older adults in the U.S., and have been associated with developing major depressive disorder.[30] Some injuries sustained through falls could lead to physical disability and immobility, which may be a drastic lifestyle change for some individuals. In severe cases, hospitalization and surgery may occur, causing elevated anxiety and apathy which are both indicators for a major depressive episode. Moreover, common factors that occur after disabling medical events are lower levels of social support, increased cognitive impairment, and delirium.[30] A prospective cohort study performed at the University of Pittsburgh Medical Center found that the onset of major depressive disorder was most common immediately after having a hip fracture.[30]

The prevalence for the fear of falling among community-dwelling older adults has been reported as anywhere between 40% to 60%.[27,29-31] Having a history of falls may lead to fear of subsequent falls, which may cause significant anxiety. In some cases, these anxieties progress into agoraphobia, a type of disorder that causes fear of environments where escape can be difficult.[27] Such somatic symptoms and emotional distress lowers self-efficacy, which leads to physical inactivity and social isolation, both of which are known risk factors for depression among older adults.[27] In a cohort study of community-dwelling older adults, depressive symptoms were more prevalent among individuals who had high perceived fall risk but low physiologic fall risk compared with those whose perceived risk was congruent with physiologic risk.[18] The predictors for the fear of falling has been associated with female gender (adjusted hazard ratio [AHR] 1.55; 95% CI 1.08, 2.23), depressive symptoms (AHR 1.16; 95% CI 1.07, 1.26), falls (AHR 1.50, 95% CI 1.01, 2.21), and clinical gait abnormality (AHR 2.07, 95% CI 1.42, 3.01).[29]

Lastly, a shared number of risk factors have been associated with both depressive symptoms and falls. Unlike the other two pathway explanations, this pathway promotes the theory that both variables are an outcome of a set of common risk factors, which include poor self-rated health, poor cognitive status, impaired activities of daily living, decreased walking speed, and existing chronic medical conditions.[26,31] A significant proportion of individuals with these five common risk factors were found to have a higher incidence of depressive symptoms and falls.

Although all three pathways have been examined in various study designs and populations, there is strong evidence supporting the association of depressive symptoms and incidence of subsequent falls and chronic disease conditions. Hoffman et al.[26] specifically studied the directionality of these variables and concluded that falls were not associated with subsequent depressive symptoms, but depressive symptoms were positively associated with falls. Given these findings, this study will further investigate the temporal relationship of depressive symptomatology and the risk of falls.

1.4 Other Risk Factors for Falls

As mentioned, the event of falling poses a significant economic, financial, and social burden on all ages, but it is especially true among older adult populations. It has been shown that as people age, the proportion of fallers and fall-related injuries increase.[5,10,12,32] This trend was analogous with both males and females: "fallers generally increased with each decade of age range after the 25 to 34 year age-group".[12] However, within each age group, excluding the oldest (aged 75 years and up), females had a higher incidence rate of falls than males.[12] In an international population-based cross-sectional study, females had a 30% higher odd of past-year fall-related injury compared to males (odds ratio [OR] 1.27; 95% CI 0.99, 1.62).[10]

The evidence that females are more likely than males to be obese has been explained as a biological plausibility for the association of age, sex, incidence of falls, and fall injuries.[32-34] Especially in regard to mid-life changes (i.e., giving birth and menopause), there is an increase in fat mass, which is predictive of poor physical functioning and disability.[32] Additionally, changes in reproductive hormones have been associated with changes in body composition and body fat distribution during the menopausal transition.[32-34]

Racial and ethnic differences may further explain the diverse distribution of falls risk among older adult populations. Two U.S. cross-sectional studies compared the proportion of falls among Whites, Hispanics, African Americans, and Asian Americans. The studies found that Asian Americans were the least likely to have falls (OR 0.62; 95% CI 0.43, 0.88) while Whites were the most likely.[35-36] With further stratification by sex and age groups (i.e., older women), the risk of falling was substantially lower for African Americans and Asian Americans when compared to Whites.[35] It is possible that these prevalence proportions were biased due to reporting bias (i.e., underreporting falls incidence) and selection bias (i.e., low response rates and limited to English-speaking participants). Despite these limitations, there are potential cultural differences across racial and ethnic groups, which may help to explain these varied rates of falls.

Socioeconomic factors such as low income and education are also predictors for falls.[1,24] A study found that lower economic status and housing quality was associated with increased risk of accidental falls, independent of demographic variables such as age, sex, and BMI.[24] Lower housing quality entails houses that are not in compliance with current building regulations, especially in regards to accessibility for elderly or individuals with physical disabilities (i.e., ramps, handrails, and grab bars). These environmental characteristics have been linked with increased risk for falls. Lower SES was additionally associated with factors of social isolation. Many elderly individuals live alone and require physical assistance for activities of daily living due to their disabilities or illnesses. Thus, the lack of social support could pose a greater risk of falls.[24] Similarly, lower education level (comparing less than high school to four-year college degree or higher) was associated with increased risk as well (HR 1.96; 95% CI, 1.60, 2.41).[24] In general, lower education levels are indicative of greater health disparities, however, very few studies have observed the association between education and falls risk.[1]

Although smoking does not directly cause falling, it has been linked to frailty and respiratory diseases such as chronic obstructive pulmonary disease, lung cancer, stroke, and coronary heart disease.[37-38] In a systematic review, five studies yielded consistent results where "baseline smoking was significantly associated with developing or worsening frailty status at follow-up […] and reduced muscle mass."[37] Elderly with increased frailty are susceptible to higher risk of cognitive impairment, falls, and fractures.

Veteran status may also be predictive of falls. According to the Department of Veterans Affairs, veteran patients are generally older in age than the civilian sector.[39] Given this profile, the veteran inpatient population are at high risk for anticipated physiological falls. There are not very many studies that have explored the differences in falls risk between veterans and civilians. Nevertheless, it is evident that veterans are exposed to extreme environmental hazards throughout their occupation (i.e., war combat). These exposures may lead to greater risk of developing physical disabilities, neurological disorders (post-traumatic stress disorder), and/or chronic health diseases (cardiovascular disease and diabetes).[39-40]

Cognitive impairment and functional disability have often been cited as being associated with falls risk. A 12-month longitudinal study of 42 older adults found that individuals with mild cognitive impairment (MCI) displayed "lower gray matter density in the bilateral middle frontal gyrus and superior frontal gyrus" compared to individuals without MCI.[41] These areas of the brain are thought to be responsible for executive functioning, such as the ability to make decisions from complex situations and working memory (i.e., storing information while simultaneously processing new information). After adjusting for age, sex, body mass index (BMI), and a history of falling at baseline, MCI individuals were found to have poor balance and a greater falls risk than non-MCI individuals.[41] Another study has yielded similar results: poor cognitive impairment, limitations in activities of daily living (ADL), instrumental activities of daily living (IADL), and physical limitations such as poor balance, have been associated with increased risk for depression and falls.[31] ADL and IADL are typically used to measure an individual's ability to complete everyday tasks as well as to determine the level of assistance an individual requires to maintain independence. Difficulty achieving basic tasks such as eating, walking, and taking medication may not only hinder an individual's independence, but it may pose a risk to their own physical safety.

Longer life expectancy among older adults have been a key factor for the growing prevalence of many chronic diseases, and chronic diseases have been associated with increased fall risk. Some diseases include hypertension, diabetes, heart disease, stroke, and arthritis. With recent revisions to the blood pressure level guidelines published by the American Heart Association, the prevalence of hypertension is predicted to increase to almost half of the U.S. adult population.[42] To control hypertension and treat heart failure, beta-blockers are often prescribed. Although beta-blockers help to reduce the risk for heart disease and stroke, it may lower blood glucose levels and lead to hypoglycemia. There are similar consequences for treatments used for diabetes: too much insulin intake and low blood sugar can cause rapid heartbeat, fatigue, seizure, and coma.[43] On the other hand, it is common for individuals with diabetes to develop peripheral neuropathy, where high blood glucose damages the nerves in different part of the body causing numbness and muscle weakness. Such symptoms may lead to a loss of motor control, balance, and coordination, increasing falls risk.[43] Arthritis is also a predictor of falls, consisting of symptoms such as joint pain, swelling, and reduced mobility. It is associated with a 2.4 times increase in fall risk. Low blood pressure, or hypotension, is prevalent among older adults, accounting for 20% of all falls.[44]

Comorbid chronic disease conditions are common among older adults – about 60% of U.S. older adults have two or more chronic disease conditions.[7] Having these comorbidities are associated with taking multiple prescription medications, which could influence the risk of falling in a few ways. For example, psychotropic medications (e.g., antipsychotics and antidepressants), often prescribed for depression, have possible side effects of impairment in coordination and weight changes. Individuals taking these drugs were found to have a two-fold increased risk for falls and fractures when compared to individuals who do not take the drugs.[44] Other drugs, such as antihypertension medication, may increase postural hypotension and cause dizziness.[44] Several studies often group different chronic disease conditions together for data analysis despite the unique characteristics of each disease. However, the purpose of this grouping is not to compare chronic diseases, rather, it is justifying how having comorbid chronic disease conditions is indicative of how many medications an individual is taking.

1.5 Study Aim and Hypothesis

The objective of this study is to estimate the association of significant depressive symptoms (SDS) on the risk of subsequent falls. By learning this association, this study anticipates to gain knowledge on whether a mental health condition can influence long-term physical and possibly biological changes in the body. Such observation may also provide evidence to recommend implementing appropriate behavioral and mental health assessments during routine medical examinations. This study aligns with current national milestones, which are to improve the mental well-being of individuals by expanding primary care physician roles. Furthermore, this topic would especially be an important focus area as falls is among one of the most prevalent and costly condition occurring in the older adult population. In sum, it is hypothesized that individuals with SDS, defined as having a CESD 8 score of 3 or more at baseline, will have an increased risk for subsequent falls when compared to individuals who do not have SDS. A causal diagram showing the mechanism of the exposure, outcome, and potential confounding variables are illustrated in Figure 1.3.

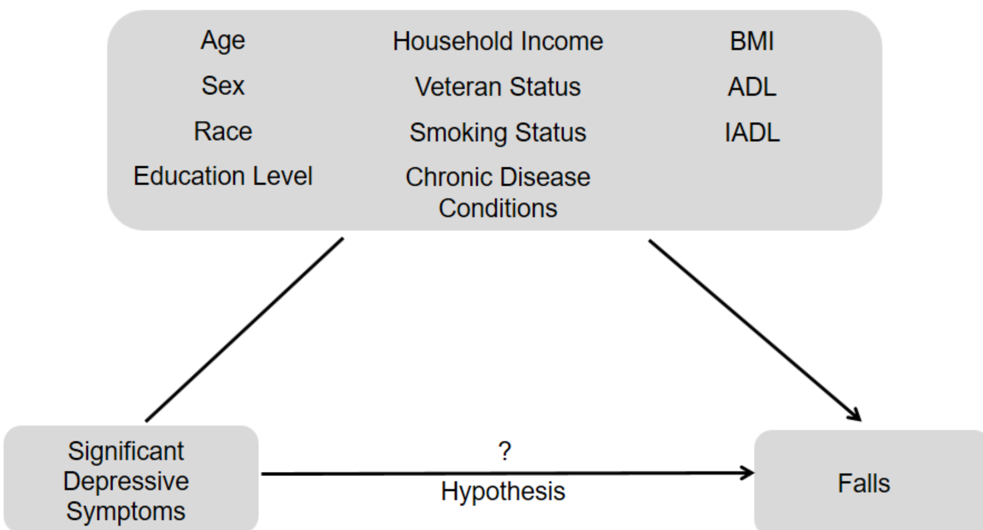


Figure 1.3: Causal diagram of the association of significant depressive symptoms on risk of falls with potential confounders

It is also anticipated that the effect of depressive symptoms on falls risk will be different by sex and BMI. Thus, it is hypothesized that the association of SDS and falls risk will be higher for females than males, and it will be higher for participants with obese and overweight BMI than participants with normal and underweight BMI. Lastly, it is hypothesized that cognitive impairment will be an intermediate between depressive symptoms and falls risk, serving as a mediator; depressive symptoms would increase the risk of cognitive impairment (indicated by cognitive function scores lower than normal [high] or scores less than 25), which would then increase the risk of falls. Thus, individuals with SDS would have lower cognitive functioning scores and be at higher risk for falls than individuals without SDS.

CHAPTER 2. METHODS

2.1 Source Data Overview

This study used public domain data from the HRS, which is managed by the University of Michigan and funded by the National Institute of Aging (NIA U01AG009740) and the Social Security Administration. The HRS is a longitudinal cohort study that conducts biennial surveys to individuals over 50 years old in the U.S. since 1992 on various topics such as income and wealth, work and retirement, use of healthcare services, health and cognition, and family structure. Data collection was performed in a multi-modal approach – interviews were done via face-to-face, telephone, and internet. Age-eligible respondents and their spouses of any age were interviewed. Baseline data for new cohorts interviewed for the first time and participants aged 80 and over were assigned an in-person interview at the participant's homes. The remaining participants were randomly assigned to face-to-face or telephone interviews.

Additionally, the HRS used a mixed-mode design with alternating interview content. Beginning in 2006, one-half of the core sample, after random sampling, was assigned an enhanced in-person interview at follow-up that included contents such as physical (e.g., blood pressure, measured height and weight, timed walking), biological, and biomarker measures. This process alternated with each half sample; the enhanced interviews were conducted every four years. There were other supplemental studies on a variety of other topics during the alternating years, or off years, for half of the samples (25% of the core sample).

Data regarding African-American and Hispanic households were oversampled at about twice the rate of Whites to account for unequal probability sampling. In efforts to increase screening and recruitment, the minority sample was further increased among the Baby Boom cohorts in 2010.[45-46]

The HRS recruited new cohorts every six years to maintain representation of the older adult population in the U.S. The study population consisted of six birth cohorts who were recruited at different years (Table A), who were defined as: 1) Asset and Health Dynamics Among the Oldest Old (AHEAD) born in 1890-1923, 2) Children of the Depression (CODA) born in 1924-1930, 3) Health Retirement Study (HRS) born 1931-1941, 4) War Babies (WB) born 1942-1947, 5) Early Baby Boomers (EBB) born 1948-1953, and 6) Mid Baby Boomers (MBB) born 1954-1959.[45]

Follow-up interviews and data were collected every other year. Data collection was generally done by phone unless the participant was over the age of 80, who had in-person interviews. Data regarding variables for this study were collected during the initial interview as well as all subsequent follow-up visits. During the event of a participant's death, HRS attempted to conduct an exit interview with a proxy (i.e., surviving spouse, child, or other informant).[45]

Additional information regarding the HRS survey design and methods may be accessed in another article.[47]

2.2 Study Population Overview (Inclusion and Exclusion Criteria)

This study utilized the HRS to conduct a secondary data analysis. All birth cohorts (HRS, AHEAD, CODA, WB, EBB, and MBB) from the HRS were included for data analysis. For baseline data of depressive symptoms and covariates, each birth cohort have different baseline wave years due to different time points in which they were recruited (Appendix A). The HRS and AHEAD baseline data corresponds to wave years 1998 and 2000. Although there were data previous to year 1998, data for the depression symptoms were not collected in 1992 to 1994, and questions regarding falls were either inconsistent or unavailable in 1996. For CODA and WB, the same baseline year was used (1998 and 2000). EBB used 2004 as baseline data, and finally, MBB used 2010. With these baseline measures, the incidence of falls was observed for all subsequent years up to 2014. Again, because birth cohorts were recruited at different timepoints, the number of subsequent years measuring incidence of falls differ slightly. For example, EBB have four subsequent years of follow-up (2008, 2010, 2012, and 2014) as opposed to MBB who have one year of follow-up (2014). This example is assuming that the participant was not lost to follow-up.

Response rates for each birth cohort differ slightly as well. Generally, with each new birth cohort, response rates declined by a few percentages, however, it remained over 70% overall. Follow-up response rates were even better, remaining over 75%.[45]

The inclusion criteria for this study were: aged 65 years and older; responses were available for both depression status and falls; responses were available for potential confounders including age, sex, race, household income, education levels, veteran status, BMI, smoking status, ADLs, IADLs, and chronic disease conditions.

The exclusion criteria for this study were: aged 64 years and younger, lack of follow-up visits (follow-up time equals zero), missing data for depression status and/or falls and prevalent cases of falls at baseline.

2.3 Falls (Outcome Variable)

Data for the outcome variable, falls, were pulled from the core FAT HRS files from each given wave year. Due to the mixed-mode design of the HRS, as mentioned in Section 2.1, falls data were collected every four years rather than every two years. Only participants who were at least 65 years of age were asked questions pertaining to falls. Three questions were asked during interviews: 1) "Have you fallen in the past two years?" or "Since the last interview period, did you fall?" 2) "[With regard to the previous question] In that all, did you injure yourself seriously?" and 3) "How many times have you fallen in the last two years?" or "Since the last interview period, how many times have you fallen?" These questions did not collect information on the severity of the fall-related injury.

By definition, experiencing falls was indicated by a response of "Yes" to the first question "Have you fallen in the past two years?" or "Since the last interview period, did you fall?" Other possible responses for the question were: "No" and "Don't Know." Participants had the option to refuse to answer (coded as "Refused"). Responses "Don't Know" and "Refused" were excluded from data analysis. Finally, the outcome variable was dichotomized to include incident falls ("Yes") and no incident falls ("No"). Because this study was only interested in understanding whether depressive symptoms have any effect on the risk of falls, the second (fall-related injury) and third question (number of falls) responses were not further categorized or analyzed.

Fall risk was determined by incidence of falls during follow-up visits in subsequent years after baseline data. For example, fall risk was measured at years 2008 and 2012 for a participant from the EBB birth cohort with baseline data from 2004.

2.4 Depression Status (Exposure Variable)

Data for the exposure variable, depression status, were pulled from the RAND HRS files from each given wave year. Participants were asked a total of eight questions regarding their feelings and behaviors ("Much of the time during the past week, would you say you felt depressed, felt that everything you did was an effort, your sleep was restless, you were happy, you felt lonely, you enjoyed life, you felt sad, and you could ‘not get going’?”) (Appendix B).

The HRS used the CESD 8, which is a subset and shortened version of the 20-Item scale (CESD). This scale is used in epidemiologic studies to measure and assess the level of depression symptoms in various populations, including older adults. Questions from the CESD 8 collected information on six negative and two positive moods (Appendix B).

Several studies have confirmed that the CESD 8 is a valid and reliable instrument to screen for clinical depression among older adults of different ethnicities. In a large cross-national European cohort study, the internal consistency and reliability of the scale (Cronbach’s alpha) was 0.84. Other studies have shown similar findings with older Hispanics. Furthermore, the depression scale was invariant across genders (older men and women). In other words, males and females scored systematically lower or higher on the CESD 8 items irrespective of the time at which they were observed.[15]

Each score recorded on the CESD 8 indicated the counts or number of depressive symptoms an individual experienced, and the summative index ranged from 0 to 8. To indicate SDS, a cutoff score of greater than or equal to 3 was used, while a score of less than 3 indicated non-SDS. Validation of the cutoff score has been explained in previous studies.[14-15] A depression index comparison study by Turvey et al.[16] confirmed a cutoff score of 3 or more on the CESD 8 showed a sensitivity of 71% and a specificity of 79% for the AHEAD Wave 2 data when compared to the Composite International Diagnostic Interview – Short Form (CIDI-SF). This implies that 71% of individuals who were classified as “depressed” on the CESD 8 were consistent with the “depressed” classification on the CIDI-SF. Conversely, 79% of the individuals who were classified as “not depressed” on the CESD 8 were consistent with the “not depressed” on the CIDI-SF. In general, the CESD 8 has a high sensitivity but lower specificity for the validation of clinically diagnosed depression.

For this study, the exposure variable focused on the relationship of depressive symptoms on the risk of falls, rather than clinical diagnosis of depression and falls risk. The exposure was defined as having a CESD 8 score of 3 or more at baseline, which was termed “significant depressive symptoms,” or “SDS.” For example, a participant from the CODA birth cohort who had a CESD 8 score of more than 3 in 1998 would be identified as having SDS.

2.5 Covariates, Confounders, Effect Modifiers, and Mediators

Potential confounders for the association of depressive symptoms and falls included age, sex, race, education level, household income, veteran status, smoking status, BMI, chronic disease conditions, ADLs, and IADLs. Justification for including these confounders have been explained in Section 1.4 from previous literature. All variables from wave years of interest were extracted from the core FAT HRS files.

Age and household income remained in their original forms and were treated as continuous variables for all analyses.

Sex remained as is from the core FAT HRS files (female and male). In addition to being a potential confounder, this study anticipated that sex would be an effect modifier as well.

Race was divided into three categories: White/Caucasian, Black/African American, and other. Black/African American and minority groups were oversampled in the original HRS recruitment, and a study has shown that the minority response rates are comparable with that of Whites and others.[40] This study did not further classify the "Other" group as each sample size would be relatively small and may not give a reliable estimate of the exposure-outcome association.

Education levels were divided into four categories: less than high school, General Education Development (GED) and high school graduate, some college, and college and above. Categorization was determined by applying what had been used in previous literature observing similar associations with comparable populations. GED was combined with high school graduates as the credentials for a high school diploma were equivalent.

Veteran status was defined as "Having ever served in the military" and remained as is from the original data file (veteran or non-veteran).

BMI was divided into four categories: underweight (less than 18.5 kg/m^2), normal (18.5 to 24.5 kg/m^2), overweight (24.6 to 30 kg/m^2), and obese (over 30 kg/m^2). Categories were based on the WHO's international classification of adult BMI and the Center for Disease Control and Prevention (CDC) BMI guidelines.[48] Similar to sex, BMI was considered as both a potential confounder and effect modifier.

There were two main measures in the HRS for smoking status, which included participant's smoking status and the quantity of cigarettes currently smoked. Participants were asked to report if they had ever smoked, and if so, they were further asked the age, year, or number of years ago that they started smoking; the age, year, or number of years ago that they stopped smoking; the quantity of cigarettes or packs smoked at the peak of consumption; and whether they were currently smoking.[14] For this study, two variables were used for smoking status: former and current smokers. This study was not interested in how the quantity of cigarettes smoked confounded the association of depressive symptoms and falls, therefore it was not further analyzed.

There were five ADLs, which included bathing, eating, dressing, getting into or out of bed, and toileting. ADLs were treated as a continuous measure of 0 to 5. Similarly, there were five IADLs, which included using a telephone, taking medication, handling money, shopping, and preparing meals. IADLs were also treated as a continuous measure of 0 to 5. Each score indicated having limitations to a particular task. For example, if an individual is unable to independently bathe but is able to do all other ADL tasks, the individual would have a total ADL score of 1. The greater the ADL or IADL score, the less independent an individual is.

Chronic disease conditions were self-reported, physician-diagnosed lifetime histories of several illnesses and conditions. These included hypertension (high blood pressure), diabetes mellitus, cancer (various types except minor skin cancers), lung disease (including emphysema but not asthma), heart disease (coronary heart disease and congestive heart failure), stroke (cerebrovascular disease), psychiatric problems (in general with the exception of major depression, depressive symptoms, and dementia), and arthritis (collection of heterogeneous diseases and musculoskeletal pain syndromes).[49] This study used each chronic disease condition as individual variables to understand its effect on risk of falls. These conditions were also used as one variable – a total count of chronic disease conditions. Each chronic disease condition a participant had was counted as one score and ultimately summed as a final count of conditions. The count of chronic disease conditions ranged from 0 to 8. For data analysis, the count of chronic disease conditions was further grouped into three categories: no chronic disease conditions (count of 0), some chronic disease conditions (count of 1 to 2), and multiple chronic disease conditions (count of 3 or more). Categories were determined from previous literature and explained briefly in Section 1.4 of this paper.

Participant's cognitive functioning was identified as a potential mediator in this study. The HRS assessed cognitive functioning using several tests, including a 10-word immediate and delayed recall test of memory, a serial 7s subtraction test of working memory, counting backwards to assess attention and processing speed, an object naming test to assess language, and recall of the president, vice president, and present date to assess orientation. Details regarding the possible scores that participants could achieve from each of these tests are listed in Appendix C. The composite score of all items were measured for cognitive functioning, with a range of 0 to 35.[50] Cognitive functioning scores were further grouped for functional classification based on the Aging, Demographics, and Memory Study (ADAMS), which is a supplement of the HRS. The ADAMS was a population-based study on dementia for elderly who were at least 70 years of age. Because the study population of the ADAMS was similar to this study, the same score classification was employed. Scores were classified as the following: low functioning (0 to 8), borderline (9 to 11), normal (low) (12 to 16), normal (medium) (17 to 20), and normal (high) (20 to 35).[50]

2.6 Statistical Methods and Data Analysis

Main exposure (depressive symptoms) and outcome (falls) variables, along with covariates and potential confounders, were merged into one dataset sorted by household identifier and person number (HHIDPN) for analysis. Variables that required coding for categorization included depressive symptoms, education levels, BMI, smoking status, chronic disease conditions (hypertension, diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problem, and arthritis), number of chronic disease conditions, and cognitive function score. Age, household income, ADLs, and IADLs remained in their original forms from the HRS data source as continuous variables. Sex and veteran status also remained in their original form, but as nominal variables.

The study population consisted of participants who were at risk for falls (did not have any falls within the last two years) at appropriate baseline wave years based on birth cohorts. A univariate analysis was performed to identify study population characteristics by frequencies and proportions for categorical variables, and by mean and standard deviation (SD) for continuous variables. Participants who had prevalent falls (falls within the last two years) were excluded from analysis as this study was interested in observing incident falls after exposure to depressive symptoms.

Next, a bivariate descriptive analysis was performed to illustrate the distribution of the study sample characteristics stratified by depressive symptoms. Again, the number of observations and proportions across each covariate were computed. This analysis showed participants who had and did not have the SDS before any incidence of falls. Results of the bivariate analysis included the frequency and row proportion of observations for categorical variables, mean and SD for continuous variables, and their respective p-values. Depending on the type of variable, p-values were based on a Pearson's Chi-squared test (categorical independent variables) or two-sample t-test (continuous independent variables). Furthermore, variables with p-values of greater than 0.05 were included for further analysis, despite their statistical insignificance, to assess their influence on the association estimates. All ordinal variables in this study had at least five levels, thus were treated as continuous variables and tested for between group differences in two-sample independent t-tests.

A multivariable log-binomial regression model was used to estimate the RR, risk difference (RD), and respective 95% CI of SDS associated with incidence of falls. This method was used assuming the key criteria of the logistic regression model, which are that the residuals of the outcome has a normal distribution (normality), there is a linear relationship between the exposure and the outcome (linearity), and there is equal variance across the entire range of the outcome (homoscedasticity). However, because the assumption of linearity is violated due to the binary outcome measure (i.e., the probability of the outcome is bounded by 0 to 1), a log transformation of the outcome was required. An autoregressive order 1 (AR[1]) with continuous time correlation structure was used with the assumption that outcome measurements were not equally spaced over time or not balanced among participants.

The unadjusted model described the sole association of SDS and incidence of falls without adjustment for the effects of potential confounders. Next, to control for effects of confounding, two models were specified: Model 1, the fully adjusted model described the association of SDS and incidence of falls inclusive of all potential confounders and Model 2, the simplified adjusted model only used some of the potential confounders after establishing which variables had multi-collinearity.

To observe whether depressive symptoms and the risk of falls was modified by sex and BMI, separate models were created for each sex (male and female) and each level of BMI (underweight, normal, overweight, and obese) using a log-binomial regression analysis. Effect measure modification occurs when a measure of association between an exposure and outcome variable differs by levels of a third variable, or the effect modifier. In this study's case, the RR would differ according to each sex (male and female) and each BMI level. For each sex, sex-specific RR, RD, and 95% CI were compared. Similarly, BMI-specific RR, RD, and 95% CI were compared as well.

Cognitive impairment (analyzed by the cognitive functioning score) was predicted to be a mediator in the association of SDS and incidence of falls. Mediators are defined as variables which are an intermediate of the mechanism, partially or fully explaining the association between the exposure and outcome variables. To examine whether cognitive impairment was a mediator in the association, a total of four models were run: Model 1 examined whether SDS increased cognitive impairment, Model 2 examined whether cognitive impairment increased risk of falls, Models 3 (including cognitive impairment) and 4 (excluding cognitive impairment) were compared. If the estimate of the association of SDS and falls risk was attenuated in Model 4 compared to Model 3, then it was determined that cognitive impairment was indeed a mediator. All models except for Model 1, which used a generalized linear mixed model with binomial distribution, were analyzed using a log-binomial regression model.

All data analyses were performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

CHAPTER 3. RESULTS

3.1 Study Population Characteristics

The process in which the study population was derived is depicted in Figure 3.1. Participants who had no follow-up visits from initial screening was excluded (N=3,165) and assumed to be lost to follow-up. Because these participants did not have any follow-up data, it was not possible to analyze data for risk of falls. A total of 5,038 participants were excluded due to having prevalent falls at baseline. In order to observe RR of falls in relation to depressive symptoms, all participants must initially be free of the outcome, in other words must not have had falls within the last two years, in order to be considered “at risk.” The participants that were excluded consisted of about 28% of the total number of screened participants.

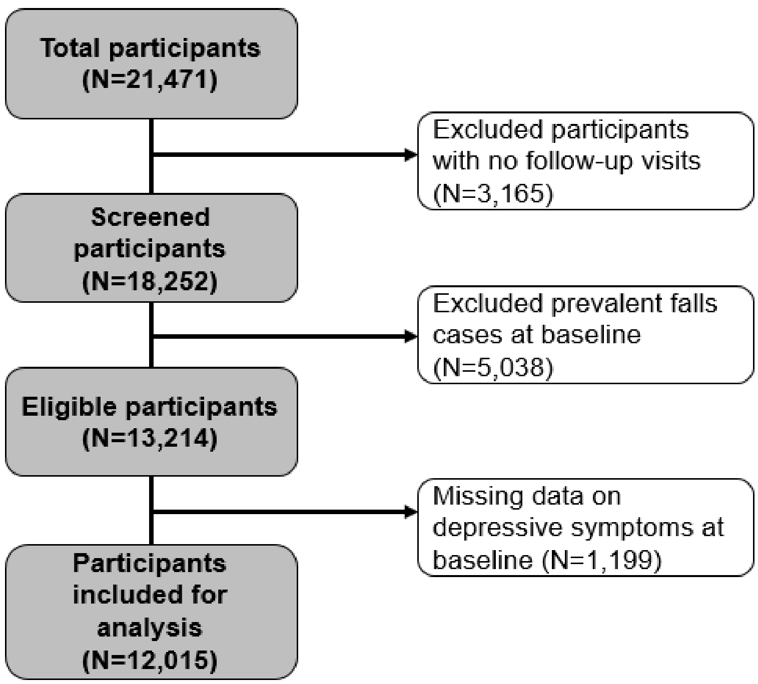


Figure 3.1: Flow diagram of study population

As shown in Table 3.1, the univariate analysis of the study population characteristics was inclusive of participants without prevalent falls at baseline. Most participants did not express SDS and were females, White/Caucasian, and had an education level of a high school degree. The mean age of all participants was 70 years old (rounded up from the value presented in Table 3.1) with a SD of approximately 6 years. Although the mean household income of participants was around $52,000, analysis showed that the SD was over $100,000. This large value was due to outliers influencing the mean household income: the maximum household income reported was over $5,000,000 (not shown in Table 3.1). However, the median household income value was $34,692. Similarly, the mean BMI for participants was 27.13 kg/m^2 with a SD of 5.17 kg/m^2, but the median BMI was 26.5 kg/m^2. Although ADLs, IADLs, and cognitive function scores were originally ordinal variables, they were treated as continuous variables for evaluating the mean between group differences in Table 3.2. Furthermore, some variables presented in Table 3.1 display results of one group rather than both to show relevant prevalence data. For example, participant with prevalent hypertension that did not have falls consisted of 6,942 participants or 97.64% of the total study population. Those without hypertension was not presented in the table, however, they consisted of 168 or 2.36% of the total study population. Other data showing prevalence data for one group included: ever smokers and all chronic disease conditions (hypertension, diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problem, and arthritis).

Table 3.2 describes the study population characteristics at baseline and does not include participants with prevalent falls. Among those at risk for falls at baseline, about 18.99% expressed SDS. Similar to the source population, the study population consisted of slightly more females than males and the majority of the participants were White/Caucasian, followed by Black/African-American and other. The mean age was higher among those with SDS than those without SDS. The results of an independent two sample t-test showed the mean age difference with a p-value of < 0.01. The mean household income on the other hand, showed a lower mean among those with SDS when compared to those without SDS. The mean BMI for SDS was 27.32 ± 5.92 kg/m^2 and for non-SDS was 27.08 ± 4.98 kg/m^2 (not shown in Table 3.2). BMI, although differed slightly between the two groups, was not drastically as different than age and household income. P-values for all continuous variables showed statistical significance at 0.01. However, given the sample size for each independent variable, it is possible that any difference between the groups would be shown as significant, no matter how small.

Participants with lower education tended to have SDS, but as education level increased, the proportion of those with SDS decreased. For example, participants with less than a high school education that had SDS consisted of 29.79%, but those with a GED or high school education consisted of 18.13% (a 12% decrease). The proportion of non-veterans with SDS were higher than veterans with SDS. Generally, participants who ever smoked had a high proportion of expressing SDS than those who did not smoke. Both mean scores for ADLs and IADLs were higher among those with SDS than those without. However, in both cases, the SDs were larger and thus the distribution of observations was sparser. Additionally, the median ADL and IADL sores were 0, and so most participants reported not having any problems with their daily routines and tasks.

Results of the bivariate analysis for hypertension, in Table 3.2, showed that 41% of observations were missing. The large amount of missing data may have been due to the how the variable was obtained: participants were asked if they ever had high blood pressure (by taking anti-hypertensive medication, or whether their high blood pressure was brought under control). Although participants were able to answer "Don't Know" or refuse to answer, such inconsistencies in the earlier birth cohorts may have influenced the missing data. Among all eight chronic disease conditions, psychiatric problems and lung disease were the most prevalent conditions among the study population. The proportion of participants with SDS increased as the number of chronic disease conditions increased.

The majority of the study population had high scores for cognitive function. The mean cognitive function score was 20.24 with a SD of 5.38 (not shown in Table 3.1 or 3.2). However, after stratification by depressive symptom, a greater proportion of participants with SDS had lower cognitive function scores compared to participants without SDS. With the exception of the lowest scores (0-8), as cognitive function scores increased, the proportion of participants without SDS increased.

During follow-up, a total of 7,918 participants had incident falls, which accounted for 65.90% of the total study population (not shown). Among those with SDS, the proportion of participants with incident falls was 90.36%, while those without SDS was 60.17% (Table 3.2). The proportion of participants with SDS that dropped out of the study was 26.21%, and those without SDS was 16.79%. In both cases, the proportions showed that participants with SDS were more likely to have incident falls as well as be lost to follow-up.

Table 3.1: Baseline study population characteristics of participants who did not reporting falling within the last two years (univariate analysis) (N=12,015)

Independent variables	Frequency (proportions [%])[a] or mean ± SD[b]
Significant depressive symptoms (CESD 8[c] score > 3)	2282 (18.99)
Non-significant depressive symptoms (CESD 8 score ≤ 3)	9733 (81.00)
Demographics	
Age[b]	69.66 ± 5.95
Males	5249 (43.69)
Females	6766 (56.31)
White/Caucasian	9911 (82.50)
Black/African-American	1675 (13.94)
Other	427 (3.55)
Less than high school education	3021 (25.14)
GED and high school graduate	4457 (37.10)
Some college education	2323 (19.33)
College education or above	2214 (18.43)
Household income (U.S. dollars)[b]	51965.94 ± 102512.57
Veteran	6937 (26.34)
Non-veteran	8842 (73.66)
Underweight BMI (< 18.5 kg/m^2)	343 (2.85)
Normal BMI (18.5 kg/m^2 ≤ BMI < 24.5 kg/m^2)	3646 (30.35)
Overweight BMI (24.6 kg/m^2 ≤ BMI < 30 kg/m^2)	5111 (42.54)
Obese BMI (≥ 30 kg/m^2)	2915 (24.26)
Smoking status	
Ever smoker	1379 (11.51)
Never smoker	10602 (88.49)
Functional status	
Activities of daily living (ADL)[b]	0.22 ± 0.69
Instrumental activities of daily living (IADL)[b]	0.16 ± 0.57

Footnotes:
[a] Proportions in each column correspond to the column percentages of observations for each independent variable. Not all groups of categories are listed and percentages are rounded to the nearest hundredth decimal place, thus may not sum to 100.00%.
[b] Continuous independent variables with mean ± standard deviation (SD).
[c] Center for Epidemiological Studies 8-Item Depression Scale (CESD 8)

Table 3.1 (continued): Baseline study population characteristics of participants who did not reporting falling within the last two years (univariate analysis) (N=12,015)

Independent variables	Frequency (proportions [%])[a] or mean ± SD[b]
Chronic disease conditions	
Hypertension (high blood pressure)	6942 (97.64)
Diabetes mellitus	2304 (19.18)
Cancer	2304 (15.14)
Lung disease	1210 (10.08)
Heart disease	2970 (24.73)
Stroke	680 (5.69)
Psychiatric problem	1409 (11.73)
Arthritis	7424 (61.82)
No chronic disease conditions (0)	1564 (13.02)
Some chronic disease conditions (1-2)	6677 (55.57)
Multiple chronic disease conditions (3+)	3774 (31.41)
Cognitive function score	
Low (0-8)	701 (5.83)
Borderline (9-11)	202 (1.68)
Normal (low) (12-16)	1174 (9.77)
Normal (medium) (17-20)	1524 (12.68)
Normal (high) (20-35)	8414 (70.03)

Footnotes:
[a] Proportions in each column correspond to the column percentages of observations for each independent variable. Not all groups of categories are listed and percentages are rounded to the nearest hundredth decimal place, thus may not sum to 100.00%.
[b] Continuous independent variables with mean ± standard deviation (SD).

Table 3.2: Baseline study population characteristics of participants who did not reporting falling within the last two years stratified by depressive symptoms status (bivariate analysis) (N=12,015)

Independent variables	Frequencies (proportions [%])[a] or mean ± SD[b]		P-value[c]	Missing
	Significant depressive symptoms (CESD 8[d] score > 3) (N=2282)	Non-significant depressive symptoms (CESD 8 score ≤ 3) (N=9733)		
Incident falls[f]	90.36	60.17	NA	NA
Loss to follow-up[g]	26.21	16.79	NA	NA
Demographics				
Age[b]	70.80 ± 6.62	69.39 ± 5.75	< 0.01	0
Males	768 (14.63)	4481 (85.37)	< 0.01	0
Females	1514 (22.38)	5252 (77.62)		
White/Caucasian	1751 (17.67)	8160 (82.33)	< 0.01	2
Black/African-American	425 (25.37)	1250 (74.63)		
Other	105 (24.59)	322 (75.41)		
Less than high school education	900 (29.79)	2121 (70.21)	< 0.01	0
GED and high school graduate	808 (18.13)	3649 (81.87)		
Some college education	352 (15.15)	1971 (84.85)		
College education or above	222 (10.03)	1992 (89.97)		
Household income (U.S. dollars)[b]	32421.95 ± 48092.88	56548.22 ± 110996.89	< 0.01	0
Veteran	407 (12.87)	2755 (87.13)	< 0.01	11
Non-veteran	1874 (21.19)	6968 (78.81)		
Underweight BMI (< 18.5 kg/m^2)	108 (31.49)	235 (68.51)	< 0.01	0
Normal BMI (18.5 kg/m^2 ≤ BMI < 24.5 kg/m^2)	681 (18.68)	2965 (81.32)		
Overweight BMI (24.6 kg/m^2 ≤ BMI < 30 kg/m^2)	882 (17.26)	4229 (82.74)		
Obese BMI (≥ 30 kg/m^2)	611 (20.96)	2304 (79.04)		

Footnotes:

[a] Proportions in each column correspond to the row percentages of observations for each independent variable in respect to significant or non-significant depressive symptoms. Not all groups of categories are listed and percentages are rounded to the nearest hundredth decimal place, thus may not sum to 100.00%.

[b] Continuous independent variables with mean ± standard deviation (SD) and p-value results from an independent two sample t-test.

[c] P-values categorical independent variables from Pearson's Chi-squared test, except for continuous independent variables. Values correspond to between group differences.

[d] Center for Epidemiological Studies 8-Item Depression Scale (CESD 8)

[e] Ordinal variables were treated as continuous variables (5 or more levels) and tested to between difference means with an independent two sample t-test.

[f] Proportions of participants who had incident falls, with or without SDS, after baseline throughout duration of study, p-values and missing values were not applicable

[g] Proportions of participants loss to follow-up, with or without SDS, after baseline, p-values and missing values were not applicable

Table 3.2 (continued): Baseline study population characteristics of participants who did not reporting falling within the last two years stratified by depressive symptoms status (bivariate analysis) (N=12,015)

Independent variables	Frequencies (proportions [%])[a] or mean ± SD[b]: Significant depressive symptoms (CESD 8[d] score > 3) (N=2282)	Frequencies (proportions [%])[a] or mean ± SD[b]: Non-significant depressive symptoms (CESD 8 score ≤ 3) (N=9733)	P-value[c]	Missing
Smoking status				
Ever smoker	333 (24.15)	1046 (75.85)	< 0.01	34
Never smoker	1942 (18.32)	8660 (81.68)		
Functional status				
Activities of daily living (ADL)[b,e]	0.62 ± 1.13	0.13 ± 0.50	< 0.01	4
Instrumental activities of daily living (IADL)[b,e]	0.43 ± 0.91	0.09 ± 0.43	< 0.01	5
Chronic disease conditions				
Hypertension (high blood pressure)	1478 (21.29)	5464 (78.71)	0.21	4905[f]
No hypertension (high blood pressure)	29 (17.26)	139 (82.74)		
Diabetes mellitus	544 (23.61)	1760 (76.39)	< 0.01	3
No diabetes mellitus	1737 (17.89)	7971 (82.11)		
Cancer	377 (20.73)	1442 (79.27)	0.04	3
No cancer	1903 (18.67)	8290 (81.33)		
Lung disease	379 (31.32)	831 (68.68)	< 0.01	7
No lung disease	1900 (17.60)	8898 (82.40)		
Heart disease	760 (25.59)	2210 (74.41)	< 0.01	6
No heart disease	1519 (16.80)	7520 (83.20)		
Stroke	192 (28.24)	488 (71.76)	< 0.01	62
No stroke	2070 (18.36)	9203 (81.64)		
Psychiatric problem	611 (43.36)	798 (56.64)	< 0.01	2
No psychiatric problem	1671 (15.76)	8933 (84.24)		
Arthritis	1648 (22.20)	5667 (77.80)	< 0.01	5
No arthritis	633 (13.80)	3953 (86.20)		

Footnotes:

[a] Proportions in each column correspond to the row percentages of observations for each independent variable in respect to significant or non-significant depressive symptoms. Not all groups of categories are listed and percentages are rounded to the nearest hundredth decimal place, thus may not sum to 100.00%.

[b] Continuous independent variables with mean ± standard deviation (SD) and p-value results from an independent two sample t-test.

[c] P-values categorical independent variables from Pearson's Chi-squared test, except for continuous independent variables. Values correspond to between group differences.

[d] Center for Epidemiological Studies 8-Item Depression Scale (CESD 8)

[e] Ordinal variables were treated as continuous variables (5 or more levels) and tested to between difference means with an independent two sample t-test.

[f] Missing data for hypertension (high blood pressure) variable consisted of 41% (4905 observations) of the total data.

Table 3.2 (continued): Baseline study population characteristics of participants who did not reporting falling within the last two years stratified by depressive symptoms status (bivariate analysis) (N=12,015)

Independent variables	**Frequencies (proportions [%])[a] or mean ± SD**		**P-value[b]**	**Missing**
	Significant depressive symptoms (CESD 8[c] score > 3) (N=2282)	**Non-significant depressive symptoms (CESD 8 score ≤ 3) (N=9733)**		
Chronic disease conditions				
No chronic disease conditions (0)	166 (10.61)	1398 (89.39)	< 0.01	0
Some chronic disease conditions (1-2)	1031 (15.44)	5646 (84.56)		
Multiple chronic disease conditions (3+)	1085 (28.75)	2689 (71.25)		
Cognitive function score[d]				
Low (0-8)	133 (18.97)	568 (81.03)	< 0.01	558
Borderline (9-11)	75 (37.13)	127 (62.87)		
Normal (low) (12-16)	400 (34.07)	774 (65.93)		
Normal (medium) (17-20)	392 (25.72)	1132 (74.28)		
Normal (high) (20-35)	1282 (15.24)	7132 (84.76)		

Footnotes:
[a] Proportions in each column correspond to the row percentages of observations for each independent variable in respect to significant or non-significant depressive symptoms. Not all groups of categories are listed and percentages are rounded to the nearest hundredth decimal place, thus may not sum to 100.00%.
[b] P-values categorical independent variables from Pearson's Chi-squared test, except for continuous independent variables. Values correspond to between group differences.
[c] Center for Epidemiological Studies 8-Item Depression Scale (CESD 8)
[d] Ordinal variables were treated as continuous variables (5 or more levels) and tested to between difference means with an independent two sample t-test.

3.2 Association Estimates for Unadjusted and Adjusted Models

The estimated measures of association (RR, RD, and respective 95% CI) are shown in Table 3.3. The unadjusted model, observing the sole relationship between depressive symptoms and falls risk, revealed that among those who were at risk for falls at baseline, participants with SDS had a 30% increased risk of falls compared to participants without SDS. To observe whether the independent variables identified as potential confounders were also potential mediators, separate models were run for each variable including: hypertension, diabetes mellitus, heart disease, stroke, psychiatric problems, arthritis, ADL, and IADL. Estimates suggested that hypertension and arthritis were not confounders or mediators (RR 1.24, 95% CI 1.21, 1.27 and RR 1.23, 95% CI 1.20, 1.26 respectively). All models herein after adjusted for all other independent variables for confounding based on previous literature and excluded hypertension and arthritis.

After adjusting for all potential confounders in the fully adjusted model (Model 1), the association was slightly attenuated but did not change the direction of the relationship (RR 1.25, 95% CI 1.22, 1.27). After establishing multicollinearity among covariates, the following independent variables were excluded in the simplified adjusted model (Model 2): education level and veteran status. The estimate from the yielded results that were identical to that of the fully adjusted model with a slightly wider 95% CI (RR 1.25, 95% CI 1.22, 1.28). Likewise, estimates for RD and 95% CI were identical.

Equation 3.1 shows the log-binomial regression equation with all potential confounders included in the model of association between depressive symptoms and fall risk (Model 1 in Table 3.3). Other equations for the unadjusted and simplified adjusted (Model 2) are not shown but RR and RD estimates are indicated on Table 3.3.

Equation 3.1: Log-binomial regression equation for the fully adjusted model

$$\begin{aligned} Log(fall) = \alpha &+ \beta_1 X_1(depressive\ symptoms) + \beta_2 X_2(age) + \beta_3 X_3(sex) + \beta_4 X_4(race) \\ &+ \beta_5 X_5(education\ level) + \beta_6 X_6(household\ income) + \beta_7 X_7(veteran\ status) \\ &+ \beta_8 X_8(BMI) + \beta_9 X_9(ever\ smoker) + \beta_{10} X_{10}(diabetes\ mellitus) \\ &+ \beta_{11} X_{11}(cancer) + \beta_{12} X_{12}(lung\ disease) + \beta_{13} X_{13}(heart\ disease) \\ &+ \beta_{14} X_{14}(stroke) + \beta_{15} X_{15}(psychiatric\ problem) + \beta_{16} X_{16}(ADL) + \beta_{17} X_{17}(IADL) \\ &+ \beta_{18} X_{18}(follow\ up\ time) \end{aligned}$$

Where:
α = intercept (estimated mean risk of falls)
β = beta coefficients (estimated mean risk of falls for participants with or without significant depressive symptoms)
X = dummy regressor

Table 3.3: Comparison of unadjusted and adjusted estimated risk ratio (RR), risk difference (RD) and 95% confidence intervals (CI) of falls by significant depressive symptoms: results of log-binomial regression analysis

Models	RR (95% CI)	RD (95% CI)	P-Values
Unadjusted	1.30 (1.27, 1.33)	0.10 (0.09, 0.11)	< 0.01
Model 1[a] (fully adjusted)	1.25 (1.22, 1.27)	0.09 (0.08, 0.10)	< 0.01
Model 2[b] (simplified adjusted)	1.25 (1.22, 1.28)	0.09 (0.08, 0.10)	< 0.01

Footnotes:
[a] Analysis adjusted for age, follow-up time, sex, race, education level, veteran status, smoking status, chronic disease conditions (including diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problems), BMI, household income, ADL and IADL
[b] Analysis adjusted for age, follow-up time, sex, race, smoking status, chronic disease conditions (including diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problems), BMI, household income, ADL and IADL

3.3 Association Estimates for Potential Effect Modifiers

Study results revealed that sex was an effect modifier in the association of SDS on the risk of falls. Table 3.4 describes the point estimates in detail. According to the adjusted model, among those at risk of falls at baseline, female participants with SDS had a 32% increased risk of falling (RR 1.32, 95% CI 1.26, 1.38) and male participants with SDS had a 17% increased risk of falling (RR 1.17, 95% CI 1.12, 1.23). Female participants with SDS were found to have a 15% higher risk for falling than male counterparts.

Table 3.4: Comparison of mean estimates with standard error (SE), estimated sex-specific risk ratios (RR), risk differences (RD), and 95% confidence intervals (CI) of significant depressive symptoms by falls risk: results of log-binomial regression analysis by potential effect modifiers

Independent variable	Mean estimate (SE)	RR (95% CI)	RD (95% CI)	P-values
Sex (unadjusted)				
Male	0.09 (0.02)	1.16 (1.12, 1.20)	0.06 (0.04, 0.07)	< 0.01
Female	0.36 (0.02)	1.43 (1.39, 1.48)	0.14 (0.12, 0.15)	< 0.01
Sex (adjusted)[a]				
Male	0.16 (0.02)	1.17 (1.12, 1.23)	0.07 (0.05, 0.08)	< 0.01
Female	0.28 (0.02)	1.32 (1.26, 1.38)	0.11 (0.09, 0.13)	< 0.01

Footnotes:
[a] Analysis adjusted for age, follow-up time, sex, race, education level, veteran status, smoking status, chronic disease conditions (including diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problems), BMI, household income, ADL and IADL

In the multivariable log-binomial model testing BMI as a potential effect modifier, results revealed that BMI modified the association of SDS and risk of falls (Table 3.5). With normal BMI as the reference group, participants who were obese with SDS had the greatest risk of falling at 24% increased risk (RR 1.24, 95% CI 1.19, 1.28), while participants who were overweight with SDS had the least risk at 12% (RR 1.12, 95% CI 1.08, 1.16). The RR and RD estimates for underweight participants with SDS (RR 1.13, 95% CI 1.07, 1.19) were similar to the overweight participants with SDS. Although estimates for underweight and overweight participants had overlapping 95% CI, it did not overlap for obese participants. Similar to the adjusted models from Table 3.3, participants with SDS, regardless of their BMI status, were at increased risk for falls compared to those without SDS.

Table 3.5: Comparison of mean estimates with standard error (SE), estimated BMI-specific risk ratios (RR), risk differences (RD), and 95% confidence intervals (CI) of significant depressive symptoms by falls risk: results of log-binomial regression analysis by potential effect modifiers

Independent variable	Mean estimate (SE)	RR (95% CI)	RD (95% CI)	P-values
BMI (unadjusted)				
Normal (18.5 kg/m^2 ≤ BMI < 24.5 kg/m^2)	Referent	Referent	Referent	Referent
Underweight (< 18.5 kg/m^2)	0.11 (0.03)	1.12 (1.06, 1.18)	0.04 (0.02, 0.06)	< 0.01
Overweight (24.6 kg/m^2 ≤ BMI < 30 kg/m^2)	0.33 (0.02)	1.39 (1.34, 1.44)	0.12 (0.11, 0.14)	< 0.01
Obese (≥ 30 kg/m^2)	0.26 (0.02)	1.30 (1.25, 1.35)	0.10 (0.08, 0.11)	< 0.01
BMI (adjusted)[a]				
Normal (18.5 kg/m^2 ≤ BMI < 24.5 kg/m^2)	Referent	Referent	Referent	Referent
Underweight (< 18.5 kg/m^2)	0.12 (0.03)	1.13 (1.07, 1.19)	0.05 (0.03, 0.07)	< 0.01
Overweight (24.6 kg/m^2 ≤ BMI < 30 kg/m^2)	0.11 (0.02)	1.12 (1.08, 1.16)	0.05 (0.03, 0.06)	< 0.01
Obese (≥ 30 kg/m^2)	0.21 (0.02)	1.24 (1.19, 1.28)	0.09 (0.08, 0.10)	< 0.01

Footnotes:
[a] Analysis adjusted for age, follow-up time, sex, race, education level, veteran status, smoking status, chronic disease conditions (including diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problems), BMI, household income, ADL and IADL

3.4 Association Estimates for Potential Mediator

Table 3.6 describes the association estimates for several models, including the association of depressive symptoms on cognitive impairment (Model 1), the association of cognitive impairment on falls risk (Model 2), and the association of depressive symptoms on falls risk explained by the potential mediator, cognitive impairment. All models included potential confounders for analysis in order to attain best estimates of the association. Model 1 showed that SDS increased the risk of cognitive impairment (RR 1.10, 95% CI 1.06, 1.16). Similarly, Model 2 showed that cognitive impairment increased the risk of falls (RR 1.16, 95% CI 1.13, 1.19). The association estimate from Model 4 (RR 1.24, 95% CI 1.21, 2.17) was almost identical compared to Model 3 (RR 1.25, 95% CI 1.23, 1.28), thus it cannot be suggested that cognitive impairment was a mediator.

Table 3.6: Estimated risk ratio (RR), risk difference (RD), and 95% confidence intervals (CI) of cognitive impairment as potential mediator in the association of depressive symptoms and falls risk

Models[a]	RR (95% CI)	RD (95% CI)	P-values
Model 1[b]	1.10 (1.06, 1.16)	0.05 (0.04, 0.06)	< 0.01
Model 2[c]	1.16 (1.13, 1.19)	0.05 (0.04, 0.06)	< 0.01
Model 3[d]	1.25 (1.23, 1.28)	0.09 (0.08, 0.10)	< 0.01
Model 4[e]	1.24 (1.21, 1.27)	0.09 (0.08, 0.10)	< 0.01

[a] All model analyses adjusted for age, follow-up time, sex, race, education level, veteran status, smoking status, chronic disease conditions (including diabetes mellitus, cancer, lung disease, heart disease, stroke, psychiatric problems), BMI, and household income
[b] Estimates of depressive symptoms in association with risk of cognitive impairment
[c] Estimates of cognitive impairment in association with risk of falls
[d] Estimates of depressive symptoms in association with risk of falls including cognitive impairment in model
[e] Estimates of depressive symptoms in association with risk of falls excluding cognitive impairment in model

CHAPTER 4. DISCUSSION

4.1 Conclusions

After adjusting for potential confounding, results revealed that participants with SDS were found to have an increased risk for falls (RR 1.25, 95% CI 1.22, 1.27). RD estimates showed that 9 of 100 cases among participants with SDS were theoretically preventable if they did not have SDS (RD 0.09, 95% CI 0.08, 0.10). Consistent with the hypothesis, participants with SDS were found to have an increased risk for subsequent falls compared to those without SDS.

To estimate the measure of impact, the attributable fraction among exposed (AFE) was calculated using the fully adjusted model estimate, shown in Equation 4.1. Assuming that SDS has a causal inference on falls risk, the AFE value showed that approximately 20% of participants with SDS that had incident falls were theoretically attributable to having SDS. Furthermore, Equation 4.2 describes the attributable number: 457 participants with incident falls could have theoretically been prevented if they did not have SDS. Considering that the exposed group (those with SDS) consisted of 2,282 participants, 457 participants accounted for about 20% of the total exposed group.

Equation 4.1: Attributable fraction among exposed (AFE)

$$AFE = \frac{(RR-1)}{RR} = \frac{(1.25-1)}{1.25} = 0.20$$

Equation 4.2: Attributable number

$$(total\ number\ of\ exposed)(AFE) = (2282)(0.20) = 457$$

As hypothesized, both sex and BMI were shown to be effect modifiers in the association of depressive symptoms and falls risk according to the RR and RD estimates. Two-hundred and fifty-two female participants with SDS would not have had incident falls if they did not have SDS. The attributable number of males was about half of females: if male participants with SDS theoretically did not have SDS, 160 participants would not have had incident falls. Previous literature have supported these results, suggesting that women and men experience hormonal and biological changes differently as they age.[32-34] Likewise, certain injuries such as hip fractures tend to occur more in older men than women, perhaps due to differences in lifetime occupation (i.e., men may engage in physically hazardous working conditions than women).[52] Other factors such as the deterioration of bone density, muscle mass, and balance has been found to be quite similar across sexes; these may contribute to the overall increased risk of falls among both males and females.

For BMI estimates, obese participants with SDS were revealed to have the highest risk of falls than any other group, when compared to participants with normal BMI. Among those that were obese, if participants theoretically did not have SDS, 206 participants would not have experienced incident falls. Consistent with the hypothesis, the association estimate for obese BMI individuals was greater than other BMI groups. However, overweight participants with SDS were shown to have a slightly lower risk of falls than underweight participants, although the difference was very minimal. While several literatures supported this finding, others have indicated that underweight participants have the highest risk for incident falls of any other BMI group due to a high prevalence of frailty.[53]

Association estimates from Models 1 and 2 in Table 3.6 showed that SDS did increase risk for cognitive impairment and cognitive impairment did increase risk for falls. These results suggest that cognitive impairment is an intermediate of depressive symptoms and falls risk, meeting the criteria of being a potential mediator. As hypothesized, participants with SDS were at increased risk for cognitive impairment, defined as having lower cognitive scores (scores less than 25), which also increased their risk of falls. However, when association estimates were stratified by cognitive impairment (Model 3, with cognitive impairment and Model 4, without cognitive impairment), the estimate was only attenuated by 1%. Based on these results, it cannot be suggested that mediation occurred by cognitive impairment, but it is possible that these results may be prone to potential biases.

It is important to note that this study observed the effect of depressive symptoms on any incidence of falls, not recurrent falls, number of falls, or severity of falls. As well, results of this study cannot infer an association of a clinical diagnosis of depression on the risk of falls.

4.2 Strengths and Limitations

There are several strengths in this study. The longitudinal study design allowed this study to directly measure the RR and observe a temporal trend. According to Hill's criteria of causation[51], temporality (e.g., the exposure must precede the outcome) is necessary to infer causality. Calculating the RR is also beneficial when an outcome is prevalent, and in this study, falls are fairly common among the older adult population. The relatively short recall period of depressive symptoms (i.e., past month) reduced some issues with misclassification. The CESD 8 was validated in this study population, giving an adequate reliability measure for the association. The large sample size helped to yield a precise measurement of the estimate and produce narrow 95% CI. There were also very few missing data (< 5%), with an exception of the hypertension variable that had 41% of missing data.

While there are strengths to this study, a number of limitations must be noted. Although a long-term trend could be measured, the time-varying nature of the exposure and outcome variables may make it difficult to conclude that depressive symptoms causes incident falls. Rather, it is more accurate to infer there is some association between these variables. To control for confounding, this study stratified and adjusted potential confounders.

Residual confounding may have resulted due to not controlling for unidentified confounders such as physical activity, neurological disorders such as dementia, and motor system diseases such as Parkinson's and amyotrophic lateral sclerosis (ALS). In this study, the 41% of missing hypertension data was unaccounted for during adjustment, which may have influenced the true estimate of the association of SDS and falls. Furthermore, osteoporosis was not included in this study, which has also been found to increase the risk of hip, spine, and wrist fractures, which could ultimately affect the risk of falling.[52]

On the other hand, over-adjustment may have occurred by including variables that were potential mediators, resulting in either over or underestimation of the effect estimates. For example, it may be possible that severe cases of SDS result in limitations for daily activities, including those that require physical independence (thus limiting ADL or IADL). Previous literature has not explicitly found that depressive symptoms directly effects limitations to ADL and IADL, therefore such adjustments were not employed in this study.

To control for possible over-adjustments, this study employed the simplified adjusted model, removing covariates that had multicollinearity shown in Table 3.3. Other models, including the potential effect modifiers and mediator models, utilized all potential confounders including those that may have multicollinearity. Thus, it is possible that association estimates may not be accurate.

Potential biases of the association include selection and information bias. To ensure representativeness and generalizability of participants in the source population, all birth cohorts and participants were included at baseline in the study population. Thus, the proportion of those exposed or not exposed in this study should reflect similar proportions in the source data. Also, it is unlikely that selection bias occurred at the source data level – investigators of the HRS were not influenced by the awareness of the outcome, which had not occurred yet. Furthermore, loss to follow-up was anticipated from this study. It is likely that healthier participants remained on the study after several years – some participants remained on the study up to twenty years. As mentioned in Section 3.1, this study compared proportion of participants that had incident falls and lost to follow-up with stratification of depressive symptoms. It was found that the proportion of participants with SDS were more likely to experience incident falls and were also more likely to have dropped out of the study. A possible explanation for this observation is that the majority of the proportions were older in age (from earlier birth cohorts), thus may have deceased during follow-up and so data was not further collected or analyzed. Additionally, older participants may have been more likely to develop multiple chronic diseases and less healthy, therefore could not continue to participate in the study.

Recall bias may have occurred given that the exposure and outcome variables were self-reported by the participants. However, this may likely be a non-differential misclassification, which would produce a conservative estimate of the association. The HRS attempted to reduce recall and interviewer bias by having a trained interviewer conduct the survey and used standardized questions with pre-determined response options.

Moreover, the exposure and outcome measures were not clinically diagnosed by a physician and thus the reliability of the measurements may be weak. Especially in regards to the outcome variable, falls, a recall period of two years may influence how accurately a participant reports having falls. As for the exposure variable, as discussed in Section 2.4, the CESD 8 has been widely used as a valid and reliable tool to screen for clinical depression. Most other variables were self-reported, with physician confirmed diagnosis, and interviews were lengthy especially for baseline data collection, therefore it is possible that recorded responses do not accurately reflect every participant's true values.

Although CESD 8 score cut-offs have been validated in the older adult populations and the HRS, not all participants that express SDS may correlate to having depression. Measuring depressive symptoms is one method in which clinical depression can be measured and predicted, not diagnosed. Also, expressing SDS may not be indicative of the type of depression an individual may have. For example, individuals with Seasonal Affective Disorder may express depressive symptoms and/or episodes during certain seasons (i.e., winter), while individuals with manic depression may have unpredictable periods of elation and depression.

Until recently, mental illness such as depression, has been regarded as a taboo to report and many individuals have avoided seeking therapy and treatment. It is possible that there was social desirability bias wherein the participants in this study underreported having experienced depressive symptoms. Specifically, studies have found that more women report depressive symptoms than men by a 2:1; despite men experience depressive symptoms as frequently as women, they are less likely to admit it.[53]

This study did not analyze how individuals with previous falls or pre-existing injuries may have influenced the risk of subsequent falls. Participants who remained on the study for a longer period would have been more likely to have incident falls than others who may have been lost to follow-up early on. After an initial incidence of falls occur, depending on the severity of the injury incurred, the participant's risk of subsequent falls will differ greatly. Recovery time may be longer for individuals that had major injuries, such as head trauma, compared to individuals with minor injuries (e.g., abrasions).

Furthermore, results from the mediator model did not support the hypothesis. The models with and without cognitive impairment (Table 3.6) revealed nearly identical results as the adjusted model in Table 3.3. and so, it cannot be suggested that the association of SDS and falls risk was mediated. Despite these findings, it is possible that there was a differential misclassification for cognitive impairment. Participants with lower cognitive function scores are more likely to have memory problems than those with higher cognitive function scores. Therefore, those with severe cognitive impairment may not have accurately reported having falls.

4.3 Recommendations

Despite the limitations of this study, it is evident that depressive symptoms have an effect on falls risk. Future studies may consider having a shorter recall period for the outcome, incident falls, in order to reduce potential recall bias and misclassification. Moreover, this study observed cognitive impairment as a potential mediator, however, there are several variables that may explain the causal mechanism of depressive symptoms and falls risk. Types of medications that are often prescribed for various chronic diseases may influence individuals' memory and cognition, as well as have side effects on physical health. The interaction of multiple medications may further complicate physical and mental well-being of individuals. It is recommended that future studies observe how types and interaction of different medications may influence this association.

Current national efforts are focused on improving the well-being of the older adult populations as well as spreading awareness about mental health illness across all age groups. While older adults experience multiple chronic and mental health illnesses, the risk of developing such conditions can be reduced if appropriate interventions and measures are taken. Especially in regards to mental and behavioral health, screening tools are available for various age groups, including middle-age and older adult populations of different race and ethnicity. Implementing depression screening as a part of routine medical examinations may help improve latter acquired chronic health issues. Other local and national efforts have consisted of developing community-based falls prevention programs. These programs focus not only on improving the physical and mental health of older adults, but also focuses on providing resources to other community members that may be caring for this population.

A team-based patient-care approach may be beneficial. Having an integrative health care plan can improve information sharing to identify patterns and indicators for falls, as well as identify vulnerable patients. Primary care physicians, who are usually the first point of contact, should collaborate with behavioral specialists and psychiatrists in order to bring comprehensive care to patients. In this manner, depressive symptoms and clinical depression could be detected early on to reduce or prevent future medical complications. These efforts can improve process efficiency for both institutions (i.e., hospitals and clinics) and patients.

Similar to older adults, middle-age adults are vulnerable to falls and have experienced increasing financial burdens in the U.S. Various studies have reiterated that the characteristics and incidence of falls are alike between middle-age and older inpatients.[11, 55] In a case control study of academic hospital inpatients, middle-age adults had the second most prevalent cases of falls, closely following older adults, and both had similar rates of injuries due to falls.[55] As such, Verma et al.[12] found that the total lifetime cost of unintentional fall-related injuries among middle-age adults was $23 billion in 2003 to 2014, the highest compared to any other age groups. Additionally, there are major hormonal changes (e.g., menopause) which may influence incident falls.[32] Although falls among older adults is a focus for many studies and is a priority in national public health objectives, the middle-age adult population should not be overlooked.[7] It is recommended that future studies investigate the effect of depressive symptoms and falls risk among middle-age adult populations.

APPENDIX A: Source of data for entry cohorts in RAND HRS data file by wave

Wave	Birth Cohort[a] by Entry Year					
	HRS HACOHORT=3[b]	AHEAD HACOHORT=0,1	CODA HACOHORT=2	WB HACOHORT=4	EBB HACOHORT=5	MBB HACOHORT=6
1	1992	1992 (HRS/AHEAD overlaps only)	Not available			
2	1994 (Wave 2H)	1993 (Wave 2A)				
3	1996 (Wave 3H)	1995 (Wave 3A)				
4	1998	1998	1998	1998	Not available	
5	2000	2000	2000	2000		
6	2002	2002	2002	2002		
7	2004	2004	2004	2004	2004	Not available
8	2006	2006	2006	2006	2006	
9	2008	2008	2008	2008	2008	
10	2010	2010	2010	2010	2010	2010
11	2012	2012	2012	2012	2012	2012
12	2014	2014	2014	2014	2014	2014

Footnotes:

[a] Birth cohort definitions: Asset and Health Dynamics Among the Oldest Old (AHEAD) born in 1890-1923, Children of the Depression (CODA) born in 1924-1930, Health Retirement Study (HRS) born 1931-1941, War Babies (WB) born 1942-1947, Early Baby Boomers (EBB) born 1948-1953, and Mid Baby Boomers (MBB) born 1954-1959

[b] HACOHORT indicates the order in which birth cohorts were recruited. The initial HRS cohort was recruited in 1992, secondly AHEAD in 1993, thirdly CODA and WB in 1998, fourthly EBB in 2004, and finally the MBB in 2010.

Source: Sonnega A, Faul JD, Ofstedal MB, Langa KM, Phillips JWR, Weir DR.[45]

APPENDIX B: Comparison of CESD 20-item scale and CESD 8-item scale by questionnaires

CESD 20-Item Scale[a]	HRS CESD 8-Item Scale[b]
"Please tell me how often you have experienced the following feelings during the past week […] all or most of the time, most of the time, some of the time, or none or almost none of the time."	"Now think about the past week and the feelings you have experienced. Please tell me if each of the following was true for you much of the time this past week. Much of the time during the past week […][c] Would you say yes or no?"
1. I was bothered by things that don't usually bother me.	
2. I did not feel like eating; my appetite was poor.	
3. I felt that I could not shake off the blues even with help from my family or friends.	
4. I felt that I was just as good as other people.	
5. I had trouble keeping my mind on what I was doing.	
6. I felt depressed.	1. You felt depressed.
7. I felt that everything I did was an effort.	2. You felt that everything you did was an effort.
8. I felt hopeful about the future.	
9. I thought my life had been a failure.	
10. I felt fearful.	
11. My sleep was restless.	3. Your sleep was restless.
12. I was happy.	4. You were happy.
13. I talked less than usual.	
14. I felt lonely.	5. You felt lonely.
15. People were unfriendly.	
16. I enjoyed life.	6. You enjoyed life.
17. I had crying spells.	
18. I felt sad.	7. You felt sad.
19. I felt that people disliked me.	
20. I could not get "going."	8. You could not get "going."

Footnotes:
[a] Participants would be requested by the interviewer to respond using a Likert scale from 1 to 4, with 1 indicating "All of almost all of the time," 2 indicating "Most of the time," 3 indicating "Some of the time," and 4 indicating "None or almost none of the time.
[b] Participants would be requested by the interviewer to respond with either "Yes" or "No."
[c] Interviewer would ask the participant one of the eight item CESD questions listed in the column in this bracket.

APPENDIX C: Details and scores from the HRS cognitive functioning measurements tests

Name of Tests[a]	Test Details[b]	Total Possible Scores[c]
Immediate Recall	Interviewer reads one of four possible lists of 10 nouns to respondent, then respondent recalls as many nouns as possible	0-10
Delayed Recall	Respondent asked to recall nouns previously presented during the Immediate Recall task approximately 5 minutes after other survey questions	0-10
Serial 7s	Respondent subtracts 7 from 100 and continue subtracting 7 from each subsequent number for a total of five trials (interviewer does not repeat the difference said by respondent after each trial)	0-5
Counting Backwards Beginning with 20	Respondent counts backwards 10 continuous numbers beginning with the number 20 as quickly as possible	0-2
Month	Respondents asked to report “today’s date (month)”	0-1
Day	Respondents asked to report “today’s date (day)”	0-1
Year	Respondents asked to report “today’s date (year)”	0-1
Day of Week	Respondents asked to report “today’s date (day of the week)”	0-1
Name Object (Scissors)	Respondents asked “What do you usually use to cut paper?”	0-1
Name Object (Cactus)	Respondents asked “What do you call the kind of prickly plant that grow in the desert?”	0-1
Name Current President	Respondents asked to name current President of the U.S.	0-1
Name Current Vice President	Respondents asked to name current Vice President of the U.S.	0-1

Footnotes:
[a] The numerical order of the tests presented in this table is not representative of the order which tests were conducted during the interview.
[b] Test details outlines the instructions that interviewers and/or respondents used to perform the test
[c] The total cognitive functioning scores (0 to 35) was derived from the summation of scores per respondent in the HRS

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