Falls and Social Vulnerability Index: Association among the Older Population in Allegheny County, PA

by

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Abstract

Background

Falls constitute a major public health concern for the U.S. geriatric population. Despite affecting all age groups, older adults experience higher rates of fall-related morbidity and mortality. The Social Vulnerability Index (SVI) indicates the social determinants of health that impact different regions and it would be significant to study its association with falls among this demographic. The public health relevance of this association in Allegheny County is indicated by the large proportion of its residential population belonging to this age group.

Objectives

This study aims to explore the association between the occurrence of falls and regional social vulnerability. Its objective is to assess the correlation between SVI and fall-related outcomes on a census tract level for Allegheny County residents aged ≥55 years.

Methods

Hospitalization data (2016-2020) from the Pennsylvania Health Care Cost Containment Council and mortality data (2016-2020) from the Pennsylvania Department of Health were used to calculate fall-outcome rates by census tracts. These rates were analyzed using SAS 9.4 and descriptive statistics were calculated for age, sex, and race, with trends visualized in Microsoft Excel. Percentile-based SVI rankings ranging between 0 and 0.999, as determined by the CDC

were used for the county, and negative binomial regression was used to assess the association between these two.

Results

The occurrence of fall-associated hospitalizations and mortality were highest in those ≥75 years— 40.22% and 78.62% respectively. These were also the highest among those who identified as White, accounting for 77.39% of hospitalizations and 92.64% of all mortality due to falls. The mean overall SVI ranking for the census tracts of Allegheny County was 0.427. For the 342 census tracts, no significant association was found between SVI and fall-related outcomes following a negative binomial regression.

Discussion

Those ≥75 years and those who identified as White were disproportionally affected. No significant association was found between fall-related outcomes and SVI. The public health significance of these findings within this population is that they can be used to identify groups that need additional targeted interventions to reduce fall-related outcomes.

Keywords

Falls, Older population, Social Vulnerability, Allegheny County

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Preface

This paper explores the intricate relationship between falls and the various social determinants that impact its occurrence within the older population of Allegheny County, PA.

I extend my sincere gratitude to my committee members for their invaluable guidance and unwavering support throughout this academic journey. Their expertise and insights have been instrumental in shaping the trajectory of this essay. Additionally, I express heartfelt appreciation to the Allegheny County Health Department for the provision of crucial data for this study possible.

I am deeply grateful for the collaborative efforts that have made this investigation possible, and I look forward to contributing meaningful insights to the field of public health.

1.0 Introduction

1.1 Falls and Their Impact

Unintentional injuries can be caused by various incidents, such as motor vehicle crashes, drownings, wounds from firearms, etc. These form one of the leading causes of death in individuals between 1 to 45 years of age in the United States (Wulz et al., 2023), and the association between their occurrence with various social determinants has been widely studied in the past. Falls are also categorized as unintentional injuries and are a particular major public health issue impacting both pediatric and geriatric populations, as statistics show that emergency department visits related to falls are more common in children less than 5 years of age and adults 65 years of age and older. Between 1992 and 1995, 147 million injury-related visits were made to emergency departments in the country, but we have to consider that this number is a grossly underreported figure as there are obstacles to reporting falls, such as not all incidents being classified as falls, or there being no major injury involved, or a patient not recalling a prior incident. Evidence suggests that, currently, 75–80% of falls are not reported at all – especially those without injuries, indicating that any retrospective studies conducted now may also suffer from under-reporting of falls (Ambrose, A. F. et al, 2013). In a prospective study of 304 ambulatory patients, Cummings et al. found that between 13% and 32% denied having had a fall depending on how long after the event they were questioned. They also found that longer intervals were associated with a lower recall (Ambrose, A. F. et al, 2013).

2.0 Introduction

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Of those 147 million injury-related visits, it was noticed that falls were the leading cause of external injury, accounting for 24% of these visits. It was reported that older adults who fall are 10 times more likely to be hospitalized for unintentional injuries and related complications, such as hip fractures, and head trauma, and are 8 times more likely to die as a result of a fall as compared to children. Fall-related injuries not only increase the chances of early death in these high-risk individuals but also impact their quality of life by making it difficult for them to live independently (Fuller, G. F., 2000).

Historically, there has been no consensus on the definition of falls -- especially when there is no apparent injury involved. Older people tend to describe a fall as a loss of balance whereas healthcare professionals generally refer to the consequences of falling, such as injuries, or deaths. Therefore, research studying injuries and deaths caused by falls done in the past followed no standard case definition, resulting in an overall low validity of their results (19). Currently, falls can be 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" (19). Falls are considered an external cause of unintentional injury and are coded as E880-E888 in the International Classification of Disease-9 (ICD-9) and as W00-W19 in ICD-10. Having a clear definition of what counts as a "fall" is the first step to measuring cases with standardization and accuracy

Generally, there are several approaches to measuring fall rates. According to a report by the Agency for Healthcare Research and Quality (AHRQ), the best way to measure falls is by using a method that can be compared over time to see if care is improving, especially in institutions like hospital units (AHRQ, 2013). One commonly used method by institution-based studies is to report the number of falls as well as the number of occupied bed days over a given time (Hirsch,

J. A. et al., 2016). In addition, self-reporting appears to be one of the efficient methods of measuring falls on a larger scale –particularly for the ones that do not result in hospitalization or death.

While there is no standardized diagnostic test, fall risk assessments are a common way to predict the risk of future falls in an individual or a community. This is necessary as the management and prevention of falls that do not result in major injuries is often complicated. Besides using physical examination, laboratory testing, and pharmacological assessment, the following fall risk assessment tools were identified by a review of 27 prospective studies (Meekes, W. M. et al, 2021):

- Timed Up and Go test
- Gait speed test (4m)
- Berg Balance Scale
- Performance Oriented Mobility Assessment- Balance
- Performance Oriented Mobility Assessment- Gait
- Functional Reach Test
- Falls history

The results of these assessments can then be used to target prevention strategies that are generally multidimensional and interprofessional.

2.2 Significance of Falls among the Aging Population

According to an international literature review on "age-friendly" communities by Luis et al., health outcomes among older individuals are impacted by their social and physical environments - including housing and urban planning. Even differences between the type of house - public versus private, have been reported to affect the health of the people living there after adjusting for confounding factors (Woo J, Yu R, Leung J, et al., 2017). The urban planning of a city is significant as it influences the overall community health by promoting physical activity among its residents and influencing their social networks and engagements (Woo J, Yu R, Leung J, et al, 2017). Most of the papers mentioned in these reviews study the self-rated health of individuals that account for not only the presence or absence of disease but also their psychological states (Woo J, Yu R, Leung J, et al., 2017).

Moreover, a worldwide demographic shift is expected in the coming years where the aging population is expected to increase drastically. Projections based on the 2010 census suggest that the population of the United States is expected to grow by approximately 79 million by the year 2060, with an average increase of 1.8 million people per year. It is mentioned that the country is "graying" as the population in the age group of 65 years and above is forecasted to double in this duration- from 49 million people in 2016 to 95 million in 2060. This age group will then account for 25% of the country's population, as opposed to the 15% it accounted for in 2016. Furthermore, the population of those aged 85 years and older is predicted to grow almost 200% by 2060- going from 6 million in 2016 to 19 million in 2060 (Vespa, J., Medina, L., & Armstrong, D., 2020). With an increase in the older population, along with an expected increase in life expectancy, issues pertinent to this

population- such as injuries due to falls and related complications, are also expected to rise in incidence. While the UN calls the increase a “major success story”, this would also bring about a shift in the diseases and conditions that burden the people as well as healthcare systems. A study estimating the increase in chronic diseases in the United States using a multi-state population model projected that 47.8% (46.1-49.7) of the population aged 50 years and above will have at least one chronic condition by 2050. While 58.54% of those with one chronic condition and 58.9% of those with multimorbidity are between 60 to 79 years, those aged 80 years and above will have the most drastic increase for having one chronic condition (244.3%) and multimorbidity (202.7%) by 2050 (Ansah, J. P., & Chiu, C.-T., 2023). Countries anticipating this increase need to be prepared to prevent, as well as treat, these conditions.

It is also important to note that the sex ratio among the older age groups generally differs from the other age groups. There are more women than men since women tend to have a longer life expectancy. As of 2017, there were 79 men for every 100 women in the age group of 65 and above and only 54 men for every 100 women in the age group of 85 years and above. However, due to a continuously increasing life expectancy among men, by 2060 these gaps between the sexes are expected to narrow and the ratios are perceived to increase to 86 men and 65 men for every 100 women in the 65+ years and 85+ years of age groups respectively. This projected change is significant for understanding the support and caregiving that older individuals are expected to have as well as the connections that they form with others in the community (Vespa, J., Medina, L., & Armstrong, D., 2020). According to the CDC, women have been reported to fall more often than men and account for three-quarters of all hip fractures caused by falls- which is significant considering that 95% of all hip

fractures are caused by falling (Sánchez-Garrido N. et al., 2021). With a change in the demographics in the upcoming decades, we can also expect a change in numbers and associations.

2.3 Falls in Allegheny County, Pennsylvania

According to the last available report by the Census Bureau in 2022, persons aged 65 years and older comprise 20.4% of all the people in Allegheny County. This is high considering that the age group of 18 years and under forms only 18.4% of the total population. These statistics signify the largely aging population in Allegheny County. (United States Census Bureau, 2022). A higher proportion of the residential population being composed of the older population creates a larger healthcare burden due to conditions that are common for this population- including falls.

To illustrate this, according to data provided by the Pennsylvania government, 4,056 individuals over the age of 75 years in the county reported an acute injury leading to hospitalization due to falls in the year 2020 from a total of 42, 512 individuals in this age group. This accounted for 54.2% of fall injuries among all age groups in that year. The rates of Fall-related injuries in the county are also considerably higher than those among other counties in Pennsylvania, followed closely only by Berks, Bucks, and Delaware counties. Montgomery and Philadelphia were the only counties with rates higher than Allegheny County (World Economic Forum, 2023).

2.4 Risk Factors and Social Determinants of Health Associated with Falls

Among those aged 65 years and above, 30% of individuals fall every year, where half of the falls are recurrent (AHRQ, 2013). The various risk factors causing falls can be grouped into the following three categories, as mentioned in a CDC guide on preventing falls among older adults (National Center for Injury Prevention and Control, 2008):

1. Behavioral risk factors
2. Biological risk factors
3. Environmental risk factors

Behavioral risk factors include inactivity, risky behaviors like improper use of step stools, alcohol use, etc. In a global literature review on falls among older adults from1995 to 2010, the most common behavioral risk factors referenced included overdose on medication (32.1%), and the fear of falling—without having ever fallen before or after the first fall (29.8 and 22.9 %, respectively) (Terroso M. et al., 2014). Additionally, behaviors like moderate alcohol consumption, not losing weight between mid- and older age, and practicing a greater number of preventive medical care were reported to reduce the risk of hip-fractures due to falls according to a case-control study conducted between 2003 to 2004 among older adults in Australia (Peel N. M. et al., 2006).

Biological risk factors like mobility problems due to muscle weakness or balance problems, medication side effects, chronic health conditions such as arthritis and stroke, vision changes and vision loss, and neurological issues like loss of sensation in feet. In the order of evidence strength, fall risk factors include a history of falls, impairment in balance, reduced muscle strength, visual problems, polypharmacy or psychoactive drugs, gait difficulty, depression, orthostasis or

dizziness, functional limits, age over 80 years, female sex, incontinence, cognitive difficulties, arthritis, diabetes, and pain. Further, " any additional physical or mental health conditions that occur as a result of having a primary disabling condition" are defined as secondary conditions. Injuries, including those caused by falls, are one of the most serious secondary conditions for individuals with disabilities along with chronic pain and problems with getting around (Xiang et al., 2014). Brophy et al.- using the 2004/2005 National Health Interview Survey (NHIS) data, reported that adults with disabilities had an increased risk of injuries and age was not a significant factor here (Xiang et al., 2014). Lastly, one of the biggest factors contributing to higher rates of falls among older adults is sarcopenia- which refers to a loss of muscle and strength that occurs when a person gets older and has decreased physical activity. This condition can be related to a food decline, a long hospital stay, as well as a long illness (AHRQ, 2013) (Appeadu, M., and Bordoni, B., 2023).

Environmental risk factors that include home and environmental hazards (clutter, poor lighting, etc.), incorrect size, type, or use of assistive devices (walkers, canes, crutches, etc.), and poorly designed public spaces, among others. An international review of literature on "age-friendly" communities by Lui et al. the impact of physical and social environments, including housing and urban planning on health outcomes has been noted (Woo J, Yu R, Leung J, et al., 2017). According to the Office of Disease Prevention and Health Promotion, social determinants of health further impact health as people age in various ways. For instance, lower-income increases the chances of older adults having disabilities earlier in life or dying early. Factors like social isolation, loneliness, and poorly accessible neighborhoods also have a detrimental impact on health- especially among older adults (CDC/ATSDR, 2022), and they directly or indirectly increase the risk of falls among this population. A previous association was established between

falls in older adults with the social relationship index which includes indicators such as living with a spouse/partner, having friends and relatives in their neighborhood, social support, religious service attendance, and formal volunteering. The overall index was associated with a 7% decrease in falls as of 2006 (IRR=0.97, 95% CI=0.95–1.00), wherein, having good friends in the neighborhood reduced the association between depression and falls by 8% (Health.gov, 2023). Another study in Portugal reported a significantly higher risk of falls among the older population with a lower socioeconomic level and lower level of literacy (The Gerontologist, Vol 56, Issue Suppl_3, Pg 366, 20166).

Falls are often caused by an interaction of multiple risk factors listed above. An individual with more risk factors has a higher chance of experiencing a fall. Following the assessment of a person's fall risk, a common way of preventing falls is to reduce or modify/ their risk factors (Office on Women's Health., 2023).

2.5 Social Vulnerability Index

The Social Vulnerability Index is a quantitative indicator of a region's social vulnerability and is traditionally used to describe combinations of social, cultural, economic, political, and institutional processes that shape socioeconomic differentials in the experience of and recovery from hazards. It provides a way to understand how the broader conditions in which people are born, live, work and age can turn an unfortunate event into a major health crisis. SVI has been used in the fields of disaster planning, environmental science, and health sciences. In recent

literature, it has also been used to predict diverse outcomes, such as the rate of COVID-19 infections and mortality (CDC/ATSDR, 2020)(CDC/ATSDR, 2021).

As observed in Table 1, the calculation of SVI is done by considering 16 variables from the American Community Survey data which can be grouped into the four categories of socioeconomic status, household characteristics, racial and ethnic minority, and housing type and transportation. These are considered to be the four these of the SVI and the variables that fall under these categories have been noted in Table 1 (CDC/ATSDR, 2020)(CDC/ATSDR, 2021).

Table 1: Depicts the 16 variables that are included in the calculation for the Social Vulnerability Index and the four themes that they are categorized into.

	Themes of Social Vulnerability Index	**Variables**
1.	Socioeconomic status	1. Below 150% poverty
		2.Unemployed
		3.Housing cost burden
		4.No high school diploma
		5.No health insurance
2.	Household characteristics	6. Aged 65 and older
		7. Aged 17 and younger
		8. Civilian with disability

		9. Single-parent household
		10. English language proficiency
3.	Racial and ethnic minority	11. Hispanic or Latino (of any race); Black or African American, not Hispanic or Latino; Asian, not Hispanic or Latino; American Indian or Alaska Native, not Hispanic or Latino; Native Hawaiian or Pacific Islander, not Hispanic or Latino; Two or more races; not Hispanic or Latino; Other races, not Hispanic or Latino
4.	Housing type and transportation	12. Multi-unit structure
		13. Mobile homes
		14. Crowding
		15. No vehicle
		16. Group quarters

2.6 Social Vulnerability Index and Public Health Outcomes

Notably, it has been previously reported in a study including all age groups across 3,141 counties, that SVI is positively associated with mean age-adjusted rates of unintentional fatal injuries in the United States. This study considered the data between the years 2015 and 2019 and it was observed that regions in the South and West had the highest SVI levels and unintentional injury rates (Wulz et al., 2023).

SVI has also been associated with other aspects of health closely linked to fall risk. A study conducted among 780 older non-Latino Black and Latino adults showed a relation between high

SVI and lower motor dexterity among Latino individuals and a decline in both global cognitive and motor functioning in non-Latino Black individuals (6). One of the first studies to assess the association between SVI and health outcomes in Latin America determined that an increase in SVI was independently associated with incident disability and mortality of its individuals (Spielman, S.E., Tuccillo, J., Folch, D.C. et al., 2020).

According to a report by AARP in 2018, one-third of adults in the United States aged 45 years or above reported feeling lonely- which was measured using the UCLA Loneliness Scale. Some factors that contribute to the perceived social loneliness of an individual include poverty, the size and diversity of a person's social network, being physically isolated, age, depression, and overall health (G. Oscar Anderson, and Thayer, C., 2018). All of these factors significantly impact a person's social vulnerability and it was found that generally, the social circumstances of older U.S. Americans deteriorated from age 60 onwards- as measured by the SVI, with a very mild decline between the age of 50 and 60 years (Abeliansky et al., 2021).

2.7 Preliminary Work

During work done at the Allegheny County Health Department as a part of an internship through Pitt Public Health's Pittsburgh Summer Institute, the demographics of Allegheny County were assessed to determine the high-risk groups for fall-related hospitalizations and deaths following preliminary analysis using the data between the years 2016 and 2020. From this, it was reported that older age corresponded with higher rates of falls and related outcomes, and the age group of 75 years and above had the highest odds of mortality [OR = 3.03 (95% CI 1.82 to 5.06)]

as well as odds of hospitalization [OR = 7.23 (95% CI 7.04 to 7.42)] as compared to those 55 years or below. Race was also noted as a significant risk factor for fall-associated outcomes. While those who self-identified as White had a higher incidence, after adjusting for other variables, those who self-identified as Black had higher odds of fall-related mortality.

Another significant finding of this analysis was the distribution of age-adjusted rates of deaths and hospitalizations caused by injuries due to falls across the various regions of Allegheny County. The county was divided into different regions based on zip codes and these rates were also mapped out using ArcGIS for better visualization of the areas with higher fall-related injuries. Finding these areas was essential as it would provide us with information about where prevention strategies need to be targeted in the County.

Following this analysis of 125 zip codes, the zip codes 15071, 15211, and 15234 had the three highest age-adjusted mortality rates of 0.32, 0.30, and 0.29 per 1000 residents respectively. Whereas, the highest age-adjusted rates for hospitalizations due to fall-related injuries were noted in the zip codes 15014, 15088, and 15112, and were 24.4, 13.4, and 12.1 per 1000 residents respectively.

2.8 Gaps in Knowledge

Social Determinants of Health (SDOH) are the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks. One of Healthy People 2030's goal is to improve health and well-being for older adults- including the prevention of fall-related injuries in

this age group. However, the current status of the associated objective is “getting worse” as the most recent data suggests that there are 78 deaths per 100,000 people due to falls, which is considerably higher than the baseline of 64.4 deaths per 100,000 people in 2018, and the target of 63.4 deaths per 100,000 people aged 65 years and above (Healthy People 2030, 2021). This indicated the need to further understand the impact of various social determinants of health to create effective prevention strategies.

The use of social deprivation indices, such as the SVI, can aid the professionals working towards fall prevention to identify and target communities that require additional interventions to modify social and environmental factors to prevent falls among their residents. The SVI could potentially be utilized to predict falls as well as analyze the upstream factors related to fall-related injuries in different regions. Having a predictive tool for this cause of injury and death could be useful in preventing them over time by creating appropriate intervention strategies (Wulz et al., 2023).

2.9 Public Health Significance

It has been mentioned that until fairly recently, Injury was described as a “neglected disease”. This is because although its occurrence was significantly noticed, injuries were accepted as a normal occurrence of living in modern society. However, according to the 1985 report “Injury in America”, injuries when approached similarly as other diseases of public health significance, would lead to a significant decline in injury rates (Mercy et al., 2007).

Learning about fall-related injuries and finding efficient prevention strategies is significant as a huge proportion of these injuries are preventable. Among hospital inpatients 20-30% falls were estimated to be preventable by assessing the involved risks based on factors like mobility, medication review, neurological factors (Morris, R., and O'Riordan, S., 2017). Effective prevention strategies often aim at creating safer environments and reducing risk factors and may include a range of strategies from installing handrails and improving lighting and visibility, to reducing tripping hazards and exercising regularly to enhance balance. Another reason for concern is that, over the past few years, deaths from falls have increased, with the largest increases occurring among persons aged 85 years and above.

3.0 Objective(s)

The overall aim of this study is to assess whether the Social Vulnerability Index is an accurate predictor of Fall-related outcomes among the aging population (55 years and above) of Allegheny County, Pennsylvania between the years 2016 to 2020.

3.1 Aims and Objectives

As per the results from the preliminary analysis mentioned above, we reported that the age and self-identified race of an individual were significantly associated with fall-related outcomes. It was also noted that certain zip codes - indicating the place of residence, showcased higher rates of fall-related mortality and hospitalizations. The aim of this paper is to further assess the relationship that was previously established between a neighborhood and its fall-related outcomes. For any place, it's social vulnerability encompasses various factors including poverty, access to transportation, and housing, among others that directly or indirectly impact the health of the community living in the region. These social determinants- as represented by the Social Vulnerability Index were analyzed for any correlation to fall-related outcomes to determine if the index can be used as a tool to predict the overall distribution of falls in a region. The objective of this paper was to evaluated the social vulnerability of each neighborhood at the level of census tracts and analyzed these rankings for any association to the fall-associated mortality and hospitalization rates of the region among those aged 55 years and above.

4.0 Methods

4.1 Participant Characteristics and Measures Used

The study includes all older adults residing in Allegheny County aged 55 years or above who have experienced a fall-related injury resulting in either hospitalization or death between the years of 2016 and 2020. This population of interest was derived from prior literature on the topic.

4.2 Data Description

This analysis was conducted using the data made available by the state of Pennsylvania between the years of 2016 and 2020. This time frame of 5 years was selected as ICD-10-CM (International Classification of Diseases, Tenth Revision, Clinical Modification went live in the United States on October 1, 2015, and new codes for unintentional fall-related injuries (W00-W19) were introduced in this (United States Census Bureau, 2022). Starting 2016 till the most recently available data in 2020, all data is uniformly coded using the ICD 10 system. The ages of 55 years and above were studied during the analysis instead on only including those aged 65 years and above to align the findings with the State of Aging report conducted by the University Center for Social and urban Research (UCSUR). This unique approach also allows us to examine not only those age 65 and older- who are known to be significantly associated with falls based on prior literature, but also the next generation of older persons, those aged 55 to 64 years.

Two separate datasets were used for analysis as a part of this project to assess the mortality and hospitalization rates in Allegheny County. The mortality data was sourced from the data provided annually by the Pennsylvania Department of Health through a cooperative agreement. These deaths are reported by funeral homes, medical professionals, coroners, and medical examiners withing four days of the date of death using an Electronic Death Registration System (EDRS) that was established in 2016. The death reports include the cause of death as defined by the International Classification of Disease, Tenth Revision (ICD-10) which acts as a means of categorizing the various causes using an alpha-numeric system and has been set forth by the World Health Organization. The hospitalization data was sourced from the Pennsylvania Health Care Cost Containment Council (PHC4) data reports which is an independent state agency that aims to highlight the cost and quality of healthcare throughout the state. The PHC4 data includes all Pennsylvania general acute care and several specialty general acute care hospitals, covering all adult (18 years and older) inpatient hospital discharges, regardless of the payer. This data is collected quarterly from inpatient hospital discharge and ambulatory/outpatient records from hospitals and freestanding ambulatory surgery centers in Pennsylvania and are then verified by the PHC4. The Allegheny County Health Department receives this dataset annually and filters it for information regarding the county's residents. It utilizes the ICD-10 codes for reporting diagnoses, hospital charges, and treatment information.

Additionally, the Social Vulnerability Index ranking for the region of Pennsylvania was obtained on a census-tract level from the publicly available CDC's 2020 SVI dataset on October 25, 2023 (CDC/ATSDR, 2022). The CDC/ATSDR updates these SVI rankings every two years based on the U.S Census Bureau data releases as the Census releases Community Survey data in December of the after when the survey was conducted (Bureau, U. C. (n.d.)). This index includes

16 variables that have been divided into four themes and can range between 0 and 1- where an increasing value indicates an increased social vulnerability of the region. This dataset contained the overall SVI ranking as well as the SVI ranking by each theme for each census tract. The SVI ranking is expressed as a percentile ranking that represents the proportion of census tracts that are equal to or lower than the tract of interest in terms of social vulnerability.

4.3 Study Design

This cross-sectional, descriptive, and correlational analysis was aimed at examining the association between the social vulnerability of a neighborhood with the rates of fall-related outcomes in these regions. For this study, a neighborhood was defined in terms of a census tract. A census tract typically consists of 1,200 to 8,000 people, and has been defined as ”small, relatively permanent statistical subdivisions of a county or statistically equivalent entity that can be updated by local participants prior to each decennial census as part of the Census Bureau’s Participant Statistical Areas Program (PSAP)”. Using a census tract helped us standardize the different regions of Allegheny County as defined on a national level as these are commonly used to provide a stable set of geographic units for the presentation of statistical data. (Appeadu, M., and Bordoni, B., 2023)

Besides understanding the association with the overall SVI ranking, the study also aimed at determining any association with the individual theme rankings of the SVI. It also explored the descriptive statistics for certain sociodemographic characteristics of the participants- age, sex, and race.

4.4 Predictor Variables

The variables considered for descriptive statistics included the age, sex, and race of the participants. These were determined after a background literature review as well as previous preliminary analysis on the topic that reported that these characteristics were associated with a higher risk of fall-associated outcomes. During the regression analysis where we determined any association between a neighborhood's social vulnerability with fall-related outcomes, the variables used consisted of the SVI rankings (overall and the four themes) along with the rate of mortality and hospitalizations due to falls in each census tract.

4.5 Statistical Analysis and Visualization

For this paper, all statistical analysis, as well as the filtering and cleaning of the data, were performed using the statistical package SAS, version 9.4 (SAS Institute, Inc., Cary, NC) and Microsoft Excel. Data visualization was done using SAS 9.4 and Microsoft Excel.

4.5.1 Filtering and Cleaning the Data

4.5.1.1 Social Vulnerability Index Data

The Social Vulnerability Index used for this analysis had been calculated by the CDC using U.S. Census data to determine the relative social vulnerability of every census tract. It uses 16 variables that have been divided into four themes Socioeconomic status, Household characteristics, Racial and ethnic minority, and Housing type and transportation (14?). This database was

statewide and consisted of 3445 observations with 158 variables and had to be filtered for the census tracts corresponding to the region of Allegheny County to be used for this study. Along with the overall SVI ranking for each census tract, the ranking according to each of the four themes of SVI- Socioeconomic STatus, Household Characteristics, racial and Ethnic minorities, and Housing Type and transportation theme have also been included. (Bureau, U. C. (n.d.)). Allegheny County includes 394 census tracts that were included in the dataset. The American National Standards Institute (ANSI) maintains the Federal Information Processing Series (FIPS) codes and has been used to uniquely identify geographic features by the Census Bureau for over 30 years. Each observation in the SVI dataset was identified by a FIPS code and the census tract had to be identified from this code. A new variable for the Census tract was created from the variable for the FIPS code (CDC/ATSDR, 2020).

4.5.1.2 Mortality Data

The region was determined on a Census tract level for the morality dataset. It consisted of 342 Census tracts that correspond to 125 Zip codes from Allegheny County. A pivot table was created in Microsoft Excel to get the total count of deaths due to falls for each county as well as counts of falls per year. There were 1357 reported cases of deaths due to falls across all age groups in Allegheny County between the years 2016 and 2020. This data is then filtered for only observations with an age of 55 years and any missing values that removed 52 and 12 observations respectively. This resulted in the dataset containing 1291 observations at the start of the analysis.

4.5.1.3 Hospitalization Data

To understand hospitalization rates at a census tract level, crosswalking analysis was performed on the PHC4 dataset- which was originally available on a zip code level, using residential ratios in Microsoft Excel. The rounded-off counts for fall-related hospitalizations obtained for 394 census tracts from this were used for analysis in SAS 9.4. On import, the data was cleaned for missing variables, and the variable types were corrected- resulting in no change in the number of observations. The census tract variable had to be extracted from the variable for the FIPS code provided in the dataset.

4.5.2 Mortality and Hospitalization Analysis

Descriptive statistics were calculated for the demographic variables Age group, Sex, and Race, which determined the proportion of individuals that experienced the outcome, when compared to the total population in the dataset. This was conducted for the total population to indicate the relevance of falls among the older population, as well as for the dataset containing information only on older adults. Doing so helped gauge the trends in mortality and hospitalization in Allegheny County due to fall-related injuries as it reported the proportion of affected individuals within that demographic, as compared to the entire population. These datasets were individually merged with another dataset containing the total population for each census tract to calculate the mortality and hospitalization rates for each region. The descriptive statistics of continuous variables obtained- including the count of fall-related deaths and hospitalizations, fall mortality rates, fall hospitalization rates, and SVI ranking (individually and by each theme) were calculated.

Prevalence rates for mortality and hospitalization data were calculated as well for the demographic variables- age, sex, and race, by calculating the proportion of individuals in the category experiencing that outcome as compared to the total number of individuals in the category. Total counts for the population in each of the demographic were determined using publicly available Census data for the year 2020. (U.S. Census Bureau, 2020).

It is noted that the variance was smaller than the mean for the variables indicating the different SVI rankings. Hence, Negative binomial regression was performed with 5 separate models- each using the rate obtained along with either the overall SVI ranking or the SVI ranking for each theme. This process was done for the hospitalization and mortality rates obtained separately.

4.5.3 Data Visualization

Graphical representation in the form of bar graphs and pie charts were created for the descriptive statistics obtained for demographic characteristics using Microsoft Excel.

5.0 Results

5.1 Descriptive Statistics

5.1.1 Mortality Data

The original dataset consisted of 1357 observations across 342 Census tracts that corresponded to 125 zip codes from Allegheny County. After filtering the dataset for the inclusion criteria (55 years or older) and missing values, it consisted of 1291 observations that were further analyzed. In Figure 2, which compares the dataset containing all age groups to the filtered dataset which only includes those aged 55 years and above, we can observe that the older population comprises a huge proportion of the total cases each year. Subsequently, as observed in Figure 1, we note that 78.62% of the cases were observed in those aged 75 years and above. This was followed by the age groups 65-74 years (13.79%) and 55-64 years (7.59%), however, the biggest burden of fall-related mortality was observed with the age group of 75 years and above. Minimal difference was noted in the proportions of occurrence of fall-related mortality between the sexes with 51.59% of deaths being reported in women and 48.41% in men- as seen in Figure 3. As reported in Figure 4, the highest percentage of falls-related mortality is in those who identified as White (92.64%), which was followed by 5.73% of fall-related deaths in those who identified as Black. This disproportionate trend in falls-related mortality across races remains the same in the total population dataset containing all age groups as compared to the dataset with only older adults, as seen in Figure 5.

For the mortality data, within Allegheny County between the years 2016-2020, 10.7 per 10,000 males and 10.7 per 10,000 females died due to a fall-related injury. Between the age groups targeted by this analysis, 100 per 10,000 individuals aged 75 years and above, 13.9 per 10,000 individuals between 64-75 years, and 5.6 per 10,000 individuals aged between 55-64 years experienced fall-related deaths. Fall-associated mortality was experienced by 12.5 per 10,000 individuals identifying as White, 4.7 per 10,000 individuals identifying as Black, 3.1 per 10,000 individuals identifying as Asian/PI, and 5.2 per 10,000 individuals belonging to other racial identities.

The highest number of total fall-associated mortality over the 5 years was observed in the census tracts 473601, 563800, 474202, and 473300 with 19 deaths being recorded in 473601, and 14 deaths recorded in the other three regions. However, the rate of incidence of fall-related mortality was recorded to be the highest in the census tracts of 459202, 497000, and 485000 with fall mortality rates of 0.019, 0.011, and 0.007 respectively. These census tracts had 14, 11, and 9 deaths and a population of 720, 1022, and 1212 respectively.

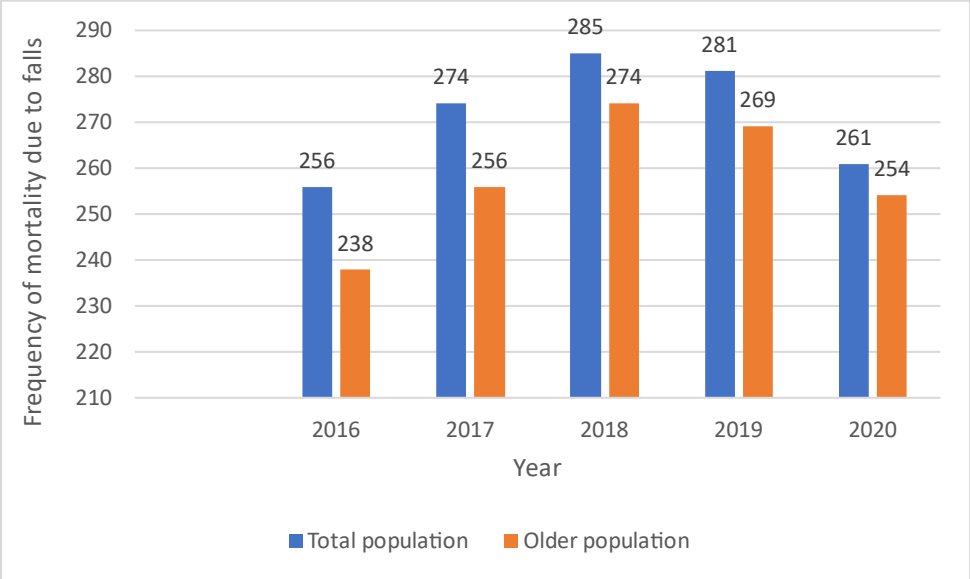

Figure 1: The graph above shows the trends of fall-associated mortality over the years and compares the frequency of deaths between the dataset before and after filtering it for missing values and inclusion criteria.

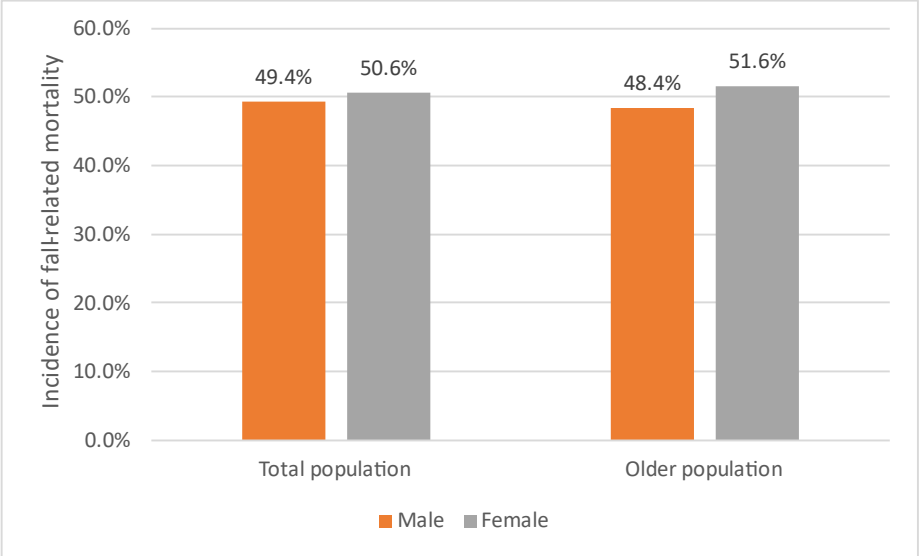

Figure 2: Percent of fall-related mortality cases reported in males and females between the years 2016 and 2020 in the original dataset as well as the filtered dataset.

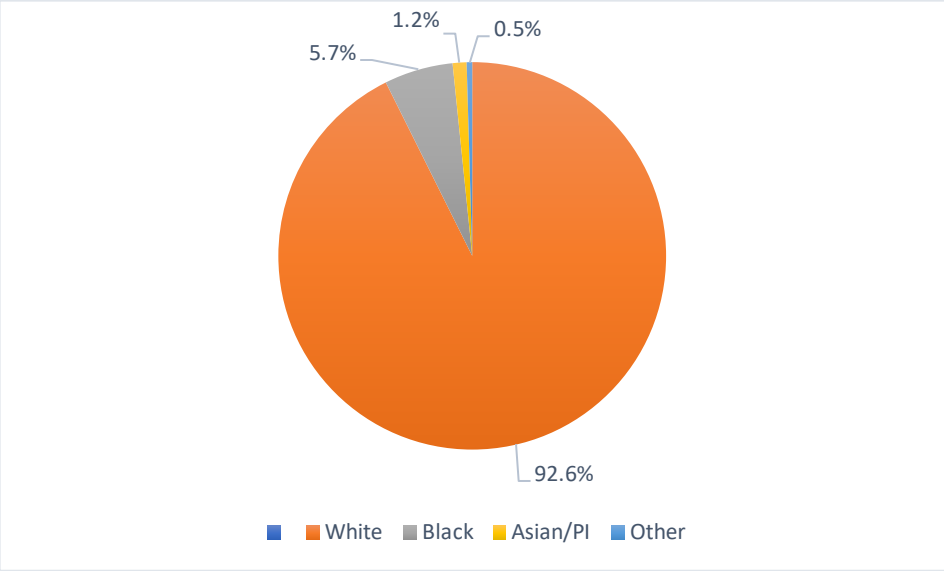

Figure 3: Percent of fall-related mortality across the reported categories of race- White, Black, Asian/PI, and Other between the years of 2016 and 2020 in the ages of 55 years and above.

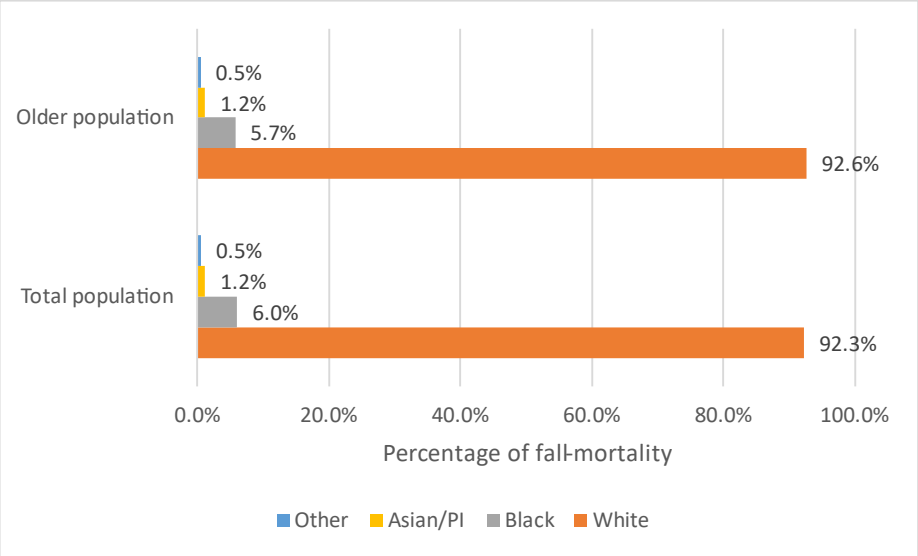

Figure 4: Percent of fall-related mortality across the reported categories of race- White, Black, Asian/PI, and Other between the years of 2016 and 2020 in the original and the filtered datasets.

5.1.2 Hospitalization Data

The original dataset for hospitalizations in Allegheny County consisted of 252,333 observations across 125 Zip codes. After filtering the dataset for the inclusion criteria (55 years or older) and missing values, it consisted of 145,390 observations that were further analyzed. In Figure 6, we note that 40.2% of the cases were observed in those aged 75 years and above. This was followed by the age group 65-74 years (31.3%) and 55-64 years (28.5%). The burden of fall-related hospitalization was observed to fall equally within the groups. Minimal difference was noted in the proportion of fall-related mortality occurring between the sexes with 53.2% of deaths being reported in women and 46.8% in men- as seen in Figure 7. As reported in Figure 8, the proportion of falls-related hospitalization is the highest in those who identified as White (77.4%), which was followed by 18.7% in those who identified as Black. This disproportionate trend in falls-related mortality across races remains the same in the total dataset containing all age groups as compared to the dataset with only older adults, as seen in Figure 9.

For the hospitalization data, within Allegheny County between the years 2016-2020, 106.7 per 10,000 males and 131.9 per 10,000 females were hospitalized due to a fall-related injury. Between the age groups targeted by this analysis, 710.6 per 10,000 individuals aged 75 years and above, 235.9 per 10,000 individuals between 64-75 years, and 122.5 per 10,000 individuals aged between 55-64 years experienced fall-related injuries leading to hospitalization. Lastly, fall-associated hospitalization was experienced by 126.3 per 10,000 individuals identifying as White, 115.1 per 10,000 individuals identifying as Black, and 100.4 per 10,000 individuals belonging to other racial identities.

The census tracts with the highest percentage of hospitalizations due to fall-related injuries over the 5 years include 487,000, 281400, 101400, and 492900 with 99 hospitalizations reported for the first three census tracts and 98 cases reported in the last census tract. The census tracts recorded with the highest fall-associated rates of hospitalization between 2016 and 2020 are 980600, 562700, and 476100 with a rate of 0.28571, 0.13469, and 0.12483 respectively. These census tracts had 2, 252, and 640 falls each in a population of 7, 1871, and 5127 respectively.

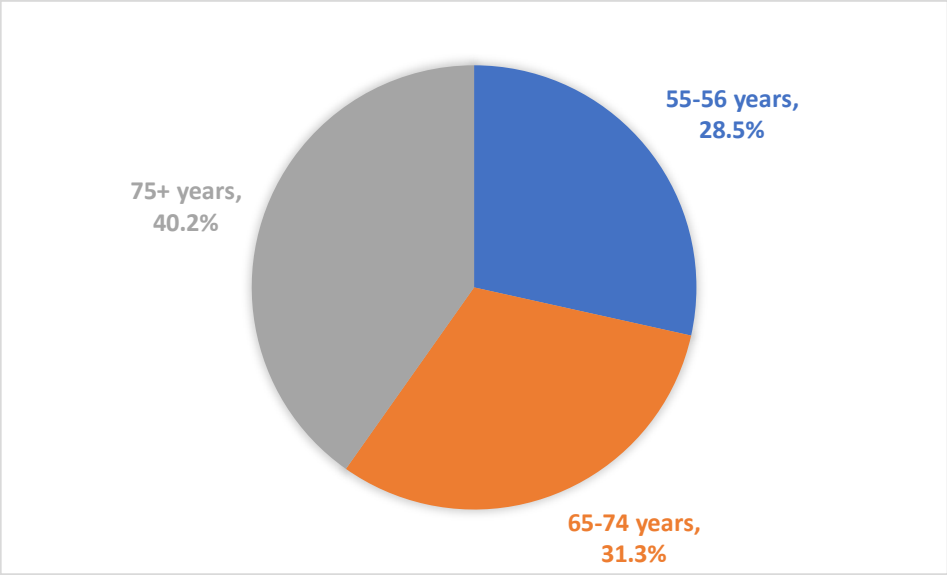

Figure 5: The graph shows the distribution of fall-related hospitalization among the age group 55-64 years, 65-74 years, and 75 years and above.

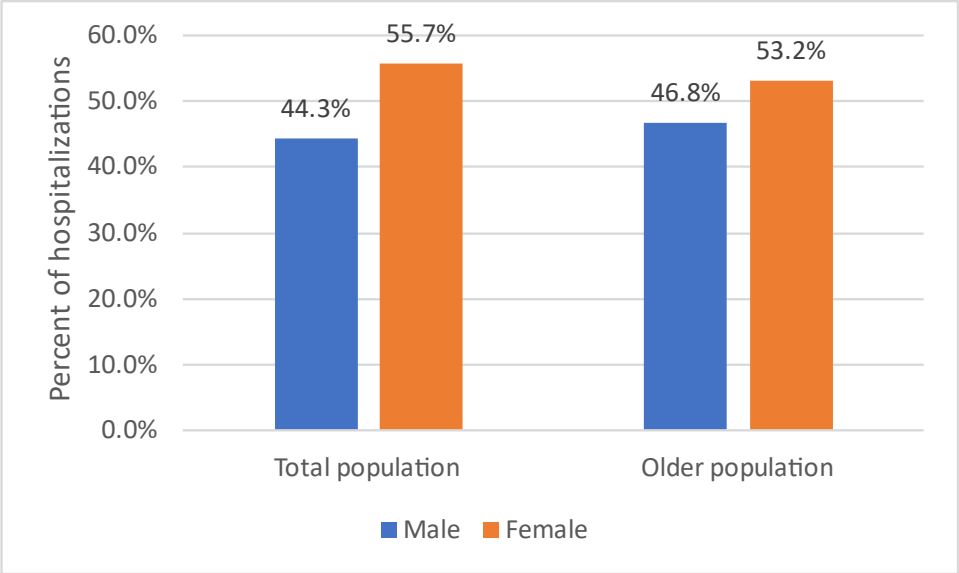

Figure 6: Percent of fall-related hospitalization cases reported in males and females between the years 2016 and 2020 in the original dataset as well as the filtered dataset.

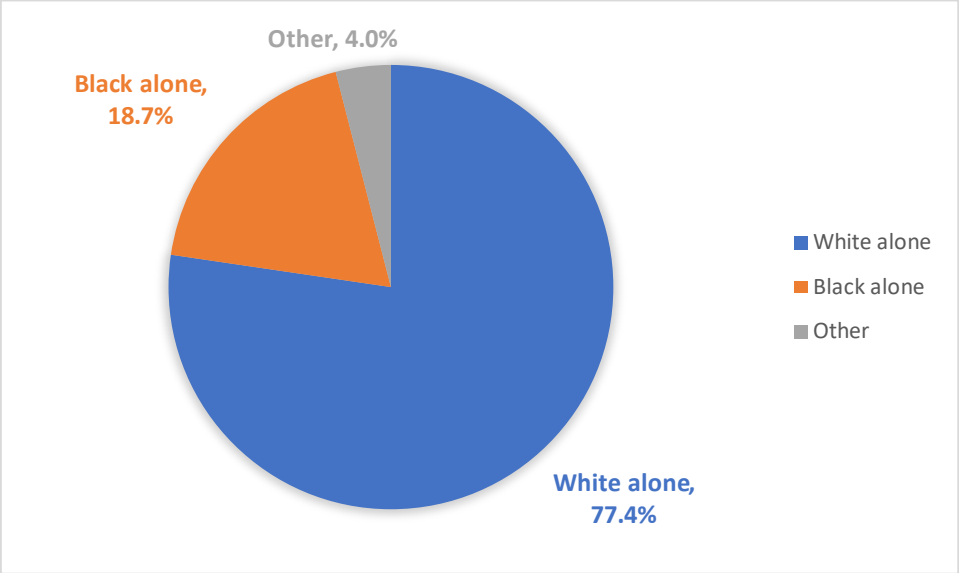

Figure 7: Percent of fall-related hospitalization across the reported categories of race- White, Black, and Other between the years of 2016 and 2020 in the ages of 55 years and above.

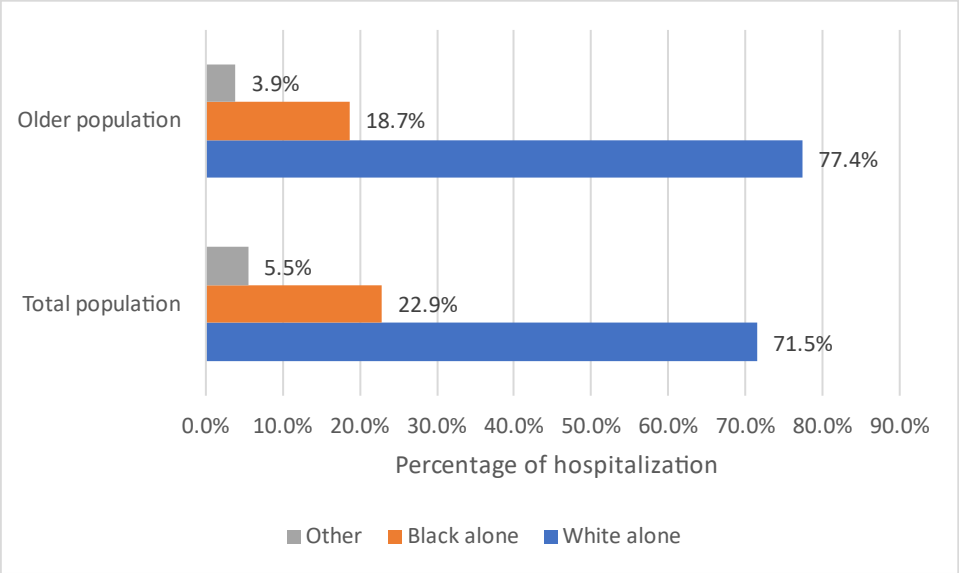

Figure 8: Percent of fall-related hospitalization across the reported categories of race- White, Black, and Other between the years of 2016 and 2020 in the original and the filtered datasets.

5.1.3 Continuous Data

Descriptive statistics were also obtained for the continuous variables relating to population statistics and SVI rankings. The mean number of fall-related deaths in the census tracts was 3.8 and the mean mortality rate was 0.0014. As of 2020, the mean overall SVI ranking for all the census tracts is 0.4271 (SD = 0.2909) indicating that on average 42% of census tracts in Pennsylvania are less vulnerable than the census tracts studied here. The mean SVI rankings of theme 1(socioeconomic status), theme 2 (household characteristics), theme3 (racial and ethnic minority), and theme 4 (housing type and transportation) were 0.4275 (SD = 0.2964), 0.4258 (SD = 0.3034), 0.5407 (SD = 0.2572), and 0.4550 (SD = 0.2908) respectively. On creating a histogram of the SVI rankings, all of the five categories did not have a normal distribution.

Table 2: Total count, mean, standard deviation, minimum value, and maximum value of all continuous variables used during the analysis for mortality and hospitalization data.

Descriptive statistics were obtained using the MEANS procedure.

Variable	N (Total number of observations)	Mean	Standard deviation	Minimum	Maximum
Mortality data					
Total count	339	3.808	2.858	1.000	19.000
Mortality rate	339	0.001	0.002	0.000	0.019
Hospitalization data					
Total count-hospitalizations	366	136.951	83.112	0	640.000
Hospitalization rate	357	0.046	0.022	0	0.286
SVI data					
Over all SVI ranking	380	0.427	0.291	0.000	0.999
SVI theme 1 ranking	381	0.427	0.296	0.000	0.996
SVI theme 2 ranking	383	0.426	0.303	0.000	0.999
SVI theme 3 ranking	385	0.541	0.257	0	0.996

SVI theme 4 ranking	382	0.455	0.291	0	0.997

5.2 Regression Analysis

5.2.1 Mortality Data Analysis

The Analysis of maximum likelihood parameter estimates yielded a non-significant estimate for the overall SVI ranking of 0.5276 (95% CI -9.7911 to 10.8463) with a p-value of 0.9202. For all of these regression models, the negative binomial dispersion parameter was estimated by maximum likelihood. These estimates for the four themes of SVI were 0.8459 (p-value = 0.8677), -0.1717 (p-value = 0.9737), 0.6554 (p-value = 0.9121), and 0.1601 (p-value = 0.9765) for theme 1 (socioeconomic status), theme 2 (household characteristics), theme3 (racial and ethnic minority), and theme 4 (housing type and transportation) respectively. Fall-related mortality shows a positive association with all of the themes of SVI, besides theme 2- with which it shows a negative association. However, all of these were found to be not significant as seen in Table 3.

5.2.2 Hospitalization Data Analysis

Similarly, for the hospitalization models, the Analysis of maximum likelihood parameter estimates yielded a non-significant estimate of 0.3196 (95% CI -1.3880 to 2.0272) with a p-value of 0.7138 when determining the association between fall hospitalization rates and overall SVI

ranking. For all of these regression models, the negative binomial dispersion parameter was estimated by maximum likelihood. These estimates were for the four themes of SVI were 0.2729 (p-value = 0.7506), 0.2232 (p-value = 0.7853), 0.0258 (p-value = 0.9789), and 0.0260 (p-value = 0.9757) for theme 1(socioeconomic status), theme 2 (household characteristics), theme3 (racial and ethnic minority), and theme 4 (housing type and transportation) respectively. Fall-related mortality shows a positive association with all of the themes of SVI, however, as observed in Table 3 all of these were found to be not significant.

Table 3: Results of the association of rates of fall-related mortality and hospitalization with SVI- overall and four themes for the ages of 55 years and above between the years 2016 and 2020 in Allegheny County, Pennsylvania.

Parameter	**Analysis of Maximum Likelihood Parameter Estimates**					
Mortality data analysis						
	Estimate	**Standard Error**	**Wald 95% Confidence limits**		**Wald Chi-Square**	**Pr>ChiSq**
Overall SVI ranking	0.528	5.265	-9.791	10.846	0.01	0.920
SVI theme 1 ranking	0.846	5.080	-9.111	10.803	0.03	0.868
SVI theme 2 ranking	-0.172	5.203	-10.370	10.026	0.00	0.974
SVI theme 3 ranking	0.655	5.937	-10.981	12.292	0.01	0.912
SVI theme 4 ranking	0.160	5.440	-10.503	10.823	0.00	0.977
Hospitalization data analysis						

Table 3: Results of the association of rates of fall-related mortality and hospitalization with SVI- overall and four themes for the ages of 55 years and above between the years 2016 and 2020 in Allegheny County, Pennsylvania. (continued)

Overall SVI ranking	0.320	0.871	-1.388	2.027	0.13	0.714
SVI theme 1 ranking	0.273	0.858	-1.410	1.955	0.10	0.751
SVI theme 2 ranking	0.223	0.819	-1.383	1.829	0.07	0.785
SVI theme 3 ranking	0.026	0.976	-1.887	-1.887	0.00	0.979
SVI theme 4 ranking	0.026	0.854	-1.648	1.700	0.00	0.976

5.3 Key Findings

Significant results from the descriptive statistics include the variables Age and Race. The proportion of individuals being hospitalized in the county for fall-related injuries between the age groups 55-64 years, 65-74 years, and 75 years and above as compared to the total number of people in the sample (28.48%, 31.20%, and 40.22% respectively), whereas the proportion of fall-related mortality in the three age groups is 7.59%, 13.79%, and 78.62% respectively. For the variable Race, the highest proportion of both fall-related hospitalization and mortality is the highest among those who identify as White (92.64% and 77.39%).

6.0 Discussion

6.1 Important Results and Trends

6.1.1 Descriptive Data Analysis

Significant trends were observed in the descriptive statistics of the demographic characteristics in relation to mortality and hospitalization data- especially for the variables of Age and Race.

Although it has been previously determined that older age groups have a higher chance of experiencing fall-associated outcomes due to an increase in the risk factors, the trends observed between the proportion of fall-related mortalities and hospitalizations between the age groups are noticeable. While a similar proportion of individuals are being hospitalized in the county for fall-related injuries between the age groups 55-64 years, 65-74 years, and 75 years and above (28.48%, 31.20%, and 40.22% respectively), the percentage of fall-related mortality is considerably higher in the age group of 75 years and above as compared to the other groups (78.62% versus 13.79%, 7.59%).

From the prevalence determined above, fall-related mortality similarly impacts both males and females- 10.7 per 10,000 individuals in each category. However, fall-related hospitalizations are more prevalent among females than males- 131.9 per 10,000 females compared to 106.7 per 10,000 males. The age group of those aged 75 years and above had the highest prevalence for fall related deaths and hospitalizations- 100 and 710.6 per 10,000 individuals in this age group

respectively. Those who identify as White experienced the highest prevalence of fall-related mortality and hospitalizations among the racial identities considered during the analysis- 12.5 and 126.3 of 10,000 White people.

As noted here, fall-associated mortality and hospitalizations are considerably higher among those who identify as White. However, as noted from results during the preliminary analysis, the odds ratio for fall-related mortality was higher in those who identify as Black when compared to individuals who are White. This indicates the potential of association between the variable race and fall-related outcomes.

6.1.2 Regression Data Analysis

As noted in the results above, the negative binomial regression models for both the mortality and hospitalization data yielded results that were not significant. This indicates that the association of the Social Vulnerability Index with fall-related deaths or hospitalizations is not significant given this data and that SVI cannot be used as an accurate predictor of fall-associated outcomes in a neighborhood.

The association between race-- as represented by SVI theme 3, and fall-related outcomes was not significant in this sample. These results were unexpected from what was theorized above based on preliminary analysis and descriptive statistics.

6.2 Strengths and Limitations

This analysis is novel in the field as it aims to determine the possibility of a pre-existing index being used as a predictor variable for falls among this high-risk population. Having a cross-sectional design provides a quick overview of the population-level risk of experiencing fall-associated mortality and hospitalization among the older adults in Allegheny County. A huge strength of this analysis was that publicly available data was used and no resources or time were spent in collecting data. The presence of complete study populations minimizes the presence of selection or attrition bias in the sampling. Using this type of data is also beneficial as this large dataset is collected independently of any research questions and is devoid of any differential misclassification.

One limitation of this study is the inability to determine the fall-associated mortality and hospitalization among the various racial groups that are characteristic of the general population in Allegheny County. According to Census.gov in 2020, the residential population of Allegheny County is made up of other racial groups such as Asian alone(4.5%), Hispanic or Latino (2.5%), American Indian and Alaska Native alone (0.2%), and Two or more races (2.6%), besides the racial groups White alone (79.1%) and Black alone(13.5%) (US Census Bureau, 2023), These racial groups were not included in the data here and a majority of them had to be grouped together to form a category called “Other” due to a lack of sufficient sample size. This does not allow us to understand the impact of fall-associated outcomes on these communities.

6.3 Implications for Future Research and Next Steps

According to the results obtained here, combined with those from the preliminary analysis conducted, it would be helpful to look into any association between SVI and racial disparities in the census tracts of Allegheny County, and how these correspond to fall rates in the region. In addition, considering that this analysis was done solely for the population for Allegheny County, it would be beneficial to conduct similar analysis for different populations. These could include regions with a large proportion of older residents or areas with high rates of falls. Instead of using different populations, specific social determinants of health- for instance, accessibility, can be identified and examined further for their association to falls. This study also aimed to demonstrate a correlation between SVI and fall-associated outcomes. Alternatively, studies could be conducted that aim to establish causality between the two. This can aid in the identification of modifiable risk factors, intervening on which can be effective in reducing rates of falls in the region.

The findings from this analysis can further be used to implement surveillance systems among the older population- this includes institutes such as long-term care facilities. This would allow the study of fall-associated risk factors and outcomes among the target population, providing with results that are more accurate for this specific group of individuals.

The public health significance of these findings is that they can be used as a foundation to examine associations between fall-related outcomes and relevant social determinants of health among different populations to help identify communities that require additional targeted interventions for reducing falls.

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