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Risk Factors of Fall Occurrence and Frequency Among Elderly South Koreans

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Abstract

Background: Falls among the elderly represent a significant public health challenge, substantially impacting morbidity, mortality, and healthcare expenditures. This study aims to provide a comprehensive understanding of fall patterns and associated risk factors among the elderly population in South Korea. **Methods:** Data from the 2021 Korean Community Health Survey, including 71,734 participants aged 65 and older, were analyzed using a zero-inflated negative binomial (ZINB) regression model to simultaneously model the occurrence and frequency of falls. **Results:** Approximately 16.73% of participants experienced at least one fall-related injury in the past year. Advancing age (1.7% for each one-year increase), male (19.2% versus female), no formal education (11% to 19% versus elementary to junior high school graduate), poverty (23.8%), poor (86.2%) or fair (17.0%) self-rated health, diabetes mellitus (29.7%), underweight (17.7%), and obese (13.6%) were significantly associated with higher incidence rate of recurrent falls. **Conclusions:** This study highlights the complex interplay of sociodemographic and health-related factors in fall risk among the elderly. The findings underscore the importance of multifaceted fall prevention strategies that consider both individual and societal factors, particularly targeting high-risk groups such as the oldest old, those with lower socioeconomic status, and individuals with chronic diseases.

Keywords : Elderly, Falls, Risk factors, Zero-inflated negative binomial regression, South Korea

JEL Classification Code: I10, J14, C35, D91

1. Introduction

Falls are a major public health problem and a leading cause of serious injury and death among the elderly population. An estimated one in three adults over the age of 65 falls every year (Bergen, 2016). Falls among the elderly population contribute to morbidity, mortality, emergency department visits, hospitalization, and early admission to long-term care facilities, which may result in 'post-fall syndrome,' comprising dependence, loss of autonomy, confusion, immobilization, and depression (Yoshida, 2007).

A recent study highlighted a substantial increase in the annual medical costs associated with falls among adults aged 65 and older. In 2020, the total medical expenditure for non-fatal fall injuries in this age group reached approximately $80 billion annually, marking a significant rise from $50 billion in 2015 (Haddad et al., 2024). Furthermore, research suggests that fall-related injuries among older adults contribute to 6.0% of total Medicare spending, underscoring the substantial fiscal impact of falls on the Medicare system (Hoffman et al., 2022).

In South Korea, the situation is similarly concerning. In 2017, medical expenses related to falls among adults aged 65 and older exceeded approximately $4.3 billion, accounting for almost 25% of the total medical expenses for this age group (Lee, 2023). These findings emphasize the critical need for fall prevention strategies and policies aimed at mitigating the healthcare burden associated with falls in the older adult population.

Although many studies have focused on the incidence of falls, it is essential to recognize the elevated risks associated with recurrent falls in the elderly. Recurrent falls, commonly characterized as multiple fall events within a defined time window, frequently signal underlying health complications, diminished functional capacity, or ongoing environmental risk factors. These factors may not be fully captured in studies that focus solely on single-fall incidents (Jehu et al., 2021).

The impact of recurrent falls extends beyond immediate physical injuries. Elderly experiencing multiple falls are at higher risk of developing fear of falling, leading to self-imposed activity restriction, reduced social participation, and accelerated functional decline. This cycle of fear and inactivity can significantly diminish quality of life and increase the likelihood of future falls, creating a vicious circle (Choi et al., 2023). Moreover, individuals who experience recurrent falls often require more intensive medical interventions, longer hospital stays, and are more likely to require nursing home care compared to those who experience single falls. This dual impact exacerbates both the personal burden on individuals and the economic strain on healthcare systems (De Vries et al., 2010). Despite the clear significance of recurrent falls, most fall prevention strategies and interventions are designed based on studies that do not differentiate between single and recurrent falls. This approach may not fully address the risk factors and intervention needs specific to recurrent falls (Fletcher & Hirdes, 2002; Gaßmann et al., 2009).

A recent study on recurrent falls among the general elderly population in South Korea, published in 2020, utilized large-scale, nationally representative data from the 2015 Community Health Survey (Jo et al., 2020). From a methodological perspective, the prior study employed multinomial logistic regression to model recurrent falls. However, this approach may not be optimal for data with excessive zero values and overdispersion as is common in falls data from the general population, as it is inadequate in addressing these issues. In cases of high data variance, the model's applicability may be limited. Furthermore, the estimation results are under the assumption that the three categories—no falls, single falls, and recurrent falls—are independent and follow identical probability distributions. If these assumptions are not met, the results could potentially be misleading. This methodological limitation underscores the need for more advanced analytical approaches that can better account for the nature of fall data, particularly in the context of recurrent falls.

By employing a zero-inflated negative binomial (ZINB) model, this study aims to address this gap by analyzing not only the occurrence of falls but also their frequency. The ZINB model reflects the distinct data generation processes, allowing for simultaneous modeling of both the occurrence and frequency of falls. Unlike multinomial logistic regression, the ZINB model is not constrained by assumptions of independence between categories or identical probability distributions. Moreover, multiple studies have demonstrated that the ZINB model provides a better model fit for datasets characterized by overdispersion and excessive zero values, which are common features in fall data (Fernandez & Vatcheva, 2022; Yusuf, Bello, & Gureje, 2017).

This study aims to provide a comprehensive understanding of fall patterns and associated risk factors among the elderly general population of South Korea by simultaneously modeling the occurrence and frequency of falls.

2. Literature Review

The multifactorial model of falls provides a comprehensive framework for understanding the complex nature of falls in the elderly population (Tinetti et al., 1988). While this model was not explicitly designed to address

recurrent falls, it has been widely applied in studies examining both single and recurrent falls. This model posits that falls result from the interaction of multiple risk factors, both intrinsic and extrinsic to the individual. The model emphasizes that no single factor typically causes a fall; rather, it is the cumulative effect of various factors that increases the likelihood of a fall occurring. According to this model, fall risk factors can be categorized into two main groups: intrinsic and extrinsic factors. Intrinsic factors are individual-specific characteristics and include demographic factors such as age and sex; physical factors like balance, gait ability, mobility, and muscle strength; sensory factors including visual impairment and peripheral sensory loss; health conditions such as cognitive function, pain, depression, orthostatic hypotension, arthritis, stroke, and Parkinson's disease history; and medication use. Extrinsic factors, on the other hand, are environmental hazards and include slippery surfaces, poor lighting, uneven terrain, and obstacles in walkways.

Recent international studies have focused on identifying multifaceted risk factors specifically for recurrent falls, defined as two or more falls within a specified period. These studies have highlighted additional risk factors for recurrent falls, including living alone, marital status, gait problems, vision issues, cardiovascular diseases, blood pressure fluctuations, fear of falling, and decreased physical function (Appeadu & Bordoni, 2023; Dai et al., 2018; Jehu et al., 2020).

While research on falls among elderly Koreans has been growing, studies specifically focusing on recurrent falls remain limited. Notable findings from Korean studies include a study using the Resident Assessment Instrument-Home Care (RAI-HC) which found that over a 90-day period, 55.7% of participants experienced a single fall, while 44.2% had recurrent falls (Yoo, 2011). Another study reported that among elderly Koreans who experienced a fall, 29.1% had a recurrent fall within one year (Park et al., 2008).

3. Methodology

3.1. Data and Study Participants

The present study utilized the data from the 2021 Korean Community Health Survey (KCHS). The KCHS is a nationwide health interview survey carried out by regional public health centers across South Korea to estimate patterns of disease prevalence and morbidity, as well as to understand the personal lifestyles and health behavior of adults aged ≥ 19 years. The KCHS has been conducted annually since 2008 by trained interviewers engaging in face-to-face interviews with participants. A complex, stratified, multistage, probability-cluster sampling method based on resident registration information was used. Approximately 90 sampling units were randomly selected from the total sampling units of each community, with 5–8 households selected from each primary sampling unit, yielding an average of 900 subjects aged 19 or older from each community. This study included a total of 71,734 participants, after excluding respondents who were younger than 65 years of age and those with missing data in outcome or covariates. The KCHS is a national public database, which is openly accessible at http://chs.cdc.go.kr. There are no confidentiality risks to the participants of this study because the survey data are anonymized (National Statistics Approval No. 117075).

3.2. Variables and Measurements

The outcome variable, which was frequency of fall-related injuries, was assessed using the question, "Did you experience a fall (slipping, tripping, or mis-stepping) that resulted in an injury this year?" If the respondent answered 'no,' it was recorded as zero count. If the respondent answered 'yes,' they were asked the additional question, "How many times have you experienced a fall-related injury this year?" and the frequency of fall-related injuries experienced was recorded.

To account for the effects of potential confounders and evaluate the association with falls and recurrent falls, we included sociodemographic and health-related covariates in the study model based on a multifactorial model of fall (Abreu et al., 2016; D. Jehu et al., 2021; Stubbs et al., 2014; Tinetti et al., 1988).

Sociodemographic variables included age, sex, educational attainment, recipient of benefits from the National Basic Livelihood Security Act (NBLSA) and marital status. Age was treated as a continuous variable. Educational attainment was categorized into five levels: no formal education, elementary school, junior high school, senior high school, and college or higher. The NBLSA was enacted in 2000 to ensure the minimum standard of living for deprived households with less than a designated minimum cost of living per month. The receipt of benefits from the NBLSA is frequently considered as a proxy measure of poverty in South Korea (Choi & Lee, 2010). Therefore, we categorized our study population as 'recipients' or 'non-recipients' of benefits from the NBLSA. Marital status was categorized as married (living with a spouse) or others (separated, divorced, widowed, or never married).

To describe the health-related characteristics of the participants, smoking, alcohol consumption, body mass index (BMI), chronic diseases, perceived stress, and self-rated health were considered. Smoking status was determined by three categories: never smoker (individuals

who had smoked fewer than 100 cigarettes in their lifetime), former smoker (smoked in the past but currently quitted), and current smoker (Park et al., 2019). Alcohol consumption was classified into “non-drinker”, “drinker”, and “high-risk drinker”. High-risk alcohol consumption was characterized as the intake of seven or more standard drinks for males, or five or more for females, in a single sitting, occurring at a frequency of twice or more per week over the preceding 12-month period (Kim & Park, 2021). BMI was defined as “underweight (<18.5)”, “normal (18.5-22.9)”, “pre-obesity (23.0-24.9)”, and “obesity (≥25)” according to the 2022 Update of Clinical Practice Guidelines for Obesity by the Korean Society for the Study of Obesity (Kim et al., 2023). To assess chronic diseases, we identified patients with physician-diagnosed chronic conditions or those currently receiving treatment for hypertension and diabetes mellitus, using the KCHS database. Participants were classified as having a chronic disease if they had been diagnosed with hypertension, diabetes, or both conditions. The stress level was assessed with the question, “Do you feel stressed in daily life?” Based on the response, stress levels were dichotomized into low (none or some stress) or high (high or very high stress) level of stress. Self-rated health status was evaluated using the question, 'How would you assess your overall health?' Responses were rated on a scale from 1 to 5, ranging from 'very good' to 'very poor,' and were categorized into three groups: good health (1-2), fair health (3), and poor health (4-5).

3.3. Statistical Analysis

Statistical procedures were conducted that account for the complex sampling design of the KCHS, including stratification, clustering, and sampling weights, to ensure nationally representative estimates. A series of descriptive analyses were conducted to summarize the sample characteristics. Sample frequency and weighted proportion for categorical variables, as well as sampling weighted mean and 95% confidence intervals (CIs) for continuous variables, were reported as summary statistics. Rao-Scott corrected chi-squared analysis was conducted for categorical variables, and univariable negative binomial regression was used for continuous variables to compare the unadjusted relationship among study participants regarding the experience of fall injury.

A negative binomial (NB) model is known to perform better than a Poisson model when modeling count data that is over-dispersed (Byers et al., 2003). Given that the frequency of fall injuries is count data and that the variance exceeds the mean, a NB model is more suitable than a Poisson model. In the present study, the frequency of fall injuries was zero-inflated because approximately 80% of participants responded 'no' regarding fall injuries (Figure 1). However, when there is a predominance of zeros in the data, ordinary count models are prone to bias and may yield invalid results (Heilbron, 1994). For this reason, the zero-inflated negative binomial (ZINB) regression model was utilized to enhance statistical robustness. The Vuong test was conducted to compare the ZINB model with the ordinary NB regression model (Vuong, 1989). Additionally, a likelihood ratio test (LRT) for over-dispersion was performed to compare the ZINB model with the zero-inflated Poisson (ZIP) model.

The variance inflation factor was assessed to determine the impact of multicollinearity in the study model. The robust standard errors (SE) for the coefficients were calculated to adjust for heterogeneity. The software package Stata/MP 17.0 (StataCorp, College Station, TX, USA) was used for statistical analysis, and the threshold for significance was set at 0.05 (two-tailed).

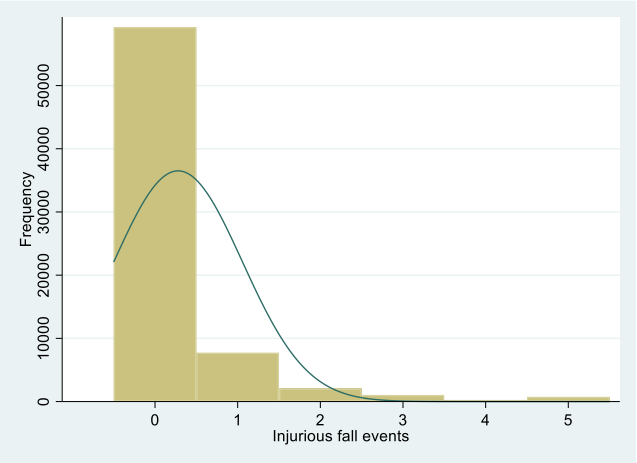

Figure 1: Zero-inflated Distribution of Fall Injuries among Study Population

4. Results

4.1. General Characteristics of Study Participants

Of the 71,314 participants, 59,235 (83.27%) did not experience an injury from a fall in the last year; 7,751 (10.90%) had experienced a fall injury once, and 4,148 (5.83%) had experienced a fall injury multiple times. The mean age was 73.8 years, ranging from 65 to 108 years. The frequency of fall injury was significantly associated with all the covariates. Being older, female, having no formal education, being a recipient of benefits from the NBLSA, not currently married, having chronic diseases, experiencing high perceived stress, and having poor self-rated health were associated with fall injury ($p < 0.001$) (Table 1).

4.2. Factors Associated with Frequency of Fall Injury Among the Elderly

Table 2 summarizes the results of the ZINB regression model, which is composed of two parts: the logistic regression to estimate the odds ratios of not experiencing fall injury (zero-count) compared with experiencing fall injury at least once (non-zero count). The negative binomial regression is used to model the frequency of fall injury for those who experienced fall injury at least once (non-zero count). A significant LRT (Chi^2 = 1.2e+04; $p < 0.001$) suggested that the data were over-dispersed; thus, a ZINB model is preferred over a ZIP model. The Vuong test was conducted, and a significant z-test indicated that the ZINB model was preferred (z = 12.15; $p < 0.001$) compared to ordinary NB models. The variance inflation factor statistics for each of the variables in the models were a maximum of 2.59, which was lower than the cut-off threshold of 10, indicating the absence of significant multicollinearity.

The result from the logistic regression model that evaluates the likelihood of falls showed that for each one-year increase in age, the odds of experiencing a fall injury increased by 3.0% (OR = 0.970; $p = 0.002$; 95% CI = 0.951 to 0.989). Participants who reported poor self-rated health had 51.2% higher odds of experiencing a fall injury compared to those who reported good self-rated health (OR = 0.488; p < 0.001; 95% CI = 0.319 to 0.746).

The results from the NB regression component of the ZINB model revealed the following associations with recurrent falls: For each one-year increase in age, the incidence rate of recurrent falls increased by 1.7% (IRR = 1.017; p < 0.001; 95% CI = 1.010 to 1.024). Females had a 19.2% lower incidence rate of recurrent falls compared to males (IRR = 0.808; p = 0.004; 95% CI = 0.698 to 0.935). Regarding education levels, compared to those with no formal education, individuals with higher education levels generally showed lower incidence rates of recurrent falls, ranging from 11% to 19% lower, except for those with college degrees (elementary school IRR = 0.894; p = 0.014; 95% CI = 0.819 to 0.977) (junior high school IRR = 0.888; p = 0.045; 95% CI = 0.790 to 0.997) (senior high school IRR = 0.809; p < 0.001; 95% CI = 0.718 to 0.910). Recipients of benefits from the NBLSA had a 23.8% higher incidence rate of recurrent falls (IRR = 1.238; p < 0.001; 95% CI = 1.115 to 1.374). For BMI, compared to those with normal weight, obese individuals had a 13.6% higher incidence rate of recurrent falls (IRR = 1.136; p = 0.003; 95% CI = 1.043 to 1.237), while underweight individuals had a 17.7% higher incidence rate (IRR = 1.177; p = 0.044; 95% CI = 1.004 to 1.380). Individuals with diabetes had a 29.7% higher incidence rate of recurrent falls compared to those without diabetes (IRR = 1.297; p < 0.001; 95% CI = 1.124 to 1.496). In terms of self-rated health status, compared to those who reported "good" health, individuals who reported "fair" health had a 17.0% higher incidence rate of recurrent falls (IRR = 1.170; p = 0.024; 95% CI = 1.021 to 1.342), while those who reported "poor" health had an 86.2% higher incidence rate (IRR = 1.862; p < 0.001; 95% CI = 1.544 to 2.246).

5. Discussions

5.1. Summary

This study advances the methodology in fall risk research among the elderly in South Korea by employing a ZINB model, overcoming limitations of previous multinomial logistic regression approaches. By analyzing the 2021 KCHS data, it provides more comprehensive and recent insights into fall occurrence and frequency. This approach not only addresses gaps in existing literature but also offers several original contributions: it provides more valid estimates of risk factors, reflects current health status and living conditions of the elderly population, comprehensively analyzes various risk factors, and contributes to the development of targeted fall prevention strategies. The findings of this study have significant implications for public health policies addressing fall risks in South Korea's aging society.

Our findings reveal that advancing age, lower education levels, poverty, unmarried status, poor self-rated health, chronic diseases, and BMI extremes (both underweight and obesity) were significantly associated with increased fall risk and recurrent falls. Sex showed a complex relationship with fall risk, with no significant difference in fall occurrence between males and females, but a lower incidence of recurrent falls among females who experienced falls.

5.2. Age and Risk of Fall

In present study, for each year increase in age, the odds of experiencing a fall increased by 3.0%, while the incidence rate of recurrent falls rose by 1.7%. These findings demonstrate a gradual escalation of fall risk with advancing age, aligning with previous studies while offering more precise quantification. Prior studies have reported significant associations between age and fall risk that individuals aged 75 and above had a higher fall experience rate (20.4%) compared to those aged 65-74 (16.3%). Results from a multivariable model indicated that those 75 and older had 12% higher fall risk than their younger counterparts

(Kim & So, 2011). Another literature suggests that physical activity levels in Korean elderly decrease significantly around age 85, highlighting the need for specialized attention to the oldest old (Park & Shin, 2019). Furthermore, the cumulative effect of age-related factors such as decreased bone density, increased fall frequency, and reduced protective responses during falls contributes to the heightened risk of recurrent falls in older adults (Rubenstein, 2006). These factors may explain why the incidence rate of recurrent falls in our study increases with each year of age.

Our study's approach of analyzing age as a continuous variable allows for a more refined analysis of age-related fall risk. It captures the progressive changes in fall risk across the age spectrum, potentially informing more tailored fall prevention strategies for different age subgroups within the elderly population. Our findings, in line with previous studies, emphasize the importance of intensified fall prevention measures for elderly age groups.

5.3. Sex Differences

Our study revealed a complex relationship between sex and fall risk. The logit model results suggest that there was no significant difference in the likelihood of experiencing a fall between male and female elderly. However, among those elderly who did experience falls, females had a significantly lower incidence of recurrent falls compared to males. This finding partially aligns with and diverges from previous studies. A prior study that only analyzed fall occurrence reported that female had a 56% higher risk of falling than male elderly (Kim & So, 2011). Our results suggest a more complex sex-fall relationship, emphasizing the need for sex-specific prevention approaches that consider not just fall occurrence but also recurrence patterns.

We hypothesize that several factors might contribute to sex difference in fall recurrence (Stevens & Sogolow, 2005; Yim et al., 2013; Yoo, 2011). Women may be more proactive in taking preventive measures after an initial fall, possibly due to their generally higher health awareness. They might also perceive the risk of falling more seriously after an initial incident, leading to more cautious behavior. Additionally, women might be more likely to modify their physical activity patterns, focusing on safer activities after a fall, while men might underestimate risks and continue with hazardous activities. Women's potentially higher utilization of medical services post-fall and greater likelihood of improving home safety could also contribute to lower recurrence rates. These hypotheses require further investigation to better understand the sex differences in fall recurrence patterns and to develop more targeted prevention strategies.

5.4. Sociodemographic Factors

Education levels showed a significant association with the frequency of recurrent falls. Compared to those with no formal education, individuals with higher education levels had significantly lower rates of recurrent falls. These results are consistent with a study on Korean elderly, which identified lower education levels as a significant socioeconomic risk factor for falls (Kim et al., 2020).

Economic status, proxy measured by receipt of the NBLSA benefits, showed a significant association with fall risk. NBLSA recipients had a higher rate of recurrent falls compared to non-recipients. This finding supports a study of systematic review which suggested higher fall rates among more socioeconomically deprived groups (Todd et al., 2010).

Marital status was also identified as a significant factor, with unmarried individuals having a higher rate of recurrent falls compared to those who were currently married. This could be attributed to the social support, shared environment management, mutual health care assistance, and immediate help in emergencies that spouses often provide (Kojima, Walters, Iliffe, Taniguchi, & Tamiya, 2020).

The associations between lower education levels, poverty, and increased fall risk may be explained by limited health literacy, socioeconomic constraints affecting access to safe environments and healthcare, challenges in chronic disease and medication management, and less engagement in health-promoting behaviors (Alfonso Mora et al., 2017; Lee et al., 2021). For recurrent falls specifically, these factors may have a compounding effect, as individuals with lower socioeconomic status may have reduced access to rehabilitation services and fall prevention programs after an initial fall, increasing their vulnerability to subsequent falls (Cakar et al., 2011). These findings highlight the complex interplay of sociodemographic factors in fall risk and underscore the need for targeted interventions, particularly for those with lower education levels and those living without a spouse.

5.5. Health Related Factors

We found that poor self-rated health, presence of chronic diseases, underweight, and obesity were all associated with increased recurrent fall risk. Our comprehensive approach, which incorporates both self-rated health perceptions and clinically diagnosed conditions, provides a more holistic view of health status and fall risk

compared to previous studies that often focused on single factors.

Poor self-rated health was significantly associated with higher fall risk in our study. This finding is consistent with previous studies that has shown self-rated health to be a reliable predictor of various health outcomes, including falls (Lim et al., 2010). The subjective nature of self-rated health may capture aspects of an individual's overall health and functional status that are not easily measured by objective indicators, making it a useful instrument in fall risk assessment.

The presence of chronic diseases, particularly diabetes, was associated with increased recurrent fall risk in our study. This result supports a meta-analysis by Yang et al., which reported a 64% increased fall risk in diabetic patients (Yang et al., 2016). Deandrea et al. (2010) found that older adults with chronic conditions have up to a 53% higher risk of experiencing recurrent falls (Jehu et al., 2021). Diabetes may contribute to recurrent fall risk through multiple mechanisms, including peripheral neuropathy, vision problems, and medication side effects (Reeves et al., 2021). Our findings underscore the importance of fall prevention strategies for individuals with chronic diseases, especially those with diabetes. While previous studies have focused on initial falls, our study extends these findings to recurrent falls. Both underweight and obesity were associated with higher recurrent fall risk in our study. This U-shaped relationship between BMI and fall risk has been investigated in prior studies. Underweight elderly may have reduced muscle mass and strength, while obese elderly may have balance and mobility issues, both of which can contribute to increased fall risk (Ogliari et al., 2021).

5.6. Limitations and Implications for Future Study

While the present study provides a comprehensive understanding of fall patterns and risk factors by utilizing ZINB models, which represents a methodological advancement in fall risk research, several limitations should be acknowledged. Firstly, the cross-sectional design of this study makes it difficult to establish causal inferences between the identified risk factors and fall occurrences. Secondly, the outcome variable that experience of falls, relies on self-reported data, which may introduce recall bias, potentially leading to under- or over-estimation of fall occurrence. Thirdly, we did not examine environmental risk factors for falls, such as home hazards or community infrastructure, which could provide additional insights into fall risk. Furthermore, while we considered chronic diseases, we lacked detailed information on medication use, which could be a significant fall risk factor. Lastly, our study did not include direct measures of physical function or balance, which are known to be closely related to fall risk.

These limitations suggest several directions for future research. Longitudinal studies could help establish causal relationships between risk factors and falls. Incorporating objective measures of falls, such as wearable technology, could reduce recall bias. Future studies should also consider environmental factors, detailed medication data, direct measures of physical function, and chronic conditions previously identified as risk factors for recurrent falls, such as stroke, arthritis, osteoporosis, and cataracts to provide a more comprehensive understanding of fall risk in the elderly population.

6. Conclusions

This study provides a comprehensive analysis of fall patterns and associated risk factors among the elderly population in South Korea using a ZINB regression model. Our findings underscore the complex interplay of sociodemographic and health-related factors in recurrent fall risk among elderly South Koreans. The study reveals that recurrent falls are associated with a combination of factors that can be addressed through targeted interventions.

Sociodemographic factors, including education level and economic status, play a crucial role in recurrent fall risk. Our results emphasize the need for comprehensive fall prevention strategies that specifically focus on preventing recurrent falls among high-risk groups, particularly those with lower socioeconomic status. These strategies should include tailored education programs, home safety assessments, and community-based interventions that address the unique needs of socioeconomically disadvantaged older adults.

Health-related factors, especially chronic diseases like diabetes, significantly contribute to recurrent fall risk. Our findings highlight the importance of targeted fall prevention strategies for individuals with chronic conditions, aiming to prevent not just initial falls but recurrent falls as well. These interventions should be integrated into chronic disease management programs to maximize their effectiveness.

Body composition also emerged as a significant factor, with both underweight and obese elderly at higher risk of recurrent falls. This U-shaped relationship suggests that weight management should be an integral part of recurrent fall prevention strategies. Interventions should focus on improving muscle strength and bone density in underweight elderly, while addressing balance and mobility issues in obese individuals.

The sex differences observed in our study emphasize the need for sex-specific prevention strategies. Healthcare providers and policymakers should consider these nuanced findings when developing interventions, ensuring that they are tailored to the specific needs of both men and women.

By enhancing our understanding of recurrent fall risk factors, this study contributes to the development of more effective fall prevention strategies. Future research should focus on evaluating the effectiveness of targeted interventions based on these findings, potentially reducing the significant personal and societal burden of recurrent falls among the elderly in South Korea. Moreover, longitudinal studies are needed to better understand the progression from first-time falls to recurrent falls, which could further inform prevention efforts.

Table 1: General Characteristics of Study Participants by Experience of Fall Injury

Variable	Experience of fall injury								Statistic	*p*
	Never (83.27%)		Once (10.90%)		Multiple times (5.83%)		Total			
	n	%	n	%	n	%	n	%		
Age (min=65; max=108)*	73.5	(73.4 to 73.6)	74.7	(74.5 to 74.9)	76.0	(75.6 to 76.3)	73.8	(73.7 to 73.9)	136.870	<0.001
Sex										
Male	27,072	87.5	2,455	8.2	1,426	4.3	30,953	45.5	182.047	<0.001
Female	32,163	79.9	5,296	13.7	2,722	6.5	40,181	54.5		
Education level										
No formal education	12,319	76.8	2,209	14.3	1,422	9.0	15,950	16.1	37.419	<0.001
Elementary school	19,776	82.0	2,658	12.2	1,419	5.9	23,853	31.1		
Junior high school	10,650	85.4	1,169	10.0	561	4.6	12,380	18.6		
Senior high school	11,332	86.3	1,217	9.7	527	4.0	13,076	17.1		
College or above	5,158	86.4	498	9.2	219	4.3	5,875	12.5		
Recipient of benefits from the National Basic Livelihood Security Act (NBLSA)										
Non-recipients	55,365	84.0	7,055	10.9	3,638	5.1	66,058	92.0	72.227	<0.001
Recipients	3,870	75.8	696	14.1	510	10.2	5,076	8.0		
Marital status										
Married	38,788	85.9	4,305	9.7	2,198	4.4	45,291	65.2	154.799	<0.001
Others	20,447	78.5	3,446	14.0	1,950	7.5	25,843	34.8		
Smoking										
Never smoker	39,062	81.5	5,807	12.5	3,008	6.0	47,877	65.9	40.172	<0.001
Former smoker	14,686	86.9	1,423	8.5	837	4.6	16,946	25.0		
Current smoker	5,487	86.8	521	8.7	303	4.5	6,311	9.1		
Alcohol consumption										
Non-drinker	39,730	81.9	5,681	12.0	3,131	6.1	48,542	65.7	26.889	<0.001
Drinker	17,399	86.0	1,895	9.7	926	4.3	20,220	30.9		
High-risk drinker	2,106	87.9	175	8.1	91	4.1	2,372	3.4		
BMI										
Underweight	2,829	77.7	458	14.0	311	8.4	3,598	4.3	9.457	<0.001
Normal	24,514	83.6	3,200	11.1	1,659	5.3	29,373	40.0		
Pre-obesity	16,117	84.7	1,956	10.4	1,004	4.9	19,077	28.1		
Obesity	15,775	82.5	2,137	11.6	1,174	5.9	19,086	27.7		
Chronic diseases										
None	23,029	85.2	2,731	10.0	1,424	4.8	27,184	34.3	12.764	<0.001
Hypertension	22,849	82.9	3,047	11.7	1,591	5.4	27,487	36.8		
Diabetes mellitus	4,150	81.2	582	11.7	354	7.2	5,086	7.6		
Hypertension and Diabetes	9,207	80.9	1,391	12.5	779	6.6	11,377	15.9		
Perceived Stress										
Low	51,049	84.8	6,251	10.6	2,937	4.6	60,237	84.1	180.851	<0.001
High	8,186	75.7	1,500	14.0	1,211	10.2	10,897	15.9		
Self-rated health										
Good	16,972	88.8	1,510	8.3	550	2.9	19,032	29.3	233.718	<0.001
Fair	24,727	85.8	2,921	10.4	1,162	3.9	28,810	41.5		
Poor	17,536	74.5	3,320	15.1	2,436	10.4	23,292	29.2		

* Presented as weighted mean and 95% confidence interval.

Note: Values are presented as sample size and weighted proportion, unless otherwise indicated. Strata with single sampling unit centered at overall mean. NBLSA, National Basic Livelihood Security Act; BMI, body mass index

Table 2: Risk Factors Associated with Fall Occurance and Frequency among South Korean Elderly

Variable	Likelihood of falls (logit model)					Frequency of recurrent falls (count model)				
	OR	SE	*p*	LL	UL	IRR	SE	*p*	LL	UL
Age (min=65; max=108)*	0.970	0.010	0.002	0.951	0.989	1.017	0.004	<0.001	1.010	1.024
Sex										
Male	1.000	ref				1.000	ref			
Female	0.108	1.353	0.099	0.008	1.526	0.808	0.074	0.004	0.698	0.935
Education level										
No formal education	1.000	ref				1.000	ref			
Elementary school	1.128	0.356	0.735	0.562	2.264	0.894	0.045	0.014	0.819	0.977
Junior high school	1.502	0.446	0.361	0.627	3.599	0.888	0.059	0.045	0.790	0.997
Senior high school	1.130	0.373	0.744	0.544	2.346	0.809	0.060	<0.001	0.718	0.910
College or above	1.179	0.478	0.731	0.462	3.008	0.941	0.089	0.494	0.790	1.121
Recipient of benefits from the National Basic Livelihood Security Act (NBLSA)										
Non-recipients	1.000	ref				1.000	ref			
Recipients	0.718	0.302	0.271	0.397	1.296	1.238	0.053	<0.001	1.115	1.374
Marital status										
Married	1.000	ref				1.000	ref			
Others	0.723	0.186	0.082	0.502	1.042	1.138	0.056	0.022	1.019	1.270
Smoking										
Never smoker	1.000	ref				1.000	ref			
Former smoker	1.016	0.177	0.928	0.718	1.437	1.018	0.074	0.806	0.880	1.178
Current smoker	1.259	0.214	0.283	0.827	1.917	1.080	0.091	0.403	0.902	1.292
Alcohol consumption										
Non-drinker	1.000	ref				1.000	ref			
Drinker	0.928	0.167	0.655	0.669	1.288	1.001	0.052	0.989	0.903	1.109
High-risk drinker	0.790	0.351	0.503	0.397	1.574	0.986	0.154	0.927	0.729	1.334
BMI										
Underweight	1.014	0.420	0.974	0.445	2.307	1.177	0.081	0.044	1.004	1.380
Normal	1.000	ref				1.000	ref			
Pre-obesity	1.093	0.179	0.619	0.769	1.554	1.073	0.047	0.137	0.978	1.176
Obesity	0.836	0.163	0.273	0.607	1.152	1.136	0.043	0.003	1.043	1.237
Chronic diseases										
None	1.000	ref				1.000	ref			
Hypertension	0.738	0.159	0.056	0.540	1.008	0.947	0.052	0.301	0.855	1.050
Diabetes mellitus	1.134	0.259	0.626	0.683	1.884	1.297	0.073	<0.001	1.124	1.496
Hypertension and Diabetes	0.891	0.184	0.529	0.621	1.277	1.052	0.056	0.369	0.942	1.174
Perceived Stress										
Low	1.000	ref				1.000	ref			
High	0.730	0.191	0.100	0.502	1.062	1.451	0.042	<0.001	1.337	1.575
Self-rated health										
Good	1.000	ref				1.000	ref			
Fair	0.929	0.214	0.730	0.610	1.413	1.170	0.070	0.024	1.021	1.342
Poor	0.488	0.216	0.001	0.319	0.746	1.862	0.096	<0.001	1.544	2.246

Note: OR, odds ratio; IRR, incidence-rate ratio; SE, standard error; CI, confidence interval; LL, lower limit of 95% CI; UL, upper limit of 95% CI; NBLSA, National Basic Livelihood Security Act; BMI, body mass index; ref, reference. Strata with single sampling unit centered at overall mean.

The Vuong test indicated that the Zero-Inflated Negative Binomial (ZINB) model was preferred over the ordinary Negative Binomial (NB) model ($z = 12.15$; $p < 0.001$).

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