BMC Geriatrics

RESEARCH

Open Access

Association of timed up and go test results with future injurious falls among older adults by sex: a population-based cohort study

Jiyun Kim[1] and Sookja Choi[2*]

Abstract

Background This study aimed to determine whether sex-specific timed up and go (TUG) test results are associated with injurious fall occurrence in older adults and to identify risk factors for injurious falls based on TUG test results.

Methods Data were obtained from an older adult cohort database provided by the National Health Insurance Service, which included 34,030 individuals aged 66 years or older who underwent life-transition health examinations in 2007 and 2008 and were followed up until 2019. To identify the risk factors for injurious falls, this study performed a Cox proportional hazard regression analysis by sex, with individual characteristics, including TUG test results, as independent variables.

Results The TUG test was associated with injurious falls occurrence in older adult men, but not in older adult women. Among men with abnormal TUG results, those with abnormal systolic blood pressure had a greater risk of injurious falls. In women, dysuria, hearing impairment, underweight, abnormal systolic blood pressure, diabetes, depressive mood, and low bone mineral density (osteopenia and osteoporosis) were identified as risk factors for injurious falls, regardless of the TUG test results. Risk factors for injurious falls after the TUG test differed by sex.

Conclusions The TUG test is useful for detecting injurious falls in older adult men. This study identified important risk factors for injurious falls in older adult women that can be targeted in prevention strategies.

Keywords Fall, Older adult, Timed up and go test, Risk factor, Sex difference

Introduction

Falls are the leading cause of injury-related morbidity and mortality among older adults. Regarding the figures on falls in this cohort, defined as those aged 65 years and over, in South Korea, the fall experience rate is 7.2%, the average number of falls per person among older adults who fell in the past year is 1.6, and 72.5% of those who fell in the past year received hospital treatment after falling [1]. Injurious falls can cause hip fractures [2, 3] and traumatic brain injury [4], as well as increase the possibility of death in people over the age of 80 years [5].

The timed up and go (TUG) test is used to assess physical function and predict falls by testing the movement and balance of older adults [6]. The advantages of the test include the fact that it does not require special equipment, facilities, or space; the existence of extensive evidence on the relationship between TUG test results and falls; and its reliability [7, 8]. Regarding the relationship between the TUG test and falls, while many studies

*Correspondence:
Sookja Choi
sjchoi2u@cau.ac.kr
[1]College of Nursing, Research Institute of AI and Nursing Science, Gachon University, 191 Hambakmoero, Yeonsu-gu, Incheon 21936, Korea
[2]Red Cross College of Nursing, Chung-Ang University, 84 Heukseok-ro, Dongjak-gu, Seoul 06974, Korea

have conducted investigations using self-reported fall data [9–11], fewer have focused on data on injurious falls obtained from medical records [12].

Since 2007, the TUG test has been included as standard for South Korean older adults aged 66 years and above undergoing a life cycle test. All South Korean citizens are covered by the national health insurance scheme, and the database of health examinations and treatments is secured and managed by the National Health Insurance Corporation [13]. Given these findings, confirming the existence of a relationship between the TUG test and injurious falls in South Korean older adults could serve as a basis for providing various interventions for individuals with poor TUG results to prevent injurious falls [12].

Research has shown that there are sex differences in the risk factors for falls [14] and the frequency of injurious falls [15] among older adults. One reason for this is sex differences in age-related changes in physical function [16]. Although aging leads to a decline in physical function in both men and women, a previous study revealed an association of lower extremity function with muscle quality and physical activity in men and an association of lower extremity function with muscle quality and body fat in women [17]. The current study longitudinally examined whether TUG test results are associated with injurious falls by sex, and the association between fall-related factors and injurious falls by physical function (as assessed through the TUG test) and sex.

Materials and methods

Study design, participants, and data sources

Study design

This is a retrospective cohort study using the National Health Insurance Service-senior (NHIS-senior) cohort dataset from South Korea [18].

Participants

The participants were older adults aged 66 years who underwent the National Screening Program for Transitional Ages (NSPTA), where the TUG test was conducted, from 2007 to 2008. As mentioned in Sect. 1, when people reach the transition age of 66 years in South Korea, the TUG test is added to the examination items of the NSPTA [18]. The exclusion criteria were a diagnosis of injury-related falls as a primary or secondary diagnosis in 2007 or 2008, missing values in the healthcare utilization database, emigration, death, and missing information on the TUG test. According to these criteria, we were left with a total sample of 34,030 participants who were included in data collection and analysis processes, including their follow-up data up until 2019 (Fig. 1).

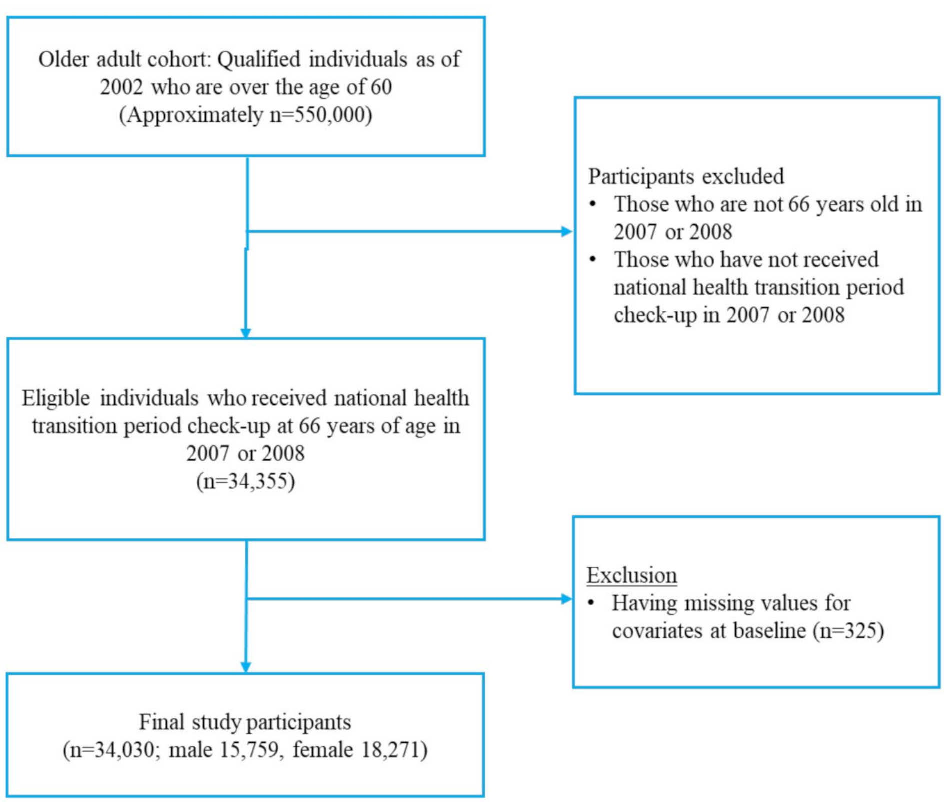

Fig. 1 Flowchart of sample selection procedure

Observations began on the date they received the examination in the NSPTA and ended either on the date of the outcome event (i.e., injurious fall or all-cause death) for participants who experienced the event, or on 31 December 2019 for participants who did not experience the event. We used survival analysis to compare the events between participants with normal and abnormal TUG test results.

Data sources

This study used NHIS-senior cohort (2002–2019) data, which were extracted through simple random sampling, to establish a representative dataset of 558,147 older adults. This dataset is developed and distributed by the Korean National Health Insurance Service (KNHIS) under the Ministry of Health and Welfare in South Korea. As a nationwide retrospective cohort that includes information from older adults randomly sampled from the National Health Information Database (also known as NHID; this Database stores all healthcare and long-term care service records in South Korea), the NHIS-senior cohort dataset encompasses approximately 10% of people aged 60 or older in the National Health Information Database in 2002, and whom were followed for 18 years (up until 2019) [19]. Participants were disqualified in the event of emigration or death. Exclusion criteria included a diagnosis of injury-related falls as a primary or secondary diagnosis in 2007 or 2008, or missing values in the medical utilization database. After excluding participants with missing information on the TUG test, a total sample of 34,030 participants and follow-up data through 2019 were collected (Fig. 1).

The NHIS-senior cohort comprises five databases (i.e., eligibility, national health screening, healthcare utilization, long-term care insurance, and healthcare provider databases), of which we utilized the eligibility, national health screening, and healthcare utilization databases. First, the eligibility database includes data on sex, age, region, and income level [19]. Second, the national health screening database includes data on clinical laboratory results, other health examinations (e.g., body mass index and blood pressure), results of questionnaire-based surveys—which are conducted during health screenings—on medical history and health behaviors (e.g., smoking and physical activity) [19], and NSPTA examination data (i.e., only conducted when older adults reach age 66 years) according to year [18]. To suit the healthcare needs of those aged 66 years and over, the NSPTA adds, into their yearly routine screening examinations, items on topics such as depressive mood, cognitive impairment, and osteoporosis, along with the (aforementioned) TUG test [20].

Third, the healthcare utilization database includes all information regarding inpatient and outpatient medical services and prescription records, including medical care information related to injurious falls [19].

Ethical approval

To conduct this study, the researcher prepared a research plan and received approval from the Institutional Review Board of Gachon University (IRB No. 1044396-202203-HR-073-01). To obtain access to the dataset, the research team applied to KNHIS for database access and analysis and attached the results of the research ethics review process to the application. When analyzing the data with permission from the KNHIS, personal identities were encrypted to ensure protection, and the requirement for informed consent was waived by the relevant authority. As detailed in subsection 2.1.2, the researcher collected the data for analysis by connecting the data from various databases, all of which were anonymized.

Variables

Injurious falls

Injurious falls were defined as falls that caused injuries requiring inpatient or outpatient treatment, as defined by the International Classification of Diseases and previous studies [14, 21]. In this study, hospital medical record claims data up to 2019 were reviewed, and injurious falls were defined as occurring when diagnosed using the codes W00, W01, W05–W10, and W17–W19 from the 10th revision of the International Classification of Diseases.

Lower extremity function

Lower extremity function was assessed using the TUG test, a reliable and valid test to quantify functional mobility in older adults and to assess fall risk in the community setting. The TUG test data used in this study stems from tests that were conducted according to the recommendations provided in the NSPTA manual [22], which recommends test performance on the day of the NSPTA physical examination. The TUG test is assessed by having the participant sit on a chair (i.e., a hospital examination chair without armrests), stand, walk three meters at a comfortable pace, return to the chair, and sit down again; the unit used for measurement is seconds. During the test, the participants wore regular shoes, and those who needed a walking aid used one. According to the criteria suggested by a previous study [23] and the NSPTA manual [22], the participants were classified into two groups according to the test results, namely normal (≤10 s) and abnormal (>10 s).

Covariates

Regarding covariates, we used the risk factors for falls proposed by Deandrea et al. [24]. Depressive symptoms were measured using three items (i.e., loss of activities/

interests, feelings of worthlessness, and feelings of hopelessness) from the Geriatric Depression Scale [20], and a positive answer to any item was defined as a depressive mood—as suggested by the NSPTA manual [22].

The NSPTA screening also involved a six-item questionnaire, in Korean, on activities of daily living (ADLs; four items on bathing, dressing, eating, and toileting) and instrumental ADL (IADL; two items on preparing meals and going out to a distance that is walkable). For each item, the participant answered "yes" if one could do the activity independently, and "no" if one could not. Following the NSPTA manual, results for this questionnaire were divided into two groups [22], as follows: if any of the six items were "no", they were coded in the ADL "poor" group; the rest were coded in the "good" group.

Visual impairment was assessed using visual acuity testing. If both eyes scored between 0.1 and 2.0 in a visual acuity testing, it was categorized as "no", but if either eye was blind, it was categorized as "yes". Hearing loss was measured using a whisper test. Hearing impairment is categorized as "yes" if the whisper test shows that either ear can correctly identify fewer than three of the six numbers called by the examiner and "no" otherwise.

Dysuria and six-month fall history were measured by asking "Do you have dysuria?" and "Have you fallen within the past six months?", respectively. For each of these two items, each group was further categorized into two groups (yes or no). Body mass index (BMI) was calculated in kilograms per meter squared, and participants were categorized as underweight (less than 18.0), normal (18.0–22.9), or overweight (23 or greater) [22]. Participants were classified into two groups (normal or abnormal) for systolic blood pressure and diastolic blood pressure according to the reference values of 140 mmHg and 90 mmHg for systolic and diastolic blood pressure, respectively [22].

Anemia was defined as serum hemoglobin (<10 g/dL for women, <12 g/dL for men,). Diabetes was defined as fasting serum glucose concentration ≥ 126 mg/dL, and dyslipidemia was defined as serum total cholesterol (TC) concentration ≥ 240 mg/dL [22].

Bone measurements were performed only in women aged 66 years and older [20] and involved any of the following methods: dual-energy X-ray absorptiometry (also known as DEXA), peripheral DEXA (also known as PDEXA), ultrasound, and computed tomography [20]. Bone mineral density (BMD) was defined according to the World Health Organization T score criteria using three groups (normal, ≥ -1.0; osteopenia, -2.4 to -1.1; osteoporosis, ≤ -2.5) [25].

Statistical analysis

Frequencies and percentages were calculated for all variables and compared by sex using the chi-square test. The Cox proportional hazards model was used to estimate hazard ratios (HRs), and a 95% confidence interval (CI) was used to find an association between TUG test results and injurious falls occurrence. The control variables were sex, six-month fall history, dysuria, visual impairment, hearing impairment, depressive mood, obesity, blood pressure, diabetes, dyslipidemia, anemia, ADL, and BMD (only for women). Using subgroup analysis and the same model, we identified the risk factors affecting injurious falls occurrence according to sex and TUG test results. All the statistical tests were two-tailed and performed using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA), with a 95% significance level.

Results

Participants' baseline characteristics by sex

Of the 34,030 participants at baseline (2007 and 2008), 15,759 (46.3%) were men. The percentages of individuals in the abnormal TUG result group were 15.3% among men and 21.1% among women, and the percentages of individuals with a six-month fall history were 8.8% and 12.7%, respectively.

On average, men showed higher rates of dysuria (19.5%), visual impairment (1.7%), hearing impairment (8.7%), diabetes (12.9%), and poor ADL (8.4%) than women. Meanwhile, women showed higher rates of a more depressive mood (37.7%) and six-month fall history (12.7%) and were overweight (69.9%) than men.(Table 1)

Incidence of injurious falls by sex

In Table 2, among the 34,030 participants, the injurious fall incidence was 873 (2.6%) by the end of 2019. Both men and women were followed for a mean of 11.7 years (maximum: 12 years), and 258 (1.6%) men and 615 (3.4%) women had suffered injurious falls by the end of 2019. Among men in the normal TUG result group, injurious fall incidence per 1,000 persons per year was 1.3, and 2.0 for those in the abnormal TUG result group. Among women in the normal TUG result group, injurious fall incidence per 1,000 persons per year was 2.8, and 3.0 for those in the abnormal TUG result group.

Association of TUG test results, subgroup characteristics, and injurious falls

Tables 3 and 4 present the results of the multivariate Cox regression model for injurious falls by sex. Regarding sex, men in the abnormal TUG result group had a significantly greater risk of injurious falls than did those in the normal TUG result group (HR: 1.52, 95% CI: 1.13–2.04). In men, the six-month fall history was also associated with a significantly greater risk of injurious falls, even after adjusting for several potentially confounding variables (HR: 2.98, 95% CI: 2.17–4.10). For men in the normal TUG result group, the multivariate Cox proportional

Table 1 Descriptive characteristics of the study participants at baseline (2007–2008)

Variables	Sample (*N* = 34,030)	Men (*n* = 15,759)	Women (*n* = 18,271)	Chi-square test	*p* value
	n(%)	*n*(%)	*n*(%)		
TUG test result (abnormal)	6,273 (18.4)	2,416 (15.3)	3,857 (21.1)	187.9	< 0.001
Six-month fall history (yes)	3,716 (10.9)	1,395 (8.8)	2,321 (12.7)	129.0	< 0.001
Dysuria (yes)	6,076 (17.8)	3,077 (19.5)	2,999 (16.4)	55.8	< 0.001
Visual impairment (yes)	494 (1.5)	266 (1.7)	228 (1.3)	11.4	< 0.001
Hearing impairment (yes)	2,614 (7.7)	1,379 (8.7)	1,235 (6.8)	47.3	< 0.001
Depressive mood (yes)	11,454 (33.7)	4,569 (29.0)	6,885 (37.7)	286.1	< 0.001
Obesity					
Underweight	759 (2.2)	443 (2.8)	316 (1.7)	242.6	< 0.001
Normal weight	10,710 (31.5)	5,527 (35.1)	5,183 (28.4)		
Overweight	22,561 (66.3)	9,789 (62.1)	12,772 (69.9)		
(BMI, kg/ m^2)*		23.8 (21.9–25.7)	24.4 (22.5–26.5)		
Systolic blood pressure (abnormal)	9,305 (27.3)	4,273 (27.1)	5,032 (27.5)	0.8	0.370
(Systolic blood pressure, mmHg)*		130.0 (120–140)	130.0 (120–140)		
Diastolic blood pressure (abnormal)	5,972 (17.5)	2,852 (18.1)	3,120 (17.1)	6.1	0.010
(Diastolic blood pressure, mmHg)*		80.0 (70–85)	80.0 (70–85)		
Diabetes (yes)	3,766 (11.1)	2,045 (12.9)	1,721 (9.4)	108.8	< 0.001
(Fasting blood glucose level, mg/dL)*		98.0 (89–111)	95.0 (87–107)		
Dyslipidemia (yes)	4,744 (13.9)	1,472 (9.3)	3,272 (17.9)	517.7	< 0.001
(Total cholesterol level, mg/dL)*		189.0 (166–214)	204.0 (179–230)		
Anemia (yes)	643 (1.9)	497 (3.2)	146 (0.8)	253.0	< 0.001
(Hemoglobin, mg/dL)*		14.4 (13.6–15.3)	12.9 (12.2–13.5)		
ADL (poor)	2,357 (6.9)	1,319 (8.4)	1,038 (5.7)	94.9	< 0.001
BMD					
Normal			2,264 (14.3)		
Osteopenia			6,194 (39.1)		
Osteoporosis			7,366 (46.6)		

Note. * Median (Interquartile Range)

Abbreviations: ADL, activities of daily living; BMD, bone mineral density; BMI, body mass index; TUG, timed up and go

Table 2 Injurious fall incidence rate according to TUG results

TUG test result	Men					Women				
	Number	Event	Censored	Duration (PYs)	Incidence rate (1,000 PYs)	Number	Event	Censored	Duration (PYs)	Incidence rate (1,000 PYs)
Normal	13,343	200	13,143	156,540.6	1.3	14,414	479	13,932	168,454.8	2.8
Abnormal	2,416	58	2,356	28,348.5	2.0	3,857	136	3,721	45,112.8	3.0

Abbreviations: TUG, timed up and go; PYs, person-years

hazards regression analysis revealed that the HRs of injurious falls increased 4.17-fold for those with a six-month fall history (95% CI: 2.98–5.84). For men in the abnormal TUG result group, abnormal systolic blood pressure (HR: 2.65, 95% CI: 1.50–4.68) and dyslipidemia (HR: 4.22, 95% CI: 2.40–7.41) increased the HRs for injurious falls. In addition, there was a 4.42-fold increase in the HR for injurious falls in patients with poor ADL (vs. good ADL; 95% CI: 2.51–7.79).

Table 4 presents the findings of the association of TUG test results with injurious falls in women. There was no significant association between TUG test results and injurious falls in women; however, dysuria (HR: 1.61, 95% CI: 1.30–2.00), depressive mood (HR: 1.21, 95% CI: 1.01–1.46), hearing impairment (HR: 0.56, 95% CI: 0.36–0.87), obesity (underweight HR: 1.99, 95% CI: 1.18–3.34), abnormal systolic blood pressure (HR: 1.79, 95% CI: 1.30–2.16), diabetes (HR: 1.68, 95% CI: 1.30–2.16), and BMD (osteopenia HR: 1.57, 95% CI: 1.12–2.20; osteoporosis HR: 1.87, 95% CI: 1.35–2.60) were significantly associated with injurious falls incidence.

Among women in the normal TUG result group, those with dysuria had 1.59 times greater risk of injurious falls (95% CI, 1.24–2.03), whereas the HR of those with hearing impairment was 0.38 (95% CI, 0.20–0.70) and 0.80 for those with overweight (95% CI, 0.64–0.99). Underweight older adult women had a 2.44 times greater risk of injurious falls (95% CI, 1.44–4.12) than did those in the normal

Table 3 Cox proportional regression analysis for men

	Total	TUG test result	
		Normal	Abnormal
	HR (95% CI)	HR (95% CI)	HR (95% CI)
TUG test result (ref: normal)	1.52 (1.13–2.04)		
Six-month fall history (ref: no)	2.98 (2.17–4.10)	4.17 (2.98–5.84)	0.37 (0.09–1.58)
Dysuria (ref: no)	0.77 (0.55–1.06)	0.81 (0.57–1.16)	0.56 (0.25–1.27)
Visual impairment (ref: no)	1.01 (0.42–2.45)	n/a	n/a
Hearing impairment (ref: no)	1.03 (0.68–1.57)	1.26 (0.81–1.96)	0.34 (0.08–1.39)
Depressive mood (ref: no)	1.00 (0.76–1.31)	1.17 (0.87–1.58)	0.68 (0.36–1.31)
Obesity (ref: normal weight)			
Underweight	0.95 (0.44–2.06)	1.01 (0.44–2.33)	0.75 (0.10–5.82)
Overweight	1.08 (0.83–1.40)	1.08 (0.80–1.45)	0.92 (0.52–1.65)
Systolic blood pressure (ref: normal)	0.99 (0.71–1.39)	0.58 (0.38–0.90)	2.65 (1.50–4.68)
Diastolic blood pressure (ref: normal)	0.69 (0.45–1.05)	1.14 (0.70–1.83)	0.23 (0.10–0.57)
Diabetes (ref: no)	1.14 (0.81–1.62)	1.18 (0.80–1.75)	1.11 (0.52–2.34)
Dyslipidemia (ref: no)	1.31 (0.89–1.92)	0.55 (0.29–1.05)	4.22 (2.40–7.41)
Anemia (ref: no)	1.34 (0.73–2.47)	1.37 (0.70–2.70)	1.40 (0.33–5.96)
ADL (ref: good)	1.41 (0.97–2.06)	0.69 (0.38–1.23)	4.42 (2.51–7.79)

Abbreviations: 95% CI, 95% confidence interval; ADL, activities of daily living; HR, hazard ratio; n/a, not applicable; TUG, timed up and go

Table 4 Cox proportional regression analysis for women

	Total	TUG test result	
		Normal	Abnormal
	HR (95% CI)	HR (95% CI)	HR (95% CI)
TUG test result (ref: normal)	1.00 (0.81–1.25)		
Six-month fall history (ref: no)	0.92 (0.70–1.20)	0.81 (0.59–1.12)	1.19 (0.71–1.97)
Dysuria (ref: no)	1.61 (1.30–2.00)	1.59 (1.24–2.03)	1.60 (1.02–2.52)
Visual impairment (ref: no)	0.85 (0.35–2.05)	1.12 (0.46–2.71)	n/a
Hearing impairment (ref: no)	0.56 (0.36–0.87)	0.38 (0.20–0.70)	1.16 (0.60–2.23)
Depressive mood (ref: no)	1.21 (1.01–1.46)	1.13 (0.92–1.39)	1.55 (1.04–2.32)
Obesity (ref: normal weight)			
Underweight	1.99 (1.18–3.34)	2.44 (1.44–4.12)	n/a
Overweight	0.95 (0.77–1.16)	0.80 (0.64–0.99)	1.89 (1.15–3.13)
Systolic blood pressure (ref: normal)	1.79 (1.30–2.16)	2.12 (1.67–2.68)	0.95 (0.57–1.60)
Diastolic blood pressure (ref: normal)	0.56 (0.73–1.17)	0.57 (0.41–0.78)	0.56 (0.28–1.15)
Diabetes (ref: no)	1.68 (1.30–2.16)	1.73 (1.30–2.29)	1.55 (0.89–2.70)
Dyslipidemia (ref: no)	0.92 (0.73–1.17)	1.01 (0.78–1.32)	0.62 (0.35–1.10)
Anemia (ref: no)	1.04 (0.39–2.79)	1.31 (0.49–3.50)	n/a
ADL (ref: good)	1.04 (0.72–1.52)	1.12 (0.74–1.71)	0.81 (0.35–1.85)
BMD (ref: normal)			
Osteopenia	1.57 (1.12–2.20)	1.55 (1.08–2.22)	1.62 (0.61–4.30)
Osteoporosis	1.87 (1.35–2.60)	1.49 (1.04–2.13)	4.42 (1.78–10.93)

Abbreviations: 95% CI, 95% confidence interval; ADL, activities of daily living; BMD, bone mineral density; HR, hazard ratio; n/a, not applicable; TUG, timed up and go

weight group. Moreover, the HR of those with abnormal systolic blood pressure was 2.12 (95% CI, 1.67–2.68), 0.57 for those with abnormal diastolic blood pressure (95% CI, 0.41–0.78), and 1.73 for those with diabetes (95% CI, 1.30–2.29). Regarding BMD, women with osteopenia had a 1.55-fold (95% CI: 1.08–2.22) greater risk of injurious falls, and women with osteoporosis had a 1.49-fold greater risk (95% CI: 1.04–2.13).

Among women in the abnormal TUG result group, dysuria (HR: 1.60, 95% CI: 1.02–2.52), depressive mood (HR: 1.55, 95% CI: 1.04–2.32), obesity (overweight HR: 1.89, 95% CI: 1.15–3.13), abnormal systolic blood pressure (HR: 1.79, 95% CI: 1.30–2.16), and BMD (osteoporosis HR: 4.42, 95% CI: 1.78–10.93) were significantly associated with injurious falls incidence.

Discussion

The TUG test is one of the most frequently used procedures to evaluate the possibility of falls in older adults [26], can be used to identify the occurrence of falls in community-dwelling older adult women [27], and its usefulness relies on high specificity rather than sensitivity [8, 28, 29]. In our sample, the TUG test results were associated with injurious falls occurrence in men but not women, resonating with the results in a previous study in which fall incidence and risk factors differed by sex [14]. Furthermore, the six-month fall history was an important factor associated with injurious falls occurrence in men. This is consistent with prior evidence showing that falls recurrence [30–32] and falling experience are risk factors for injurious falls [14, 33].

Among older adult men, the risk of injurious falls was greater in the abnormal TUG result group in patients with abnormal blood pressure, dyslipidemia, and poor ADL. In a cohort study conducted in Sweden, an association between high systolic pressure and injurious falls occurrence was confirmed in a group with low functional status [34]. Similar to the evidence in the current study, the results of Ek et al. 's research showed that injurious falls risk differed depending on ADL performance in men, but not in women [14]. Meanwhile, the literature shows that accurate detection of groups at high risk for falls, coupled with the implementation of appropriate interventions, can help avoid the negative impacts of falls among older adults [28]. In fact, various interventions have been shown to decrease fall rates, with reductions in the range of 20–40% [35]. Therefore, more interventions are needed to prevent falls among older adult men with abnormal TUG results [35]. Furthermore, important focus points for fall prevention interventions focused on this group may include cardiovascular health management, including cholesterol management, and ADL change detection.

In older adult women, the risk factors for injurious falls were dysuria, underweight status, and low bone density, regardless of the TUG test results. Indeed, urinary dysfunctions, such as dysuria, are well-known risk factors for injurious falls in hospitals [36]. Underweight older adult women in our sample showed a greater risk of injurious falls than did their normal-weight counterparts. In previous investigations, low body weight was also shown to be a risk factor for increased fractures or falls [37–39]; however, the mechanisms by which low body weight increases the likelihood of injurious falls remain unclear. Some hypotheses for this finding are presented herein. A lower BMI has been associated with decreased BMD, soft tissue loss, and muscular weakness, thereby increasing the risk of falls or fractures [40]. Additionally, while a lower BMI is associated with a lower BMD, a BMI increase has been shown to be associated with an increase in adipose tissue, providing further protection against fractures [41]. Being underweight often relates to undernutrition or malnutrition, and if persistent, both can worsen BMD [42], thereby increasing injurious fall risk. Prolonged exposure to trauma in the absence of a fat cushion has also been depicted to potentially influence the risk of falls or fractures [43, 44]. In addition, a low BMI was demonstrated to be strongly associated with sarcopenia development, which in turn diminishes physical strength and muscular performance, leading to injuries that increase the probability of a fall or fracture [45, 46]. Nonetheless, muscle mass may not provide adequate bone protection, and reduced muscle strength may increase the risk of fall-related injuries [47, 48].

Studies have also demonstrated that hearing loss is associated with a high probability of falling [49]. However, in this study, hearing loss in women with normal TUG results was associated with a reduced risk of injurious falls. It is possible that the risk of injurious falls in older adults diagnosed with hearing loss is lower because those with hearing loss may engage in less outdoor activity than those without hearing loss [50]. However, follow-up studies are required to confirm the relationship between hearing loss and injurious falls.

In summary, the TUG test is a relatively simple test that has been shown, based on our findings, to be potentially useful in health interventions aimed at dealing with injurious fall risk factors and tailored to individuals by sex. In male older adults, fall prevention interventions could be designed to divide participants into normal and abnormal groups according to their TUG test results. Moreover, since the TUG test was not associated with falls in older adult women, future research is needed to further assess whether the TUG test can be useful in examining falls in this population.

Regarding study limitations, this study could not control for the participants' demographic characteristics. As we tracked and analyzed individuals reaching the age of 66, we considered demographic variables such as sex and age. However, other factors such as education level and marital status, were not included in our analysis because they are not available in the NHIS-senior cohort data. Moreover, this study could not analyze data on BMD T scores for older adult men, as their claims data did not contain this information. In addition, many of the measured covariates (e.g., fall history, dysuria, depressive mood, ADL abilities, etc.) were collected via participant self-report, which is a major limitation of this study. This study's results may have also underestimated injurious fall incidence because the claims data were analyzed while tracking older adults in the community who underwent lifecycle examinations. This implies that cases of minor injurious falls that did not require hospitalization or treatment were not considered in the analysis. In the case of an injury due to a fall, treatment costs are high, and people could become impaired in the performance of their ADLs; therefore, identifying the related risk factors for cases of minor injurious falls and using them in preventive techniques may be important steps of future research. Regarding strengths, this study examined injurious falls using objective claims data from the KNHIS, which encompassed more than 10 years of follow-up data from people who turned 66 years old in 2007 and 2008. Still, this long follow-up procedure might have increased the likelihood of other variables affecting the risk of falling. Since this study identified various risk factors in addition to the TUG test results, interventions aimed at the elderly in the community can be tailored to address these identified factors.

Conclusion

The TUG test was associated with injurious falls in older adult men but not in older adult women. In older adult women, various factors were related to injurious falls regardless of the TUG test. In addition, the factors associated with injurious falls differed by sex. When developing interventions to prevent injurious falls, these differences should be considered.

Abbreviations

ADL	Activities of daily living
BMD	Bone mineral density
BMI	Body mass index
TUG	Timed up and go
CI	Confidence interval
HR	Hazard ratio

Acknowledgements
None.

Author contributions
Jiyun Kim led the study design, interpreted the data, and wrote the paper. Sookja Choi performed the statistical analysis and assisted with the data interpretation and wrote the paper.

Funding
This research was funded by the National Research Foundation of Korea (NRF) grant number NRF-2020R1F1A1076167.

Data availability
Data from this study must be used in accordance with National Health Insurance Service policies. The information on how to request the database is available at https://nhiss.nhis.or.kr/bd/ab/bdaba021eng.do. The details and cost of the database are described in https://nhiss.nhis.or.kr/bd/ab/bdaba022eng.do. To request the database, visit https://nhiss.nhis.or.kr/bd/ay/bdaya001iv.do. (only available in Korean).

Declarations

Ethics approval and consent to participate
This study was reviewed and approved by the Institutional Review Board of Gachon University (IRB No. 1044396-202203-HR-073-01), and permission to analyze the data remotely was provided by the National Health Insurance Service (NHIS). Access to the National Health Insurance Sharing Service database (NHISS) for research purposes was provided only through legal procedures after deliberation (NHIS-2022-2-362). In addition, it was impossible to confirm the patient's personal information because the information was provided to researchers already encrypted. The ethics committees of Gachon University have waived the requirement to obtain informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
not applicable.

Received: 3 June 2024 / Accepted: 26 November 2024
Published online: 23 December 2024

References

1. Lee Y, Kim S, Hwang N et al. *2020 Survey of the Elderly*. 2020.
2. Berry SD, Miller RR. Falls: Epidemiology, pathophysiology, and relationship to fracture. Curr Osteoporos Rep. 2008;6(4):149–54. https://doi.org/10.1007/s11914-008-0026-4
3. Gong XF, Li XP, Zhang LX, et al. Current status and distribution of hip fractures among older adults in China. Osteoporos Int. 2021;32(9):1785–93. https://doi.org/10.1007/s00198-021-05849-y
4. Hawley C, Sakr M, Scapinello S, Salvo J, Wrenn P. Traumatic brain injuries in older adults—6 years of data for one UK trauma centre: retrospective analysis of prospectively collected data. Emerg Med J. 2017;34(8):509–16. https://doi.org/10.1136/emermed-2016-206506
5. Soomar SM, Dhalla Z. Injuries and outcomes resulting due to falls in elderly patients presenting to the Emergency Department of a tertiary care hospital – a cohort study. BMC Emerg Med. 2023;23(1):1–10. https://doi.org/10.1186/S12873-023-00784-Z/TABLES/4
6. Rodrigues F, Teixeira JE, Forte P. The reliability of the timed up and go test among Portuguese Elderly. Healthc 2023. 2023;11(7):928. https://doi.org/10.3390/HEALTHCARE11070928
7. Rikli RE, Jones CJ. Development and Validation of Criterion-Referenced clinically relevant Fitness standards for maintaining physical independence in later years. Gerontologist. 2013;53(2):255–67. https://doi.org/10.1093/GERONT/GNS071
8. Barry E, Galvin R, Keogh C, Horgan F, Fahey T. Is the timed up and go test a useful predictor of risk of falls in community dwelling older adults: a systematic review and meta- analysis. BMC Geriatr. 2014;14(1):14. https://doi.org/10.1186/1471-2318-14-14
9. Viccaro LJ, Perera S, Studenski SA. Is timed up and go Better Than Gait Speed in Predicting Health, function, and Falls in older adults? J Am Geriatr Soc. 2011;59(5):887–92. https://doi.org/10.1111/j.1532-5415.2011.03336.x
10. Alexandre TS, Meira DM, Rico NC, Mizuta SK. Accuracy of timed up and go test for screening risk of falls among community-dwelling elderly. Braz J Phys Ther. 2012;16(5):381–8. https://doi.org/10.1590/S1413-35552012005000041
11. Yamada M, Uemura K, Mori S, et al. Faster decline of physical performance in older adults with higher levels of baseline locomotive function. Geriatr Gerontol Int. 2012;12(2):238–46. https://doi.org/10.1111/j.1447-0594.2011.00757.x
12. Hars M, Audet MC, Herrmann F, et al. Functional performances on Admission Predict In-Hospital Falls, Injurious Falls, and fractures in older patients: a prospective study. J Bone Miner Res. 2018;33(5):852–9. https://doi.org/10.1002/jbmr.3382
13. Kim YI. *2022 National Health Insurance & Long-Term Care Insurance System in Republic of Korea.*; 2021.
14. Ek S, Rizzuto D, Fratiglioni L, et al. Risk factors for Injurious Falls in older adults: the role of sex and length of Follow-Up. J Am Geriatr Soc. 2019;67(2):246–53. https://doi.org/10.1111/JGS.15657
15. Ek S, Rizzuto D, Calderón-Larrañaga A, Franzén E, Xu W, Welmer AK. Predicting First-Time Injurious Falls in Older men and women living in the community: development of the first injurious fall Screening Tool. J Am Med Dir Assoc. 2019;20(9):1163–e11683. https://doi.org/10.1016/j.jamda.2019.02.023
16. Okabe T, Suzuki M, Goto H, et al. Sex differences in age-related physical changes among Community-Dwelling adults. J Clin Med. 2021;10(20):4800. https://doi.org/10.3390/jcm10204800
17. Straight CR, Brady AO, Evans E. Sex-specific relationships of physical activity, body composition, and muscle quality with lower-extremity physical function in older men and women. Menopause. 2015;22(3):297–303. https://doi.org/10.1097/GME.0000000000000313
18. Shin DW, Cho J, Park JH, Cho B. National General Health Screening Program in Korea: history, current status, and future direction. Precision Future Med. 2022;6(1):9–31. https://doi.org/10.23838/pfm.2021.00135

19. Kim YI, Kim YY, Yoon JL, et al. Cohort Profile: National health insurance service-senior (NHIS-senior) cohort in Korea. BMJ Open. 2019;9(7):e024344. https://doi.org/10.1136/bmjopen-2018-024344
20. Kim HS, Shin DW, Lee WC, Kim YT, Cho B. National Screening Program for Transitional ages in Korea: a New Screening for strengthening primary Prevention and follow-up care. J Korean Med Sci. 2012;27:70–5. https://doi.org/10.3346/jkms.2012.27.S.S70
21. Welmer AK, Rizzuto D, Calderón-Larrañaga A, Johnell K. Sex differences in the Association between Pain and Injurious Falls in older adults: a Population-based longitudinal study. Am J Epidemiol. 2017;186(9):1049–56. https://doi.org/10.1093/AJE/KWX170
22. National Health Insurance Corporation Big data operation department. NHIS-Senior DB 2.0 User Manual (Ver 1.0). Accessed September 10. 2024. https://nhiss.nhis.or.kr/lp/j/c/001/lpjc001m01.do
23. Son KY, Shin DW, Lee JE, Kim SH, Yun JM, Cho B. Association of anemia with mobility capacity in older adults: a Korean nationwide population-based cross-sectional study. BMC Geriatr. 2020;20(1):469. https://doi.org/10.1186/s12877-020-01879-z
24. Deandrea S, Lucenteforte E, Bravi F, Foschi R, La Vecchia C, Negri E. Risk factors for falls in community-dwelling older people. Epidemiology. 2010;21(5):658–68. https://doi.org/10.1097/EDE.0b013e3181e89905
25. on the Prevention WHOSG, of Osteoporosis. (2000: Geneva S. Prevention and management of osteoporosis : report of a WHO scientific group. Published online 2003:192 p.
26. Beck Jepsen D, Robinson K, Ogliari G, et al. Predicting falls in older adults: an umbrella review of instruments assessing gait, balance, and functional mobility. BMC Geriatr. 2022;22(1):615. https://doi.org/10.1186/s12877-022-03271-5
27. Chen JC, Liang CC, Chang QX. Comparison of fallers and nonfallers on four physical performance tests: a prospective cohort study of Community-Dwelling Older Indigenous Taiwanese women. Published online 2017. https://doi.org/10.1016/j.ijge.2017.04.006
28. Kojima G, Masud T, Kendrick D, et al. Does the timed up and go test predict future falls among British community-dwelling older people? Prospective cohort study nested within a randomised controlled trial. BMC Geriatr. 2015;15(1). https://doi.org/10.1186/S12877-015-0039-7
29. Shumway-Cook A, Brauer S, WM. Predicting the probability for falls in community-dwelling older adults using the timed up & go test - PubMed. Phys Therapy Rehabilitation J. 2000;80(9):896–903. https://pubmed.ncbi.nlm.nih.gov/10960937/. Accessed October 17, 2023.
30. Sri-on J, Tirrell GP, Bean JF, Lipsitz LA, Liu SW, Revisit S, Hospitalization. Recurrent fall, and death within 6 months after a fall among Elderly Emergency Department patients. Ann Emerg Med. 2017;70(4):516–e5212. https://doi.org/10.1016/J.ANNEMERGMED.2017.05.023
31. Lam C, Kang JH, Lin HY, Huang HC, Wu CC, Chen PL. First fall-related injuries requiring hospitalization increase the risk of recurrent injurious falls: a Nationwide Cohort Study in Taiwan. PLoS ONE. 2016;11(2). https://doi.org/10.1371/JOURNAL.PONE.0149887
32. Lam FMH, Leung JCS, Kwok TCY. The clinical potential of Frailty indicators on identifying recurrent fallers in the community: the Mr. Os and Ms. OS Cohort Study in Hong Kong. J Am Med Dir Assoc. 2019;20(12):1605–10. https://doi.org/10.1016/J.JAMDA.2019.06.019
33. Bergland A, Wyller TB. Risk factors for serious fall related injury in elderly women living at home. Inj Prev. 2004;10(5):308–13. https://doi.org/10.1136/IP.2003.004721
34. Welmer AK, Wang R, Rizzuto D, Ek S, Vetrano DL, Qiu C. Associations of blood pressure with risk of injurious falls in old age vary by functional status: a cohort study. Exp Gerontol. 2020;140. https://doi.org/10.1016/J.EXGER.2020.111038
35. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Reviews. 2012;2021(6). https://doi.org/10.1002/14651858.CD007146.pub3
36. Jung H, Park HA, Hwang H. Improving prediction of Fall Risk Using Electronic Health Record Data with various types and sources at multiple Times. CIN: Computers Inf Nurs. 2020;38(3):157–64. https://doi.org/10.1097/CIN.0000000000000561
37. Trevisan C, Crippa A, Ek S, et al. Nutritional status, body Mass Index, and the risk of Falls in Community-Dwelling older adults: a systematic review and Meta-analysis. J Am Med Dir Assoc. 2019;20(5):569–e5827. https://doi.org/10.1016/j.jamda.2018.10.027
38. Xue S, Kemal O, Lu M, Lix LM, Leslie WD, Yang S. Age at attainment of peak bone mineral density and its associated factors: the National Health and Nutrition Examination Survey 2005–2014. Bone. 2020;131:115163. https://doi.org/10.1016/j.bone.2019.115163
39. Han S, Park J, Nah S, Jang HD, Han K, Hong JY. Severity of underweight and risk of fracture: a Korean nationwide population-based cohort study. Sci Rep. 2022;12(1):10153. https://doi.org/10.1038/s41598-022-14267-x
40. Nielson CM, Srikanth P, Orwoll ES. Obesity and fracture in men and women: an epidemiologic perspective. J Bone Miner Res. 2012;27(1):1–10. https://doi.org/10.1002/jbmr.1486
41. Shapses SA, Sukumar D. Bone metabolism in obesity and weight loss. Annu Rev Nutr. 2012;32(1):287–309. https://doi.org/10.1146/annurev.nutr.012809.104655
42. Fawzy T, Muttappallymyalil J, Sreedharan J, et al. Association between Body Mass Index and Bone Mineral density in patients referred for dual-energy X-Ray Absorptiometry scan in Ajman, UAE. J Osteoporos. 2011;2011:1–4. https://doi.org/10.4061/2011/876309
43. Bonjour JP, Schurch MA, Rizzoli R. Nutritional aspects of hip fractures. Bone. 1996;18(3):S139–44. https://doi.org/10.1016/8756-3282(95)00494-7
44. Lee HD, Han S, Jang HD, et al. Cumulative burden of being Underweight increases the risk of hip fracture: a Nationwide Population-based Cohort Study. Healthcare. 2022;10(12):2568. https://doi.org/10.3390/healthcare10122568
45. Landi F, Liperoti R, Russo A, et al. Sarcopenia as a risk factor for falls in elderly individuals: results from the ilSIRENTE study. Clin Nutr. 2012;31(5):652–8. https://doi.org/10.1016/j.clnu.2012.02.007
46. Tokeshi S, Eguchi Y, Suzuki M, et al. Relationship between skeletal muscle Mass, Bone Mineral density, and trabecular bone score in Osteoporotic Vertebral Compression fractures. Asian Spine J. 2021;15(3):365–72. https://doi.org/10.31616/asj.2020.0045
47. Scott D, Daly RM, Sanders KM, Ebeling PR. Fall and fracture risk in Sarcopenia and Dynapenia with and without obesity: the role of Lifestyle interventions. Curr Osteoporos Rep. 2015;13(4):235–44. https://doi.org/10.1007/s11914-015-0274-z
48. Pérez-López FR, Ara I. Fragility fracture risk and skeletal muscle function. Climacteric. 2016;19(1):37–41. https://doi.org/10.3109/13697137.2015.1115261
49. Jiam NTL, Li C, Agrawal Y. Hearing loss and falls: a systematic review and meta-analysis. Laryngoscope. 2016;126(11):2587–96. https://doi.org/10.1002/LARY.25927
50. Iwagami M, Kobayashi Y, Tsukazaki E, et al. Associations between self-reported hearing loss and outdoor activity limitations, psychological distress and self-reported memory loss among older people: analysis of the 2016 Comprehensive Survey of living conditions in Japan. Geriatr Gerontol Int. 2019;19(8):747–54. https://doi.org/10.1111/ggi.13708

Publisher's note