Liang et al. BMC Geriatrics (2025) 25:170
https://doi.org/10.1186/s12877-025-05814-y

BMC Geriatrics

RESEARCH

Open Access

A fall risk prediction model based on the CHARLS database for older individuals in China

Xue-Zhen Liang[1,3], Jin-Lian Chai[2], Guang-Zheng Li[2], Wei Li[1], Bo-Chun Zhang[1], Zhong-Qi Zhou[2] and Gang Li[3*]

Abstract

Background Falls represent the second leading cause of injury-related mortality among older adults globally. The occurrence of falls is the consequence of the interaction of numerous complex risk factors. The objective of this study was to develop a validated fall risk prediction model for the Chinese older individuals.

Methods The study used data from the China Health and Retirement Longitudinal Study (CHARLS), a dataset representative of the Chinese population. Thirty-eight indicators including biological factors, behavioral factors and health status were analyzed in this study. The study cohort was randomly divided into the training set (70%) and the validation set (30%). Variables were screened using LASSO regression analysis, the best predictive model based on 10-fold cross-validation, logistic regression model was applied to explore the correlates of fall risk in the older individuals, a nomogram was constructed to develop the predictive model, calibration curves were applied to assess the accuracy of the nomogram model, and predictive performance was assessed by area under the receiver operating characteristic curve and decision curve analysis.

Result A total of 4,913 cases from the 2015 CHARLS database for people aged 60 years and older were ultimately included, and a total of 1,082 (22.02%) of the older individuals had experienced a fall within two years. Multivariate logistic regression analysis showed that Sleeping time, Hearing, Grip strength, ADL score, Cognition, Depression, Health, KD, and Pain DRUG were predictors of fall risk in the older individuals. These factors were used to construct nomogram models that showed good agreement and accuracy. The AUC value for the predictive model was 0.644 (95% CI = 0.621–0.666), with a specificity of 0.695 and a sensitivity of 0.522. For the internal validation set, the AUC value was 0.644 (95% CI = 0.611–0.678), with a specificity of 0.629 and a sensitivity of 0.577. The Hosmer-Lemeshow test value of the model for the training set is $p = 0.9368$ and for the validation set is $p = 0.8545$ (both > 0.05). The calibration curves show a more significant agreement between the nomogram model and the actual observations. The ROC and DCA indicate a better predictive performance of the nomogram.

Conclusion The comprehensive nomogram constructed in this study is a promising and convenient tool for assessing the risk of falls in the Chinese older individuals and to help older adults understand the risk level of falls, avoid and eliminate modifiable risk factors, and reduce the incidence of falls.

*Correspondence:
Gang Li
sdszylg@163.com
Full list of author information is available at the end of the article

Clinical trial number Not applicable.

Keywords Prediction model, Falls risk, CHARLS database, Older individuals, China

Background

As the world's population ages and human life expectancy increases, the physiological changes that accompany the aging process such as decreased physical function, balance, limb coordination, and the presence of other factors such as depressive states, cognitive impairments, chronic diseases, and medication use increase the risk of falls and fall-related injuries [1–3]. A fall is a sudden, involuntary, unintentional change in the position of an individual's body, which is a fall of the body to the ground or a lower plane [4]. According to the World Health Organization, the annual incidence of falls in the older population aged 65 years and older is 28–35%, and the incidence rate grows to 32–42% in the older population aged 70 years and older. According to the Global Burden of Disease, Injury and Risk Factor Study, 12% of unintentional injury deaths originate from falls, and the proportion of deaths due to falls has risen to 65%. Falls are the second leading cause of injury deaths among older persons globally and the second leading cause of unintentional injury-related deaths after road traffic injuries. The incidence of falls also shows some variation across countries. In the United States, about 25% of the older individuals aged 65 years or older experience falls each year, with a fall mortality rate of 36.7 per 100,000; in Canada, about 20–30% of the older individuals experience one or more falls each year, with a fall mortality rate of 9.4 per 100,000; and in China, the annual incidence of falls among the older individuals ranges from 14.7 to 34%, with a fall mortality rate of 44.3 per 100,000 for the population aged 65 years or older. Falls not only cause death of the older individuals, but also lead to hip fractures, traumatic craniocerebral injuries and other related serious injuries [5], decrease in self-care ability, daily activities, independence of movement, and quality of life of the older individuals, making it impossible for them not to receive long-term care, and at the same time greatly increasing, directly or indirectly, the expenditure on medical expenses and economic consumption [6]. The U.S. Centers for Disease Control and Prevention recommends that at least Annual fall risk screening for older individuals to intervene as early as possible to address modifiable fall risk factors [7–9]. Falls risk assessment therefore becomes a key component of falls prevention.

A plethora of risk assessment tools exists for the purpose of evaluating potential hazards associated with the fall. Such as Functional evaluation of upper and lower limbs, muscle strength measure [10], fall efficacy scale [11], Romberg test [12], STRATIFY fall risk assessment [13], post-fall assessment tool [14], and falls risk for older individuals in the community assessment [15], to name a few. However, most of these tools are based on a single factor or a limited combination of variables, making it difficult to comprehensively reflect the complexity of fall risk in older individuals, in addition to the fact that most of the existing models are mainly focused on European and American populations and lack targeted research on the Chinese older individuals [16–18]. Although the study by Pereira et al. proposed a framework for fall risk assessment based on multidimensional factors, their model was mainly based on data from Western populations, and the differences in genetic-biological factors and environmental lifestyles among different populations limit the population to which the model can be applied.

We identified a selection of potential factors that may influence falls based on previous studies, which were screened and included in the prediction model. Factors such as cognitive impairment, physical fitness (covering strength, flexibility, agility, balance and aerobic endurance), gait, body composition, physical activity (including light, moderate or strenuous exercise), health status, environmental hazards and other factors have been frequently reported to be strongly associated with fall risk in previous studies [3, 19]. Based on this, this study constructed a comprehensive fall risk prediction model for the first time for the Chinese older individuals based on the China Health and Retirement Longitudinal Study (CHARLS) database. In addition, this study innovatively introduced the tool of nomogram. Nomograms can effectively quantitatively integrate the predicted values of multiple variables, providing clinicians and public health workers with an intuitive risk assessment tool that enables them to quickly and easily assess the risk of falls, and then accurately identify high-risk populations, which can provide a powerful support for the identification and prevention of fall risk.

Information and methods

Study design

We use data from the China Health and Retirement Longitudinal Study (CHARLS), which is publicly available at http://charls.pku.edu.cn. Published by the National Development Research Institute of Peking University (NDI-Peking University), CHARLS is a tracking survey representative of mainland China's population aged 45 years and older, aiming to build a high-quality public micro-database to collect information covering multiple dimensions such as socioeconomic status and health status to meet the needs of scientific research on aging [20]. The data of this project is of high quality and has the characteristics of a large sample, which provides real and effective data support for the analysis of this thesis.

Data from the 2015 CHARLS in the older individuals aged 60 years and older were selected for analysis in this study, and our study followed the Declaration of Helsinki. The original CHARLS was approved by the Ethics Review Board of Peking University (Beijing, China) (IRB00001052-11015), and all participants signed an informed consent form at the time of participation. No ethical issues were addressed in this paper. The study population was the older individuals aged 60 years and above in China, and the actual number of cases was 4,913 after excluding some of the people with missing outcome variables or those who did not meet the inclusion criteria.

Of 21,095 respondents in the CHARLS 2015 dataset, we removed all individuals whose study inclusion variables contained missing data, including (1): exclusion of 183 individuals with missing data on falls; (2) exclusion of 325 individuals with missing data on age, sex, residence, and marital status; (3) exclusion of 4838 individuals with missing data on height, weight, waist circumference, and grip strength; (4) 323 who excluded missing data on self-reported health status and data on pain status; (6) 6 who excluded missing data on smoking; (7) 9 who excluded missing data on alcohol consumption; (8) 202 who excluded missing data on sleep duration and quality of sleep; (10) 5,144 who excluded missing data on ADL scores; (11) 205 who excluded missing data on cognitive function; and (12) 205 who excluded missing data on the CES-D -10 questionnaire-related data were missing in 815 individuals; (13) chronic disease and disease medication data were missing in 58 individuals, and individuals over 60 years of age (4074 individuals under 60 years of age were excluded) were selected to be included in the construction of the prediction model, and finally 4,913 respondents were included in the construction of the prediction model after rigorous data screening.

Data collection

Falls

Fall in this study was defined as the presence or absence of a fall in the last two years.

Biological factors

Biological factors included age, sex, obesity level, place of residence, and marital status. Age: ≥ 60 years. Sex: defined as male or female. Degree of obesity: considered obese if BMI ≥ 24 and non-obese if BMI < 24. Place of residence: participants were considered to be urban if they were in the main urban area or urban-rural combined area, and rural if they were in the town center, town-rural combined area, special area, town center, and villages; marital status: participants were considered to be married if they were currently married and living or cohabitating with their spouse; participants were defined as unmarried if they were not currently living with their spouse due to work or other reasons, were separated, divorced, widowed, or had never been married. unmarried.

Behavioral factors

Behavioral factors included smoking history, alcohol consumption history, sleep quality, and nighttime sleep duration. Smoking history: never smoked is considered no history of smoking; current and past smoking is considered a history of smoking. Alcohol consumption history: alcohol use was considered a history of alcohol use; never using alcohol was considered no history of alcohol use. Quality of sleep: Assessment was based on the response “I have a very restless sleep” and was divided into two groups according to the true time of the statement during the week, with ‘Rarely or none of the time’ and ‘Some or a little of the time’ defined as good quality sleep; Occasionally or a moderate amount of the time and ‘Most or all of the time’ defined as poor quality sleep. Nightly sleep duration: data from the question “In the past month, how many hours of actual sleep did you get each night (average number of hours per night)?”

Health status

Referring to international guideline [21] and in conjunction with the foundation of previous research, the health factors selected as predictors of fall risk included vision, hearing, waist circumference, grip strength, body pain, activities of daily living, cognitive function, self-perceived health status, depressive state, history of chronic disease (hypertension, dyslipidemia, diabetes, cancer, chronic lung disease, liver disease, heart disease, stroke, kidney disease, digestive disease, mental illness, memory-related disorders, arthritis or rheumatism, or asthma) and disease medication (hypertension medication, diabetes medication, oncology medication, stroke medication, prostate disease, and analgesics). Vision: Based on the answers to the questions “How well do you see things in the distance? For example, can you recognize a friend across the street (including with glasses)” and “How well do you see things up close?“. For example, can you read a newspaper with your glasses on?“The assessment was carried out in two groups: “excellent”, “very good” and “good” were considered “good”, while “fair” and “poor” were considered “bad”. “Fair” and “poor” were considered “bad”. Waist circumference: exclude those greater than or equal to 500. Grip strength: Take the average of the left and right hand grip strength data from the four times in the dataset Physical pain: based on self-reported diagnosis, defined as “yes” or “no”. Activities of daily living: measured using the Katz Activities of Daily Living (ADL) [22], the CHARLS questionnaire includes six items: eating, dressing, transferring, toileting, bathing, and incontinence; for "No, I don't have difficulty" and " I have difficulties but I can still do it", a score of 1 was assigned, and for "Yes, I have difficulties and need help" and "I cannot do it", a score of 0 was assigned; therefore, the total Katz ADL score indicates the degree of dependence, with lower scores indicates a higher degree of dependence. Visuospatial skills were assessed by redrawing two overlapping pentagons; 1 point was awarded for correctly redrawing the pictures and 0 points for failure. Memory is measured by mean scores on immediate and delayed recall of ten Chinese words; each correctly recalled word is scored as one point; Orientation and Attention are measured by the Telephone Interview for Cognitive Status (TICS-10), which calculates scores based on responses to questions about the year, month, day, day of the week, season, and the successive subtraction of seven (up to five times) from 100, with each correct answer scored as one point, with a The total score is 0–10; the sum of the above dimensions is the Total Cognitive Functioning Score, which ranges from zero to 21, with a higher score indicating better cognitive functioning [23]. Self-perceived health: based on the answer to the question "What do you think of your health?" was assessed and divided into two groups: "excellent", "very good", "good" was considered "good", "fair" and "poor" were considered "bad". Depression is assessed by the Center for Epidemiologic Studies Depression Scale (CES-D-10) [24] used in the questionnaire, which is a widely used instrument for measuring mental health, and consists of 10 items, with the options for each entry being "rarely or not at all," "not too much," "sometimes or half the time," and "most of the time," and a score of 1 to 4 is assigned accordingly depending on the actual questio, scores are added up to obtain a higher total score indicates a higher degree of depression, the total score of 30 points, 10 points or more Defined as depressed [25]. Chronic disease history: Based on self-reported diagnosis, defined as "yes" or "no". Disease medication use: based on self-reported use of medications for the chronic disease in question, defined as "yes" or "no".

Statistical methods

Data from the 2015 CHARLS database were selected for analysis. Percentiles were calculated for each potential risk factor for falls, as well as one-factor ratio with measurements expressed as medians and interquartile ranges, and between-group comparisons were analyzed using the rank-sum test. Categorical variables were expressed as percentages, and between-group comparisons were analyzed using the χ^2 test or Fisher exact test.

The data were randomly divided into training and validation sets in a 7:3 ratio. With the selection of falls in the last 2 years as predictors, the model was developed and validated using Least Absolute Shrinkage and Selection Operator (LASSO) regression analysis [26] was applied to confirm the appropriate tuning parameter (λ) of the LASSO regression analysis to screen out the significant risk predictors with a P-value of less than 0.05, which were sequentially incorporated into the multifactorial logistic regression analysis to make predictions [27], and then nomograms were used to Visualize the effects and interconnections of various variables related to fall risk in different individuals of the older individuals [25]. In addition, the ability to discriminate between key risk factors for falls in the model was determined using area under the curve (AUC)-based participant work characteristics (ROC) analyses, examining the ability of the constructed model to discriminate between fallers and non-fallers and determining risk thresholds for each of these key factor outcomes [28]. Hosmer-Lemeshow goodness-of-fit tests were used and to determine the overall fit between predicted probabilities and observations. Decision curve analysis (DCA) was used to assess clinical validity.

All analyses in this study were performed using R software (version 4.3.2). All tests were two-tailed and $P < 0.05$ was considered statistically significant.

Results

Participant characteristics

Participant Characteristics A total of 4913 people were included in this study. The demographic and clinical characteristics of the participants are listed in Table 1. There were 2246 males (45.7%) and 2667 females (54.3%), and 6.7% were aged 80 years or older. The data were randomized into a training set ($n = 3439$) and a validation set ($n = 1474$).

Incidence of falls and related variables

The prevalence of falls was 22.02% (1082/4913). Several factors including Gender, Residence, Smoking, Sleep quality, Sleeping time, Vision, Hearing, Grip strength, ADL score, Cognition, Health, Depression, HTN, DBS, CLD, LiverD, HD, KD, DigestD, MentalD, AR, Asthma and Pain DRUG differed significantly ($p < 0.05$) between those who fell and those who did not.

LASSO and logistic regression

In the LASSO regression model, non-zero coefficients were selected as potential predictors of falls in this study (Fig. 1A and B). Then, we further used the 'rms' package in R software to incorporate these potential factors associated with falls into the multivariate logistic regression model. Ultimately, Sleeping time (0.0315), Grip strength (0.0377), ADL score (0.0018), Hearing (0.0021), Cognition (0.0349), Depression (1.86e-05), Health (0.0099), KD (0.0002) and Pain DRUG (0.0120) were associated with the occurrence of falls (Table 2).

Table 1 Baseline characteristics of the study population

Variable	Total	Non-fall	Fall	*P*
	4913	**3831**	**1082**	
Age group(%)				0.614
60–70	3113(63.4)	2439(63.7)	674(62.3)	
70–80	1498(30.5)	1162(30.3)	336(31.1)	
>=80	302(6.1)	230(6.0)	72(6.7)	
Gender(%)				< 0.001
Female	2667(54.3)	2007(52.4)	660(61.0)	
Male	2246(45.7)	1824(47.6)	422(39.0)	
Obesity(%)				0.051
BMI < 24	2867(58.4)	2264(59.1)	603(55.7)	
BMI > = 24	2046(41.6)	1567(40.9)	479(44.3)	
Residence(%)				0.003
Rural	4061(82.7)	3133(81.8)	928(85.8)	
Urban	852(17.3)	698(18.2)	154(14.2)	
Marital status(%)				0.664
Unmarried	1136(23.1)	880(23.0)	256(23.7)	
Married	3777(76.9)	2951(77.0)	826(76.3)	
Smoking(%)				0.001
No	2718(55.3)	2069(54.0)	649(60.0)	
Yes	2195(44.7)	1762(46.0)	433(40.0)	
Drinking(%)				0.562
No	2989(60.8)	2322(60.6)	667(61.6)	
Yes	1924(39.2)	1509(39.4)	415(38.4)	
Sleep quality(%)				< 0.001
Poor	1922(39.1)	1421(37.1)	501(46.3)	
Good	2991(60.9)	2410(62.9)	581(53.7)	
Sleeping time (hour) mean(SD)	6.1(2.1)	6.3(2.1)	5.8(2.2)	< 0.001
Vision(%)				0.002
Poor	4302(87.6)	3325(86.8)	977(90.3)	
Good	611(12.4)	506(13.2)	105(9.7)	
Hearing(%)				< 0.001
Poor	3687(75.0)	2823(73.7)	864(79.9)	
Good	1226(25.0)	1008(26.3)	218(20.1)	
Waist(mean(SD))	85.2(14.1)	85.2(14.1)	85.3(14.0)	0.781
Grip strength(mean(SD))	24.7(8.9)	25.2(8.9)	22.8(8.6)	< 0.001
Pain(%)				1
No	255(5.2)	199(5.2)	56(5.2)	
Yes	4658(94.8)	3632(94.8)	1026(94.8)	
ADL score(mean(SD))	5.9(0.5)	5.9(0.4)	5.8(0.7)	< 0.001
Cognition(mean(SD))	9.2(4.4)	9.4(4.4)	8.5(4.4)	< 0.001
Health(%)				< 0.001
Poor	4172(84.9)	3192(83.3)	980(90.6)	
Good	741(15.1)	639(16.7)	102(9.4)	
Depression(%)				< 0.001
No	2853(58.1)	2364(61.7)	489(45.2)	
Yes	2060(41.9)	1467(38.3)	593(54.8)	
HTN(%)				0.036
No	3181(64.7)	2510(65.5)	671(62.0)	
Yes	1732(35.3)	1321(34.5)	411(38.0)	
DL(%)				0.416
No	4186(85.2)	3273(85.4)	913(84.4)	
Yes	727(14.8)	558(14.6)	169(15.6)	

Table 1 (continued)

Variable	Total	Non-fall	Fall	P
	4913	**3831**	**1082**	
DBS(%)				0.001
No	4448(90.5)	3496(91.3)	952(88.0)	
Yes				
CA(%)				0.749
No	4861(98.9)	3789(98.9)	1072(99.1)	
Yes	52(1.1)	42(1.1)	10(0.9)	
CLD(%)				0.007
No	4214(85.8)	3314(86.5)	900(83.2)	
Yes	699(14.2)	517(13.5)	182(16.8)	
LiverD(%)				0.004
No	4717(96.0)	3695(96.5)	1022(94.5)	
Yes	196(4.0)	136(3.5)	60(5.5)	
HD(%)				0.026
No	3947(80.3)	3104(81.0)	843(77.9)	
Yes	966(19.7)	727(19.0)	239(22.1)	
STK(%)				0.058
No	4775(97.2)	3733(97.4)	1042(96.3)	
Yes	138(2.8)	98(2.6)	40(3.7)	
KD(%)				< 0.001
No	4539(92.4)	3589(93.7)	950(87.8)	
Yes	374(7.6)	242(6.3)	132(12.2)	
DigestD(%)				0.004
No	3760(76.5)	2968(77.5)	792(73.2)	
Yes	1153(23.5)	863(22.5)	290(26.8)	
MentalD(%)				0.011
No	4849(98.7)	3790(98.9)	1059(97.9)	
Yes	64(1.3)	41(1.1)	23(2.1)	
MRD(%)				0.055
No	4799(97.7)	3751(97.9)	1048(96.9)	
Yes	114(2.3)	80(2.1)	34(3.1)	
AR(%)				< 0.001
No	3008(61.2)	2438(63.6)	570(52.7)	
Yes	1905(38.8)	1393(36.4)	512(47.3)	
Asthma(%)				0.014
No	4624(94.1)	3623(94.6)	1001(92.5)	
Yes	289(5.9)	208(5.4)	81(7.5)	
HTN DRUG(%)				0.145
No	4654(94.7)	3639(95.0)	1015(93.8)	
Yes	259(5.3)	192(5.0)	67(6.2)	
DBS DRUG(%)				0.291
No	4833(98.4)	3773(98.5)	1060(98.0)	
Yes	80(1.6)	58(1.5)	22(2.0)	
CA DRUG(%)				0.704
No	4894(99.6)	3815(99.6)	1079(99.7)	
Yes	19(0.4)	16(0.4)	3(0.3)	
STK DRUG(%)				0.64
No	4871(99.1)	3800(99.2)	1071(99.0)	
Yes	42(0.9)	31(0.8)	11(1.0)	
Prostate DRUG(%)				0.318
No	4727(96.2)	3692(96.4)	1035(95.7)	
Yes	186(3.8)	139(3.6)	47(4.3)	
Pain DRUG(%)				< 0.001

Table 1 (continued)

Variable	Total	Non-fall	Fall	*P*
	4913	**3831**	**1082**	
No	4443(90.4)	3524(92.0)	919(84.9)	
Yes	470(9.6)	307(8.0)	163(15.1)	

Legend HTN(Hypertension), DL(Dyslipidemia), DBS (Diabetes or high blood sugar), CA(Cancer or malignant tumor), CLD (Chronic Lung Disease), LiverD (Liver Disease), HD (Heart Disease), STK(Stroke), KD (Kidney Disease), DigestD (Stomach or other digestive disease), MentalD (Emotional, nervous, or psychiatric problems), MRD(Memory-related disease), AR (Arthritis or Rheumatism)

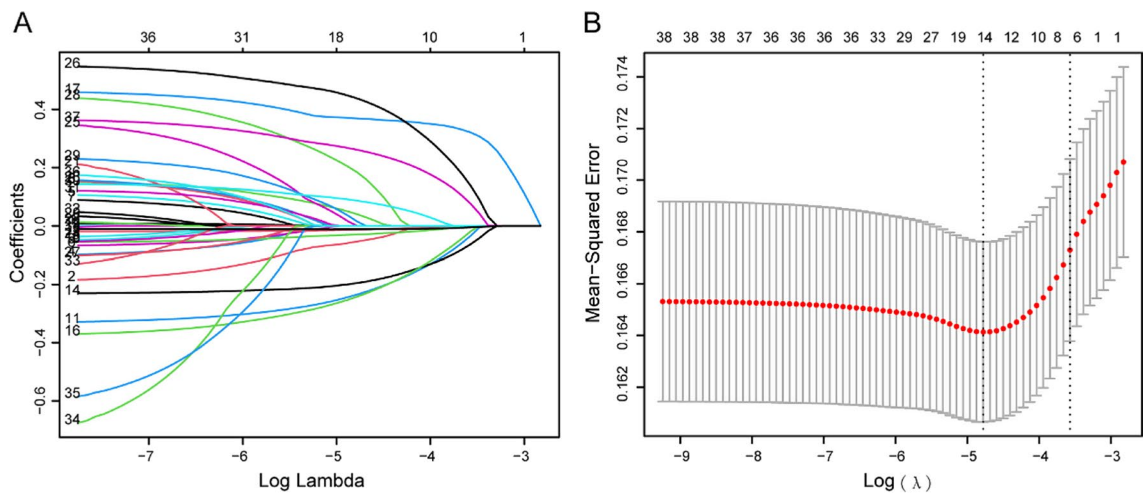

Fig. 1 Selection of demographic and clinical characteristics using the LASSO regression model. **A** Coefficient profiles were generated from the log (lambda) series, and nonzero coefficients were generated from the optimal lambda. **B** The optimal parameter (lambda) in the LASSO model was selected by ten-fold cross-validation using the minimum criterion. Partial likelihood deviation (binomial deviation) curves are plotted relative to log (lambda). A virtual vertical line is drawn at the optimum using one SE of the minimum criterion (1-SE criterion)

Table 2 The prediction model with multivariate logistic regression

Variable	Multivariate analysis	*P*
	OR (95%CI)	
Sleeping time	0.957(0.92–0.996)	0.0315
ADL score	0.782(0.67–0.913)	0.0018
Hearing	0.715(0.576–0.883)	0.0021
Cognition	0.978(0.958–0.998)	0.0349
Depression	1.475(1.235–1.763)	$1.86*10^{-5}$
Health	0.694(0.522–0.911)	0.0099
KD	1.728(1.296–2.292)	0.0002
Pain DRUG	1.388(1.072–1.788)	0.0120
Grip strength	0.987(0.976–0.999)	0.0377

Predictive model development

LASSO regression analysis was used to screen the model for the best predictor variables based on 10-fold cross-validation, and multivariate logistic regression was performed to create predictive models. The predictive model consisted of variables with p-values less than 0.05 in multivariate logistic regression. These variables included Sleeping time, ADL score, Hearing, Grip strength, Cognition, Depression, Health, KD, and Pain DRUG as predictors. The predictive model is presented in a nomogram and can be used to quantitatively predict the risk of falls in the older individuals (Fig. 2).

Validation of the prediction model

Differentiation AUC values were calculated to assess the ability of the predictive model to differentiate the model by examining the incidence of fall risk in the older adult population in the training and validation sets. As shown in Fig. 3A and B, in the training set, the prediction model had an AUC value of 0.644 (95% CI = 0.621–0.666), with a specificity of 0.695 and a sensitivity of 0.522. In the validation set, the AUC value was 0.644 (95% CI = 0.611–0.678), with a specificity of 0.629 and a sensitivity of 0.577. These data suggest that nomograms have some discriminatory ability and predictive value, and that they can somewhat correctly identify the risk of falling or not in the older individuals.

Calibration of the prediction model

The nomograms were evaluated using calibration plots and the Hosmer-Lemeshow goodness-of-fit test ($p > 0.05$ indicating a very good model fit). The test results showed that the model fit well to both the training set ($\chi2 = 2.9609$, $df = 8$, $p = 0.9368$) and the validation set ($\chi2 = 4.0294$, $df = 8$, $p = 0.8545$). Figure 4A and B Calibration curves based on the multifactor logistic regression model show a high degree of agreement between the

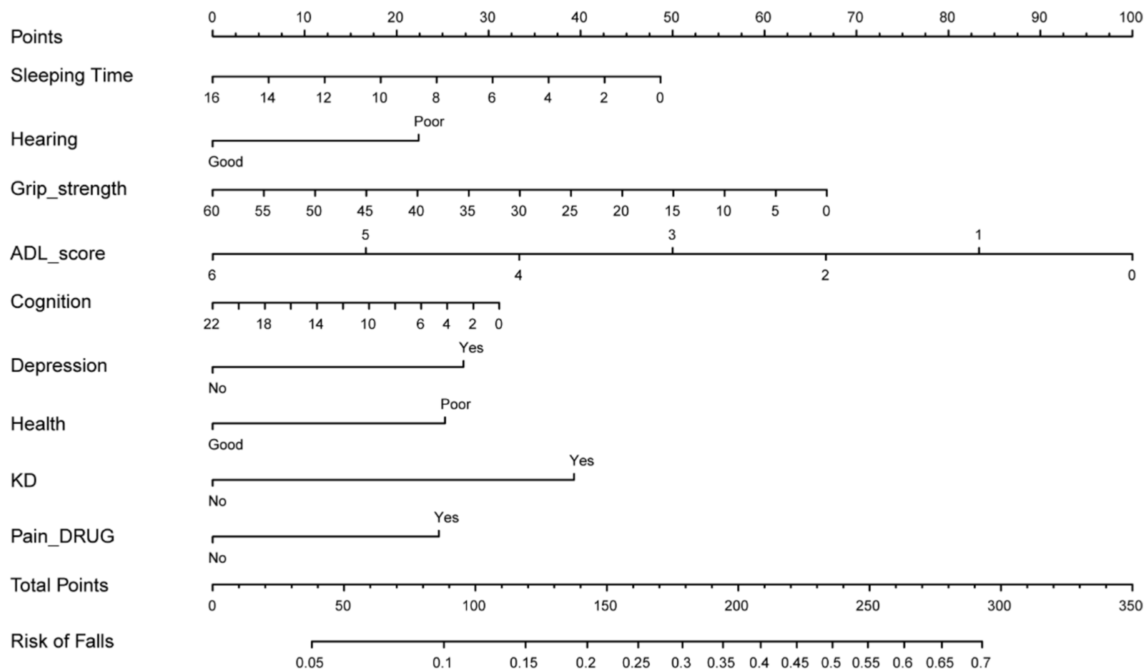

Fig. 2 Nomogram used to quantitatively predict the risk of falls in the older individuals

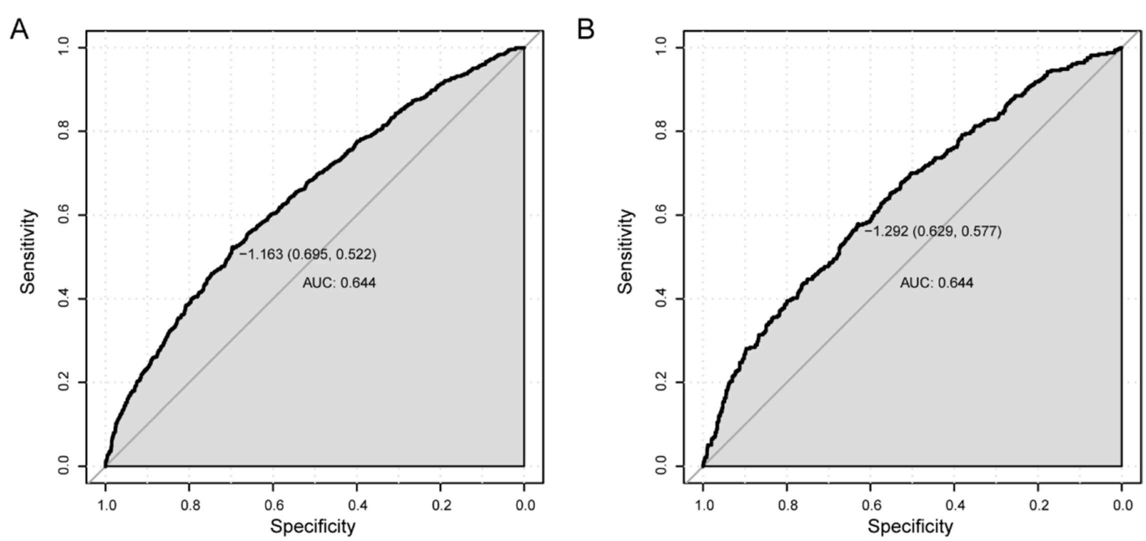

Fig. 3 Nomogram ROC curves for quantitative prediction of fall risk in the older individuals. **A**. ROC curves generated using the training dataset. **B** ROC curves generated using the validation dataset

predicted and actual probability of falls in the older individuals in both the training and validation sets.

Assessment of clinical effectiveness

The clinical validity of the model was assessed using a decision curve analysis (DCA) approach, and the results are shown in Fig. 5A and B. The results are shown in Fig. 5A. The decision curves show that the net benefit of the predictive model for the internal validation set is higher than the two extreme scenarios, indicating that the nomogram model has a higher net benefit and predictive accuracy.

Discussion

Falls are a significant public health concern, being the leading cause of injury-related deaths among Chinese older individuals, with a substantial impact on their quality of life and healthcare costs. The prevalence of falls among Chinese people aged 60 years and older in this study was 22.02%, which was not much different from previous reports on the prevalence of falls, which ranged

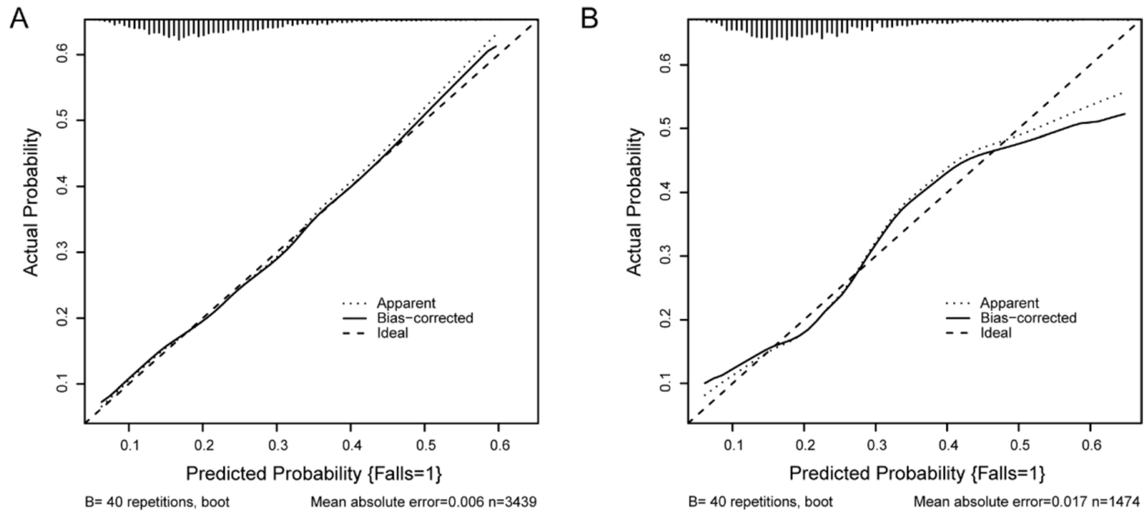

Fig. 4 Calibration plots for quantitative prediction of fall risk in the older individuals. **A**. Calibration plots generated using the training dataset. **B**. Calibration plots generated using the validation dataset

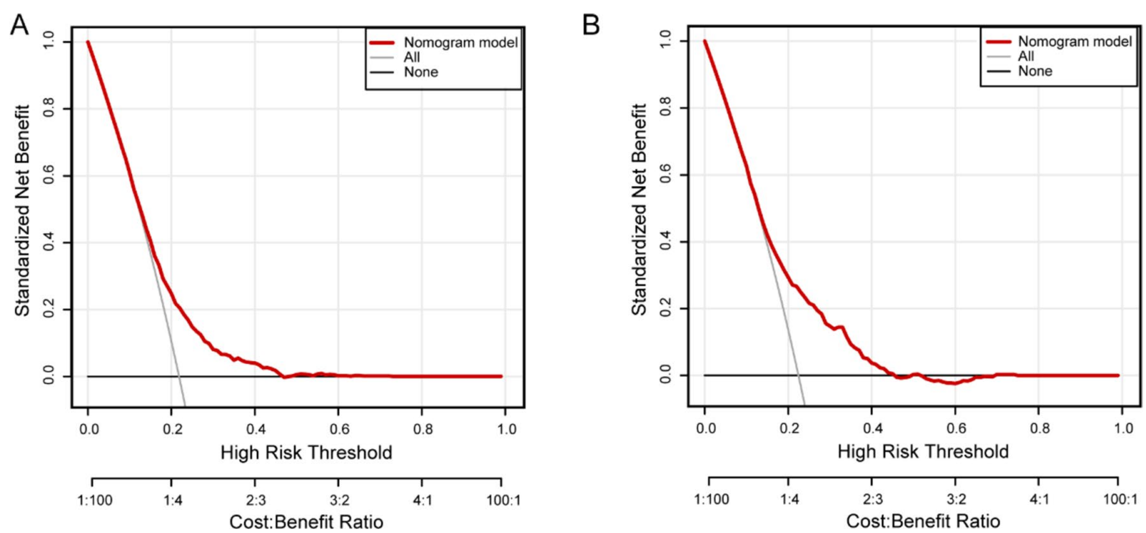

Fig. 5 Decision curve plots for quantitative prediction of fall risk in the older individuals. **A**. DCA plots generated using the training dataset. **B**. DCA plots generated using the validation dataset

from about 14.7–34% [29–33]. Falls are strongly associated with the occurrence of hip fractures, craniocerebral injuries, disability, and death [34], and their prevention and management has become a major public health issue to be focused on and addressed in the process of healthy aging [35]. Therefore, identifying high-risk individuals is important for preventing falls and their associated adverse outcomes, especially for the older individuals. Falls in older individuals are not an accident, but a potential hazard [36]. Falls are the result of a complex combination of risk factors that interact with each other [37]. In this study, Sleeping time, Hearing, Grip strength, ADL score, Cognition, Depression, Self-reported health status, Chronic Kidney Disease, and the use of pain medication were selected as predictors of falls in the Chinese older individuals, and the associations of these factors with falls were similar to those of previous studies [38–44].

Sleep disorders are a common health problem among the older individuals, and shorter sleep duration at night caused by insomnia, difficulty in falling asleep, and early awakening is one of the main manifestations [45–47]. In this study, the incidence of falls was predicted to be greater in those with sleep deprivation and poor health. Piovezan et al. hypothesized that sleep disorders can lead to an imbalance between catabolic and anabolic hormones in the body, resulting in an enhanced inflammatory response and a decrease in energy expenditure, which partly explains the increased risk of falls in older individuals with increased sleep status [48]. A cross-sectional study by Machado et al. using data from the

Brazilian Longitudinal Study of Aging (ELSI-Brazil) 2015–2016 also confirmed that self-reported low sleep quality was significantly associated with an increased incidence of falls in adults older than 50 years [49]. Sosnoff et al. analyzed 2,819 subjects from 23 studies and showed that decreased gait parameters, decreased balance, decreased physical functioning, cognitive impairment, and sleep deprivation were found to be significant predictors of increased fear of falling [50]. The results of many previous studies support the conclusion that sleep duration can be used as a predictor of falls, but relatively few studies have used self-reported health status as a predictor of falls. Pereira et al. showed that if older individuals are less fit, in an unhealthy state and less likely to engage in strenuous physical activity, the higher the probability of being at risk of falling during strenuous physical activity [51]. Our findings are somewhat supported by the results of Kiyoshi-Teo H et al. which showed that self-reported health status was associated with concern about falls, that older adults in better health should be less concerned about falls, and that those who were more concerned about falls had higher fall risk scores [52].

Numerous studies conducted in different countries and regions with ethnically diverse populations have found a potential correlation between hearing loss and falls [53]. Studies have shown that older adults with hearing loss have a 2.4 times greater risk of falling than their normal-hearing peers [54]. Hearing loss limits the ability of older individuals to monitor and perceive auditory cues for spatial orientation, resulting in balance and orientation deficits, reduced stability of postural control, and potentially an increased risk of falls [55]. In addition, older individuals with hearing loss are prone to loneliness, depression, anxiety, and social isolation due to reduced speech perception and impaired communication, and may even experience varying degrees of cognitive dysfunction [56]; cognitive decline affects the ability of older individuals to avoid hazards and increases the risk of falls [37, 57]. The results of this study also confirm that hearing impairment, depressive state and cognitive decline are predictors of fall risk.

The results of this study suggest that comorbid kidney disease and the use of pain medication were both independent predictors of increased risk of falls and predictors that led to multifactorial analysis. Considering kidney disease can lead to multiple structural and functional changes in the kidneys. Kidney function declines and glomerular filtration rate decreases, leading to a weakening of the body's overall metabolism and detoxification capacity, and this decline in function affects older people's stamina and endurance, which in turn affects their balance and gait, and increases the risk of falls [58]; at the same time, people with kidney disease often need to restrict their protein intake, which can lead to malnutrition that affecting muscle strength and bone health [59], which can also increase the risk of falls. In addition, older individuals with chronic kidney disease are often associated with impaired cognitive function and ability to perform activities of daily living [60], further increasing the risk of falls. Age-related cognitive dysfunction, communication difficulties, and lowered pain thresholds lead to challenges in the medication of chronic pain in the older individuals. Common medications for pain are categorized by pharmacological characteristics into acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), tramadol, opioids, compounded analgesics, antidepressants, and others [61]. Opioid painkillers work by decreasing alertness or depressing the central nervous system, which may cause older individuals to experience symptoms such as drowsiness, confusion or disorientation, or cause postural hypotension, side effects that may increase the risk of falls; meanwhile, less common side effects of opioids include unconscious contractions of the muscles (myoclonus), which may affect balance and coordination, and thus increase the risk of falling [62]. In addition, a history of chronic disease and irrational drug application can interact. Non-steroidal anti-inflammatory drugs (NSAIDs) can sometimes cause fluid retention and swelling, and regular use of NSAIDs can also increase the risk of kidney disease, and in some cases, kidney failure [63, 64], further aggravating the risk of falls. In order to reduce the risk of falls due to the use of painkillers in the older individuals, doctors should fully inform patients of the risks involved when prescribing painkillers, such as opioids, for the treatment of chronic pain; patients should use painkillers reasonably under the guidance of their doctors, pay attention to the dosage of the drugs and the duration of the medication, and avoid going out alone for a certain period of time after taking the medication, so as to minimize the risk factors for falls.

In addition to the inclusion of the above factors as predictors in the prediction model construction, the results of this study also found differences between the falls population non-falls population in terms of gender, place of residence, smoking status, sleep quality, visual acuity, HTN, DBS, LivrD, HD, DigestD, MentalD, AR, and Asthma.Some of the previous findings include women as one of the risk factors for hip fracture. Jerng et al. recruited older individuals residents in a long-term care facility in Taiwan to conduct a multivariate analysis to identify factors associated with falls, and the results showed that gender had a significant relationship with the risk of falls [65]. Yao et al.'s results showed a statistically significant difference in the association between frailty status and falls between the male and female groups (male OR: 1.49, 95% CI: 0.71–3.13; female OR: 7.54, 95% CI: 1.13–50.32, p for interaction = 0.035), revealed an interaction effect of gender on the increased incidence of falls [66]. zhou et al. showed that the main risk factor for falls in stroke survivors was female [67].

The impact of living conditions on the older individuals has been controversial. Ursenbach et al. showed that falls were not associated with rural residence or age [68], whereas Zhao et al. showed significant differences in place of residence, living alone and falls [69]. Ding et al. also found that specific variables such as gender (male), residence with elevator (or lift), and sleep quality (acceptable/poor) were negatively associated with falls, which is generally consistent with the results of the present study [70], suggesting that there is a higher risk of falls in the older individuals living in rural areas than in urban areas.

Smoking is generally recognized as a risk factor for declining quality of life in older individuals, leading to impaired neuromuscular function and decreased balance; it also increases the probability of adverse outcomes such as hypertension, coronary heart disease, and cognitive impairment in older individuals [71], all of which contribute to an increased risk of falls. Jonas et al. showed that higher self-reported prevalence of unintentional injuries and falls was associated with higher number of smoking packs (OR: 1.01, $P=0.001$) [72]. The results of a prospective cohort study conducted by Zhao et al. in 27 villages in rural Ningxia, China, suggest that smoking is a risk factor for falls among the older individuals in rural China [73]. Our study shows that the risk of falls in elderly smokers is lower than that of non-smokers. The reason for this is that nicotine released from smoking can stimulate the brain, making it in a state of euphoria and pleasure, thus making it difficult to fall into negative emotions such as fear of falling, which may reduce the risk of falling to a certain extent, and it will be necessary to explore the correlation between smoking and falling in the future.

Low vision is a major global health problem that affects the personal, economic, psychological, and social lives of individuals. Abraham et al. conducted a review study review aimed at determining the overall prevalence of falls and associated factors in individuals with low vision globally, and the results showed that the risk of falls increased significantly with increasing visual impairment [74]. And Ehrlich et al. showed that the prevalence of falls was associated with poor contrast sensitivity, but not with near or far vision [75]. Participants in this study our results were similar to those of previous studies, with a higher rate of falls in the self-reported poor vision population (22.71%) than in the self-reported good vision population (17.18%), but but due to the limitations of the database, our assessment of visual acuity was based only on subjective reports of near and far vision and did not take into account other visual problems (e.g., contrast sensitivity, visual field, etc.), which may have a important impact, so further research into the relationship between falls and visual acuity is still needed.

The results of this study show that there are differences in multiple chronic disease states between the falls and non-falls populations. Currently, the prevalence of multiple chronic diseases among Chinese older individuals has reached 53.8%, and the number of people with multiple chronic diseases is 2.4 times higher than that of people with a single chronic disease, and with the increase in the number of diseases, there will be more incapacitation, disability, mental stress, and other health losses, and some chronic diseases or coexisting multiple diseases, such as osteoporosis, hypertension, COPD, diabetes mellitus, stroke, urinary incontinence, and cardiovascular disease, are also Risk factors for falls [76, 77]. Pharmacologic factors are one of the most important risk factors that can be intervened to reduce the risk of falls in older individuals today [78–81]. Cross-sectional studies based on U.S. Medicare data have shown that the incidence of falls among drug users is as high as 10.29% compared to the 5.42% incidence of falls among the drug-naïve population(people not taking drugs) [82]. Against the backdrop of the high prevalence of multiple chronic diseases among Chinese older individuals, streamlining the types and number of medications taken can have a significant effect on preventing many adverse outcomes, including falls, but we believe that reducing chronic disease prevalence by preventing and treating chronic diseases may be a better way to address the root causes of this problem than reducing the number of medications taken directly.

Research into falls prevention, both nationally and internationally, has shown that effective interventions include health education [83], exercise and physiotherapy [84], and environmental modifications [85]. However, nomogram for predicting falls in older individuals based on CHARLS population data have not been reported previously. Nomogram are a predictive model commonly used in clinical research that use planar coordinates connected by discontinuous line segments to represent functional relationships between variables and can be applied to predict the probability of clinical outcome events. Nomogram can specifically quantify the probability of outcome risk in the form of a cumulative score, which can provide a personalised risk assessment for each individual, while being relevant and generalisable. In this study, the results showed that the older adult population with less sleep, poor hearing, poor grip strength, low ADL scores, low cognitive ability, poor health, comorbid kidney disease, and pain medication were more likely to fall, with some of the risk factors being consistent with previous findings.The prediction model was constructed based on these nine factors affecting the risk of falls in the older individuals, showing good discriminatory ability, calibration and clinical validity, which is valuable for the effective identification of Chinese elderly individuals with a high risk of fall incidence. As an efficient and accurate assessment tool, our prediction model can identify fall-risk populations as soon as possible and is suitable for risk screening of large populations for early detection, prevention and intervention.

Second, this study is based on a cross-sectional design of the CHARLS database, which has inherent limitations, such as the inability to determine causality or directionality. For example, poor physical health, depression, anxiety, activity limitations, and fear of falling may increase the risk of falls, but serious injuries related to falls may also contribute to these problems [86]. Third, The present study, with reference to Pereira et al., only included risk factors that have a small impact on health status in the short term [87], however, potential confounders such as hip fracture, gait, home environment, mobility, public environment, social status and economic conditions were not statistically analyzed, which limits the reliability of the model to a certain extent, and the above factors are also considered to be risk factors for falls [88]. In the future, consider incorporating more factors associated with falls, using multiple databases for joint validation, and exploring the use of more advanced statistical methods to improve the predictive performance of the model.

Conclusion

In this study, we constructed a nomogram model based on the CHARLS database to predict the risk of falls in Chinese older adults. The model showed moderate discriminatory ability (AUC = 0.644). However, cross-sectional design, recall bias, and self-reported fall definitions limited the full assessment of the model's predictive ability. Future studies need to use longitudinal design, multi-centre validation and optimisation of the model to improve predictive performance. Despite its limitations, the model provides a preliminary tool for identifying high-risk individuals and has some application.

Abbreviations

ROC	Receiver operating characteristic curve
AUC	Area under the curve
DCA	Decision curve analysis
ADL	Activities of daily living
OR	Odds ratio
CI	Confidence interva
HTN	Hypertension
DL	Dyslipidemia
DBS	Diabetes or high blood sugar
CA	Cancer or malignant tumor
CLD	Chronic Lung Disease
LiverD	Liver Disease
HD	Heart Disease
STK	Stroke
KD	Kidney Disease
DigestD	Stomach or other digestive disease
MentalD	Emotional, nervous, or psychiatric problems
MRD	Memory-related disease
AR	Arthritis or Rheumatism

Acknowledgements
We thank Peking University for providing open data resources and all the researchers involved in the study.

Author contributions
LXZ created the study protocol, performed data collection, statistical analysis, and wrote the first draft. LGZ and LW assisted with the study design and data collection. ZBC and ZZQ confirmed the data and assisted with the statistical analyses. CJL was involved in the interpretation of the data and revision of the manuscript. LG, as the senior author, reviewed and edited all versions of the manuscript. All authors read and approved the final manuscript.

Funding
This work was supported by the National Natural Science Foundation of China (No. 82205154, No.82074453) and the Natural Science Foundation of Shandong Province (No. ZR2021QH004, No.ZR2021LZY002).

Data availability
The datasets generated and/or analyzed for the current study are available in the CHARLS repository at http://charls.pku.edu.cn.

Declarations

Ethical approval and consent to participate
This was a retrospective study based on the CHARLS database. Patients' information was hidden before the study. Informed consent from patients was not required and there was no ethical conflict. The original CHARLS was approved by the Ethics Review Board of Peking University (IRB00001052-11015), and all participants signed an informed consent form at the time of participation. The study followed the guidelines of the Declaration of Helsinki.

Publishing consent
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]First College of Clinical Medicine, Shandong University of Traditional Chinese Medicine, Jinan, Shandong 250355, China
[2]College of Traditional Chinese Medicine, Shandong University of Traditional Chinese Medicine, Jinan, Shandong 250355, China
[3]Orthopaedic Microsurgery, Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Jingshi Road, 16369, Jinan, Shandong 250014, China

Received: 23 August 2024 / Accepted: 24 February 2025
Published online: 13 March 2025

References

1. Guirguis-Blake JM, Michael YL, Perdue LA, et al. Interventions to prevent falls in older adults: updated evidence report and systematic review for the US preventive services task Force. JAMA. 2018;319(16):1705–16.
2. Peel NM. Epidemiology of falls in older age. Can J Aging. 2011;30(1):7–19.
3. Wang J, Chen Z, Song Y. Falls in aged people of the Chinese Mainland: epidemiology, risk factors and clinical strategies. Ageing Res Rev. 2010;9(Suppl 1):S13–17.
4. Cillis FD, Simio FD, Guido F et al. Fall-detection solution for mobile platforms using accelerometer and gyroscope data. Annu Int Conf IEEE Eng Med Biol Soc. 2015:3727–30.
5. Zhang K, Qi J, Zuo P, et al. The mortality trends of falls among the elderly adults in the Mainland of China, 2013–2020: A population-based study through the National disease surveillance points system. Lancet Reg Health West Pac. 2022;19:100336.
6. Heinrich S, Rapp K, Rissmann U et al. Cost of falls in old age: a systematic review. osteoporosis international: a journal established as result of Cooper

ation between the European foundation for osteoporosis and the nationa L osteoporosis foundation of the USA. 2010;21(6):891–902.
7. Gardiner S, Glogowska M, Stoddart C et al. Older people's experiences of falling and perceived risk of falls in the community: A narrative synthesis of qualitative research. Int J Older People Nurs. 2017;12(4).
8. Ang SG, M, O'Brien AP, Wilson A. Understanding carers' fall concern and their management of fall risk among older people at home. BMC Geriatr. 2019;19(1):144.
9. Stevens JA, Phelan EA. Development of STEADI: a fall prevention resource for health care providers. Health Promot Pract. 2013;14(5):706–14.
10. Pijnappels M, van der Burg PJ, Reeves ND, et al. Identification of elderly fallers by muscle strength measures. Eur J Appl Physiol. 2008;102(5):585–92.
11. Büla CJ, Martin E, Rochat S, et al. Validation of an adapted falls efficacy scale in older rehabilitation patients. Arch Phys Med Rehabil. 2008;89(2):291–6.
12. Vassallo M, Poynter L, Sharma JC, et al. Fall risk-assessment tools compared with clinical judgment: an evaluation in a rehabilitation ward. Age Ageing. 2008;37(3):277–81.
13. Vassallo M, Stockdale R, Sharma JC, et al. A comparative study of the use of four fall risk assessment tools on acute medical wards. J Am Geriatr Soc. 2005;53(6):1034–8.
14. Miceli DG, Strumpf NE, Reinhard SC, et al. Current approaches to postfall assessment in nursing homes. J Am Med Dir Assoc. 2004;5(6):387–94.
15. Russell MA, Hill KD, Blackberry I, et al. The reliability and predictive accuracy of the falls risk for older people in the community assessment (FROP-Com) tool. Age Ageing. 2008;37(6):634–9.
16. Hong J, Kong HJ, Yoon HJ. Web-Based telepresence exercise program for Community-Dwelling elderly women with a high risk of falling: randomized controlled Trial. Volume 6. JMIR Mhealth Uhealth; 2018. p. e132. 5.
17. Mirelman A, Rochester L, Maidan I, et al. Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial. Lancet (London England). 2016;388(10050):1170–82.
18. Tricco AC, Thomas SM, Veroniki AA, et al. Comparisons of interventions for preventing falls in older adults: A systematic review and Meta-analysis. JAMA. 2017;318(17):1687–99.
19. Phelan EA, Ritchey K. Fall prevention in Community-Dwelling older Adults. Ann Intern Med. 2018;169(11):Itc81–96.
20. Zhao Y, Hu Y, Smith JP, et al. Cohort profile: the China health and retirement longitudinal study (CHARLS). Int J Epidemiol. 2014;43(1):61–8.
21. Montero-Odasso M, van der Velde N, Martin FC et al. World guidelines for falls prevention and management for older adults: a global initiative. Age Ageing, 2022, 51(9).
22. Shelkey M, Wallace M. Katz index of independence in activities of daily Living. J Gerontol Nurs. 1999;25(3):8–9.
23. Huang W, Zhou Y. Effects of education on cognition at older ages: evidence from China's great Famine. Soc Sci Med. 2013;98:54–62.
24. Mohebbi M, Nguyen V, McNeil JJ, et al. Psychometric properties of a short form of the center for epidemiologic studies depression (CES-D-10) scale for screening depressive symptoms in healthy community dwelling older adults. Gen Hosp Psychiatry. 2018;51:118–25.
25. Bu F, Deng XH, Zhan NN, et al. Development and validation of a risk prediction model for frailty in patients with diabetes. BMC Geriatr. 2023;23(1):172.
26. Hu JY, Wang Y, Tong XM, et al. When to consider logistic LASSO regression in multivariate analysis?. Eur J Surg Oncol. 2021;47(8):2206.
27. Lyu J, Li Z, Wei H, et al. A potent risk model for predicting new-onset acute coronary syndrome in patients with type 2 diabetes mellitus in Northwest China. Acta Diabetol. 2020;57(6):705–13.
28. Pereira C, Fernandes J, Raimundo A, et al. Increased physical activity and fitness above the 50(th) percentile avoid the threat of older adults becoming institutionalized: A Cross-sectional pilot Study. Rejuvenation Res. 2016;19(1):13–20.
29. Jiang J, Long J, Ling W, et al. Incidence of fall-related injury among old people in Mainland China. Arch Gerontol Geriatr. 2015;61(2):131–9.
30. Chen X, Lin Z, Gao R et al. Prevalence and associated factors of falls among older adults between urban and rural areas of Shantou City, China. Int J Environ Res Public Health. 2021;18(13).
31. Gao ML, Song YT. Meta-analysis of the prevalence of fall in elderly in China. Beijing Med. 2014;36(10):796–8.
32. Xia QH, Hu J, Zhou P. Epidemiological characteristics and risk factors on falling at home of elderly. Chin J Disease Control &Prevention. 2013;17(10):865–7.
33. Yao MH, Zhou RJ, Yang L, et al. An epidemiological analysis on injury among residents in Nanning city. Injury Med (Electronic). 2012;1(02):11–5.
34. Ates Bulut E, Soysal P, Isik AT. Frequency and coincidence of geriatric syndromes according to age groups: single-center experience in Turkey between 2013 and 2017. Clin Interv Aging. 2018;13:1899–905.
35. Pefoyo AJ, Bronskill SE, Gruneir A, et al. The increasing burden and complexity of multimorbidity. BMC Public Health. 2015;15:415.
36. Nithman RW, Vincenzo JL. How steady is the STEADI? Inferential analysis of the CDC fall risk toolkit. Arch Gerontol Geriatr. 2019;83:185–94.
37. Palumbo P, Becker C, Bandinelli S, et al. Simulating the effects of a clinical guidelines screening algorithm for fall risk in community dwelling older adults. Aging Clin Exp Res. 2019;31(8):1069–76.
38. Similä H, Immonen M. Disease state fingerprint for fall risk assessment. Annu Int Conf IEEE Eng Med Biol Soc. 2014;2014:3176–9.
39. GholamHosseini H, Baig MM, Connolly MJ, et al. A multifactorial falls risk prediction model for hospitalized older adults. Annu Int Conf IEEE Eng Med Biol Soc. 2014;2014:3484–7.
40. Alazrai R, Mowafi Y, Hamad E. A fall prediction methodology for elderly based on a depth camera. Annu Int Conf IEEE Eng Med Biol Soc. 2015;4990–4993.
41. Yamashita T, Noe DA, Bailer AJ. Risk factors of falls in community-dwelling older adults: logistic regression tree analysis. Gerontologist. 2012;52(6):822–32.
42. Sharifi F, Fakhrzadeh H, Memari A, et al. Predicting risk of the fall among aged adult residents of a nursing home. Arch Gerontol Geriatr. 2015;61(2):124–30.
43. Wu H, Ouyang P. Fall prevalence, time trend and its related risk factors among elderly people in China. Arch Gerontol Geriatr. 2017;73:294–9.
44. Kearns WD, Fozard JL, Becker M et al. Path tortuosity in everyday movements of elderly persons increases fall prediction beyond knowledge of fall history, medication use, and standardized gait and balance assessments. Journal of The American Medical Directors Association, 2012, 13(7): 665.e667-665.e613.
45. Chen TY, Lee S, Hsu KW, et al. Poor sleep health predicts the onset of a fear of falling among community-dwelling older adults. Sleep Health. 2024;10(1):137–43.
46. Alissa N, Rehan R, Al-Sharman A, et al. Cognitive status and sleep quality can explain the fear of falling and fall history in people with Parkinson's disease. Int J Rehabil Res. 2023;46(4):338–43.
47. Cámara-Calmaestra R, Martínez-Amat A, Aibar-Almazán A et al. Falls and Sleep Disorders in Spanish Alzheimer's Disease in Nursing Homes: An Observational Study. Healthc (Basel), 2023, 11(21).
48. Piovezan RD, Poyares DLR, Tufik SJSS. Frailty and sleep disturbances in the elderly: possible connections and clinical implications. 2013, 6: 175–9.
49. Santos APD, Cordeiro JFC, Abdalla PP, et al. Sleep quality and falls in middle-aged and older adults: ELSI-Brazil study. Rev Esc Enferm USP. 2024;58:e20240027.
50. Abou L, Peters J, Freire B, et al. Fear of falling and common symptoms of multiple sclerosis: physical function, cognition, fatigue, depression, and sleep - A systematic review. Mult Scler Relat Disord. 2024;84:105506.
51. Pereira C, Veiga G, Almeida G, et al. Key factor cutoffs and interval reference values for stratified fall risk assessment in community-dwelling older adults: the role of physical fitness, body composition, physical activity, health condition, and environmental hazards. BMC Public Health. 2021;21(Suppl 2):977.
52. Kiyoshi-Teo H, De Lima B, Dieckmann NF, et al. Impact of documented Fall-Risk, Self-Reported health and confidence to prevent falls on concern about falling among Community-Dwelling older adults: secondary analysis of a randomized clinical Trial. Clin Interv Aging. 2024;19:1273–80.
53. Joseph A, Kumar D, Bagavandas M. A review of epidemiology of fall among elderly in India. Indian J Community Med. 2019;44(2):166–8.
54. Campos L, Prochazka A, Anderson M, et al. Consistent hearing aid use is associated with lower fall prevalence and risk in older adults with hearing loss. J Am Geriatr Soc. 2023;71(10):3163–71.
55. Ademoyegun AB, Ogundiran O, Kayode AJ, et al. Hearing loss, gait and balance impairments and falls among individuals with sub-acute stroke: A comparative cross-sectional study. Heliyon. 2024;10(5):e26880.
56. Ku Y-C, Liu M-E, Tsai Y-F, et al. Associated factors for falls, recurrent falls, and injurious falls in aged men living in Taiwan veterans Homes. Int J Gerontol. 2013;7(2):80–4.
57. Muir SW, Gopaul K, Montero Odasso MM. The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. Age Ageing. 2012;41(3):299–308.
58. ChenSJ, ChenHP LL. Situation analysis on kidney damage of the 1088 elderly health examination people. Chin J Geriatr, 2012, (12): 1124–6.
59. Hallan SI, Matsushita K, Sang Y, et al. Age and association of kidney measures with mortality and end-stage renal disease. JAMA. 2012;308(22):2349–60.

60. Gołębiowski T, Augustyniak-Bartosik H, Weyde W, et al. Geriatric syndromes in patients with chronic kidney disease. Postepy Hig Med Dosw (Online). 2016;70(0):581–9.
61. Kleinmann B, Wolter T. Managing chronic Non-Malignant pain in the elderly: intrathecal Therapy. Drugs Aging. 2019;36(9):789–97.
62. Seppala LJ, Wermelink A, de Vries M et al. Fall-Risk-Increasing Drugs: A Systematic Review and Meta-Analysis: II. Psychotropics. J Am Med Dir Assoc, 2018, 19(4): 371.e311-371.e317.
63. American Geriatrics Society updated Beers. Criteria for potentially inappropriate medication use in older adults. J Am Geriatr Soc. 2012;60(4):616–31.
64. Marcum ZA, Hanlon JT. Commentary on the new American geriatric society beers criteria for potentially inappropriate medication use in older adults. Am J Geriatr Pharmacother. 2012;10(2):151–9.
65. Lee HC, Hsieh CJ, Jerng JS. Incidence and factors associated with falls in older people in a Long-Term care facility: A prospective study in Taiwan. Healthc (Basel), 2024, 12(10).
66. Jiang L, Yang L, Hong Z et al. Association between frailty status and falling in older adults with hip fracture: a cross-sectional study. Postgrad Med, 2024: 1–8.
67. Tian X, Mai YH, Guo ZJ et al. Contributing factors and interventions for fear of falling in stroke survivors: a systematic review. Top Stroke Rehabil, 2024: 1–16.
68. Dal Bello-Haas VPM, O'Connell ME, Ursenbach J. Comparison across age groups of causes, circumstances, and consequences of falls among individuals living in Canada: A cross-sectional analysis of participants aged 45 to 85 years from the Canadian longitudinal study on Aging. PLoS ONE. 2024;19(3):e0300026.
69. Yuan L, Yibo W, Yuqian D, et al. The relationship between fall and loneliness among older people in China: the mediating role of personality trait. Front Psychiatry. 2023;14:1204544.
70. Wang C, Zhang Y, Wang J, et al. A study on the falls factors among the older adult with cognitive impairment based on large-sample data. Front Public Health. 2024;12:1376993.
71. Gazibara T, Kurtagic I, Kisic-Tepavcevic D, et al. Falls, risk factors and fear of falling among persons older than 65 years of age. Psychogeriatrics. 2017;17(4):215–23.
72. Bikbov MM, Kazakbaeva GM, Gilmanshin TR, et al. Unintentional injuries and falls in populations in Russia. The ural eye and medical study and the ural very old study. Heliyon. 2024;10(10):e31348.
73. Wang Q, Wang G, Wang B, et al. Risk factors of falls in rural elderly of Ningxia in China: a prospective cohort study. Inj Prev; 2024.
74. Ekemiri K, Ekemiri C, Ezinne N, et al. Global burden of fall and associated factors among individual with low vision: A systematic-review and meta-analysis. PLoS ONE. 2024;19(7):e0302428.
75. Jin H, Zhou Y, Stagg BC, et al. Association between vision impairment and increased prevalence of falls in older US adults. J Am Geriatr Soc. 2024;72(5):1373–83.
76. Vieira ER, Palmer RC, Chaves PH. Prevention of falls in older people living in the community. BMJ. 2016;353:i1419.
77. Summary of the Updated American Geriatrics Society/British Geriatrics. Society clinical practice guideline for prevention of falls in older persons. J Am Geriatr Soc. 2011;59(1):148–57.
78. Hart LA, Phelan EA, Yi JY et al. Use of fall Risk–Increasing drugs around a fall-Related injury in older adults: A systematic Review. 2020, 68.
79. Milos V, Bondesson Å, Magnusson M, et al. Fall risk-increasing drugs and falls: a cross-sectional study among elderly patients in primary care. BMC Geriatr. 2014;14:40.
80. van der Velde N, Stricker BH, Pols HA, et al. Risk of falls after withdrawal of fall-risk-increasing drugs: a prospective cohort study. Br J Clin Pharmacol. 2007;63(2):232–7.
81. de Groot MH, van Campen JPCM, Moek MA, et al. The effects of fall-risk-increasing drugs on postural control: a literature review. Drugs Aging. 2013;30(11):901–20.
82. Watanabe JH. Medication use, falls, and Fall-Related worry in older adults in the united States. Consult Pharm. 2016;31(7):385–93.
83. Heng H, Jazayeri D, Shaw L, et al. Hospital falls prevention with patient education: a scoping review. BMC Geriatr. 2020;20(1):140.
84. Lam J, Liamputtong P, Hill K. Falls, falls prevention and the role of physiotherapy and exercise: perceptions and interpretations of Italian-born and Australian-born older persons living in Australia. J Cross Cult Gerontol. 2015;30(2):233–49.
85. de Quadros DV, Wachs P, de Magalhães AMM, et al. Daily work variability in falls prevention of hospitalized patients: nursing team's perception. BMC Health Serv Res. 2023;23(1):931.
86. Merchant RA, Chen MZ, Wong BLL, et al. Relationship between fear of falling, fear-Related activity restriction, frailty, and Sarcopenia. J Am Geriatr Soc. 2020;68(11):2602–8.
87. Pereira CL, Baptista F, Infante P. Role of physical activity in the occurrence of falls and fall-related injuries in community-dwelling adults over 50 years old. Disabil Rehabil. 2014;36(2):117–24.
88. van Weel C, Vermeulen H, van den Bosch W. Falls, a community care perspective. Lancet (London England). 1995;345(8964):1549–51.