Int J Clin Exp Med 2017;10(7):10753-10763
www.ijcem.com /ISSN:1940-5901/IJCEM0050977

Original Article

Comorbidity increased the risk of falls in Chinese older adults: a cross-sectional study

Wenhua Bao[1,2*], Dapeng Hu[1,2*], Xiaohong Shi[1], Liang Sun[1], Xiaoquan Zhu[1], Huiping Yuan[1], Yige Yang[1], Yuhong Zhang[3], Yi Zhao[3], Caiyou Hu[4], Zeping Lv[4], Yuetao Song[5], Zheng Chen[5], Leilei Duan[6], Yuliang Er[6], Wei Tian[7], Ze Yang[1]

[1]MOH Key Laboratory of Geriatrics, Beijing Hospital, National Center of Gerontology, Beijing, P. R. China; [2]Department of Respiratory, The First Affiliated Hospital of Jiamusi University, Jiamusi, P. R. China; [3]Ningxia Medical College, School of Public Health, Yinchuan, China; [4]Guangxi Zhuang Autonormous District Jiangbin Hospital, Nanning, China; [5]Beijing Geriatric Hospital, [6]China Disease Control and Preventive Center, Beijing, P. R. China; [7]Beijing Jishuitan Hospital, Fourth Clinical College of Peking University, Beijing, P. R. China. [*]Equal contributors.

Received February 16, 2017; Accepted May 12, 2017; Epub July 15, 2017; Published July 30, 2017

Abstract: *Objective*: Today, there are no state-level investigations on falls involving elderly individuals with comorbidity and risk factors associated with falls and multi-comorbidity by sex and age strata reported in China. Additionally, the relationship between comorbidity and falls remains unknown. We investigated the prevalence of falls in Chinese elderly with comorbidities and determined the risk factors. *Methods*: A total of 4419 elderly subjects (age_{range}: 52-110 years old) were involved in the cross-sectional study, including 3081 with comorbidity and 1338 without comorbidity. In a face-to-face interview, we recorded the history of falls, demographic characteristics and information for 28 chronic diseases. *Results*: The prevalence of falls in patients with comorbidity was higher than that for patients without comorbidity (21.8% vs. 6.4%, P<0.001). The risk of falls in the comorbidity group was higher than that in the group without comorbidity (OR=4.05, 95% CI: 3.20-4.87, P<0.001). When patients were stratified by age (more than 75 years old and less than 75 years old), we showed that patients who experienced falls associated with aging were more susceptible to comorbidity (OR_{range}3.51-4.68, P_{range}0-0.0001). *Conclusion*: We observed that the prevalence of falls with comorbidity was 21.8% in the elderly. We showed that falls in the elderly are markedly related to comorbidity.

Keywords: Comorbidity, fall, fall risks, elderly

Introduction

Population aging is a global process that is even more serious in developing countries, such as China. Today, 125 million people are 80 years or older. According to WHO reported in 2015, by 2050, there will be nearly as many (120 million) people 80 years old or older living in China alone. With the increase in population aging, new problems have arisen, such as frailty, urinary incontinence, delirium, pressure ulcers and, more seriously, falls.

Falling among the elderly is a significant health problem, and fall-related injuries among the elderly (age 65 and older) are the cause of nearly 750,000 hospitalizations and 25,000 deaths per year in the United States [1]. However, data on falls among the elderly in China are still not clear.

Comorbidity is commonly defined as simultaneous coexistence of two or more chronic conditions in the elderly [2]. The prevalence of comorbidity increases with increasing age, and the prevalence of falls also increases with increasing age. Then, is comorbidity one of the causal factors affecting the elderly who fall? Although the relationship between comorbidity and falls has not been reported, we postulated that comorbidity could be a fall risk factor for the elderly. Therefore, we aimed to investigate the risk association between comorbidity and falls as well as increasing age. This study is a national cross-sectional epidemiologic study designed to understand the risk of multi-comorbidity on

Table 1. Demographic characteristic of the subjects

	N	Percentage	Mean±SD
Gender			
Male	2233	50.5%	-
Female	2183	49.4%	
Age			
>75	2785	37%	71.95±8.1
<75	1634	63%	
The use of walking aid			
Use	718	16.2%	-
Do not use	3678	83.2%	
Ability of daily living			
Independent	3530	79.9%	-
Taken care by families	639	14.5%	
Taken care by caregivers	245	5.5%	
Education level (years)			
Uneducated (0)	842	19.1%	7.65±5.19
Elementary school (1-5)	1613	26.3%	
Junior high school (6-8)	1083	24.5%	
High school (9-12)	690	15.6%	
College or above (12-)	640	14.5%	

falls in the elderly and clarify the correlation between comorbidity and falls in Chinese elderly.

Materials and methods

This study consists of elderly people from China. To date, we completed the collection of a baseline database, including demographics, general characteristics and clinical information, for 4419 subjects with a mean age of 71.9 years (range 52-110 years) from 6areas in China. Each patient provided written informed consent before participation in our study, and the study was conducted with the approval of the Ethics Committees of the Beijing Hospital, Ministry of Health and the National Center of Gerontology.

Fall investigation and assessment

Each participant was interviewed in person about falls, including questions about whether the patient experienced falls during the previous 12 months, and we recorded all answers. Falls are commonly defined as "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional changes in position to rest on furniture, walls or other objects".

Multi-comorbidity study and assessment

All subjects were interviewed about comorbidities via a questionnaire. A total of 28 diseases were recorded in the study, including the following: depression, cognitive impairment, delirium, stroke, Parkinson's disease, cerebellar diseases, cervical spondylosis, vestibular dysfunction, peripheral neuropathy, hydrocephaly, orthostatic hypotension, hypertension, hypotension, arrhythmia, heart failure, vision system diseases, cataract, glaucoma, visual impairment, musculoskeletal disorders, osteoarthritis, fracture, osteoporosis, muscular disorders, urinary incontinence, diabetes mellitus, hypoglycemia and syncope. All patients with comorbidity were diagnosed by clinical physicians, surgeons or specialists from local city- or county-level hospitals. According to the illness status of the patients, the subjects were classified as a comorbidity group and a non-comorbidity (NC) group.

Covariates

The demographic characteristics including the age, gender, education level, use of a walking aid and ability to participate in activities of daily living were recorded for all participants. We classified the ability to perform daily living based on "Guideline of Fall Prevention in Elderly Population" published by the Chinese ministry of health.

Statistical analysis

The demographic variables between two groups were examined by Student's unpaired t-test and one-way analysis of variance (ANOVA). The prevalence of falls was compared between age specific strata (more than 75 years old and less than 75 years old), and the rate of falls was compared between two groups using the Chi-square test. The correlation analysis between falls with chronic comorbidities and other risk factors was tested by the Pearson test. Data analyses were performed using SPSS software package, version 17.0. The significance level was designated as $P<0.05$.

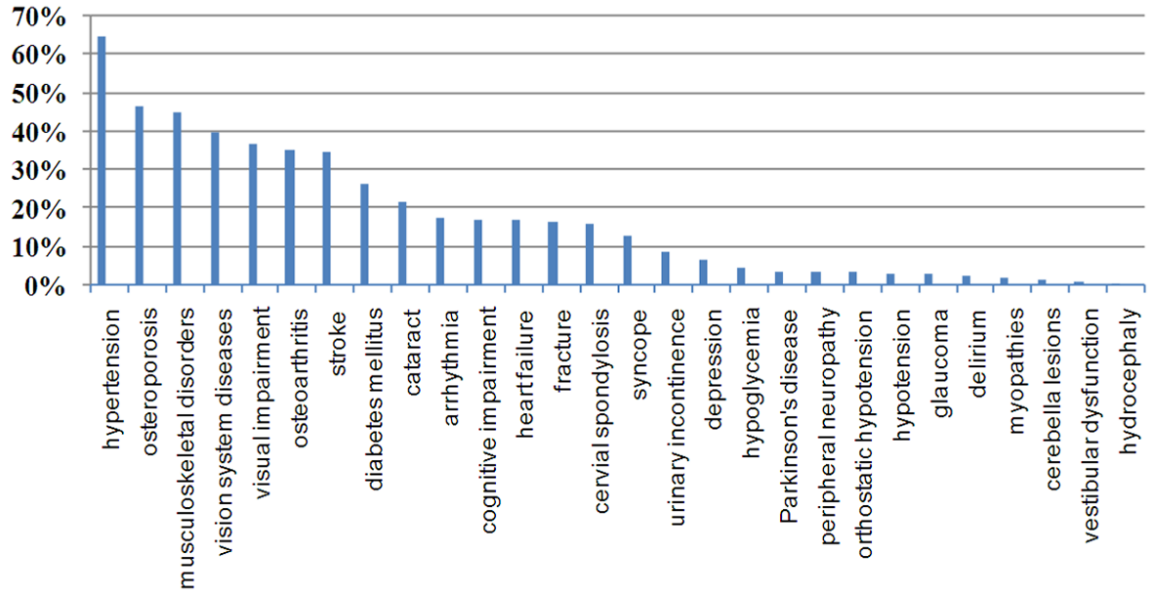

Figure 1. The prevalence of comorbidity in fallers.

Results

Demographic data and general characteristics of the subjects

A total of 4419 subjects were recruited in our study; the mean age was 71.95±7.76 years (range 52 to 110 years), and the sex ratio was almost one (2233 males and 2183 females). Additionally, the demographics and general characteristics, including the age, gender, education attainment, use of a walking aid and ability to participate in activities of daily living, are listed in **Table 1**. In our study, we observed that the overall prevalence of falls was 17.1% and that the aggregate prevalence of comorbidities was 69.5%.

Prevalence of falls in elderly with comorbidity

The number of patients who reported one or more falls during the last 12 months was 758; among those who fell, 671 had comorbidities, and 87 did not. The prevalence of falls in comorbid patients was 21.8% (671/3071), which was 3.4 times higher than that in the NC group (87/1348, 6.4%). The prevalence of comorbidity in people who had fallen is shown in **Figure 1**. Among 27 with comorbidities, approximately 22 diseases were associated with falls ($P< 0.05$), which are as follows: cognitive impairment (129/389, 58.8%), delirium (20/43, 46.5%), cervical spondylosis (120/482, 45.6%), syncope (99/237, 41.8%), fracture (152/376, 40.4%), depression (50/124, 40.3%), glaucoma (23/84, 39.4%), Parkinson's disease (29/77, 37.6%), urinary incontinence (60/186, 32.2%), orthostatic hypotension (27/84, 32.1%), vestibular dysfunction (9/31, 29%), osteoporosis (355/1244, 28.5%), arrhythmia (133/474, 28.0%), osteoarthritis (267/999, 26.7%), peripheral neuropathy disorders (29/109, 26.6%), heart failure (128/496, 25.8%), musculoskeletal disorders (341/1381, 24.7%), diabetes mellitus (201/883, 22.7%), cataracts (166/733, 22.6%), vision system diseases (302/1429, 21.1%), visual impairment (279/1332, 20.9%) and stroke (50/758, 6.5%). The correlations between falls and comorbidity are shown in Supplementary Table 1.

Analysis by age strata

In comparison by age-specific strata (more than 75 years old and less than 75 years old), we showed that the prevalence of falls in individuals more than 75 years old was higher (358/1634, 22%) than that in individuals less than 75 years old (400/2785, 14.3%). The prevalence of fall patients more than 75 years old in the comorbidity group (335/1307, 25.6%) was higher than that in the less than 75 years old comorbidity group (336/1764, 19.0%). The distribution of the study population according

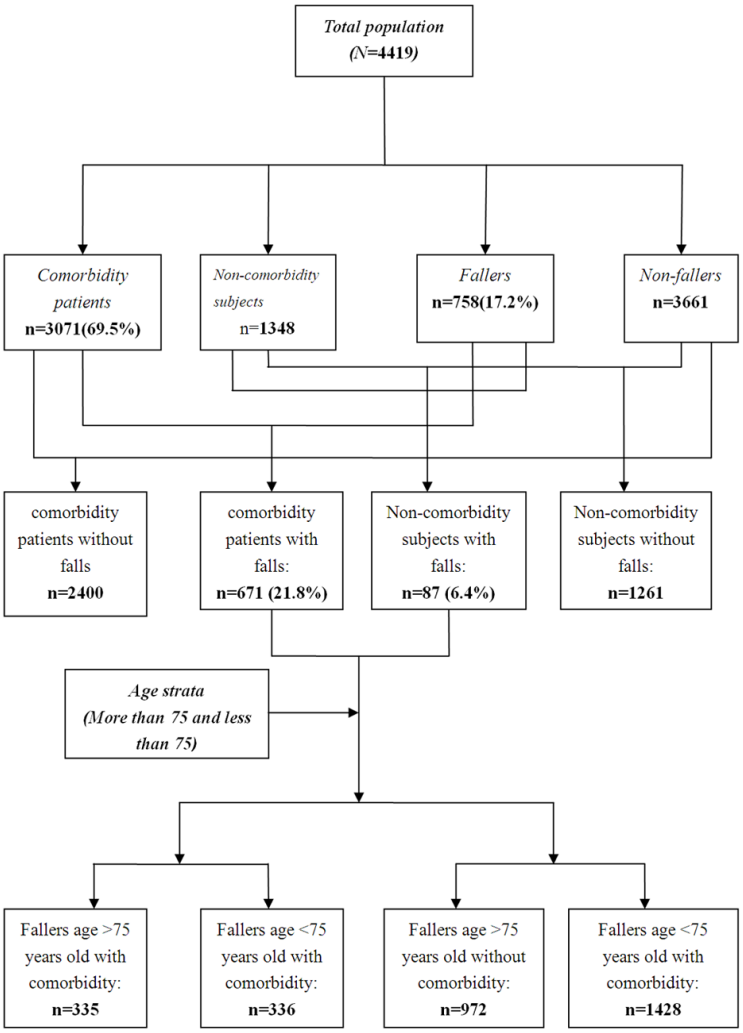

Figure 2. Distribution of study population according to comorbidity, falls and age strata.

to comorbidity, falls and age strata is shown in **Figure 2**.

Age and comorbidity as fall risk factors

Compared with the NC group, patients with comorbidity have an increased risk of falls (OR=4.05, 95% CI: 3.20-4.87, P<0.001). Additionally, a higher risk of falls was observed in advanced age patients (OR=1.67, 95% CI: 1.42-2.00, P<0.001) than in those less than 75 years of age. Additionally, comorbid patients with advancing age (more than 75 years old) had higher odds of falls (OR=1.46, 95% CI: 1.23-1.81, P<0.001) than comorbidity patients who were less than 75 years old. There were 403 participants who had fallen and sustained fall-related injuries. Of those who had a fall-related injury, there were 362 (89.8%) patients with comorbidity and 41 non-comorbidity subjects. The comorbidity group had a higher prevalence of fall-related injury than the NC group (OR=3.16, 95% CI: 2.06-3.99, P<0.0001). Fall risk comparative analysis by age strata between the comorbidity and NC groups is shown in **Table 3**.

Other fall risk factors

In our study, we found that walking aid use was associated with an increased risk of falls compared to not using a walking aid (OR=3.57, 95% CI=2.98-4.49,P<0.0001).Additionally, patients who have caregivers have a greater risk of falls than independent individuals (OR=3.86, 95% CI=2.93-5.49, P<0.0001) and those cared for by family members (OR=1.41, 95% CI=1.03-2.22, P<0.05). **Table 2** summarizes the prevalence and odds ratios for falls in the last year by demographic variables.

Discussion

In this national cross-sectional study, we demonstrated that comorbidity could increase the prevalence of falls and fall risks. The prevalence of falls in comorbidity patients (21.6%) was higher than that (6.4%, P<0.001) in the NC group; the fall risk in the comorbidity group was approximately 4 times that in the NC group (OR=4.05, 95% CI: 3.20-4.87, P<0.001). In addition to comorbidities, the data in our study show that other risk factors, including the use of walking aids (OR=3.57, 95% CI: 2.89-4.49, P<0.0001) and receiving care from families and caregivers (OR_{range}: 1.41-3.86, P_{range}: 0-0.05), play important roles in falls. Of note, there is a cumulative effect of increasing the risk of falling between these fall risk factors. The analysis of the cumulative effect for the

Table 2. Prevalence and odds ratios for falls in last one year by demographic variables

	Falls		OR (95% CI)	P
	n/N	%		
Gender				
Male	368/2233	16.4%	1	
Female	389/2183	17.8%	1.09 (0.93-1.30)	0.23
Age				
>75	400/2785	14.4%	1	-
<75	365/1634	22.3%	1.67 (1.42-2.00)	<0.001
The use of walking aid				
Do not use	497/3678		1	-
Use	257/718		3.57 (2.98-4.50)	<0.001
Ability of daily living				
Independent	475/3530	13.5%	1	-
Taken care by families	191/639	29.9%	2.74 (2.25-3.48)	<0.001
Taken care by caregivers	92/245	37.6%	3.86 (2.93-5.50)	<0.001

OR: odds ratio, CI: confidence interval.

Table 3. Fall risk comparative analysis by age strata between Comorbidities and NC group

Age	Falls	Comorbidity group	NC group	X^2	P	OR	95% CI
<75	Fall	336	64	85.8	0.001	3.52	2.66-4.39
	Non-fall	1428	957				
>75	Fall	335	23	52.8	0.000	4.56	2.92-6.38
	Non-fall	972	304				
Summary	Fall	671	87	53.133	0.000	2.90	2.15
	Non-fall	2400	1261				

NC: Non-comorbidity.

risk of falls is listed in Supplementary Table 2. Therefore, we speculate that the prevalence of falls in comorbidity patients will increase with fall risk factors and further investigation in a larger population should be performed.

Numerous chronic diseases can contribute to falls in the elderly. A few studies have reported that visual field damage increases the risk for falls [3, 4]. In our study, we found a correlation (r=0.038, P=0.012) between glaucoma and falls in the elderly. As previously reported [5-7], glaucoma is associated with an increased risk of falls due to damage to the visual field [8-11]. With the pace of population aging around the world, glaucoma-related falls and injuries will place an increasing burden on society [12, 13]. In addition, cataracts are another important cause of visual impairment, and Tang Y [14] claimed that age-related cataracts (ARCs) are a main cause of visual impairment in China. A previous study suggested a 3-fold increase in fall risk in those with cataracts [15]. We detected that elderly patients with cataracts were associated with falls (r=0.065, P< 0.001). Therefore, visual field damage caused by comorbidity increases the risk for falls.

It is well known that cardiovascular disease (CVD) is associated with fall risks. Previous research [16-18] has suggested that comorbid diseases related to heart failure (HF) place HF patients at a greater risk of falls. Our work showed that HF is associated with falls in the elderly (r=0.082, P< 0.001). This result implies that cerebral hypoperfusion because of HF was probably the cause of falls in the older population. In addition, orthostatic hypotension (OH) was considered another important risk factor for falls in elderly. McDonald C [19] and his colleagues, in a prospective study, observed that OH, which was defined according to 2011 criteria, is associated with falls and the time to first fall in geriatric patients. Based on the American Academy of Neurology 2011 Orthostatic Hypotension criteria, OH is defined as a 20-mmHg drop in systolic BP and/or a 10-mmHg drop in diastolic BP within 3 min of standing unless either (1) the participant has supine hypertension in which a decrease in systolic BP of at least 30 mmHg is required for diagnosing OH or (2) the BP nadir occurred within the first 15 s of standing wherein a 40-mmHg systolic BP and/or 20-mmHg diastolic BP was required for diagnosing OH. Our results demonstrated that OH was correlated with falls (r=0.053, P<0.001). Therefore, cardiovascular diseases were more likely to

result in falls due to cerebral hypoperfusion or dizziness.

As a common disease among the elderly, syncope is often defined as a sudden loss of consciousness due to transient global cerebral hypoperfusion. Bhangu J [20] demonstrated that there is evidence of an overlap between syncope and unintentional falls in the elderly, and we observed that syncope was correlated with falls (r=0.155, P<0.001). Additionally, arrhythmias are an important cardiac cause of syncope in the elderly. Recently, Jansen S [21] reported that cardiac arrhythmias were associated with a risk of falls. This study showed that arrhythmias were associated with falls (r= 0.077, P<0.001). Therefore, we have provided evidence that strengthens the association between arrhythmias, as a comorbidity in the elderly, and falls. Impaired hemodynamic function that results from arrhythmia is probably the underlying mechanism for falls.

Our study demonstrated that patients with musculoskeletal system disease, including musculoskeletal disorder, osteoarthritis (OA), osteoporosis and fracture, were more likely to fall. A previous study [22] demonstrated an association with OA and fall risk. A study conducted by Sturnieks [23] suggested that elderly patients with lower limb arthritis are at increased risk for falling. Our study demonstrated that there was a correlation between OA and falls (r=0.137, P<0.0001), which can be explained by changes in joint kinematics resulting from OA. Additionally, we demonstrated that osteoporosis was correlated (r=0.189, P<0.01) with falls. Seyfizadeh N [24] reported that there was a significant association between age and osteoporosis. A possible explanation for our result is that reduced flexibility, lower bone density, muscular weakness and postural imbalance from osteoporosis predispose patients to falls. Our results also suggest that fracture was associated with falls (r=0.188, P<0.0001). Fracture can be both a cause and a consequence of a fall event. Perez-Lopez [25] reported that fragility fractures are remarkably related to falls, which we found was consistent with a previous study. A possible reason for the correlation between fractures and falls was gait deficit, restricted physical function, and muscle weakness of the lower limb caused by previous fractures.

Musculoskeletal disorders (MSDs) are a potential cause of falls. Several studies [26, 27] have focused on low back pain, which is the most common symptom in patients with MSDs. Prospective studies [28, 29] demonstrated that there was a positive association between back pain and falls, and we showed that MSDs were associated (r=0.135, P<0.001) with falls in the elderly, which suggests that low back pain from MSDs was a reason for falls in older adults.

In this study, we showed neurological disorders, including Parkinson's disease, peripheral neuropathy, cognitive impairment, delirium and depression, can lead to falls in various ways (P<0.001). Rumalla K [30] reported that a greater proportion of fall-related traumatic brain injury occurs in PD patients compared to patients without PD, indicating that PD patients have a high risk of falls and suffer from fall-related injury (r=0.069, P<0.001). The results from the present study revealed an association between PD and falls.

Peripheral neuropathy often resulted in falls in elderly patients. The results from this study revealed an association (r=0.04, P<0.01) between peripheral neuropathy and falls. A study conducted by Kolb NA [31] suggested that the sensory symptoms of chemotherapy-induced peripheral neuropathy were an indicator of an increased risk of falling. Falls in elderly patients with diabetic peripheral neuropathy were previously identified [17, 32]. Based on this finding, we can infer that balance impairment due to peripheral neuropathy was the main reason for increasing the fall risk in seniors.

Consistent with previous findings [33], we found that delirium, as a comorbidity, seems to be a risk factor for geriatric falls. Additionally, there is an association (r=0.077, P<0.001) between delirium and falls in elderly. Our study revealed that falls in elderly were associated with gait disturbance and involuntary movements due to delirium.

Depressive symptomatology was identified as a risk factor for falls in a previous study [34]. In our study, we found a correlation (r=0.104, P<0.001) between depression and falls in elderly. Therefore, the severe anxiety caused by depression may be a potential cause of falls, and further research to investigate the relation-

ship between anxiety and falls in older depression patients should be performed.

Falls are common in the elderly with cognitive impairment (CI) and dementia. Holtzer R [35] identified CI as a risk factor for falls in aging. A study conducted by Taylor ME [36] demonstrated that elderly individuals with mild-moderate CI had an increased risk of multiple falls. A correlation between cognitive impairment and falls in elderly individuals was found in our study (r=0.132, P<0.001). This finding was consistent with prior studies in older adults, and the result suggests that cognitive deficit-related gait disorders are possible mechanisms for falls.

Older adults with type 2 diabetes have a significantly higher prevalence of falls than those without type 2 diabetes mellitus. Recently, Hewston P [37] claimed that falls may be attributed to the damage caused by type 2 diabetes affecting various systems, including the somatosensory system, visual system, vestibular system, muscular system and cognitive system. Consistent with previous studies, our study demonstrated that type 2 diabetes mellitus is associated with falls in older adults (r=0.074, P<0.001). Our work highlights that visual damage caused by diabetic retinopathy and gait disorder from diabetic foot ulcers or peripheral vascular disease in the lower extremities can contribute to falls beyond the diseases previously reported in the participants we studied.

Urinary incontinence is a “geriatric syndrome”, which is a major problem in the elderly. A previous study [38] showed that urinary incontinence is associated with the fall risk. In our study, we revealed that urinary incontinence (r=0.102, P<0.001) was correlated with falls, and the association between increased fall risk and urinary incontinence reveals those elderly who suffered from urinary incontinence tend to experience falls as a consequence of the need to rush to the toilet.

Studies have demonstrated that balance and stepping impairments following small balance disturbances, including delayed and declined muscle activations, decreased control of the trunk [39], abnormal muscle activation patterns [40], and asymmetrical weight bearing [41], are common in stroke survivors, which may often result in falls. In agreement with previous studies, we found stroke (r=0.20, P<0.001) was associated with falls in elderly patients.

Our study also found that cervical spondylosis was associated (r=0.071, P<0.001) with falls. McCormick WE [42] reported that the most common characteristic symptoms of cervical spondylotic myelopathy are gait instability, loss of fine motor control of the upper limbs, neck pain with reduced range of motion in this region and urinary emergency. In addition, a previous study [43] identified that poor gait was associated with fall risks; therefore, it can be seen that cervical spondylotic myelopathy patients are at an increased risk of falls.

Fall risk factors

Age was an independent risk factors for falls [44]. In our study, we found that increasing age increased the risk of falls in the elderly by 1.6-foldand that comorbid patients with advancing age (over 75 years) had higher odds of falling (OR=1.46, 95% CI: 1.23-1.81, P<0.001) than comorbid patients younger than 75 years of age. This result indicates that a variety of effects of aging increase the risk of falling. Additionally, we found that age and comorbidity have a cumulative effect (shown in Supplementary Table 2) on the risk of falling.

In the present study, we showed that the use of a walking aid is a risk factor for falls in the elderly. Rubenstein LZ [45] found that the use of a walking aid was associated with a 2.6-fold increased risk of falling. In our study, we detected that the use of walking aid increased the risk of falls in elderly people by 3.5 times. Based on our findings, the association between the increased fall risk and use of a walking aid reveals elderly who use a walking aid tend to fall because of gait disorders, musculoskeletal dysfunction and other risk factors beyond that falls are caused by the walking aid itself.

Notably, we found that there was no significant difference between the patient genders in our study. In other words, gender is not a risk factor for falls, which does not agree with some previous studies. Existing evidence [43, 46, 47] has showed that being female is a risk factor for falls because women lose more bone mass and have less lean mass and muscle strength than

men. However, we detected that there were 368 males and 389 females who fell; the ratio of males and females who fell was almost 1, and the discrepancy in the gender distribution from the present study is likely due to differences in the patient selection criteria and effect of comorbidities.

Conclusion

In conclusion, this study confirms that comorbidity was markedly related to falls in the elderly and increased the risk of falling. In addition, a low education level, the use of a walking aid and receiving care from caregivers were risk factors that contribute to falls in geriatric patients. Therefore, it is important to study the risk association between comorbidity and falls. Further research should focus on monitoring the elderly with risk factors of FRI and aims to develop effective prevention and intervention measures, which can be applied and improve the life expectancy of older adults in the community.

Acknowledgements

This work was funded by the National Natural Science Foundation of China (81400790, 81061120527, 81370445, 81472408, 8157-1385), funding from National Department Public Benefit Research Foundation by Ministry of Health P. R. China (201302008), and 12th 5 Year National Program from the Ministry of Scientific Technology (2012BAI10B01, 2015BAI06B03).

Disclosure of conflict of interest

None.

Authors' contribution

Z.Y. and W.-H.B. designed and directed this study; D.-P.H. and Z.Y. wrote the manuscript; Z.Y. and D.-P.H. extracted and analyzed the data; X.-H. S., L.S., X.-Q.Z., Y.-G.Y., Y.-H.Z., Y.Z., C.-Y.H., Z.-P.L., Y.-T.S., Z.C., L.-L.D., Y.-L.E., W.T. and Z.Y. developed the investigation, collected information and established databases; all authors reviewed this manuscript and approved the final draft.

Address correspondence to: Ze Yang, MOH Key Laboratory of Geriatrics, Beijing Hospital, National Center of Gerontology, 1 Dahua Road, Dongdan, Beijing 100730, P. R. China. Tel: 0086-10-58115043; Fax: 0086-10-65237929; E-mail: yang_ze@sina.com

References

[1] Crandall M, Duncan T, Mallat A, Greene W, Violano P, Christmas AB, Barraco R. Prevention of fall-related injuries in the elderly: an Eastern association for the surgery of trauma practice management guideline. J Trauma Acute Care Surg 2016; 81: 196-206.

[2] Valderas JM, Starfield B, Sibbald B, Salisbury C, Roland M. Defining comorbidity: implications for understanding health and health services. Ann Fam Med 2009; 7: 357-363.

[3] Herndon JG, Helmick CG, Sattin RW, Stevens JA, DeVito C, Wingo PA. Chronic medical conditions and risk of fall injury events at home in older adults. J Am Geriatr Soc 1997; 45: 739-743.

[4] Lord SR, Smith ST, Menant JC. Vision and falls in older people: risk factors and intervention strategies. Clin Geriatr Med 2010; 26: 569-581.

[5] Black AA, Wood JM, Lovie-Kitchin JE. Inferior field loss increases rate of falls in older adults with glaucoma. Optom Vis Sci 2011; 88: 1275-1282.

[6] Haymes SA, Leblanc RP, Nicolela MT, Chiasson LA, Chauhan BC. Risk of falls and motor vehicle collisions in glaucoma. Invest Ophthalmol Vis Sci 2007; 48: 1149-1155.

[7] Lamoureux EL, Chong E, Wang JJ, Saw SM, Aung T, Mitchell P, Wong TY. Visual impairment, causes of vision loss, and falls: the singapore malay eye study. Invest Ophthalmol Vis Sci 2008; 49: 528-533.

[8] Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: the Blue Mountains Eye Study. J Am Geriatr Soc 1998; 46: 58-64.

[9] Klein BE, Klein R, Lee KE, Cruickshanks KJ. Performance-based and self-assessed measures of visual function as related to history of falls, hip fractures, and measured gait time. The Beaver Dam Eye Study. Ophthalmology 1998; 105: 160-164.

[10] Freeman EE, Munoz B, Rubin G, West SK. Visual field loss increases the risk of falls in older adults: the Salisbury eye evaluation. Invest Ophthalmol Vis Sci 2007; 48: 4445-4450.

[11] de Boer MR, Pluijm SM, Lips P, Moll AC, Volker-Dieben HJ, Deeg DJ, van Rens GH. Different aspects of visual impairment as risk factors for falls and fractures in older men and women. J Bone Miner Res 2004; 19: 1539-1547.

[12] Yuki K, Asaoka R, Tsubota K. Investigating the influence of visual function and systemic risk

factors on falls and injurious falls in glaucoma using the structural equation modeling. PLoS One 2015; 10: e0129316.
[13] Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. Br J Ophthalmol 2006; 90: 262-267.
[14] Tang Y, Wang X, Wang J, Huang W, Gao Y, Luo Y, Yang J, Lu Y. Prevalence of age-related cataract and cataract surgery in a Chinese adult population: the Taizhou eye study. Invest Ophthalmol Vis Sci 2016; 57: 1193-1200.
[15] McCarty CA, Fu CL, Taylor HR. Predictors of falls in the Melbourne visual impairment project. Aust N Z J Public Health 2002; 26: 116-119.
[16] Lee K, Pressler SJ, Titler M. Falls in patients with heart failure: a systematic review. J Cardiovasc Nurs 2016; 31: 555-561.
[17] Schwartz AV, Vittinghoff E, Sellmeyer DE, Feingold KR, de Rekeneire N, Strotmeyer ES, Shorr RI, Vinik AI, Odden MC, Park SW, Faulkner KA, Harris TB; Health, Aging, and Body Composition Study. Diabetes-related complications, glycemic control, and falls in older adults. Diabetes Care 2008; 31: 391-396.
[18] Jung D, Shin S, Kim H. A fall prevention guideline for older adults living in long-term care facilities. Int Nurs Rev 2014; 61: 525-533.
[19] McDonald C, Pearce M, Kerr SR, Newton J. A prospective study of the association between orthostatic hypotension and falls: definition matters. Age Ageing 2016; [Epub ahead of print].
[20] Bhangu J, McMahon CG, Hall P, Bennett K, Rice C, Crean P, Sutton R, Kenny RA. Long-term cardiac monitoring in older adults with unexplained falls and syncope. Heart 2016; 102: 681-686.
[21] Jansen S, Kenny RA, de Rooij SE, van der Velde N. Self-reported cardiovascular conditions are associated with falls and syncope in community-dwelling older adults. Age Ageing 2015; 44: 525-529.
[22] Zasadzka E, Borowicz AM, Roszak M, Pawlaczyk M. Assessment of the risk of falling with the use of timed up and go test in the elderly with lower extremity osteoarthritis. Clin Interv Aging 2015; 10: 1289-1298.
[23] Sturnieks DL, Tiedemann A, Chapman K, Munro B, Murray SM, Lord SR. Physiological risk factors for falls in older people with lower limb arthritis. J Rheumatol 2004; 31: 2272-2279.
[24] Seyfizadeh N, Seyfizadeh N, Negahdar H, Hosseini SR, Nooreddini H, Parsian H. ABO blood group and prevalence of osteoporosis and osteopenia in the elderly population: an Amirkola Health and Ageing Project (AHAP)-Based Study. J Clin Densitom 2016; [Epub ahead of print].
[25] Perez-Lopez FR, Ara I. Fragility fracture risk and skeletal muscle function. Climacteric 2016; 19: 37-41.
[26] Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, Shibuya K, Salomon JA, Abdalla S, Aboyans V, Abraham J, Ackerman I, Aggarwal R, Ahn SY, Ali MK, Alvarado M, Anderson HR, Anderson LM, Andrews KG, Atkinson C, Baddour LM, Bahalim AN, Barker-Collo S, Barrero LH, Bartels DH, Basanez MG, Baxter A, Bell ML, Benjamin EJ, Bennett D, Bernabe E, Bhalla K, Bhandari B, Bikbov B, Bin Abdulhak A, Birbeck G, Black JA, Blencowe H, Blore JD, Blyth F, Bolliger I, Bonaventure A, Boufous S, Bourne R, Boussinesq M, Braithwaite T, Brayne C, Bridgett L, Brooker S, Brooks P, Brugha TS, Bryan-Hancock C, Bucello C, Buchbinder R, Buckle G, Budke CM, Burch M, Burney P, Burstein R, Calabria B, Campbell B, Canter CE, Carabin H, Carapetis J, Carmona L, Cella C, Charlson F, Chen H, Cheng AT, Chou D, Chugh SS, Coffeng LE, Colan SD, Colquhoun S, Colson KE, Condon J, Connor MD, Cooper LT, Corriere M, Cortinovis M, de Vaccaro KC, Couser W, Cowie BC, Criqui MH, Cross M, Dabhadkar KC, Dahiya M, Dahodwala N, Damsere-Derry J, Danaei G, Davis A, De Leo D, Degenhardt L, Dellavalle R, Delossantos A, Denenberg J, Derrett S, Des Jarlais DC, Dharmaratne SD, Dherani M, Diaz-Torne C, Dolk H, Dorsey ER, Driscoll T, Duber H, Ebel B, Edmond K, Elbaz A, Ali SE, Erskine H, Erwin PJ, Espindola P, Ewoigbokhan SE, Farzadfar F, Feigin V, Felson DT, Ferrari A, Ferri CP, Fevre EM, Finucane MM, Flaxman S, Flood L, Foreman K, Forouzanfar MH, Fowkes FG, Franklin R, Fransen M, Freeman MK, Gabbe BJ, Gabriel SE, Gakidou E, Ganatra HA, Garcia B, Gaspari F, Gillum RF, Gmel G, Gosselin R, Grainger R, Groeger J, Guillemin F, Gunnell D, Gupta R, Haagsma J, Hagan H, Halasa YA, Hall W, Haring D, Haro JM, Harrison JE, Havmoeller R, Hay RJ, Higashi H, Hill C, Hoen B, Hoffman H, Hotez PJ, Hoy D, Huang JJ, Ibeanusi SE, Jacobsen KH, James SL, Jarvis D, Jasrasaria R, Jayaraman S, Johns N, Jonas JB, Karthikeyan G, Kassebaum N, Kawakami N, Keren A, Khoo JP, King CH, Knowlton LM, Kobusingye O, Koranteng A, Krishnamurthi R, Lalloo R, Laslett LL, Lathlean T, Leasher JL, Lee YY, Leigh J, Lim SS, Limb E, Lin JK, Lipnick M, Lipshultz SE, Liu W, Loane M, Ohno SL, Lyons R, Ma J, Mabweijano J, MacIntyre MF, Malekzadeh R, Mallinger L, Manivannan S, Marcenes W, March L, Margolis DJ, Marks GB, Marks R, Matsumori A, Matzopoulos R, Mayosi BM, McAnulty JH, McDermott MM, McGill N, McGrath J, Medina-Mora ME, Meltzer M, Mensah GA, Merriman TR, Meyer AC, Miglioli V, Miller M, Miller TR, Mitchell PB, Mocumbi AO, Moffitt TE, Mokdad

AA, Monasta L, Montico M, Moradi-Lakeh M, Moran A, Morawska L, Mori R, Murdoch ME, Mwaniki MK, Naidoo K, Nair MN, Naldi L, Narayan KM, Nelson PK, Nelson RG, Nevitt MC, Newton CR, Nolte S, Norman P, Norman R, O'Donnell M, O'Hanlon S, Olives C, Omer SB, Ortblad K, Osborne R, Ozgediz D, Page A, Pahari B, Pandian JD, Rivero AP, Patten SB, Pearce N, Padilla RP, Perez-Ruiz F, Perico N, Pesudovs K, Phillips D, Phillips MR, Pierce K, Pion S, Polanczyk GV, Polinder S, Pope CA 3rd, Popova S, Porrini E, Pourmalek F, Prince M, Pullan RL, Ramaiah KD, Ranganathan D, Razavi H, Regan M, Rehm JT, Rein DB, Remuzzi G, Richardson K, Rivara FP, Roberts T, Robinson C, De Leon FR, Ronfani L, Room R, Rosenfeld LC, Rushton L, Sacco RL, Saha S, Sampson U, Sanchez-Riera L, Sanman E, Schwebel DC, Scott JG, Segui-Gomez M, Shahraz S, Shepard DS, Shin H, Shivakoti R, Singh D, Singh GM, Singh JA, Singleton J, Sleet DA, Sliwa K, Smith E, Smith JL, Stapelberg NJ, Steer A, Steiner T, Stolk WA, Stovner LJ, Sudfeld C, Syed S, Tamburlini G, Tavakkoli M, Taylor HR, Taylor JA, Taylor WJ, Thomas B, Thomson WM, Thurston GD, Tleyjeh IM, Tonelli M, Towbin JA, Truelsen T, Tsilimbaris MK, Ubeda C, Undurraga EA, van der Werf MJ, van Os J, Vavilala MS, Venketasubramanian N, Wang M, Wang W, Watt K, Weatherall DJ, Weinstock MA, Weintraub R, Weisskopf MG, Weissman MM, White RA, Whiteford H, Wiersma ST, Wilkinson JD, Williams HC, Williams SR, Witt E, Wolfe F, Woolf AD, Wulf S, Yeh PH, Zaidi AK, Zheng ZJ, Zonies D, Lopez AD, Murray CJ, AlMazroa MA, Memish ZA. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012; 380: 2163-2196.

[27] Makris UE, Fraenkel L, Han L, Leo-Summers L, Gill TM. Epidemiology of restricting back pain in community-living older persons. J Am Geriatr Soc 2011; 59: 610-614.

[28] Marshall LM, Litwack-Harrison S, Makris UE, Kado DM, Cawthon PM, Deyo RA, Carlson NL, Nevitt MC; Osteoporotic Fractures in Men Study Research G. A prospective study of back pain and risk of falls among older community-dwelling men. J Gerontol A Biol Sci Med Sci 2016; [Epub ahead of print].

[29] Mazur K, Wilczynski K, Szewieczek J. Geriatric falls in the context of a hospital fall prevention program: delirium, low body mass index, and other risk factors. Clin Interv Aging 2016; 11: 1253-1261.

[30] Rumalla K, Gondi KT, Reddy AY, Mittal MK. Association of Parkinson's disease with hospitalization for traumatic brain injury. Int J Neurosci 2017; 127: 326-333.

[31] Kolb NA, Smith AG, Singleton JR, Beck SL, Stoddard GJ, Brown S, Mooney K. The association of chemotherapy-induced peripheral neuropathy symptoms and the risk of falling. JAMA Neurol 2016; 73: 860-866.

[32] Richardson JK, Ching C, Hurvitz EA. The relationship between electromyographically documented peripheral neuropathy and falls. J Am Geriatr Soc 1992; 40: 1008-1012.

[33] Inouye SK, Westendorp RG, Saczynski JS, Kimchi EY, Cleinman AA. Delirium in elderly people--authors' reply. Lancet 2014; 383: 2045.

[34] Kvelde T, Lord SR, Close JC, Reppermund S, Kochan NA, Sachdev P, Brodaty H, Delbaere K. Depressive symptoms increase fall risk in older people, independent of antidepressant use, and reduced executive and physical functioning. Arch Gerontol Geriatr 2015; 60: 190-195.

[35] Holtzer R, Friedman R, Lipton RB, Katz M, Xue X, Verghese J. The relationship between specific cognitive functions and falls in aging. Neuropsychology 2007; 21: 540-548.

[36] Taylor ME, Lord SR, Delbaere K, Kurrle SE, Mikolaizak AS, Close JC. Reaction time and postural sway modify the effect of executive function on risk of falls in older people with mild to moderate cognitive impairment. Am J Geriatr Psychiatry 2017; 25: 397-406.

[37] Hewston P, Deshpande N. Falls and balance impairments in older adults with type 2 diabetes: thinking beyond diabetic peripheral neuropathy. Can J Diabetes 2016; 40: 6-9.

[38] Noguchi N, Chan L, Cumming RG, Blyth FM, Handelsman DJ, Seibel MJ, Waite LM, Le Couteur DG, Naganathan V. Lower urinary tract symptoms and incident falls in community dwelling older men: the concord health and ageing in men project. J Urol 2016; 196: 1694-1699.

[39] Marigold DS, Eng JJ. Altered timing of postural reflexes contributes to falling in persons with chronic stroke. Exp Brain Res 2006; 171: 459-468.

[40] Di Fabio RP. Lower extremity antagonist muscle response following standing perturbation in subjects with cerebrovascular disease. Brain Res 1987; 406: 43-51.

[41] Mansfield A, Inness EL, Komar J, Biasin L, Brunton K, Lakhani B, McIlroy WE. Training rapid stepping responses in an individual with stroke. Phys Ther 2011; 91: 958-969.

[42] McCormick WE, Steinmetz MP, Benzel EC. Cervical spondylotic myelopathy: make the difficult diagnosis, then refer for surgery. Cleve Clin J Med 2003; 70: 899-904.

[43] Deandrea S, Lucenteforte E, Bravi F, Foschi R, La Vecchia C, Negri E. Risk factors for falls in community-dwelling older people: a systematic review and meta-analysis. Epidemiology 2010; 21: 658-668.

[44] Kwan MM, Close JC, Wong AK, Lord SR. Falls incidence, risk factors, and consequences in Chinese older people: a systematic review. J Am Geriatr Soc 2011; 59: 536-543.
[45] Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. Clin Geriatr Med 2002; 18: 141-158.
[46] Milat AJ, Watson WL, Monger C, Barr M, Giffin M, Reid M. Prevalence, circumstances and consequences of falls among community-dwelling older people: results of the 2009 NSW Falls Prevention Baseline Survey. N S W Public Health Bull 2011; 22: 43-48.
[47] Stenhagen M, Ekstrom H, Nordell E, Elmstahl S. Falls in the general elderly population: a 3- and 6-year prospective study of risk factors using data from the longitudinal population study 'Good ageing in Skane'. BMC Geriatr 2013; 13: 81.

Supplementary Table 1. Correlations between falls and comorbidity

Comorbidities	r	P
Stroke	0.205	0.000
Osteoporosis	0.189	0.000
Fracture	0.188	0.000
Syncope	0.155	0.000
Osteoarthritis	0.137	0.000
Musculoskeletal disorders	0.135	0.000
Cognitive impairment	0.132	0.000
Depression	0.104	0.000
Urinary incontinence	0.102	0.000
Arrhythmia	0.1	0.000
Heart failure	0.082	0.000
Delirium	0.077	0.000
Diabetes mellitus	0.074	0.000
Vision system diseases	0.073	0.000
Cervical spondylosis	0.071	0.000
Parkinson's disease	0.069	0.000
Visual impairment	0.066	0.000
Cataract	0.065	0.000
Orthostatic hypotension	0.053	0.000
Peripheral neuropathy	0.040	0.008
Glaucoma	0.038	0.012

Supplementary Table 2. Analysis of cumulative effects of comorbidity and other risk factors contribute to fall risk

Comorbidity	Total	% of Variance	Cumulative %
Musculoskeletal disorders	2.661	24.089	24.089
Cardiovascular diseases	1.559	10.823	34.912
Education level	1.511	6.295	41.207
Urinary incontinence	1.218	5.075	46.282
Glaucoma	1.159	4.831	51.113
Diabetes	1.096	4.565	55.678
Neuropathy	1.013	4.22	59.898
Age	0.609	2.536	62.434