Maturitas 75 (2013) 51–61

Contents lists available at SciVerse ScienceDirect

Maturitas

journal homepage: www.elsevier.com/locate/maturitas

Review

Risk factors for falls among older adults: A review of the literature

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ARTICLE INFO

Article history:
Received 15 January 2013
Received in revised form 18 February 2013
Accepted 19 February 2013

Keywords:
Fall risk
Aging
Gait
Balance

ABSTRACT

Falls are one of the major causes of mortality and morbidity in older adults. Every year, an estimated 30–40% of patients over the age of 65 will fall at least once. Falls lead to moderate to severe injuries, fear of falling, loss of independence and death in a third of those patients. The direct costs alone from fall related injuries are a staggering 0.1% of all healthcare expenditures in the United States and up to 1.5% of healthcare costs in European countries. This figure does not include the indirect costs of loss of income both to the patient and caregiver, the intangible losses of mobility, confidence, and functional independence. Numerous studies have attempted to define the risk factors for falls in older adults. The present review provides a brief summary and update of the relevant literature, summarizing demographic and modifiable risk factors. The major risk factors identified are impaired balance and gait, polypharmacy, and history of previous falls. Other risk factors include advancing age, female gender, visual impairments, cognitive decline especially attention and executive dysfunction, and environmental factors. Recommendations for the clinician to manage falls in older patients are also summarized.

Contents

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0378-5122/$ – see front matter
http://dx.doi.org/10.1016/j.maturitas.2013.02.009

1. Introduction

Falls are a leading cause of injury and death among older adults and a significant public health issue [1]. Falls affect one in three adults over the age of 65 annually [2], and 50% of adults over the age of 80 [3]. Twenty to thirty percent of these patients will suffer moderate to severe injuries interfering with their ability to continue living in the community, require hospitalization and have an increased risk of death [4]. In 2009, 2.2 million nonfatal fall injuries occurred among older adults in the United States that required treatment in emergency departments and more than 581,000 of these patients were hospitalized [5]. In the same year, over 19,000 older adults died from unintentional fall injuries making falls the fifth leading cause of death in adults above age 65[5].

Older individuals have an increased susceptibility for injury due to the higher prevalence of comorbidities, age-related physiological changes, and delayed functional recovery, which in turn leads to further de-conditioning and more falls [6]. About 30–50% of falls result in minor lesions such as bruises or lacerations, however, 5–10% of falls lead to major injuries such as fractures [7] or traumatic brain injury (TBI) [6]. Falls are the most common cause of TBI in older adults, and also account for 46% of all fall related deaths in TBI patients [5]. Although the rate of hip fractures following a fall is only 1%, 90% of all hip fractures are caused by a fall [7]. In the first year following a hip fracture, 25% of older patients will die [8], 76% will have a decline in their mobility [9], 50% will have a decline in their ability to perform activities of daily living (ADL) [8] and 22% will move into a nursing home [9]. Among the older adults who fall, approximately one-half are unable to get up and remain on the ground [10]. These "long-lies" lead to dehydration, rhabdomyolysis, pressures sores, and pneumonia [10]. In addition, many older adults who fall will also develop a marked fear of falling, and up to 40% will restrict their activities of daily living. This set up a vicious spiral with further declines in physical fitness, social isolation and depression [11] and in turn, further increases the risk of falls.

Falls and their consequences are responsible for a large part of preventable health care costs. In the United States, the total direct medical costs for fall-related injuries among older adults in 2008 were US$23.3 billion, and the fall related costs were reported to be US$1.6 billion in the United Kingdom [12]. These expenditures are expected to approach $55 billion by 2020 as the population ages globally, increasing the at-risk sample [5]. Furthermore, falls or fall related medical events, account for 40% of nursing home placements and contribute to further increases in healthcare costs [13]. National fall related costs of prevalence-based studies are 0.85–1.5% of total healthcare expenditures [14].

Here we review the factors that contribute to fall risk in older adults.

2. Methods

Though there have been many studies that have reported various risk factors for falls; the results have been mixed. In a recent review of 12 studies that examined fall risk factors, Inouye et al. identified older age, prior history of falls, functional impairment, use of a walking aid or assistive device, cognitive impairment or dementia, impaired mobility or low activity level, and balance abnormalities as the main causes for falls in older adults [15]. However in an earlier review of 12 retrospective fall studies involving 3628 falls, Rubenstein et al. identified the major causes of falls in elderly adults as being accident or environment related (31%), gait or balance disorders (17%), dizziness (13%), drop attack (9%) and confusion (5%). Risk factors such as postural hypotension (3%), visual disorders (2%) and syncope (0.3%) accounted for a very low proportion of falls in this review [6]. Ganz et al. reported that the most consistent predictors of future falls were clinically abnormal gait or balance disorders (likelihood ratio range, 1.7–2.4) [16]. Visual impairment, medication variables, decreased activities of daily living, and impaired cognition or orthostatic hypotension did not consistently predict falls across studies in this review [16]. A more recent systematic review found that previous falls, medications, and impairments in strength, gait and balance were the risk factors that were the most highly correlated with fall risk [17].

In this narrative review, we aim to identify the epidemiology, etiology and risk factors of falls in the elderly population. The bibliographic search strategy focused on articles published in peer-reviewed, English language journals up to September 2012. The databases used included PubMed, CINAHL and Scopus. When they existed, RCT and meta-analyses were selected preferentially and, in their absence, we used clinical trials. Editorial, case reports, letter or other type of commentaries were not considered. We did not apply formal meta-analysis methods.

3. Definition

The medical and lay communities do not always perceive falls similarly, especially if there is no injury [18]. There is evidence that 75–80% of all falls without injury are not reported at all [10]. Retrospective studies may also suffer from under-reporting of falls. In a prospective study of 304 ambulatory patients, Cummings et al. found that between 13 and 32% denied having had a fall depending on how long after the event they were questioned; longer intervals were associated with lower recall [19].

To standardize clinical and research efforts the Prevention of Falls Network Europe (ProFANE) group defined a fall as "an unexpected event in which the participant comes to rest on the ground, floor, or lower level." [20]. A similar definition was proposed in 1987 by the Kellogg International Working Group [21] and later by the Frailty and Injuries Cooperative Studies of Intervention Techniques (FICSIT) [22,23]. Most of the studies on falls require that the fall was unintentional and that it was not caused by extrinsic events such as a car accident. Generally, falls that are a result of a syncopal event or heart attack are also excluded from epidemiological studies. The variations across the definitions for falls and methods employed (self-report, informant interview, or fall diaries) may partly explain some of the disparities among different studies.

4. Epidemiology

About one-third of community-dwelling older adults above age 65 fall every year [2,24] while 40% of those over age 80 experience one or more falls [25]. Patients who have fallen in the past year are more likely to fall again [likelihood ratio range: 2.3–2.8] [16,26]. Among hospitalized patients, fall rates vary from 3 to 20 per 1000 bed-days [27]. Falls in a hospital often result in increased mortality and morbidity [28,29]. In a 3-year retrospective study of 900 falls, Nadkarni and colleagues identified 42 patients with orthopedic injuries; eighteen (42%) of who had sustained hip fractures, 9 died and had an average additional stay of 1–5 weeks per patient [30]. The cost of treating these injuries amounted to about GBP 70,000 [30]. The mean fall incidence in nursing home residents is about three times the rate for community-living elderly persons (mean 1.5 falls/bed/year) [31]. The higher reported rate of falls results from the more frail nature of persons in institutions and maybe also from a more accurate reporting and monitoring of falls in institutional settings [31].

5. Risk factors

Fall risk factors are often categorized as person specific (or intrinsic) and environmental (or extrinsic) [32]. Personal factors include characteristics of the individual such as age, functional abilities, chronic diseases and gait disturbances [33]. Environmental risk factors refer to fall hazards in and around the home such as poor fitting footwear, slippery floor or loose rugs, tripping hazards, lack of stair railings or grab bars, unstable furniture, and poor lighting [34]. The risk of falling increases with the number of risk factors present and with age [35]. Table 1 summarizes the risk factors reviewed here.

Table 1
List of fall risk factors discussed in review.

Intrinsic risk factors for falls	Demographic	Age
		Gender
		Race
	Systems	Gait and balance
		Strength
		Vision
		Cognition
	Symptoms/diseases	Dizziness/vertigo
		Cardiovascular disease
		Dementia
		Depression
	Medications	
Extrinsic risk factors for falls	Home	
	Footwear	

5.1. Age

The chances of falling and of being seriously injured in a fall increase with age due to both physiologic and pathologic changes. In 2009, the CDC reported that rate of fall-injuries for adults 85 and older was almost four times that for adults between 65 and 74 in the U.S. [5,35]. Normal aging is associated with declines in several physiological systems including musculoskeletal, cardiovascular, visual, vestibular and proprioception, coordination, slowed postural responses, and cognitive function (especially dual tasking and executive function), all of which, have been shown to increase the risk of falls [36]. In the Longitudinal Study of Aging (LSOA), over 4000 seniors were interviewed at 2 yearly intervals over a period of 6 years for decline in functional status [37]. Age related conditions such as arthritis, diabetes, prior cerebro-vascular disease (CVD), incontinence, and impaired vision were significant predictors of moderate functional limitation [37], which, in turn was strongly associated with increasing risk of falls.

5.2. Gender and race

Women were reported to be 58% more likely than men to suffer a nonfatal fall injury [37]. On the other hand, after taking age into account, the death rate associated with falls was 46% higher for men than for women [5,38]. Among older women, white women are 2.5 times more likely to die from falls as their black counterparts [5]. In 2007, there were 264,000 hip fractures in the US [5] and the rate for women was almost three times the rate for men [5]. In another study of hip fractures, a proxy for falls, white women had significantly higher hip fracture rates than black women [26]. In contrast, in the Concord Health and Ageing in Men Project (CHAMP study), a cohort study of men aged 70 years and over living in Sydney, Australia, the rate of falls was compared between Italian-born men living in Australia with their age matched Australian counterparts [39]. After adjustment for fall risk factors, Italian-born men remained significantly less likely to fall with a 43% lower fall rate (IRR = 0.57, 95% CI = 0.39–0.85) [39]. However, the difference in fall rates between the two groups was not explained by adjustment for any known falls risk factors and was thought to relate to other unmeasured biological or environmental factors.

5.3. Gait and balance

5.3.1. Normal aging effects

Gait and balance disorders have been consistently identified in multiple reviews as among the strongest risk factor for falls [25,31,40]. The gait pattern in older people tends to be stiffer and less coordinated with poorer posture control. Body-orienting reflexes, muscle strength and tone, and the step length and height all decline with aging and impair the ability to avoid a fall after an unexpected trip or slip [41]. Older adults may also be less capable of weight shifting or taking a rapid step to avoid falls when their balance is perturbed. Due to this ineffective stepping reaction, they have a tendency to take several smaller unsteady steps instead of one smooth step [42,43]. They also demonstrate difficulty initiating arm reactions to maintain balance or fail to recover equilibrium quickly after a perturbation [44]. Although older adults appear to be more reliant on arm reactions than young adults, they are less able to execute reach-to-grasp reactions rapidly [45]. These difficulties appear to be even more pronounced in individuals with a history of falling [46].

In the Baltimore Longitudinal Study of Aging, maximal and comfortable walking speeds and gait characteristics were compared among middle-aged (32–57 years; $N = 27$), old-age (58–78 years; $N = 125$), and oldest-age (79–93 years; $N = 38$) [47]. Older age was associated with slower self-selected walking speed, shorter stride length, and greater propensity of landing flat-footed [47]. With older age, hip generative mechanical work expenditure (MWE) for thigh rotation was lower about the antero–posterior (AP) axis (hip abduction and adduction) during stance and higher about the medio-lateral (ML) axis (hip extension and flexion) during late stance. Knee absorptive MWE for shank rotation about the AP axis (knee abduction and adduction), during early stance, was also lower with older age. These age-related gait patterns may represent a compensatory effort to maintain balance and may also reflect mobility limitations and increase the risk of falls [47]. When elderly patients who had fallen in the previous six months were compared to a matched group that had no falls, 57% of the fallers were unable to walk at the fastest speed, had shorter stride lengths, smaller lateral sway as well as smaller ankle plantar flexion and hip extension during push-off [48]. In addition, fallers had increased variability of kinematic measures compared with the non-fallers [48].

In a study of 266 older adults, frequent fallers were three times more likely to report missteps than non-fallers [49]. Subjects who reported multiple missteps were more likely to fall prospectively (relative risk = 3.89) [50]. A history of missteps was also associated with higher depressive symptoms and anxiety [50].

5.3.2. Pathological aging

Not surprisingly, patients with "neurological" gait pathologies (e.g., hemiparetic, frontal, Parkinsonian, unsteady, neuropathic, and spastic) have an increased risk of falls (risk ratio 1.49, 95% CI 1.11–2.00) [51]. Unsteady (risk ratio 1.52, 95% CI 1.04–2.22), and neuropathic gait (risk ratio 1.94, 95% CI 1.07–3.11) were the two gait subtypes that predicted risk of falls [51]. In another study by the same group, slower gait speed (risk ratio [RR] per 10 cm/s decrease 1.069, 95% confidence interval [CI] 1.001–1.142) was associated with higher risk of falls after adjusting for multiple confounders [52]. Among the six gait features studied, worse performance after accounting for cognitive impairment and disability on swing (RR 1.406, 95% CI 1.027–1.926), double-support phase (RR 1.165, 95% CI 1.026–1.321), swing time variability (RR 1.007, 95% CI 1.004–1.010), and stride length variability (RR 1.076, 95% CI 1.030–1.111) predicted fall risk [52]. Cadence was not predictive of falls [52]. In a retrospective study of 100 patients with detailed force-plate balance assessments during their post-stroke rehabilitation, Mansfield et al. found that a significant correlation between the difference in unipedal balance fluctuations between the 2 limbs and the risk of future falls [53]. This relationship was not seen in other balance measures that require bipedal support such as the Berg Balance Scale [53].

The term "higher-level gait disorder" (HLGD) or "cautious gait" has been used to indicate gait abnormalities that result from involvement of higher cortical centers. Older adults with HLGD often walk reduced stride length and increased stride-to-stride variability; they also have relatively high rate of falling [49]. In a study of 96 patients with moderate Alzheimer's disease, Nakamura described a significant correlation between the severities of dementia, stride length variability and falls [54]. This may be secondary to white matter changes seen on MRI in regions related to the motor system, including those along the cortico-spinal tract, the superior cerebellar peduncles, as well as in cognitive and affective-related areas, including the anterior limbs of the internal capsule and the genu of the corpus callosum [55].

5.4. Lower extremity strength

In a meta-analysis of 30 studies, Moreland and colleagues found that the combined odds ratio (OR) for the association of knee extension strength, ankle dorsiflexion strength, chair stands and falling was 1.76 (95% CI 1.31–2.37) [56]. Exercise intervention programs have been tested to reduce fall risk. Most studies have used some combination of resistance exercises, balance exercises, endurance exercises, and flexibility [57,59]. A meta-analysis of these studies did not show any significant reduction in falls in frail nursing home residents. Among community-dwelling older adults with deficits in strength and balance who underwent a 6 months strength training exercise program, the adjusted incidence ratio was 0.91 (95% CI 5 0.48–1.74) [58,59]. Although strength training by itself may not reduce the risk of falls, it generally should be included as part of a multi-modal intervention to reduce falls risk [32,58–60].

5.5. Vertigo and dizziness

Vestibular dysfunction is common in older people as a result of attrition of neural and sensory hair cells [61]. This often results in impairments in posture and gait, characterized by postural instability and a broad-based, staggering gait pattern with unsteady turns [60] placing the older adult at an increased risk of recurrent falls [60]. Still, there has not been a clear causal relationship between age-associated changes in vestibular function and falls, especially in subjects with intact visual and peripheral sensation [61,62]. However, Di Fabio and Kristinsdottir showed a relationship with increased risk of falls using more precise measurement of vestibular function [63,64]. Adequate function of the peripheral vestibular system also requires an intact vestibulo-ocular reflex (VOR), a network of neural connections between the peripheral vestibular system and the extraocular muscles. This is essential for maintaining stable vision during head movements. Decreased visual acuity resulting from an impaired peripheral vestibular system may impede balance and postural control and place an individual at risk of falling [65].

5.6. Vision

With impoverished visual input, balance control and obstacle avoidance abilities become impaired due to misjudgment of distances and misinterpretation of spatial information. Impaired depth perception has been found to be among the strongest visual risk factors for multiple falls in community-dwelling older people [66]. The Beaver Dam Study showed impaired visual acuity to be associated with an increased risk of falls; odds ratios for two or more falls in the past year for the poorest category of visual function (best corrected vision of 20/25 or worse) were 2.02 (95% CI, 1.13–3.63) for current binocular acuity and 1.85 (95% CI, 1.10–3.12) for visual sensitivity [67]. Two thirds of patients with age-related macular degeneration were found to have visuomotor and balance deficits resulting in clumsiness and an increased risk of falls [68,69]. Visual field loss was found to be the primary vision component increasing the risk of falls Both central visual impairment and peripheral visual impairment were independently associated with increased risk for falls and falls with injury 4 years after the initial examination in a dose–response manner in the Salisbury Eye Evaluation study [70]. These findings suggest that the ability to accurately judge distances and perceive spatial relationships is important for making appropriate decisions to move safely in the environment. Contrast sensitivity has also been found to be particularly useful in identifying older people at risk of falling [67,71]. A loss of edge contrast sensitivity may predispose older people to tripping over obstacles such as steps, curbs, tree roots, footpath cracks and surface misalignments [71]. In a systematic review of 19 prospective falls studies, Salonen et al. reported poor depth perception and stereoacuity as well as poor low-contrast visual acuity as risk factors of recurrent falls [66,72]. However, the evidence for discrepant vision, decrease in visual acuity and loss of visual field were less convincing. The relationships between poor visual acuity and poor contrast sensitivity and the risk of recurrent falls remain controversial [72,73].

Further evidence for the role of vision comes from interventions studies. Early cataract surgery was shown in several randomized clinical trials to significantly reduce the risk of falls (OR 0.66, 95% CI 0.45–0.96) [74,75]. Similarly, changing bifocal and multifocal spectacles reduced the rate of falls [76,77]. However, a randomized clinical trial in Australia conducted by Cumming et al. found that comprehensive vision and eye assessment with appropriate treatment increased the risk of falls and fractures in frail seniors randomized to the treatment arm compared to an usual care control group [78]. This paradoxical result was thought to result from increased mobility in seniors following vision correction that increased their fall risk exposure.

5.7. Cognition

5.7.1. Cognitive processes and falls

Although cognitive deficits, other than dementia have been recognized as a risk factor for falls, its role is less widely understood and appreciated. Postural stability is a complex skill dependent upon the coordination of motor and sensory systems to perceive environmental stimuli and respond accordingly to perturbations to control body movement [79,80]. The motor and sensory systems are linked by higher order cortical processes, which are required for planning movements, solving problems, divided attention and responding to changes within the environment.

In a meta-analysis of 27 studies, Muir et al. identified impairment on global measures of cognition to be associated with increased fall risk (summary estimate of OR = 2.13 (1.56–2.90)) and a fall resulting in a fracture (RR + 1.78 (1.34–2.37)) [81]. In community-dwelling older adults [81], Gleason et al. found that the risk of any fall increased by 20% for every point decrease on the Mini Mental Status Exam (MMSE) [82]. Specific cognitive domains, such as executive function (EF) impairment, (summary estimate of OR = 1.44 (1.20, 1.73)) were consistently associated with an increased fall risk. [81,83]

Another review described four cognitive domains that impacted falls: attention especially dual tasking, executive function, and information processing and reaction time [84]. Attention is the ability to focus on the relevant stimuli while suppressing most others. Among its subtypes, divided attention, which refers to the ability to carry out more than one task at the same time, i.e., dual tasking [85], has been found to be most related to balance, gait and fall risk [86]. In situations, which require both attention to a task and gait, subjects with limited attentional resources will show a decline in one task or both [84]. This effect has been shown in elderly fallers and patients with neurological disease, such as stroke, Alzheimer's disease (AD) or Parkinson's disease (PD), compared with healthy older adults [84,86]. In a study of 172 cognitively normal, elderly patients who underwent a neuro-cognitive battery, speed/executive attention were found to be associated with increased risk of single and recurrent falls [86,87]. Lower scores on Verbal IQ were related only to increased risk of recurrent falls. In contrast, memory was not associated with either single or recurrent falls [86].

5.7.2. Neurodegenerative diseases

A diagnosis of dementia, in both community and institution-dwelling older adults, confers a high risk for any fall or recurrent falls [88]. Studies in the past 10 years have documented a significantly higher prevalence of falls in Alzheimer's disease (AD) patients than in age-matched normal elders. Patients with AD have been observed to change their gait pattern and walk with increased gait instability [88]. In the meta-analysis by Muir et al., a diagnosis of dementia, without specification of dementia subtype or disease severity was associated with risk for falls but not serious fall injury in institution-dwelling older adults [81]. Similarly, patients with Parkinson's disease (PD) who had greater impairments in attention and executive function had a higher incidence of falls compared to non-PD patients (67% vs. 18%) [89]. They performed worse on a panel of executive function tests, although the scores were significantly different only on the verbal fluency test (17.0 vs. 28.3, $P = 0.009$) [89]. Interestingly, Bohnen et al. in a brain PET imaging study found that dopamine was less critical to falls in PD, while reduced cholinergic activity was associated with falls [90].

Intervention studies further support from the role of attention and executive function in fall risk [91]. For example, a small, but provocative randomized single blind pilot study among community living older adults suggests that gait and fall risk may respond to cognitive remediation [91]. Subjects who received attention training without any gait training improved gait velocity over the controls both during normal walking and walking while simultaneously carrying out another task (odds ratio = 3.5, 95% confidence interval = 1.5–8.0) [91].

5.8. Cardiovascular disease

5.8.1. Orthostatic hypotension

Orthostatic hypotension (OH) is a common condition affecting up to 30% of the general population over 65, and up to 70% of people living in nursing homes [92]. The definition put forward by American Autonomic Society, American Academy of Neurology, and subsequently endorsed by the European Federation of Autonomic Societies and the World Federation of Neurology is '. . .a sustained reduction of systolic blood pressure of at least 20 mm Hg or diastolic blood pressure of 10 mm Hg within 3 min of standing or head-up tilt to at least 60° on a tilt table [93]. Gangavati and colleagues reported that older adults with systolic OH at 1 min and uncontrolled hypertension were at greater risk of falls (hazard ratio = 2.5, 95% confidence interval = 1.3–5.0) than those with uncontrolled hypertension without OH. OH by itself was not associated with falls [94].

5.8.2. Hypertension

In a small study of 24 patients, Hausdorff et al. compared the gait characteristics of normal and otherwise healthy hypertensive older adults [95]. There was a small, but significant, association between some of the balance and gait measures with measures of blood pressure and heart rate. The normotensive subjects had more stable gaits (reduced stride-to-stride variability during swing phase), better performance on the timed Up and Go, higher fractal scaling index of gait (less random), and better postural control. Conversely patients with elevated blood pressure (BP) had worse performance. Elevated standing systolic BP was correlated with worse Up and Go times. Higher standing heart rates were associated with better performance in balance and gait [95].

5.8.3. Atrial fibrillation (AF)

Sander et al. evaluated 442 patients who came to the emergency room with a fall and divided them into those with an accidental fall (e.g., tripping, slipping) and those with a non-accidental fall [96]. There was a higher prevalence of AF in patients with non-accidental falls compared to the patients with accidental fall (26% vs. 15%, $P = 0.01$). The study also identified AF as an independent risk factor for non-accidental falls in elderly patients. The underlying mechanisms that may explain the above findings include decreased cardiac output, co-existing sinus-node disease, and impaired baroreflex in patients with AF. The same study reported that there was a significantly greater incidence of hypertension in the group with non-accidental falls versus accidental falls (63% vs. 51%, $P = 0.01$) [96].

5.9. Medications

5.9.1. Psychotropic

Psychotropic medications including antidepressants, drugs used to treat bipolar, anxiolytics/hypnotics, drugs used in dementia, and antipsychotics have been shown to increase the risk of falling by 47% in older adults living in the community [97,98]. People taking two or more psychotropic drugs have a further increased risk of falling [97]. In a literature review, Hill et al. identified a study that showed an increasing risk of falls with the use of benzodiazepines (long acting (OR 1.41; 95% CI 1.20, 1.71), antipsychotics (OR 1.39; 95% CI 0.94, 2.00) including atypical and typical, and antidepressants (OR 1.36; 95% CI 1.13, 1.76), in particular SSRIs and TCAs [99].

5.9.2. Diabetes medications

A literature review done by Berlie et al. showed that the risk of falls in insulin-treated patients versus non-diabetic controls was significant (RR 2.76; CI 1.52–5.01), whereas the risk of falls associated with non-insulin-treated patients with diabetes compared to nondiabetic controls was not significant (RR 1.18; CI 0.87–1.60) [100]. Metformin has not been directly linked to falls. It does, however, cause neuropathy secondary to vitamin B12 deficiency, which can predispose patients to falls. Secretagogues are not linked to falls [100]. Patient taking thiazolidinediones, although they are not at a higher risk of falls, are more prone to having fractures after a fall [101].

5.9.3. Nonsteroidal anti-inflammatory drugs (NSAID)

A systematic review done by Hegeman et al. suggested increased fall risk with NSAID exposure [102]. There was, however, a large variation in ORs, 95% CI, and sample sizes of the studies they looked at with four studies presenting a significantly increased OR and eight studies presenting a non-significantly increased OR. Many studies showed OR for NSAIDS that were in the range of the OR for accidental falls for benzodiazepines [102].

5.9.4. Cardiovascular medications

Huang et al. [102] performed a comprehensive review of the current cardiac medication associated fall literature, similar to the meta-analysis done by Leipzig et al. [103] which showed cardiovascular medications implicated in fall risk includes digoxin (OR 1.22 CI 1.05, 1.42), type 1 a anti-arrhythmic (OR 1.59; CI 1.02, 2.48) and diuretics (OR 1.08; CI 1.02, 1.16 [102–106]). Physicians should be careful in changing diuretics medication or increasing the dose because there is an increased risk in falling the day following a change (OR = 2.08; 95% CI = 0.89, 4.86) [106].

5.9.5. Antiepileptics

Limited data is available for the association of falls and use of ant-epileptics. However the CNS side effects of these drugs such as sedation, dizziness and ataxia can increase the risk of falls. Enrud et al. reported that community dwelling women on anti-epilectics were 75% more likely to fall when compared to non-users (OR + 1.75[95% CI 1.49, 4.41]) [107].

5.9.6. Vitamin D

13 randomized control trials were evaluated in one Cochrane review of the efficacy of vitamin D supplementation with and without calcium. The overall analysis of vitamin D versus control found no significant difference in fall rate when provided to unselected community-dwelling elderly (RR 0.95, 95% CI 0.80–1.14) [108]

5.10. Depression

Mood disorders such as depression are common in certain neurological conditions such as stroke (30–60%), Parkinson's disease (40%), Alzheimer's disease (20–40%), and dementia (17–31%) [109,110]. These conditions can limit mobility, worsen balance and predispose to falls. In a study of nursing home residents, the presence of depression was associated with a five-fold fall risk increase amongst depressed older adults on multiple medications, a six-fold risk was found amongst depressive elders using ancillary devices, and an 11-fold increased fall risk was seen in depressed elders with neurological diseases [111]. In a small pilot study looking at the relationship between major depressive disorder (MDD), gait speed, dual tasking and executive function, the MDD group had significantly slower walking speed when performing tasks with the highest cognitive demand and greater impairments with dual-tasks [112]. Both of these correlated with performance on traditional measures of executive functioning. No group differences were observed during gait associated with tasks requiring least cognitive demand. Balance-impaired older adults with MDD demonstrate increased stepping time under cognitively demanding conditions, reflecting executive dysfunction and an additional contribution to increased fall risk [112].

The role of depressive symptoms in fall risk is supported by a study that examined the effects of anti-depressive medications on gait and other fall risk factors. Therapy resulted in improvement in depression and cognitive measures while also showing small but significant improvement on several gait measures [113].

5.11. Environment

5.11.1. Home environment

Environmental or extrinsic factors are also important in contributing to falls risk. Poor lighting and objects around the home, such as loose rugs may increase the risk of falls. These factors are more problematic in individuals with visual impairment [114]. Contrast sensitivity diminishes in the elderly, and may be further compromised by concurrent ocular disease. Thus assessment of the home circumstances of patients including lighting would be another avenue for intervention in reducing falls risk [113].

The benefit of home interventions and assessments has been demonstrated in several studies that confirmed that home hazard assessment and modification resulted in fewer falls [113]. Still, generally speaking, reducing home hazards by itself is usually not sufficient to reduce the risk of falls [32].

5.11.2. Footwear

Another important environmental risk factor includes footwear, which effects postural stability and thus influences the incidence of accidental falls [114,115]. A large number of older adults tend to wear slippers while they are at home [116]. In a systematic review, Menant et al. reported that elderly people who wore slippers had a higher falls risk score than those whom walked barefoot or with fastened shoes [117]. Walking barefoot or with socks also can increase the risk of falling by up to 11 fold compared to walking with athletic or canvas shoes [117,118]. The design of the shoe is also important. Shoes with heels that are greater than 2.5 cm high are associated with a higher risk of fall compared to canvas shoes (odds ratio: 1.9) [117,118].

6. Assessment

A simple clinic based assessment of gait and fall risk could include chair rise and subsequent observation of the walking pattern. Asymmetrical, slow or shuffling gait, wide-based stance or walk, stooped postures and swerving from side to side as well as the use of an assistive devices for balance or mobility may all suggest an increased risk of falling during transfers or ambulation [16]. To more objectively quantify fall risk, many functional performance-based tests have been developed. A summary of some of the tests that are available can be found here: http://www.chcr.brown.edu/geriatric_assessment_tool_kit.pdf. The large number of tests that have been developed over the years attests to the importance and magnitude of the problem and, perhaps, also to the fact that to date the perfect, optimal test has yet to be developed. We briefly summarize a few of the commonly used tests below. Before that, we note that since a history of falls is generally a good predictor of future falls, it is important to specifically ask all patients if they have fallen in the past year [32].

6.1. Performance-oriented mobility assessment

The performance-oriented mobility assessment (POMA), also referred to as the Tinetti Gait & Balance test, is probably one of the earliest tests developed specifically to assess fall risk [119]. This test was developed by Dr. Mary Tinetti and has become a widely used clinical assessment tool for evaluating gait and balance abilities in older adults. This test is a very good indicator of fall risk. The two-part scale includes a total balance score of 16 and total gait score of 12, for a total possible score of 28. Scores of 25–28 indicate low fall risk, 19–24 medium fall risk, and <19 high fall risk [119]. The test and retest values for the POMA varied between 0.72 and 0.86. The inter-rater reliability values varied between 0.80 and 0.93. A number of studies evaluated the predictive value; one reported sensitivity of 61.5% and specificity of 69.5% in a group of community dwelling older persons. These numbers will vary depending on the specific nature of the cohort.

6.2. Four square step test

The four square step test (FSST) requires subjects to rapidly change direction while stepping forwards, backwards, and sideways over a low obstacle. Time to complete the test is measured. The test has been validated in older adults with a sensitivity of 85% and specificity of 88–100% in predicting fall risk [120,121].

6.3. Short Physical Performance Battery

The short physical performance battery (SPPB) consists of three types of physical maneuvers: balance tests, gait speed test, and the chair stand test. The SPPB is highly reliable in older adults (ICC = 0.83–0.89) and has demonstrated a strong and consistent association with health status measures and many outcomes, even when accounting for socioeconomic and cultural differences [122].

6.4. Berg balance scale

The Berg balance scale (BBS) is widely used to objectively determine a patient's ability (or inability) to safely balance during a series of predetermined tasks [123]. It is a set of 14 simple balance related tasks, ranging from standing up from a sitting position to standing on one foot, and takes approximately 20 min to complete [124]. The BBS has been shown to have excellent inter-rater (ICC = 0.98) and intra-rater reliability (ICC = 0.98), and is internally consistent (0.96) [125,126]. Limitations of the BBS include the fact that it places minimal emphasis on gait and dynamic balance, has ceiling and floor effects in certain populations, lack of items requiring postural response to external stimuli or uneven support surfaces, and a poor predictor of falls in some cohorts [127].

6.5. mini-balance evaluation systems test

The mini-balance evaluation systems test (mini-BEST) is a performance based measure that classifies balance problems into six underlying systems that may be impaired: biomechanical, stability limits, postural responses, anticipatory postural adjustments, sensory orientation, dynamic balance during gait and cognitive effects. The mini-BEST has been shown to be a reliable (ICC = 0.91) and valid measure of balance in older adults [123].

6.6. The dynamic gait index

The dynamic gait index (DGI) was developed as a clinical tool to assess gait, balance and fall risk [128]. It evaluates not only usual steady-state walking, but also walking during more challenging tasks. Eight functional walking tests are performed by the subject and scored on a scale of 0–3. The best possible score is 24. Scores of 19 or less have been related to an increased incidence of falls. The DGI showed high test-retest reliability and evidence of concurrent validity with other balance and mobility scales. It is a useful clinical tool for evaluating dynamic balance in ambulatory people with vestibular deficits and chronic stroke [129]. The DGI, although susceptible to ceiling effects, appears to be an appropriate tool for assessing function in healthy older adults [130].

6.7. Timed Up and Go test

The timed Up and Go test (TUG) is a relatively simple test used to assess a person's mobility and requires both static and dynamic balance. The TUG is used frequently in the elderly population, as it is easy to administer and can generally be completed by most older adults [131]. It uses the time that a person takes to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down. During the test, the person is expected to wear their regular footwear and use any mobility aids that they would normally require. A score of 13.5 s (some suggest 14 s) indicates that the person may be prone to falls [132]. The Timed up and Go test has excellent inter-rater correlation (ICC) = 0.99, and high intra-rater reliability (ICC = 0.99) [133]. A systematic literature review of 11 articles using the TUG showed that the cut-off time separating non-fallers and fallers varied from 10 to 32.6 s [54]. All retrospective studies showed a significant positive association between the time taken to perform the TUG and a history of falls with the highest odds ratio (OR) calculated at 42.3 [5.1–346.9]. In contrast, only one prospective study found a significant association of the TUG with occurrence of future falls [54]. In a separate study of 256 healthy adults, only the TUG was found to have a correlation with executive function and future falls, while 2 other balance measures, the Berg balance test and the dynamic gait index were not [55]. Perhaps because of its simplicity and short time to administer, recent guidelines suggest using the TUG in the clinical setting to assess fall risk [32].

6.8. Dual tasks

A number of studies have shown that fall risk is also related to cognitive function, especially executive function and the ability to walk and carry out other tasks, i.e., dual tasking [84,86]. Intuitively, this makes sense since everyday walking takes places in a complex environment that requires planning, scanning, multi-tasking and obstacle negotiation [84]. Building on this idea, a number of investigators have suggested that tests of gait while the subject carries out another, dual task may also be effective at predicting fall risk as well as other clinical outcomes [134,135]. Lundin-Olsson et al. observed that the inability to maintain a conversation while walking predicted falls in older nursing home residents [136]. Observing people walking while they perform a secondary attention-demanding task, the "dual task paradigm", has been used to assess the interactions between cognition, gait, and the risk of falls [137]. During the dual task, the subject performs an attention-demanding task while walking to assess any modifications, compared to the reference, single task condition, in either the cognitive or the walking subtasks [137]. The underlying hypothesis is that two simultaneously performed tasks interfere and compete for brain cortical resources. A recent systematic review suggested that increased dual task cost during gait assessment is associated with an increased fall risk in older adults. [138] A study among 1038 older adults found that a dual task cost of 18% or more prospectively predicts falls in individuals who walk at 95 cm/s or faster [odds ratio: 1.07, 95% CI (1.04–1.10)] [139].

7. Recommendations

The current recommendations from the American and British Geriatric Societies are that all older individuals should be asked if they fell in the past year or have experienced difficulties with walking or balance [32]. In those who respond positively or do poorly on a standardized gait and balance test, a trained clinician should conduct a multi-factorial fall risk assessment (see Table 2). This assessment should also include the individual's perceived functional ability and fear related to falling. A detailed history of the patient's falls with detailed description of the circumstances of the fall, frequency, and symptoms at time of fall, injuries, and other consequences should be obtained. Acute or chronic medical problems with special emphasis on osteoporosis, urinary incontinence, cardiovascular disease, vertigo, lower extremity weakness and a thorough review of all prescribed and over-the-counter medications with dosages should also be summarized.

The physical exam should include detailed assessment of gait, balance, and mobility levels and lower extremity function. The neurological exam should consist of a cognitive evaluation, lower extremity peripheral nerves testing, proprioception, reflexes, and tests of cortical, extrapyramidal and cerebellar function. Other tests should include muscle strength testing of the lower extremities, cardiovascular status examination of heart rate and rhythm, postural pulse and postural blood pressure, and if appropriate heart rate and blood pressure responses to carotid sinus stimulation and assessment of visual acuity. Feet and footwear should be examined. Finally, the patient's activities of daily living skills, including use of adaptive equipment and mobility aids, should be assessed to stratify the patient's functional status.

Strategies to reduce the risk of falls should include multifactorial assessment of known fall risk factors and management of the risk factors identified. The components most commonly included in effective interventions were (a) adaptation or modification of home environment (b) withdrawal or minimization of psychoactive medications (c) withdrawal or minimization of other medications (d) management of postural hypotension (e) management of foot problems and footwear, (f) exercise, particularly balance, strength, and gait training. Other interventions include vitamin D supplementation of at least 800 IU per day, cataract surgery if indicated; avoiding wearing multifocal lenses while walking, dual-chamber cardiac pacing should be considered for older persons with cardioinhibitory carotid sinus hypersensitivity who experience unexplained recurrent falls. Education complementing and addressing issues specific to the intervention being provided customized to individual cognitive function and language is a necessary component [32].

The 2012 U.S. Preventive Services Task Force (USPSTF) recommends exercise or physical therapy and vitamin D supplementation to prevent falls in community-dwelling adults aged 65 years or older who are at increased risk for falls [120]. According to the Institute of Medicine, the recommended daily allowance for vitamin D

Table 2

AGS/BGS clinical practice guideline: prevention of falls in older persons
Summary of recommendations
Screening and assessment
1. All older individuals should be asked whether they have fallen (in the past year).
2. An older person who reports a fall should be asked about the frequency and circumstances of the fall(s).
3. Older individuals should be asked if they experience difficulties with walking or balance.
4. Older persons who present for medical attention because of a fall, report recurrent falls in the past year, or report difficulties in walking or balance (with or without activity curtailment) should have a multifactorial fall risk assessment.
5. Older persons presenting with a single fall should be evaluated for gait and balance.
6. Older persons who have fallen should have an assessment of gait and balance using one of the available evaluations.
7. Older persons who cannot perform or perform poorly on a standardized gait and balance test should be given a multifactorial fall risk assessment.
8. Older persons who have difficulty or demonstrate unsteadiness during the evaluation of gait and balance require a multifactorial fall risk assessment.
9. Older persons reporting only a single fall and reporting or demonstrating no difficulty or unsteadiness during the evaluation of gait and balance do not require a fall risk assessment.
10. The multifactorial fall risk assessment should be performed by a clinician (or clinicians) with appropriate skills and training.
11. The multifactorial fall risk assessment should include the following:
Focused history
a. History of falls: detailed description of the circumstances of the fall(s), frequency, symptoms at time of fall, injuries, other consequences.
b. Medication review: all prescribed and over-the-counter medications with dosages
c. History of relevant risk factors: acute or chronic medical problems, (e.g., osteoporosis, urinary incontinence, cardiovascular disease).
Physical examinations
d. Detailed assessment of gait, balance, and mobility levels and lower extremity joint function.
e. Neurological function: Cognitive evaluation, lower extremity peripheral nerves, proprioception, reflexes, tests of cortical, extrapyramidal and cerebellar function.
f. Muscle strength (lower extremities).
g. Cardiovascular status: Heart rate and rhythm, postural pulse, blood pressure, and, if appropriate, heart rate and blood pressure responses to carotid sinus stimulation.
h. Assessment of visual acuity.
i. Examination of the feet and footwear.
Functional assessment
j. Assessment of activities of daily living (ADL) skills including use of adaptive equipment and mobility aids, as appropriate.
k. Assessment of the individual's perceived functional ability and fear related to falling.
(Assessment of current activity levels with attention to the extent to which concerns about falling are protective [i.e., appropriate given abilities] or contributing to deconditioning and/or compromised quality of life [i.e., individual is curtailing involvement in activities he or she is safely able to perform due to fear of falling]).
Environmental Assessment
1. Environmental assessment including home safety.

The complete guideline is published on the American Geriatrics Society's Web site (http://www.americangeriatrics.org/healthcare_professionals/clinical_practice/clinical_guidelines_recommendations/2010/).

is 600 IU for adults aged 51–70 years and 800 IU for adults older than 70 years. The American Geriatrics Society recommends 800 IU per day for persons at increased risk for falls. The U.S. Department of Health and Human Services recommends that older adults get at least 150 min per week of moderate-intensity or 75 min per week of vigorous-intensity aerobic physical activity, as well as muscle-strengthening activities twice per week [140]. It also recommends balance training 3 or more days per week for older adults at risk for falling because of a recent fall or difficulty walking [140].

Interestingly, the USPSTF does not recommend automatically performing an in-depth multi-factorial risk assessment in conjunction with comprehensive management of identified risks to prevent falls in community-dwelling adults aged 65 years or older because the likelihood of benefit is small. In determining whether this service is appropriate in individual cases, patients and clinicians should consider the balance of costs and benefits based on the history and circumstances of prior falls and comorbid medical conditions as well as including patient preferences in the management plan [32]. As noted above, however, a simple, but helpful screen is to ask the patient if they have fallen in the past year.

8. Summary and conclusions

Falls in older adults are common but are not necessarily an inevitable by-product of aging. Falls have been associated with a number of different risk factors. Some of these, like age or gender, cannot be altered. However, many other fall risk factors are amenable to interventions (e.g., muscle strength, balance, number of medications, cognitive function). Appropriate assessments can help to identify those subjects who have an increased risk of falls, the underlying causes, and, ultimately, reduce the negative impact of falls in older adults.

Contributors

Anne Felicia Ambrose created concept and framework for the paper, gathered references and wrote the first draft, and each subsequent draft, Formatted the paper to fit into journals requirements.

Geet Paul did the preliminary database searches and wrote the sections on cardiovascular disease (5.8) medications (5.9).

Jeffrey Hausdorff wrote section on assessment (6) and recommendations (7), provided editorial input.

Competing interests

The authors declare no conflict of interest.

Funding information

The authors have not received any funding for this article.

Provenance and peer review

Commissioned, externally peer reviewed.

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