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What is the role of falls?

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There is now firm evidence to support interventions in the prevention of falls in older people, and emerging data support prevention of falls as a method of fracture prevention. This chapter discusses the epidemiology of falls, risk factors associated with an increased risk of falling, assessment of the older faller, and evidence-based approaches to the prevention of falls in the older person. Several randomized controlled trials have found that hip protectors, if worn, probably prevent hip fractures, but that poor compliance is a major issue limiting the effectiveness of this form of intervention. More data are needed to support the role of prevention of falls in preventing fractures, as well as comparative cost-effectiveness data with other evidence-based approaches to preventing fractures in an older population.

Key words: Falls; Accidents; Aged; Prevention; Intervention; Hip protectors.

The evidence base for preventing fractures through the diagnosis and therapeutic management of a defined disease—osteoporosis—has been in existence for many years and is supported by large randomized controlled clinical trials funded predominantly by the pharmaceutical industry. With a reasonably robust mechanism for diagnosis (dual energy X-ray absorptiometry, DEXA) and a range of proven treatment options available, one might reasonably question why more fractures are not prevented through the clinical assessment and management of bone health.

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A fall, on the other hand, is not a diagnosis and often reflects a multiplicity of risk factors associated with normal physiological ageing, deconditioning from inactivity, and superimposed acute and chronic disease. There are those who see a fall as a surrogate or intermediate marker for fracture, similar to the use of bone mineral density (BMD) as a marker of fracture risk, and openly question the value of a fall as an outcome measure. However, unlike BMD, a fall is of direct clinical relevance to an individual, with a clear impact and all too often a negative outcome in terms of health and quality of life.

Over many years, a substantial literature has accumulated comprising epidemiological data identifying specific risk factors for falls. On the basis of these risk factors, various diagnostic assessments have emerged. It was not until 1990, however, that the first attempt was made to formally test whether interventions could prevent falls in randomized controlled trials.[1]

EPIDEMIOLOGY OF FALLS

Incidence

One third of the population aged 65 years and above fall each year[2,3], rising to 50% of people aged 85 years and above.[4] Of those who fall, 50% do so repeatedly.[5] Older community-dwelling women experience significantly more falls than do older men[3], and even after allowing for physical and social factors women are 1.5 times more likely to fall than men.[6] Women living alone are at greater risk of falling and sustaining an injury.[2] The incidence of falls and fall-related injuries in institutional settings has been reported in several studies, with the mean fall incidence calculated from these at 1.5 falls/bed per year.[7] The incidence is higher after relocation to a new environment, where the rate of falls can double and then return to baseline after 3 months.[8]

Location

The majority of older people live in their own homes, and 65% of women and 44% of men who fall do so within their usual residence and in the most commonly used rooms.[9] Most falls occur in peak activity periods, and only 20% occur at night. However, the external environment with its fast-moving vehicles and soft, slippery and irregular ground surfaces can be challenging for older people, and other studies have reported 33–50% of falls occurring outside the home.[3]

Consequences of a fall

Falls are the leading cause of injury-related hospitalization in persons aged 65 years and over, and account for 14% of emergency admissions[10] and 4% of all hospital admissions in this age group.[11] People aged 75+ spend an average of 18 days in hospital if admitted after an 'accident' at home, the commonest category of which is a fall.[12] Falls are mentioned as a contributing factor in 40% of admissions to nursing homes.[13]

Up to 10% of falls result in serious injury, of which 5% are fractures.[13–15] Whilst the proportion of falls which result in a fracture is low, the absolute number of older people who suffer a fracture is high, and this places heavy demands on health-care systems.

Falls account for 40% of injury-related deaths and 1% of total deaths in people aged 65 years and above.[16] Overall, the mortality associated with falls affecting older people is probably underestimated, but accurate estimates will remain unclear until falls are clearly characterized and recorded as clinical entities and a more pragmatic approach to death certification is identified.

FALLS RISK FACTORS

Maintaining balance is a complex task involving many systems which are affected by ageing and susceptible to impairments induced by disease. There has been a great deal of research focusing on risk factors for falling, and over 400 potential risk factors have been proposed.[17] Fall risk factors are generally considered to be either intrinsic (i.e. those pertaining to the physical and cognitive status of the individual) or extrinsic (i.e. environmental hazards or factors affecting the interface between the individual and the environment, such as footwear, assistive devices or spectacles). This section focuses on intrinsic factors. To help clarify the relative importance of the risk factors, a rating system has been employed based largely on the strength of the published evidence. A summary of the relative strength of the evidence for these risk factors is contained in Table 1.

As falls are generally considered to be associated with physical frailty, it is not surprising that advancing age and impaired ability in performing activities of daily living have been found to be strong risk factors for falls. Community-dwelling women have also been shown to have higher rates of falls than men, which may be due to reduced strength[18] and delayed execution of protective stepping responses.[19] An unexpected finding is that alcohol consumption has not been found to be a risk factor for fall[20,21]—indeed, there is some evidence that moderate drinkers have fewer falls than those who abstain.[14,20,22]

One of the strongest risk factor domains is impaired balance, mobility and gait, and many prospective studies have shown that tests of standing, leaning, reaching, stepping and walking can delineate fallers from non-fallers. Generally speaking, the more challenging the balance task, the stronger is its association with falls. For example, postural sway when standing on a compliant foam rubber mat is more predictive of falls than postural sway when standing on a firm surface[18,22,23], and tasks which require transfers of the body's centre of mass (such as leaning and reaching) are more useful for indicating risk of falls than assessments of steady standing.[24]

Impaired functioning of sensory and neuromuscular systems due to age, inactivity or disease processes are also strong risk factors for falls. Measures of vision, peripheral sensation, strength and reaction time have been shown to significantly and independently contribute to discrimination between fallers and non-fallers.[18,22,23] Vestibular function is less amenable to assessment with simple screening tests compared with other sensory and neuromuscular systems. However, recent studies using direct measurement of vestibular function have also provided evidence that impaired vestibular function is an important risk factor for falls and fall-related fractures in older people.[25,26]

Medical conditions strongly associated with falls include impaired cognition, stroke and Parkinson's disease. However, other conditions commonly posited as fall risk factors—such as vestibular disease, dizziness, orthostatic hypotension and arthritis—require more rigorous investigation to adequately establish their contribution to falls. Furthermore, establishing an association between falls and intermittent conditions

Table 1. Relative strength of evidence of intrinsic falls risk factors.

Domain	Risk factor	Association
Psychosocial/demo-graphic	Advanced age	***
	History of falls	***
	Walking aid use	***
	ADL limitations	***
	Female gender	**
	Living alone	**
	Inactivity	**
	Alcohol consumption	–
Mobility and balance	Impaired gait and mobility	***
	Impaired ability in standing up	***
	Impaired ability with transfers	***
	Impaired leaning/reaching ability	**
	Slow voluntary stepping	**
	Inadequate responses to perturbation	*
Gait patterns	Reduced gait velocity	***
	Reduced cadence	***
	Reduced step length	***
	Increased stance duration	***
Sensori-motor	Vision	
	Poor visual contrast sensitivity	***
	Decreased depth perception	***
	Poor visual acuity	***
	Visual field loss	**
	Increased visual field dependence	*
	Sensation	*
	Reduced peripheral sensation	
	Reduced vestibular function	**
	Poor hearing	*
	Strength	
	Reduced muscle strength	***
	Reduced muscle power	*
	Reduced muscular endurance	*
	Reaction time	
	Simple reaction time	***
	Choice reaction time	***
Medical conditions	Impaired cognition	***
	Stroke	***
	Parkinson's disease	***
	Foot problems	***
	Depression	**
	Arthritis	**
	Abnormal neurological signs	**
	Dizziness	*
	Orthostatic hypotension	*
	Vestibular disorders	–
Medications	Use of multiple medications	***
	Psychoactive medications	***
	Benzodiazepines	***
	Antidepressants	***
	Antipsychotics	***
	Antihypertensives	*

(Continued on next page)

Table 1 (*continued*)

Domain	Risk factor	Association
	Analgesics	–
	Anti-inflammatory	–

*** Strong evidence (consistently found in good studies); ** moderate evidence (usually but not always found); * weak evidence (occasionally but not usually found); and – little or no evidence (not found in published studies despite research to examine the issue).

(such as orthostatic hypotension) is inherently difficult, as subjects may test negatively at baseline and follow-up, but experience drops in blood pressure leading to falls during prospective study periods.

Both community and institutional studies have consistently found strong associations between falls and use of multiple medications and psychoactive drugs.[27] Results of studies into use of antihypertensive medications have been inconsistent, and a recent meta-analysis concluded that there was not sufficient evidence to consider the use of these drugs to be a risk factor for falls.[28]

IDENTIFICATION OF PEOPLE AT RISK OF FALLS

Falls risk assessment is particularly important in older people with osteoporosis, as over 60% of older people with femoral neck osteoporosis have fall-related risk factors,[29] and 90% of hip fractures result from a fall.[30] It is therefore likely that an understanding of clinical falls risk factors when combined with biochemical and radiological indicators of bone density will improve the accuracy of predicting future fracture risk.

It is important to differentiate between measures used to simply identify people at increased risk of falling and tools used to identify risk factors amenable to intervention to provide a basis for tailoring a falls prevention strategy. People at risk can be identified on the basis of age, place of presentation, usual place of residence, number of diseases and prescribed medications. Older people living in institutional care or presenting to the Emergency Department are well-documented high-risk populations.[10,31]

The predictive validity of published falls risk assessment screens has been examined in several recent reviews.[32–34] Oliver et al[33] found that of 45 screens designed for use in hospitals, only six underwent prospective validation, and only two (the Morse scale and the STRATIFY tool) were validated in two or more cohorts. It has also been suggested that many of theses tools lack either sensitivity or specificity and classify too few or too many people as fallers.[33] Further validation of screening tools for relevant populations is required.

CLINICAL ASSESSMENT OF THE OLDER FALLER

History

When trying to establish the cause of a fall it is important to remember that most falls occur as a result of an interaction between intrinsic and extrinsic factors and that multiple risk factors increase the risk of falls.[35] There are many disease processes seen more commonly in the older population that contribute to an increased risk of falls mainly through impairing postural stability. Table 2 highlights some of the disease processes that impact on the ability to maintain balance.

Table 2. Diseases having a direct impact on maintenance of the upright posture.

Diseases affecting sensory input	Vision	Age-related refractive error
		Senile macular degeneration
		Glaucoma
		Cataracts Stroke causing visual field defect
	Sensation	Diabetes
		Vitamin B12 deficiency
		Syphilis (rare)
		Degenerative joint disease, especially of neck and knees
	Vestibular	Age-related middle and inner ear changes
		Chronic ear infections
		Perforated ear drum
		Labyrinthitis
		Meniere's disease
Diseases affecting central processing	Cerebrum	Cerebrovascular disease (stroke)
		Dementia
		Brain tumour (benign and malignant)
	Cerebellum	Cerebrovascular disease (stroke)
		Long-term alcohol misuse
		Idiopathic cerebellar degeneration
	Basal ganglia	Cerebrovascular disease (stroke)
		Parkinson's disease
	Brain stem	Cerebrovascular disease (stroke)
		Atherosclerosis
		Postural hypotension
Diseases affecting effector response	Spinal cord and nerves	Any condition causing narrowing of spinal cord
		Motor neurone disease
		Multiple sclerosis
		Foot drop (common peroneal nerve)
	Muscles	Cerebrovascular disease (stroke)
		Motor neurone disease
		Muscular dystrophy
		Multiple sclerosis
		Polymyalgia rheumatica
		Polymyositis
		Hypothyroidism
		Vitamin D deficiency
		Diabetes
		Muscle disuse following fracture, injury or prolonged Immobility
	Joints	Osteoarthritis
		Rheumatoid arthritis
	Other	Foot deformities
		Poorly fitting shoes

A detailed history of the events surrounding a fall is essential. Corroborative information should be sought in those with limited recollection of the incident. In addition, there is a significant overlap between syncope and falls due to instability, with many older people having amnesia for the event.[36] It is important to establish cognitive ability as patients with a dementing illness may provide misleading information.

In addition to a detailed falls history, it is important to get an accurate medical and drug history. As previously highlighted, drugs commonly associated with an increased risk of falling include sedatives, antidepressants and antipsychotics. Polypharmacy (four or more regularly prescribed medications) has been consistently associated with falls although in most cases is primarily an indicator of underlying chronic disease.

Examination

Clinical examination of the older faller should be tailored to the history associated with the fall. At the end of the assessment, further evaluation and/or investigations may be required. Assessment of postural stability is a key area in the management of an older person at risk of falling.

Assessment of postural stability

Both the AGS/BGS/AAOS Guidelines[37] and the NICE guidelines[34] recommend the timed-up-and-go test (TUGT) as a simple screening tool to identify people warranting more detailed assessment of gait and balance.[38] It involves measuring the time taken for a participant to rise from a chair, walk 3 m at normal pace and with usual assistive devices, turn, return to the chair and sit down. Three retrospective studies have shown that TUGT performance can discriminate between fallers and non-fallers, and that a time of 15 or more seconds to complete the test indicates impaired functioning.[39–42]

Perell et al[32] have examined the predictive validity of functional mobility assessment tools for predicting falls. They concluded that, in addition to the TUGT, the Tinetti performance-oriented mobility assessment[42], the Berg balance scale[43], the modified gait abnormality rating scale[44], and the elderly fall screening test[45] were useful tests. Whilst useful as a screening tool to identify older people with problems relating to postural stability, these tests do not provide detailed information regarding the impairments in physiological domains that contribute to falls risk, and therefore provides little in the way of information about how to target intervention strategies.

A recently developed comprehensive assessment tool (the physiological profile assessment, PPA) is now available and takes a physiological approach to evaluating falls risk factors.[46] This involves assessment of sensorimotor factors that contribute to postural stability, including vision (visual acuity, contrast sensitivity and depth perception), peripheral sensation (tactile sensitivity, vibration sense and proprioception), strength (ankle dorsiflexion and knee flexion and extension), reaction time (hand and foot), postural sway (on a firm surface and foam rubber mat) and leaning balance (maximal balance range and coordinated stability). In a series of large prospective studies, this combination of tests has been shown to be able to discriminate between fallers and non-fallers with an accuracy of 75%, with a similar sensitivity and specificity.[22,23,47] A web-based software program has been developed to assess an individual's performance in relation to a normative database, which enables the calculation of an overall falls risk score - a single index score derived from a discriminant functional analysis of previous large-scale prospective studies.[3] The program also generates a profile of individual test performances (using z-scores) to identify physiological strengths and weaknesses, and allows for tailored intervention based on the deficits identified (Figure 1).

Investigations

Investigations should be tailored to the history and clinical examination. An ECG may identify conduction defects, whilst blood tests may be warranted for patients with a fever, an unexplained peripheral neuropathy, clinical anaemia etc. Urinalysis can identify urinary tract infections.

Where the cause of a fall is unclear or there is associated dizziness, palpitations or loss of consciousness, then further cardiovascular investigation is warranted. A routine ECG might be followed up by a 24-hour ECG and carotid sinus studies looking for evidence of carotid sinus hypersensitivity (an abnormal haemodynamic response to massage of the carotid sinus characterised by a sudden drop in blood pressure or pulse on massage of the carotid sinus).[48] The European College of Cardiology has produced a useful clinical algorithm to assist with the assessment and diagnosis of possible syncope.[49] CT and an EEG might be considered if epilepsy is a possible diagnosis.

A full blood count and renal, liver, thyroid and bone profiles tend to be part of a comprehensive geriatric assessment, but these tests rarely identify primary causes of falls. Exceptions might include undetected hypothyroidism or vitamin D deficiency. A standard osteoporosis screen should be considered in those for whom therapeutic intervention is being considered.

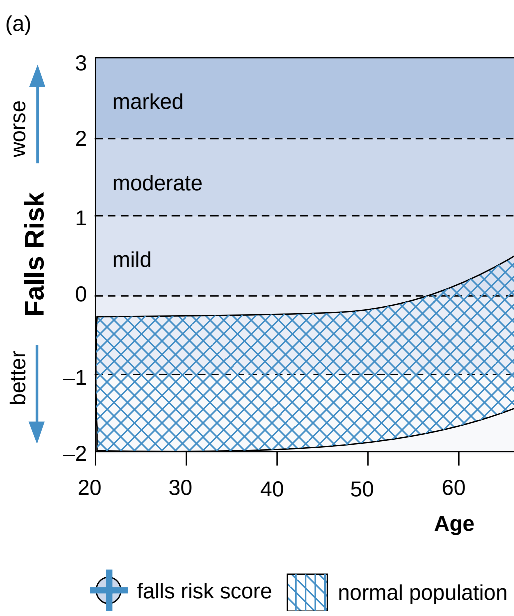

Figure 1. (a) Example of a falls risk score graph. (b) Example of a subject's test performance profile graph.

(b)

Test	Z-score
Visual acuity (high contrast)	–0.5
Visual acuity (low contrast)	–2.26
Edge contrast sensitivity	–1.06
Depth perception	–1.26
Proprioception	–0.44
Tactile sensitivity-ankle	–0.43
Vibration sense-knee	–1.23
Ankle dorsiflexion strength	–0.03
Knee extension strength	0.02
Knee flexion strength	–1.05
Reaction time hand	0.02
Reaction time foot	–0.19
Sway on floor-eyes open	0.59
Sway on floor-eyes closed	0.07
Sway on foam-eyes open	–0.2
Sway on foam-eyes closed	0.38
Co-ordinated stability	–0.29

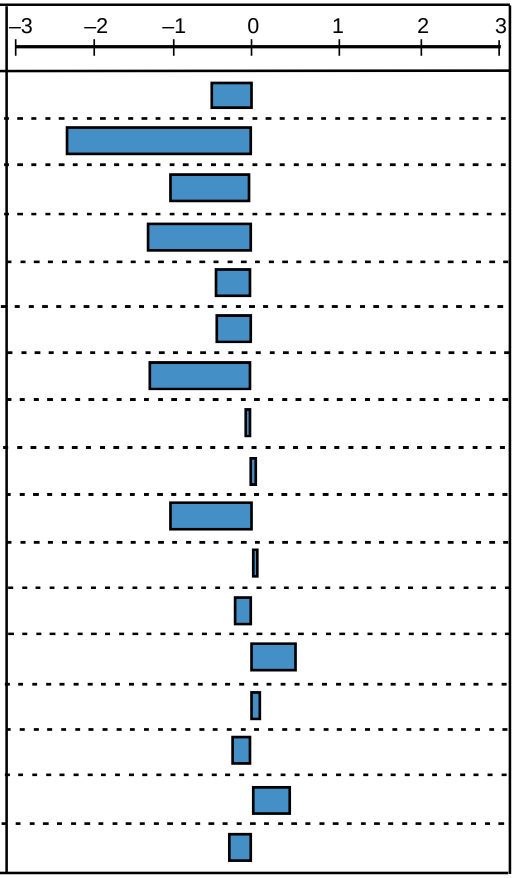

Figure 1 (*continued*)

INTERVENTIONS TO PREVENT FALLS/FRACTURES

There is now good evidence that falls can be prevented in older people in a variety of populations and clinical settings: community-dwelling populations, care-home residents, older people presenting to the Emergency Department with a fall, inpatients, and those being discharged home from hospital. Figure 2 identifies the different populations studied and whether single or multifaceted interventions have been shown to prevent falls in these populations. Both single[50–57] and multifaceted[58–62] approaches have been shown to be effective in community-dwelling populations, whilst a multifactorial approach seems to be required for inpatients[63,64] and care-home residents.[65–67] Trials involving older people presenting to the Emergency Department[10,68,69] have predominantly recruited community-dwelling older people. In contrast, Shaw et al[70] examined the benefits of intervening in cognitively impaired people largely from care homes and was not able to show any benefit from comprehensive assessment and intervention. These findings are likely to reflect levels

Emergency Department attendees	**Hospital inpatients**
Single interventions	*Single interventions* – Nil
Kenny et al, 2001 [68]	*Multifaceted interventions*
Multifaceted interventions	Haines et al,2004 [63]
Close et al, 1999 [10]	Healey et al, 2004 [64]
Davison et al, 2005 [69]	

Community dwelling population	**Care-home residents**
Single interventions	*Single interventions* – Nil
Wolf et al, 1996 [50]	*Multifaceted interventions*
Campbell et al, 1999 [51]	Ray et al, 1997 [65]
Campbell et al, 1997 [52]	Jensen et al, 2002 [66]
Cumming , 1999 [53]	Becker et al, 2003 [67]
Barnett et al, 2003 [54]	
Lord et al, 2003 [55]	
Robertson et al, 2001 [56]	
Harwood et al, 2005 [57]	
Multifaceted interventions	
Tinetti et al, 1994 [58]	
Hornbrook et al, 1994 [59]	
Day et al, 2002 [60]	
Nikolaus and Bach, 2003 [61]	
Wagner et al, 1994 [62]	

Figure 2. Successful prevention strategies by populations identified and type of intervention.

of co-morbidity as well as impaired physical and cognitive functioning. Table 3 provides a detailed review of each of the RCTs which have shown benefit in reducing falls in older people. Community-dwelling populations studied show marked heterogeneity ranging from a sample selected randomly from an electoral roll and via advertisements[60] to studies which recruit those with predetermined risk factors.[54,58]

There is no single all-encompassing approach to prevent falls, but the existing evidence does at least provide some clear guidance for service development. Exercise in the form of strength and balance training is effective in a variety of populations

Table 3. Randomized controlled trials (RCTs) which have shown evidence of benefit in preventing falls.

Population and numbers	Setting	Interventions and duration of follow-up	Single (S) or multiple (M) intervention	Outcome	Author(s) Year Country Reference
RCT multifactorial risk factor abatement strategy Age: 70+ years $n=301$	C	I: Nurse assessed participants for risk factors and targeted interventions accordingly. Therapist gave home exercise routines C: Friendly visits	M	1-year follow-up; fewer falls in intervention group: 35% versus 47% ($P=0.04$) CER: 47% IER: 35% RRR: 26%	Tinetti et al 1994 USA[58]
Community dwellers from HMO Mean age 73 years Subjects: 3182	C	Both groups had home assessment and falls safety hazards check I: Remove/repair safety hazards Falls information groups including group exercise C: No repair advice or group sessions Follow-up period: 23 months	M	Fewer falls in the intervention group ($P < 0.05$) but no statistically significant effect on number of medical care falls CER: 44% IER: 39% RRR: 11% ARR: 5%	Hornbrook et al 1994 USA [59]
Community-dwelling HMO enrolees Mean age 72 years $n=1559$		(a) 60-90-min assessment and tailored intervention (b) Chronic disease prevention nurse visit (c) Usual care 1-year follow-up period	M	Significant reduction in number of falls: RR 0.75 (0.64, 0.88) CER: 37% IER: 28% RRR: 24% ARR: 9%	Wagner et al 1994 USA[62]
Community dwellers recruited by local advertisement Mean age 76.9 years $n=200$	C	1: Tai Chi 2: Conventional balance training 3: Education Follow-up 7-20 months	S	4-month follow-up. Significant reduction in falls: RR 0.51 (0.36, 0.73). When excluding stumbling from falls definition: RR 0.67 (0.41, 1.09)	Wolf et al 1996 USA[50]

(Continued on next page)

Table 3 (*continued*)

Population and numbers	Setting	Interventions and duration of follow-up	Single (S) or multiple (M) intervention	Outcome	Author(s) Year Country Reference
RCT of consultation service to reduce falls in nursing homes Mean age 82 years *n*=499	NH	I: Structured individual assessment with advice on prescribing, environmental concerns and transfer and ambulation C: Usual care 1-year follow-up period	M	1-year follow-up. Significant difference in mean proportion of recurrent fallers but not in injurious falls CER: 54.1% IER: 43.8% RRR: 19% ARR: 19.1%	Ray et al 1997 USA[65]
Community-dwelling women from GP register Mean age 84.1 years *n*=233	C	I: Individually tailored programme of strength and balance training in the home. Four 1-hour sessions with physiotherapist in the first 2 months of the study + three 30-min walks per week C: Social visits Regular phone contact for both C and I 1-year follow-up period	S	Significantly fewer falls in the intervention group (152 versus 88) CER: 52.9% IER: 45.7% RRR: 13.6% ARR: 7.2%	Campbell et al 1997 NZ[52]
Community-dwelling people on centrally acting medications from GP registers Mean age:74.7 years *n*=93	C	2×2 Factorial design I1: Gradual withdrawal of psychotropic medication I2: Home-based exercise programme I3: both I4: nil 44-week follow-up	M	Fewer falls in medication withdrawal group (RR 0.34; 95%CI 0.16–0.74) No significant reduction in falls in the exercise group or with the addition of exercise to medication withdrawal CER: 37.7% IER: 22.9% RRR: 39% ARR: 14.8%	Campbell et al 1999 NZ[51]
Community-dwelling people aged 65+ years presenting to ED with a fall Mean age 78.2 years *n*=397	C	I: comprehensive geriatric assessment and OT home assessment C: Usual care 12-month follow-up	M	Significant reduction in falls, fallers, recurrent fallers and in functional status RR 0.61 (0.49, 0.77) CER: 52% IER: 32% RRR: 38% ARR: 20%	Close et al 1999 UK[10]

Community-dwelling people discharged from hospital setting Mean age 77 years $n=530$	C	I: OT home assessment targeted on environmental modifications in older people discharged from hospital C: Usual care 1-year follow-up period	S	Reduction in number of falls in intervention group as compared to control ($P=0.05$) Intervention only effective in those with history of falls: RR 0.64 (0.49, 0.84) CER: 44.7% IER: 36.3% RRR: 18.8% ARR: 8.4%	Cumming et al 1999 Australia [53]
People presenting to Emergency Department with non-accidental fall Mean age 73 years $n=175$	C	I: Dual chamber pacing for unexplained falls and cardio-inhibitory form of carotid sinus syndrome 1-year follow-up period	S	Significant reduction in syncopal events: RR 0.48 (0.32, 0.73); also significant reduction in falls CER: 54% IER: 26.1% RRR: 51.7% ARR: 27.9%	Kenny et al 2001 UK [68]
Community population Mean age 80.9 years $n=240$	C	I: District nurse delivery of strength and balance training programme	S	Significant reduction in number of falls: IRR 0.54 (0.32, 0.9) CER: 42.9% IER: 31.4% RRR: 26.8% ARR: 11.5%	Robertson et al 2001 New Zealand [56]
Factorial design Community dwellers identified from electoral role Mean age 76.1 years $n=1107$	C	Groups: a) Group exercise b) Home hazard management c) Vision management + various combinations of above 18-month follow-up period	M	RR for exercise: 0.82 (0.7, 0.97) Significant effects for combinations that involved exercise Strongest effect was for all three interventions: RR 0.67 (0.51, 0.88)	Day et al 2002 Australia [60]
Nine residential homes Mean age 83 years $n=439$	RH	I: 11-week multidisciplinary intervention C: Usual care 34-week follow-up period	M	Significant reduction in number of falls CER: 56% IER: 44% RRR: 21.4% ARR: 12%	Jensen et al 2002 Sweden [66]

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Table 3 (*continued*)

Population and numbers	Setting	Interventions and duration of follow-up	Single (S) or multiple (M) intervention	Outcome	Author(s) Year Country Reference
Retirement village residents Mean age 79.5 years $n=551$	C	I: weight-bearing group exercise designed to improve activities of daily living C: flexibility and relaxation groups 12-month follow-up	S	Significant reduction in number of falls IRR: 0.78 (0.62, 0.99) CER: 47% IER: 42.1% RRR: 10.4% ARR: 4.9%	Lord et al 2003 Aus [55]
Community dwellers admitted to hospital and showing functional decline Mean age 81.5 years $n=360$	C	I: Comprehensive geriatric assessment and multidisciplinary diagnostic intervention in person's own home C: Comprehensive geriatric assessment + recommendations and usual care 12-month follow-up	M	Significant reduction in number of falls: IRR 0.69 (0.51, 0.97); most effective in those reporting two or more falls in previous year: IRR 0.63 (0.43, 0.94) CER: 65.5% (based on history of 2+ falls in last year) IER: 39.6% RRR: 39.5% ARR: 25.9%	Nikolaus and Bach 2003 Germany [61]
Community-dwelling older people identified as at risk of falling Mean age 74.9 years $n=163$	C	I: Weekly exercise group - total of 37 classes + information on how to avoid falls C: Information on how to avoid falls	S	Significant reduction in falls, fallers and recurrent fallers; IRR for falls 0.6 (0.36–0.99) CER: 50% IER: 35.5% RRR: 29% ARR: 14.5	Barnett et al 2003 Australia [54]

Nursing-home residents in Germany (six homes) Mean age 85 years $n = 981$	NH	I: Staff and resident education, advice on environmental modifications, strength and balance training and hip protectors C: Usual care 1-year follow-up period	M	Significant reduction in falls, fallers and recurrent fallers; no significant reduction in fracture rates Falls RR: 0.55 (0.41, 0.73) CER: 52.3% IER: 36.9% RRR: 29% ARR: 15%	Becker et al 2003 Germany [67]
Inpatients on three subacute wards in Australia Mean age 80 years $n = 626$	I/P	I: Multifactorial intervention targeted at identified risk factors, including education, physiotherapy, OT and use of hip protectors C: Usual care Patients followed up until point of discharge or death	M	Significant reduction in number of falls 30% fewer falls in the intervention group Falls RR 0.78 (0.56, 1.06) CER: 22.5% IER: 17.4% RRR: 22.7% ARR: 5.1%	Haines et al 2004 Australia [63]
Inpatients on a mix of acute and rehab settings in UK Mean age 81 years $n = 1654$	I/P	I: Multifactorial intervention targeted at identified risk factors, including vision, drugs, blood pressure, exercise and environmental modification C: Usual care 6-month follow-up following introduction of the intervention	M	Significant reduction in falls; no reduction in injury rates Falls RR 0.71 (0.55,0.9)	Healey et al 2004 UK [64]
Women referred for cataract surgery $n = 306$	C	I: Expedited cataract surgery (4 weeks) C: Routine surgery (12 months)	S	Improved outcomes for intervention group 34% reduction in rate of falling: 0.66 (0.45,0.96) No difference in number of participants who fell at least once Significant reduction in number of fractures 12 (8%) versus 4 (3%) CER: 45% IER: 49%	Harwood et al 2005 UK [57]

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Table 3 (*continued*)

Population and numbers	Setting	Interventions and duration of follow-up	Single (S) or multiple (M) intervention	Outcome	Author(s) Year Country Reference
Cognitively intact people aged 65+ years presenting to the Emergency Department with a fall and a history of a previous fall in the 12 months prior to presentation Mean age 77 years $n=313$ (data analysed on 293)	C	I: Comprehensive geriatric assessment (medicine, physiotherapy and OT) including detailed cardiovascular investigations and targeted intervention C: Usual care	M	36% significant reduction in number of fall but not in number of fallers Falls RR 0.64 (0.46, 0.9) CER: 68% IER: 65% RRR: 4.4% ARR: 3%	Davison et al 2005 UK [69]

NH/RH, nursing home/residential home; C, community; H, hospital; I/P, inpatient; OT, occupational therapy; RR, relative risk; OR, odds ration; IRR, incidence rate ratio; CER,control event rate; IER, intervention event rate; RRR, relative risk reduction; ARR, absolute risk reduction.

and settings, although it needs to be part of a multifaceted approach in higher-risk populations. Exercise needs to be progressive, with a maintenance programme undertaken in the long term as the benefits of exercise are lost when exercise is discontinued.

Where there is no clear attributable cause for a fall or there is a history of dizziness or syncope, then patients should have access to detailed cardiovascular investigations, including testing for the carotid sinus syndrome.

High-risk populations are most likely to benefit from intervention, and there is no requirement to undertake long and detailed assessments to identify these populations; they are easy to identify in terms of care-home residents, inpatients, and those presenting to the Emergency Department or living in the community and with a history of falls.

The role vitamin D plays in the prevention of falls has undergone critical review of late and provides an area of commonality for those with an interest in osteoporosis and those interested in falls. Vitamin D deficiency is prevalent amongst older fallers[71], and with vitamin D receptors present in both muscle and nervous tissue there is certainly a clear rationale for vitamin D having an important role in postural stability and falls. A recent meta-analysis has shown the benefits of vitamin D supplementation in the prevention of falls.[72] With 72% of a Falls Clinic population shown to be vitamin-D-deficient[71], there may well be a role for widespread use of vitamin D in high-risk populations.

Until recently, no data existed to show that prevention of falls could also prevent fractures. This reflects the sample size of each of the trials undertaken to date which have been powered to detect differences in a more common event, i.e. falls, and have been of an order of magnitude smaller than most of the major osteoporosis trials. Logically, given that most peripheral osteoporotic fractures occur as a result of a fall, there is good reason to believe that if studies were adequately powered, fracture prevention is likely to result. Meta-analysis of existing studies presents difficulties in terms of heterogeneity of sample populations, definitions used in terms of falls, injury and fracture, and duration of follow-up.

Harwood et al[57] have recently published a paper examining the benefits of expediting cataract extraction (4 weeks compared to a 12-month wait) and showed a 34% reduction in falls as well as a statistically significant difference in number of peripheral fractures at 12 months: 12 control versus 4 intervention ($P = 0.04$). Whilst numbers of fractures were small, this is an encouraging finding and indicates that fracture prevention can be enhanced with fall prevention strategies. No trial exists as yet which takes a combined approach to fracture prevention (i.e. maintaining bone health and preventing falls), and no economic analysis has been undertaken to compare the costs of the different approaches to fracture prevention.

Use of hip protectors in the clinical setting

It may be possible to decrease the likelihood that a fall will result in a fracture by changing the interaction between the faller and the surface on which they fall. This can be undertaken by modifying the surface onto which the person falls or by placing a barrier between the person and the hard surface onto which they fall. Hip protectors are designed to fulfil this latter role.

Hip protectors are worn by the individual and are designed both to absorb energy and to transfer load from the bone to the surrounding soft tissues.[73] The original hip protectors, designed in Denmark[74], have a firm outer shell and an inner foam section. Another version is made of dense plastic without an outer shell.[75] The protector is either removable and fits into pockets in special underwear or non-removable and built into underwear. Early research into hip protectors led to international enthusiasm about the potential for preventing hip fractures in high-risk groups such as nursing home residents with a relatively low-cost intervention with minimal side-effects. The original Danish model was tested in a randomized controlled study among 701 residents of a nursing home.[74] The risk of fracture was significantly decreased in the intervention group (relative risk 0.44). Although eight members of the intervention group suffered hip fractures, none was wearing the hip protectors at the time of fracture. A further study in Sweden[76] tested a different model of hip protector and also found a decreased fracture rate among residents of a randomly selected nursing home who were offered hip protectors compared with a control nursing home (relative risk 0.33).

However, further research into the efficacy and practicality of hip protector use has not been as positive. It is now thought that the results from the early trials may have overestimated the efficacy of hip protectors, due partly to incorrect analysis given their cluster-randomized designs.[77] Subsequent trials with individual randomization have not shown such positive results. The Cochrane review on this topic[77] finds that 'pooling of data from five individually randomized trials conducted in nursing/residential care settings (1426 participants) showed no statistically significant reduction in hip fracture incidence (hip protectors 37/822 (4.5%), controls 40/604 (6.6%), RR 0.83, 95% CI 0.54 to 1.24)' and that two individually-randomized studies which recruited community-dwelling elderly people 'did not achieve a statistically significant reduction in the incidence of hip fractures (27/484 (5.6%) in hip protector group versus 24/482 (5.0%) in controls, RR 1.11, 95% CI 0.65 to 1.90)'. A more recent cluster-randomized trial[78] among residents of 127 aged care facilities (4117 occupied beds) also failed to find an effect on fracture rates of hip protectors (rate ratio for the intervention group compared to the control group of 1.05 (95% CI 0.77, 1.43).

When worn correctly, hip protectors probably work well to prevent hip fractures. The majority of fractures in intervention groups of hip protector studies occur while the hip protector is not actually being worn or is incorrectly positioned.[77] A recent study compared protected and unprotected falls among high-risk nursing home residents and found that the risk of hip fracture was reduced to less than a third in protected falls compared with unprotected falls.[79]

Compliance seems to be the major limitation to efficacy of hip protectors. Many of the trials included in the Cochrane review[77] had compliance rates less than 40% by the end of the studies. For example the recent study by O'Halloran et al[78] found that initial acceptance of the hip protectors was 37.2% (508/1366) with adherence falling to 19.9% (272/1366) at 72 weeks. Several studies found that many potential participants declined to be involved in the study (e.g. 79% declined in Birks et al[80]). A systematic review[81] found very variable acceptance (37–72%, median 68%) and compliance with hip protectors (20–92%, median 56%). Key reasons for poor compliance were: not being comfortable (too tight/poor fit); the extra effort needed to wear the device; urinary incontinence; and physical difficulties/illnesses. In some settings, cost may be a barrier to hip protector use.[82]

Hip protectors do not decrease the risk of other fractures—e.g. pelvic fractures[77]—but have been found to improve falls self-efficacy.[83]

Despite their limitations, hip protectors can be useful clinically as a hip fracture prevention strategy among those at high risk of falls who are willing and able to wear them. More work is required to establish the optimum design for hip protectors.[77,82]

SUMMARY

The complexity of the interaction between physiological variables, intrinsic disease and the external environment has often led to a nihilistic approach to the prevention of falls in older people and a view that falls are an inevitable consequence of ageing. However, there is now sound evidence to support the effectiveness of falls prevention programmes. Using assessments based on evidence-based risk factors amenable to correction, it is possible to identify and intervene in those most likely to benefit from preventative strategies.

Strength and balance training appears to be the most effective single intervention in the prevention of falls, although gait and balance problems are not the only risk factors for falls, and other investigative approaches are required for those in whom a cause of a fall is unclear. A multifactorial approach is needed in higher-risk individuals such as those in hospital or care homes and those presenting to the Emergency Department as a result of a fall. Compliance has been highlighted as an issue limiting the effectiveness of hip protectors, and more evidence is needed on the acceptability of other interventions shown to be effective but not as yet evaluated outside the research setting.

Despite only preliminary evidence to support falls prevention as a means of fracture prevention, it is likely that if we are to have a meaningful impact on fracture rates, it is imperative that a broader approach to fracture prevention is taken. Bone health and falls prevention should not be considered in isolation, and practitioners need to develop service models that match clinical knowledge and expertise with the needs of the patient population. No data currently exist to guide us as to the most cost-effective approach to falls and fracture prevention; further comparative work is required to establish the clinical effectiveness and cost efficiency of the interventions on offer.

Practice points

- a fall in an older person is often a result of intrinsic physiological ageing and underlying chronic disease interacting with the external and challenging environment
- risk factors associated with postural stability have been consistently shown to predict risk of falls
- it is possible to objectively quantify risk of falling and use assessment measures to tailor intervention
- strength and balance training is the single intervention which has the strongest evidence base for preventing falls
- multifaceted interventions are of benefit in higher-risk populations
- other interventions have a role (cataract surgery, pacemakers, home safety modifications) in defined at risk populations
- hip protectors can prevent hip fractures among older people who are willing and able to wear them correctly; however, poor compliance limits their usefulness and has led to findings of poor efficacy in recent studies

Research agenda

- at present there is no evidence of benefit when intervening in older people with cognitive impairment and dementia (usually defined as MMSE $<$ 24)
- the cost of the different approaches to falls prevention is largely unknown
- more evidence is needed to support falls prevention as a means of fracture prevention
- numbers needed to treat to prevent a fracture for various falls prevention strategies are as yet unknown
- optimal design of hip protectors is required to minimize discomfort and inconvenience yet maximize fracture prevention potential

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