

Prevention of falls and consequent injuries in elderly people



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Injuries resulting from falls in elderly people are a major public-health concern, representing one of the main causes of longstanding pain, functional impairment, disability, and death in this population. The problem is going to worsen, since the rates of such injuries seem to be rising in many areas, as is the number of elderly people in both the developed and developing world. Many methods and programmes to prevent such injuries already exist, including regular exercise, vitamin D and calcium supplementation, withdrawal of psychotropic medication, cataract surgery, professional environment hazard assessment and modification, hip protectors, and multifactorial preventive programmes for simultaneous assessment and reduction of many of the predisposing and situational risk factors. To receive broader-scale effectiveness, these programmes will need systematic implementation. Care must be taken, however, to rigorously select the right actions for those people most likely to benefit, such as vitamin D and calcium supplementation and hip protectors for elderly people living in institutions.

Introduction

Falls and fall-induced injuries in elderly people are common worldwide, and ageing populations will further raise the burden and costs (figure 1).^{1–8} Around 30% of people aged 65 years or older living in the community and more than 50% of those living in residential care facilities or nursing homes fall every year, and about half of those who fall do so repeatedly.^{1,9–12} This rate rises with age, with functional impairment and disability being highest in those older than 90 years.^{4,13}

Although not all falls lead to injury, about 20% need medical attention, 5% result in a fracture, and other serious injuries—such as severe head injuries, joint distortions and dislocations, and soft-tissue bruises, contusions, and lacerations—arise in 5–10% of falls.^{1,4,13–16} These percentages can be more than doubled for women aged 75 years or older.¹²

Importantly, fall-induced injuries represent one of the most common causes of longstanding pain, functional impairment, disability, and death in elderly populations.^{7,15,17–21} Injury is the fifth leading cause of death in elderly adults, and most of these fatal injuries are related to falls.^{1,4,7,14,22–24} Falls account for over 80% of injury-related admissions to hospital of people older than 65 years.^{4,5,25} A fall and related injury, or even a fear of their consequences, such as social withdrawal, loss of independence and confidence, and admission to a long-term care facility, can cause severe depression and anxiety.^{4,19,26}

Prevention of falls and injuries is not easy, however, because they are complex events caused by a combination of intrinsic impairments and disabilities (ie, increased liability to fall) with or without accompanying environmental hazards (ie, increased opportunity to fall) (figure 2). The aim of this review is to update and summarise the evidence-based knowledge of prevention of falls and subsequent injuries in elderly adults.

Prevention of falls and fall-induced injuries

Since falling is the main risk factor for fractures and other injuries in elderly people and since many of the risk factors for falls and for serious injuries caused by falls are similar and correctable,^{10,15,19,27,28} fall prevention is

essential in the planning of effective injury prevention. Interventions have used two different approaches: a single-intervention strategy (such as exercise, vitamin D, or withdrawal of psychotropic drugs); or more multifactorial preventive programmes, including simultaneous assessment and reduction of many of the individual's predisposing and situational risk factors. In prevention of injury despite falling, an approach of injury-site protection (hip protectors) has been used. Additionally, a traditional approach for one specific injury group or bone fracture has been prevention and treatment of osteoporosis. This approach has been widely addressed in published work, with several recommendations,^{2,29–38} and is not discussed here in detail. Briefly, maximising peak bone-mass and preventing bone loss by regular exercise, calcium and vitamin D, and treatment of osteoporosis with pharmacological agents (hormone replacement therapy, bisphosphonates, selective oestrogen receptor modulators, calcitonin, and parathyroid hormone) have a firm scientific basis and have been recommended by many authorities and consensus conferences.^{30,31,35,38} In addition, new bone-specific drugs, such as strontium ranelate, will probably soon become clinically available.³⁸

Theoretically, a multifactorial intervention for elderly people should be more effective than its single-intervention counterpart since causes and risk factors of falling are usually multiple with striking intraindividual (fall to fall) and interindividual variation.³⁹ On the other hand, a single-factor intervention such as exercise could also reduce many impairments and disabilities and

Lancet 2005; 366: 1885–93

Published online

October 25, 2005

DOI:10.1016/S0140-6736(05)67604-0

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Search strategy and selection criteria

This review is based on Medline and PubMed searches for meta-analyses and systematic reviews on prevention of falls and related injuries in elderly people. Additionally, the newest randomised controlled trials not included in the most recent meta-analyses and systematic reviews were identified from the databases, relevant journals, and congress abstracts up to May 31, 2005, and have been added.

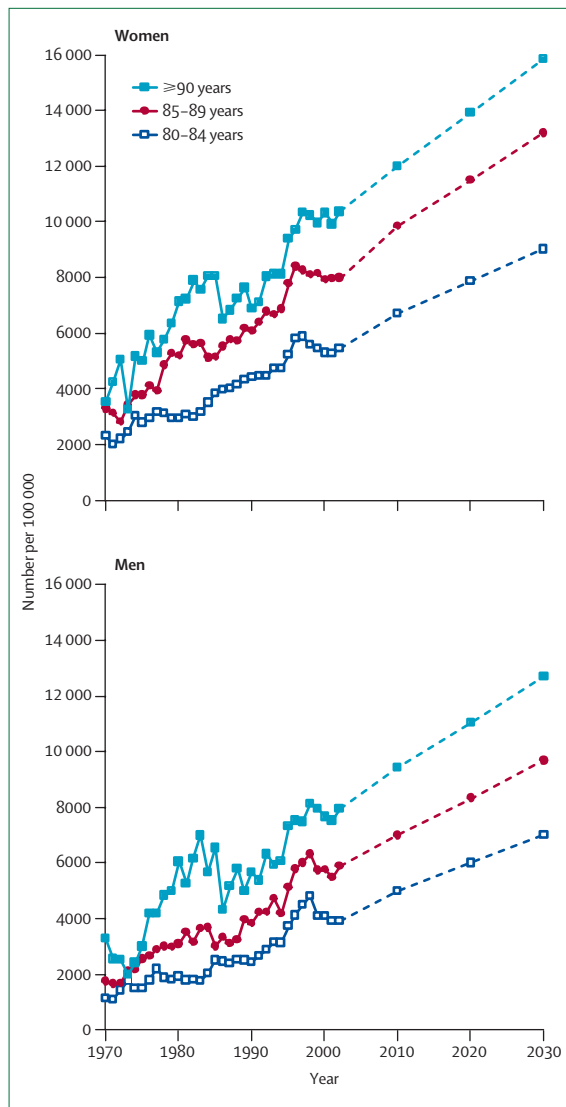


Figure 1: Incidence of hospital-treated fall-induced injuries in Finnish people aged 80 years or older in 1970–2002

Broken lines=incidence prediction until the year 2030. Prediction was calculated with linear regression model based on data for 1970–2002.

more distant risk factors for falling simultaneously (figure 2). Because direct comparisons of the effectiveness of a multidimensional intervention to a single-factor intervention are very rare,⁴⁰ straightforward conclusions should be avoided.

Fall prevention: single-intervention strategies Strength and balance training

Randomised trials have almost without exception shown, and meta-analyses and systematic reviews confirmed, that strength and balance training for elderly adults living in the community can reduce the risk of both non-injurious and injurious falls by 15–50%—even cost-effectively.^{10,16,22,40–58} Four of these randomised studies suggested that not only individually tailored training but

also more untargeted group exercise programmes are effective in preventing falls,^{47,48,52,55} especially if the training programme involves Tai Chi or other exercises that challenge balance.^{52,56,59}

The preventive effects of a programme for strength and balance training are to be expected because they can improve many risk factors of falling, such as muscle strength, flexibility, balance, coordination, proprioception, reaction time, and gait—even in very old and frail people.^{40,43,48,51,52,57,60–62} Further investigation is needed to establish the effects of the programme on fall risk in such people, many of whom live in care homes or other institutions. Also, the optimum type, frequency, duration, and intensity of exercise need to be examined further, as do ways to improve long-term adherence to physical activity. The high cost of regular strength and balance training may sometimes restrict access and therefore reduce the long-term benefit of increased activity.

We know of only one sufficiently powered study that has assessed the effect of exercise on fracture risk.⁶³ This 10-year prospective follow-up showed that for postmenopausal women randomly assigned to regular back-strengthening exercises for 2 years, the risk of vertebral fractures was reduced by more than 60%.⁶³ Another randomised trial from Oulu, Finland, showed that impact exercise (jumping and balance training) for 30 months reduced fracture risk in 72–74-year-old women by over 60%.⁶⁴ These findings accord with those of many epidemiological studies, which consistently showed that past and current physical activity is protective against hip fracture, the risk reduction being 20–70%.^{65–70} Of various activity types, weight-bearing activity seems most protective, and even standing, daily walking, and climbing stairs can be effective.⁶⁹ In addition, many of the epidemiological studies have shown an inverse dose-response relation between the exercise exposure and the fracture risk, the best example being the detailed Nurses' Health Study in the USA.⁶⁹ What is needed is a large randomised study to examine the effects of increased daily activity, or more specific strength and balance training, on risk of fall-induced fractures.

Thus, with respect to fall and injury prevention, regular strength and balance exercises can be recommended for elderly people. This view is reinforced by the fact that regular physical activity provides substantial other health related benefits and is cheap, safe, readily available, and a largely acceptable way of maintaining musculoskeletal health and reducing the propensity to fall.^{43,71–75}

Vitamin D and calcium

In addition to an essential role in calcium and bone metabolism, vitamin D might have an important role in improving muscle function (ie, alleviation of muscle atrophy) and musculoskeletal performance. In a randomised trial of frail elderly women with vitamin D

deficiency, tablet supplementation (cholecalciferol) with calcium (versus calcium alone) for 12 weeks resulted in improvement in muscle strength and dynamic musculoskeletal performance, and an almost 50% reduction in risk of falling.⁷⁶ The fall preventing effect was of the same size in a 3-year study by the same research group.⁷⁷ Similarly, after surgery for hip fracture, the fall risk was reduced by about 50% in the groups of women supplemented with vitamin D.⁷⁸ The investigators also noted that effects of vitamin D could be more pronounced with calcium co-supplementation. The issue of adequate calcium and vitamin D intake in fall prevention is noteworthy: treatment with alfacalcidol, a synthetic prodrug of the D-hormone, resulted in a significant reduction in the number of elderly fallers, only if the daily calcium intake was more than 500 mg.⁷⁹

In a new meta-analysis,⁸⁰ vitamin D supplementation seemed to reduce risk of falls in ambulatory or institutionalised elderly individuals with stable health by more than 20%. A dose-dependency was also noted. These findings clearly differ from the inconclusive findings of earlier reviews with vitamin D in fall prevention^{16,81} and especially from the negative results of two new large randomised trials.^{82,83}

With respect to prevention of osteoporotic fractures, an area in which vitamin D and calcium are likely to be effective, especially via increasing bone density and strength, a recent population-based 3-year intervention study with vitamin D and calcium supplementation showed a reduction in fractures of 16% in elderly men and women.⁸⁴ This finding is nicely in line with the results of some trials,^{85–88} although others have not confirmed the fracture-preventing effect of vitamin D,^{89–91} which has been attributed to low dosing of vitamin D. Both Venning's review⁹² and Bischoff-Ferrari and colleagues' meta-analysis⁹³ have shown that the dose should be a minimum of 700–800 IU per day to see the positive effects. Challenging this view, two new trials from the UK showed no fracture preventing effect of vitamin D or calcium, alone or in combination, in elderly people living in the community, despite the fact that the dose of the vitamin D was 800 IU per day in both these studies.^{82,83}

Although many important issues, such as optimum type and dose of vitamin D and calcium, and the true fall and fracture preventing effects of these supplementations are unresolved, vitamin D with calcium could reasonably be recommended for most elderly individuals—at least those known to be at high risk for deficiency of these substances (ie, frail elderly adults living in institutions). A clear advantage of calcium and vitamin D is that the treatment is safe, cheap, and easy to accomplish⁸⁰—which holds true for any prevention strategy that is non-selective and population-based. With normal doses, adverse effects of these agents are rare but could include difficulties in taking the tablets and

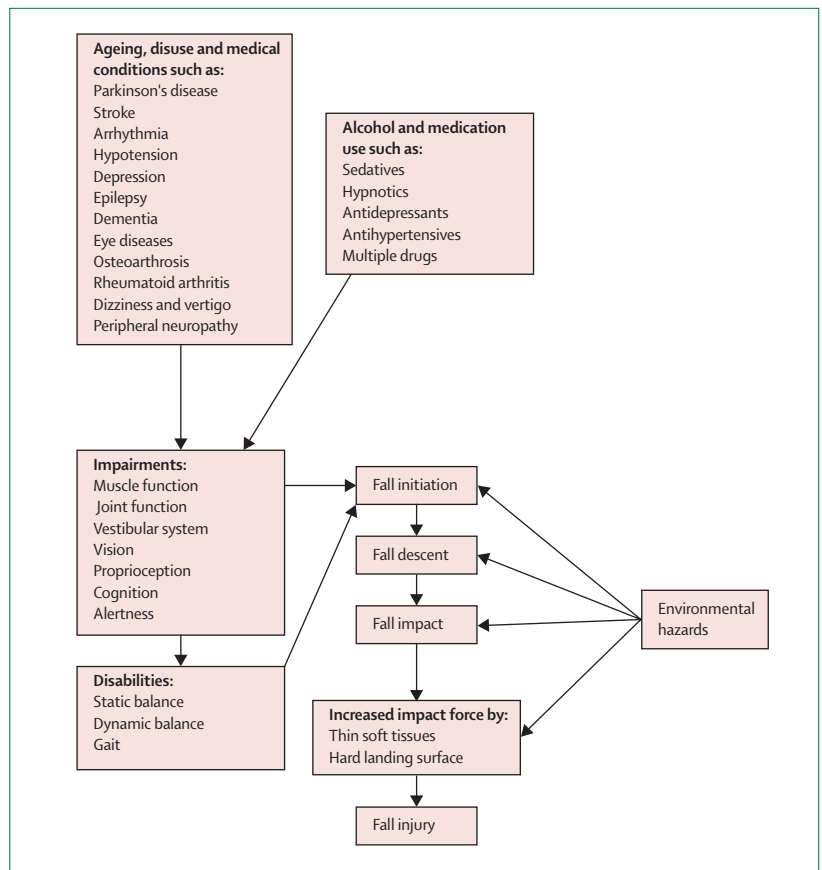


Figure 2: Flow diagram showing the determinants of falls and injuries

Adapted from Carter N, Kannus P, Khan KM.⁴³

gastrointestinal symptoms, and, more seriously, hypercalcaemia, kidney stones, and renal insufficiency.

Reduction of psychotropic medication

Psychotropic medication increases the risk of falling.^{3,54,94} One randomised trial only has been done, and it showed that gradual withdrawal of psychotropic drugs reduced the risk of falling by 66%.⁹⁵ This type of strategy is of utmost importance in our modern pharmaceutically oriented health care, and further investigation is needed.

Expedited cataract surgery

Visual impairments, especially poor contrast sensitivity and poor depth perception, have proved major risk factors for falling and fall-induced injuries in elderly people.^{96–98} We do not know whether visual corrections with glasses would reduce risk of falling, although a recent randomised trial in elderly women indicated that, compared with surgery-waiting controls, expedited surgery for first cataract reduced the rate of falling by 34% in the intervention group.⁹⁹ Significantly fewer participants in the operated group (four people, 3%) than in the control group (12 people, 8%) had fractures during follow-up. These favourable results could be

explained by improvements in visual function, confidence, activity, anxiety, depression, and handicap in the intervention group.⁹⁹ In addition, cataract surgery seems to improve postural stability.¹⁰⁰ Since cataract-induced visual impairment is common in elderly people, these findings could have major public health implications. Future studies are needed in older men and other target groups.

Cardiac pacing

Some elderly adults have cardioinhibitory carotid sinus hypersensitivity and could develop hypotension, bradycardia, paroxysmal asystole, syncope, and subsequent falls. In the SAFE PACE I study,¹⁰¹ reductions of 58% in falls and 70% in fall-induced injuries were seen after cardiac pacing of elderly adults with this syndrome. However, findings have not been so clear cut in the pacemaker group of the frailer and cognitively impaired patients of the SAFE PACE II study.¹⁰²

Home hazard assessment and modification

According to the most recent Cochrane review¹⁶ with three randomised trials as the database, home hazard assessment and modification that is professionally prescribed for elderly people with a history of falling is likely to reduce the risk of falling by about a third. Pure home visits or home hazard reduction in lower-risk elderly populations seem ineffective.^{40,53,59,103–105}

Multiple-intervention strategies

Effectiveness of multiple interventions in prevention of falls

Many randomised trials have shown, and meta-analyses and systematic reviews corroborated, that multiple-intervention strategies can prevent falls in elderly adults by 20–45% by simultaneously affecting many intrinsic and extrinsic risk factors.^{9,10,16,22,40,46,50,53,54,106–113} The number of people falling is also reduced. On the other hand, less favourable results have been reported in care or nursing home residents.^{114–116} Kerse and co-workers¹¹⁶ reported that fall risk was even higher in the intervention homes than in control homes. This finding is of serious concern and warrants further research since fall and injury rates in institution residents are much higher than in community-dwellers.^{54,117}

Systematic reviews of inpatients have shown no consistent evidence so far for prevention of falls.^{22,50,118} Two additional randomised trials have shed light on this issue. Healey and colleagues¹¹⁹ examined the effect of a simple core-care plan targeting risk factor reduction in elderly care wards of a general hospital and showed, compared with the control wards, a 30% relative risk reduction in falls in the intervention wards. Haines and co-workers¹¹¹ also reported that a targeted falls prevention programme in a subacute hospital setting resulted in 30% reduction in falls. These results are

encouraging, but need confirmation in other hospital settings.^{11,52,118}

Information about prevention of falls in elderly men is sparse. In a recent randomised trial the investigators suggested, in a secondary analysis of subgroups, that cognitive-behavioural learning in a small group environment can reduce falls effectively in men (68% risk reduction in men vs no effect in women).¹¹⁰ Since risk for fall-induced severe injury and death is at least as high in very old men as in women of same age,^{7,120} this observation warrants investigation.

Components of the multiple interventions

The content of the multifaceted interventions has varied substantially from study to study, including components such as strength, balance, and gait training; improving transferring and ambulation with or without the use of aids; footwear improvements; investigation and management of untreated medical problems; medication review and adjustment (especially psychotropic drugs); vision tests with referral to an optometrist or ophthalmologist if necessary; hip protectors; patient and staff education about fall prevention; fall risk alert cards; post-fall assessments; and environmental and home risk assessment and management. This heterogeneity not only indicates the complexity of the falls problem, but also prevents direct study-to-study comparisons and thus straightforward recommendations for optimum multiple intervention for fall prevention. General guidelines for fall prevention seem to have accommodated effective single interventions and used them as the basis for the various components of multipart interventions.^{10,16,22,50,53,54,117,121–123}

Multiple interventions for injury prevention

Prevention of fall-induced injuries and fractures by multiple intervention programmes is uncertain, especially since almost all randomised fall-prevention trials have lacked adequate power to detect significant changes in the frequency of injuries. However, one study showed a non-significant 28% reduction in injurious falls in the intervention group,¹¹¹ and results of three others suggested that fracture rates could be lower for elderly people who participated in a multifactorial intervention.^{106,108,113} Furthermore, controlled population-based (non-randomised) falls-prevention programmes have shown a downward trend in fall-related injuries of elderly adults, with relative risk reduction ranging from 6% to 33% in the intervention populations.¹²⁴ On the other hand, in three randomised studies no difference in the incidence of fall-induced injuries was noted.^{109,116,119}

Clearly, further large multifactorial multicentre studies to detect injury and fracture rates are needed, and economic evaluation should be built into the outcome assessment protocol. Similar requirements are needed in single-factor interventions. The barriers and

facilitators in large multifactorial interventions that affect the extent to which programmes are effective also need investigation.¹²⁴

Limitations of multiple interventions

A major limitation with the interpretation of the findings of multidisciplinary fall-prevention interventions is that they cannot distinguish between the independent role of individual modified risk factor, and thus which part of the intervention is effective and which is not cannot be established. A great deal of time and effort might be put into implementing a complex intervention, when, in truth, the use of one or two of its components is equally effective.¹¹⁸ Insufficient long-term compliance and adherence to any of the treatments and interventions might also be a difficulty. In such cases, there is a danger that we deem the content of the intervention ineffective, when the truth might be that insufficient effort went into implementing the protocol. An additional difficulty with multifactorial falls prevention interventions is that they can be labour intensive and become expensive for the individual, society, or both.^{11,43} In other words, in the long-term these targeted programmes might not provide a cost-effective strategy to prevent falls and related injuries—not at least in lower-risk elderly populations.

There are strong indications that pure home visits or home hazard reductions in low-risk elderly adults cannot reduce the frequency of falls.^{40,59,103–105,107} In addition, multifactorial interventions to prevent falls in elderly people with cognitive impairment and dementia did not lead to favourable results.^{125,126} Thus, the importance of careful selection of the content and target group of a multifaceted fall prevention programme cannot be overemphasised.¹²⁷

Protection of susceptible sites

Hip protectors

In most cases of hip fracture, the immediate cause of the fracture is a sideways fall with direct impact on the greater trochanter of the proximal femur.^{28,128–132} Hence, a logical option to prevent fracture would be a specially designed device to protect the hips, so that the force and energy of the impact are attenuated and diverted away from the greater trochanter by the protector. During the past decade interest in this area has grown, but the biomechanical force-attenuation capacity of different protector designs (foam pads, plastic shields, or combinations of the two) and their user compliance and fracture-preventing effects have not been consistent. Unfortunately most commercially available hip protectors have reached the market with a spectacular dearth of basic science and clinical research, although in an ideal situation research with any specific protector model should start with the biomechanical antifracture effectiveness in vitro and in

actual falls, continuing with compliance and adherence with users, and end with a user-control comparison in a randomised trial.

In a review of hip protector use in 14 randomised trials the investigators concluded that in institutions with very high rates of hip fracture, the use of protectors might help to reduce the risk of fracture, but there is no evidence of benefit from hip protectors for lower-risk elderly people.¹³³ This conclusion accords with a recent cost-benefit analysis, in which external hip protectors were shown to be a cost-saving intervention in the US nursing home setting, suggesting that Medicare could save \$136 million in the first year of a hip protector reimbursement programme, with net lifetime savings of \$223 per resident.¹³⁴

Thus, hip protector models that have proved effective can be one option in efforts to reduce the risk of hip fracture in high-risk people. Since the most common general problem with hip protectors is related to compromised user compliance and adherence, there is a clear need to educate and motivate frail elderly adults to regularly wear the hip protectors and to further develop, test, and study the protector models. Head-to-head randomised trials are needed to compare various models with each other.

Protection of sites other than the hip

Detailed injury mechanisms of fractures other than hip fracture have been of little interest for fall and fracture researchers, although improved knowledge of these issues would offer valuable clues and possibilities for fracture prevention. Our recent prospective controlled study revealed that most of the elderly adults' arm fractures (ie, fractures of the proximal humerus, elbow, and wrist) are caused by a direct, fall-induced impact on the fracture site¹³⁵ (figure 3). This observation provides a firm basis for possibilities to prevent arm fractures by protection of the injury site. However, methods to protect bony sites other than the hip are not developed, and therefore recommendations for protecting elderly adults' shoulders, elbows, or wrists cannot be made at present.

The same holds true for head protection for elderly people. Although most traumatic brain injuries and related deaths of elderly adults are the result of falls^{5,136–139} and the number and incidence of these events have risen sharply during past decades,^{7,120} we do not know whether regular use of a helmet would reduce risk of injury. From various sports and from bicycling and motorcycling, we know that helmets can be effective for prevention of head injuries,^{140–142} but for frail elderly adults there are many difficult questions to be answered before a recommendation can be made. In a population with a high frequency of cognitive impairment and dementia, questions on ethics and effectiveness of regular helmet wear will have top priority.

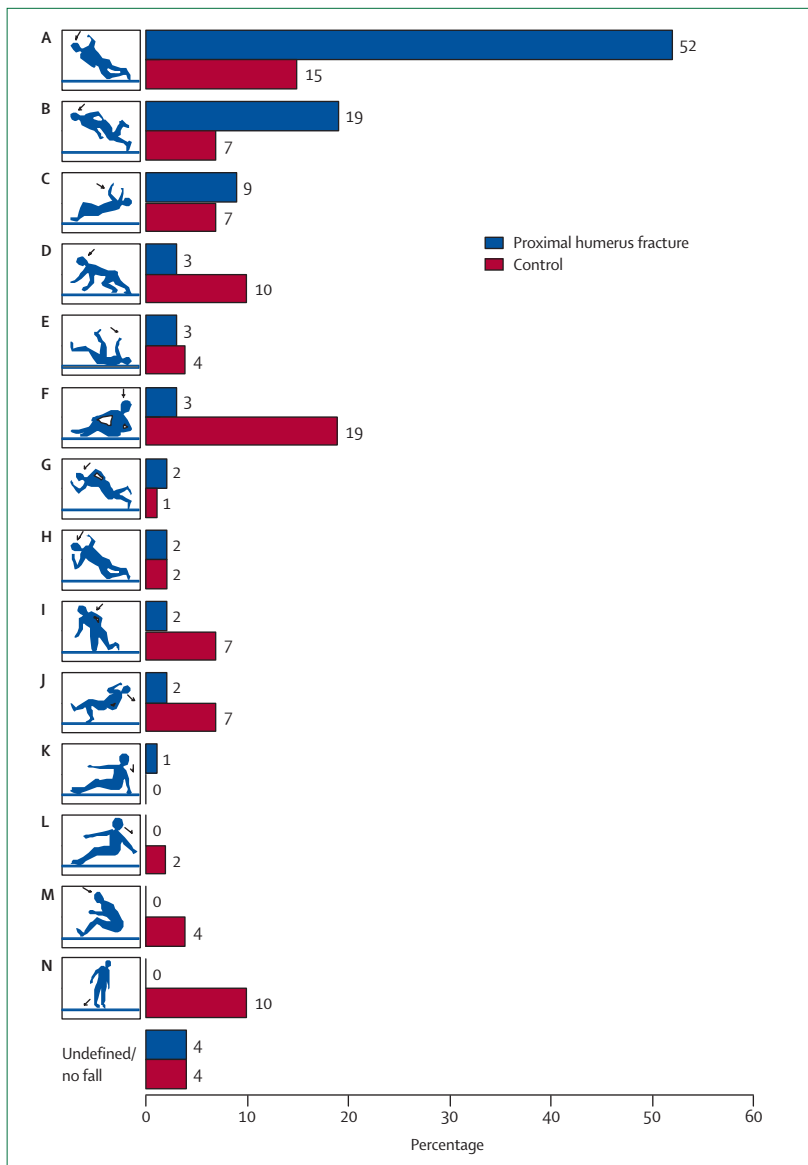


Figure 3: Fall characteristics of patients with a proximal humerus fracture (n=112) and controls without fracture (n = 108) (%)

In boxes A–N, the patient is facing the left side of the figure and the left arm is the fractured arm. Horizontal bars=%. Percentages have been rounded. Adapted from Palvanen M, Kannus P, Parkkari J, et al.³⁵

Conclusions

Thus, fall prevention in elderly people consists of regular strength and balance training, vitamin D and calcium supplementation, reduction of the number and doses of psychotropic medication, cataract surgery, and professional home-hazard assessment and management in people with a history of falling. Programmes for simultaneous assessment and reduction of many of the predisposing and situational risk factors are also effective in prevention of falls, although their implementation might be expensive. In prevention of fall-induced injuries, strength and balance training

provides the most consistent and best evidence, followed by vitamin D and calcium supplementation, and, for hip fractures, use of hip protectors can be an effective alternative. Vitamin D, calcium, and hip protectors are probably most effective for institutionalised people at high risk.

Much work needs to be done, and many subgroups, such as frail elderly men and people with cognitive impairment or chronic stroke, will need further investigation. Future studies should be large enough to see the effect of the intervention on not only falls but also fall-induced injuries and fractures. Also, before recommendations can be made, any old or new potential intervention for prevention of falls and related injuries, such as bed or chair alarms, movement detectors, canes, walkers, use of restraints or less resistant floorings, footwear improvements, or visual correction with glasses, have to be tested in the same rigorous way.

Acknowledgments

We thank Seppo Niemi for his assistance in preparing the review. This work was supported in part by the Medical Research Fund of Tampere University Hospital, Tampere, Finland, Ministry of Education, Helsinki, Finland, and the Juho Vainio and Paulo Research Foundations, Helsinki, Finland.

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