Exercise in preventing falls and fall related injuries in older people: a review of randomised controlled trials

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Review

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Abstract

***Objective*—To assess the effectiveness of exercise programmes in preventing falls (and/or lowering the risk of falls and fall related injuries) in older people.**

***Design*—A review of controlled clinical trials designed with the aim of lowering the risk of falling and/or fall injuries through an exercise only intervention or an intervention that included an exercise component**

***Main outcome measures*—Falls, fall related injuries, time between falls, costs, cost effectiveness.**

***Subjects*—A total of 4933 men and women aged 60 years and older.**

***Results*—Eleven trials meeting the criteria for inclusion were reviewed. Eight of these trials had separate exercise interventions, and three used interventions with an exercise programme component. Five trials showed a significant reduction in the rate of falls or the risk of falling in the intervention group.**

***Conclusions*—Exercise is effective in lowering falls risk in selected groups and should form part of falls prevention programmes. Lowering fall related injuries will reduce health care costs but there is little available information on the costs associated with programme replication or the cost effectiveness of exercise programmes aimed at preventing falls in older people.**

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Keywords: exercise; elderly; falls; cost effectiveness

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Falls in older people are an important but often overlooked problem. A third of people aged 65 years and older fall each year and half of those in their eighties fall at least once a year.[1] Falls are the most common cause of injury in people aged 65 years and older and may result in institutionalisation and death.[2 3]

Muscle weakness and poor balance have been well established as risk factors for falls in prospective cohort studies.[4–7]

Appropriately targeted exercise programmes of sufficient intensity will increase and improve muscle strength, balance, and cardiovascular fitness in older people.[8 9] Exercises to improve strength and balance have therefore been central to most fall prevention programmes.

The purpose of this review is to examine the evidence for the value of exercise in preventing falls in older people.

Methods

SEARCH METHODS

Six computerised databases were accessed in August 1999 for relevant articles in English. Medline, Psychlit, Index New Zealand, Current Contents, and the databases for Cumulative Index of Nursing and Allied Health Literature (CINAHL) were searched using Ovid. The databases were searched within the following periods: Medline 1990–1999; Psychlit 1991–1999; Current Contents 1995–1999, and CINAHL 1982–1999. The Web of Science was also searched from 1990 to 1999. Keywords for searching included controlled trials, public health, health promotion, elderly, old, exercise, physical activity, falls, fall injuries, fall prevention, costs, and cost effectiveness.

DATA EXTRACTION

Studies were reviewed if they met the following criteria: (*a*) included a control group; (*b*) participants were aged 60 years or older; (*c*) the intervention included an exercise component with details provided on exercise type, frequency, and duration; (*d*) prevention of falls and/or fall related injuries was an aim. The following factors were considered in each study: study design, eligible population, population agreeing to be randomised, age distribution, setting, inclusion and exclusion criteria, generalisability, use of blinding, form of intervention, duration of the intervention, co-intervention or contamination, measurement of outcomes, numbers lost to follow up, evidence of intervention effects, adverse effects, level of evidence, costs of the intervention, and effect on health care costs.

Results

Eleven controlled trials meeting the inclusion criteria were identified and reviewed. The results of one trial were reported both at one year and after two years of follow up.[10 11] In all

Table 1 Summary of randomised controlled falls prevention exercise intervention trials

Article, study aims, age, number in study, duration	*Interventions*	*Compliance to exercise programmes*	*Intermediate and other effects*	*Effect on falls and fall injuries*	*Comments*
●Reinsch *et al*[18]: ●To investigate the effectiveness of exercise and cognitive behavioural programmes compared with a discussion control group in reducing falls and injuries ●>60 years; n=230; 1 year	●2 × 2 factorial design: ●Intervention 1: exercise classes (stand-up/step-down procedure) 1 hour 3 days a week for 1 year ●Intervention 2: Cognitive behavioural group sessions 1 hour once a week for 1 year (health and safety curriculum to prevent falls, relaxation and video game playing) ●Control group: discussion sessions 1 hour once a week for 1 year covering health topics of interest to seniors (and not specifically related to falls)	●Not reported	At 1 year: ●No difference in balance, strength, fear of falling inside the home, self-rated present health	●No difference between the 4 groups in the number of fallers, time to first fall, fall rate or level of severity of fall-related injury	●No evidence that the exercise programme or cognitive behavioural approach should be implemented to prevent falls in older people ●Analysis compared the 4 groups (rather than each intervention with its control group) and for first fall only
●MacRae *et al*[20]: ●To determine the effect of low intensity exercise on falls, fall-related injuries and risk factors for falls in older women ●Women >60 years; n=80;1 year	●Intervention group: exercise classes (stand-up/step-down procedure) 1 hour 3 days a week for 1 year ●Control group: health promotion and safety education classes 1 hour a week for 1 year	●Not reported	At 1 year: ●Control group declined in knee and ankle strength (p<0.002), both groups declined in hip strength (p<0.002) ●No difference in balance and gait	●No difference between groups in the number of fallers who completed the study (n=59)	●Small sample size with small number of fall events ●Programme had a maintenance ●Exercise intervention of insufficient intensity to lower falls riskeffect on muscle strength
●Mulrow *et al*[21]: ●To investigate the effectiveness of physical therapy on physical function (including falls) and self perceived health in frail long stay nursing home residents ●>60 years; n=194; 4 months	●Intervention group: one-on-one 30–45 minute exercise sessions with physical therapist 3 times a week for 4 months ●Control group: one-on-one friendly visits 3 times a week for 4 months	●89% of scheduled physical therapy sessions were attended	At 4 months: ●No improvement in Physical Disability Index, Sickness Impact Profile or activities of daily living ●Improvement in mobility subscale of the Physical Disability Index (15.5%; 95% CI 6.4% to 24.7%)scores ●Physical therapy group less likely to use assistive devices and wheelchairs for locomotion (p<0.005)	●No difference in proportion of falls compared with hypothesised value (50% of total number of falls experienced by both groups)	●No evidence to support implementation of one-on-one physical therapy in this group of frail long stay nursing home residents to prevent falls ●Short follow up time ●Falls not reduced but modest improvements in function
●Lord *et al*[22]: ●To determine whether a 12 month programme of regular exercise would improve physical function and reduce the rate of falling in older women ●Women ⩾60 years; n=197; 1 year	●Intervention group: exercise classes 1 hour 2 days a week for 4 10–12 week terms for 1 year ●Control group: no active intervention	●Participants attended 26–82 (32%–100%) classes ●On average 60 (73%) of classes were attended by the 75 participants who completed the year	At 1 year: ●Exercise group improved in reaction time, lower limb muscle strength, neuromuscular control and body sway measures	●No difference in the proportion of people falling at least once, or recurrently at 1 year	●Good objective evidence of improvements in physical function risk factors for falls ●Exercise programme may be more effective in higher risk group
●Wolf *et al*[23]: ●To evaluate the effects of Tai Chi and computerised balance training on specified indicators of frailty and the occurrence of falls ●⩾70 years; n=200; up to 20 months	●Intervention group 1: Tai Chi: group classes 2 times a week for 15 weeks; also instructed to practise Tai Chi 2 times daily for 15 minutes ●Intervention group 2: one-on-one computerised balance training 1 day a week for 15 weeks ●Control group: 1 hour discussion of topics of interest to older people once a week for 15 weeks	●Participants who missed class were rescheduled for next session or to make them up individually ●Tai Chi home practice sessions not monitored	At 4 months: ●Grip strength declined in all groups (p=0.025) ●People in the Tai Chi group were less afraid of falling than control group (p=0.046)	●Tai Chi reduced rate of falls by 47.5% (risk ratio = 0.525; p=0.01)	●Programme was most effective in the prevention of recurrent falls ●Tai Chi warrants further investigation

Table 1 Continued

Article, study aims, age, number in study, duration	*Interventions*	*Compliance to exercise programmes*	*Intermediate and other effects*	*Effect on falls and fall injuries*	*Comments*
●Buchner *et al*[24]: ●To determine the effect of strength and endurance training on gait, balance, physical health status, falls risk and use of health services ●68–85 years with at least mild deficits in strength and balance; n=105; up to 25 months	●Intervention group 1: strength training using weights machines ●Intervention group 2: endurance training using stationary bicycles ●Intervention group 3: combination of strength + endurance training ●All interventions: Centre based, supervised 1 hour sessions 3 days a week for 24–26 weeks then self supervised ●Control group: instructed to maintain usual activity levels	●Exercise participants remaining at 6 months (71%) attended 95% of scheduled sessions ●At 9 months 58% of participants reported carrying out the exercises ⩾3 times a week, 24% twice a week and 5% not at all	At 6 months: ●Improvement in hip and knee strength in strength training group (knee only in combination training group) ●No effect of exercise on measures of gait, balance or physical health status	●Exercise increased time to first fall (relative hazard 0.53; 95% CI 0.30 to 0.91) ●Controls had a higher fall rate (relative risk 0.61; 95% CI 0.39 to 0.93)	●Evidence for exercise other than balance to lower falls risk in older people ●Evidence for lack of improvement in gait and balance with short term strength and endurance training in people with minor deficits in gait and balance
●Campbell *et al*[10]: ●To determine the effectiveness of an individually tailored home based exercise programme in reducing falls and injuries in elderly women ●Women ⩾80 years; n=233; 1 year	●Intervention group: home based strength and balance retraining exercises were prescribed and modified over 4 home visits by a physiotherapist ●Control group: equivalent number of social visits by nurse and usual care	●77% were exercising ⩾3 times a week over 2 month supervised period (unpublished) ●At one year 62.9% were exercising ⩾2 times a week (unpublished) and 42% were exercising ⩾3 times a week	At 6 months: ●Balance score and chair stand test improved in exercise group At 1 year: ●Exercise group maintained physical activity level and falls self efficacy score (self confidence for daily activities without falling)	●Mean (SD) rate of falls reduced in exercise group (0.87 (1.29) vs 1.34 (1.93) falls per year; difference 0.47; 95% CI 0.04 to 0.90) ●Relative hazard for first 4 falls for exercise group 0.68; 95% CI 0.52 to 0.90 ●Relative hazard for a fall resulting in moderate or severe injury 0.61; 95% CI 0.39 to 0.97	●Targeted high risk group for falling ●Programme was most effective in the prevention of recurrent falls ●Designed for wider implementation
●Campbell *et al*[11]: ●To assess the effectiveness of an individually tailored home based exercise programme over two years (see also Campbell *et al*[10]) ●Women ⩾80 years; n=233 year 1; n=152 year 2; 2 years	●Intervention group: exercise programme established in year 1; in year 2 participants were phoned every 2 months by the physiotherapist and encouraged to maintain/increase exercise sessions ●Control group: no active intervention in year 2	●31 of 71 (44%) of the exercise participants were carrying out the exercises ⩾3 times a week at 2 years	●No intermediate variables assessed	●Relative hazard for all falls for exercise group 0.69; 95% CI 0.49 to 0.97in second year of trial ●Relative hazard for a fall resulting in moderate or severe injury 0.63; 95% CI 0.42 to 0.95	●Evidence that fall rate reduction was sustained over 2 years
●Campbell *et al*[25]: ●To determine the effectiveness of gradual withdrawal of psychotropic medication and a home based exercise programme in reducing falls ●⩾65 years and currently taking psychotropic medication; n=93; 44 weeks	●2 × 2 factorial design: ●Intervention 1: psychotropic medication withdrawal, active ingredient gradually withdrawn over 14 week period ●Control group for medication withdrawal intervention: continue with original medication ●Intervention 2: exercise intervention (see Campbell *et al*[10]) ●Control group for exercise intervention: no active intervention	●20 of 32 (63%) of the exercise participants were carrying out the exercises ⩾3 times a week at 44 weeks ●23 of 32 (72%) of the exercise participants were walking twice a week at 44 weeks	At 6 months: ●Exercise group improved in tests of balance and strength: functional reach (p=0.02), knee extensor strength (p=0.004), chair stand test (p=0.01), time to walk up and down 4 steps (0.02) (unpublished)	●Relative hazard for falling in medication withdrawal group compared with original medication group 0.34; 95% CI 0.16 to 0.74) ●Exercise did not reduce the risk of falling	●Very large reduction in falls by psychotropic medication withdrawal ●Small sample size

11 studies, participants were randomly allocated to an intervention or control group. Two randomised controlled trials were excluded because the article lacked sufficient detail about the exercise intervention, and one controlled health promotion trial was also excluded for the same reason.[12–14] One study was excluded because all the participants took part in the exercise programme.[15] Four of the trials are from the frailty and injuries: cooperative studies of intervention techniques (FICSIT) group of studies concerning physical frailty and injuries in later life.[16] Three other FICSIT trials had an exercise component and contributed to data reported in a preplanned meta-analysis of the trials.[17] Information on intervention efficacy in reducing falls in these studies was not available from individual articles.

Tables 1 and 2 give the study aims, sample, interventions used, exercise compliance, intervention effects, and relevant comments based on the review of the studies. In nine of the 12 articles, exercise was a separate intervention (see table 1), and in three studies exercise was included with other interventions in a multifactorial or dual approach (see table 2). Three of the studies included costs of the intervention or total health care costs as outcome measures. Table 3 summarises these results.

STUDIES WITH EXERCISE AS A SEPARATE INTERVENTION

Reinsch *et al*[18] assessed the effectiveness of two interventions: exercise and cognitive behavioural strategies on falls and fall related injuries. Men and women aged 60 years and older (n = 230) attending senior centres were recruited and randomised by centre to one of four groups. Participants in the exercise and exercise cognitive groups took part in "stand up/step down" exercise classes, first proposed by Liss[19] for the prevention of falls. The exercise programme included standing up from a seated position and stepping up on to a six inch high stepping stool. At one year there was an attrition rate of 20%, with no age difference between the participants who dropped out of the programme and those who continued. There was no difference in the number of fallers, time to first fall, and fall rate among the four groups. The authors suggest that the exercise programme may not have been of sufficient intensity to reduce falls and that the cognitive behavioural group sessions may not have been frequent enough.

MacRae *et al*[20] also assessed the effectiveness of the stand up/step up routine in a sample of 80 community dwelling women aged 60 years and older. Participants were randomised by senior centre to an exercise (n = 42) or attention control group (n = 38). Initially participants stood up five times from a sitting position and carried out five step ups on to a six inch stall, with the number of repetitions increasing over the programme. At one year, 26% attrition rates were reported. Non-dropouts were similar to dropouts with regard to age and fall history. Randomly chosen intervention and control participants underwent assessments of gait at one year (n = 20). Maintaining quadriceps and ankle strength in the exercise group did not result in a reduction in the number of fallers or fall related injuries. This trial again provided no evidence for the use of the stand up/step up procedure for falls prevention in community dwelling people aged 60 years and older.

The San Antonio FICSIT trial targeted nursing home residents aged 60 years and older (mean (SD) age 79.7 (8.5) years in the intervention group, 81.4 (7.9) years in the control group), living in the rest home for at least three months and dependent in at least two activities of daily living.[21] Only a small percentage of the long stay nursing home residents were eligible for participation (19%). Over half the participants (58%) used wheelchairs for locomotion, and 75% had at least three co-morbid conditions. The most common reason for ineligibility in the trial was impaired cognitive functioning (26%). Randomisation was in groups of four and stratified by nursing home. Most intervention participants (94%) received strength and endurance exercises. Physical therapy was progressive and also included transfer and gait training. Of the 14 people (7%) who did not complete the follow up assessments at four months, 12 had died. Modest improvements in physical functioning were reported, and there was no significant difference between the intervention and control groups in the number of fallers, falls, serious fall injuries, and falls requiring health care use.

Lord *et al*[22] studied the effect of regular exercise on balance, strength, and falls in older women randomly selected from the community. Women (mean (SD) age 71.6 (5.4) years) were randomly allocated to an exercise group (n = 100) or a control group (n = 97). Exercise classes were held in two community sites easily accessible by public transport, and the classes emphasised enjoyment and social interaction. The exercise sessions incorporated warm up, conditioning, stretching, and cool down periods to music. Sensorifunction assessments provided quantitative measurements of systems contributing to balance that could be enhanced by exercise. The investigators reported that structured general exercise classes were effective in significantly improving leg muscle strength and other outcomes, without the use of specific strengthening equipment. There was no significant difference between the exercise or control groups in the proportion of fallers and recurrent fallers, although a trend towards lower fall frequency was observed in participants who attended 75% or more of the exercise classes. The authors suggested that incorporating interventions in addition to the exercise programme, such as checking and modifying vision, may be a more effective falls prevention strategy.

The effects of two different exercise approaches on physical functioning and falls were studied at the Atlanta FICSIT trial site.[23] Men and women aged 70 years and older living in the community were randomised to one of three arms: Tai Chi classes (n = 72; mean (SD) age 76.9 (4.8) years), computerised balance

Table 2 Summary of randomised controlled falls prevention multiple intervention trials with an exercise component

Article, study aims, age, number in study, duration	*Interventions*	*Compliance to exercise components*	*Intermediate and other effects*	*Effect on falls and fall injuries*	*Comments*
●Hornbrook *et al*[26]: ●To prevent falls with a programme addressing home safety, exercise and behavioural risks ●≥65 years; n=3182; 2 years	●Intervention group: informed about potential home hazards and encouraged to make changes; 4 weekly 90 minute group meetings, instruction on environmental, behavioural and physical falls risk factors, 20 minutes of supervised exercise, participants were given a manual and instructed to walk 3 times a week; quarterly maintenance sessions ●Control group: informed about potential home hazards, but no repair advice or assistance was given	●Participants monitored their exercises and walking sessions using a monthly checklist, but compliance rates not reported	●No intermediate variables assessed	●Intervention decreased odds of falling by 0.85 ●Average number of falls among those who fell reduced by 7% (NS) ●No difference in time to first injurious fall (medical care, fracture, hospitalised)	●Analysis by individual although randomisation was by household ●Exercise programme not sufficiently supervised and too general ●Minimal evidence to recommend this intervention for a falls prevention programme
●Tinetti *et al*[27]: ●To investigate whether the risk of falling could be reduced by modifying known risk factors ●≥70 years, with at least 1 of the 8 targeted risk factors for falling; n=301; 1 year	●Intervention group: specific interventions based on baseline assessment of risk factors for falling (sedative medications, ≥4 prescription medications, postural hypotension, environmental hazards, gait impairments, balance or transfer impairments, leg or arm muscle strength or range of movement impairments) ●Primary physician adjusted medications; physiotherapist prescribed individually tailored home based exercise programme to be carried out twice daily for 15–20 minutes ●Control group: equivalent number of home visits by social work students	●65% of the participants took part in at least 70% of the exercise sessions, 85% took part in over half the recommended sessions	●At reassessment the percentage of intervention participants with risk factors still present decreased for 3 risk factors: ≥4 prescription medications (p=0.009), balance impairment (p=0.001), impairment in toilet transfer skills (p=0.05) ●Improved self confidence for performing daily activities without falling (p=0.02)	●Reduction in proportion of fallers (p=0.04) ●Adjusted incidence-rate ratio for falling lower in the intervention group (0.69; 95% CI 0.52 to 0.90)	●Good evidence to support the use of a targeted multifactorial approach for the prevention of falls
●McMurdo *et al*[28]: ●To investigate the effect of weight bearing exercise on bone density and falls ●Women ≥60 years; n=118; 2 years	●Exercise intervention group: exercise classes 3 times weekly for each of three 10 week terms a year for 2 years + 1000 mg calcium supplementation daily ●Calcium group: 1000 mg calcium supplementation daily	●46–100% attendance at exercise classes ●Mean of 76% classes attended	●Increase in ultradistal forearm bone mineral density in the calcium + exercise group versus calcium only group (p=0.009)	●Fewer women in the exercise + calcium group fell during the 2 years (NS, but significant between 12 and 18 months, p=0.011)	●Young sample (age range 60–73 years) may explain non significant effect of programme on number of fallers at two years

Table 3 Results from studies reporting intervention and total health care service costs

Article, study sample, length of time, falls monitored	*Interventions and number being compared, length of intervention phase*	*Type of currency, year of costs, time period costs measured*	*Costs measured*	*Intervention costs*	*Health care service costs*	*Measures of cost effectiveness*
●Mulrow *et al*[21]: ●Residents (≥3 months) from 9 nursing homes, dependent in ≥2 activities of daily living, mean (SD) age intervention group 79.7 (8.5) years, control group 81.4 (7.9) years ●4 months	●One-on-one sessions with physical therapist (n=97) *v* friendly visits (n=97) ●4 months	●US dollars ●Participants recruited 1992* ●4 months	●Intervention charges (wages and fringe benefits for personnel time, travel expenses, equipment based on annual depreciation, overhead costs) ●Nursing home, hospitalisation, physician and other health professional visits, emergency department visits, procedures, and medication charges estimated from reimbursement fees, reference prices and prevailing allowable charges	●Mean charge per intervention participant $1220 (95% CI $412 to $1832) ●Mean charge per control participant $189 (95% CI $80 to $298)	●Mean per participant $11 398 (95% CI $10 929 to $11 849), no difference between groups	
●Tinetti *et al*[27] (also reported in Rizzo *et al*[29]): ●Patients from an HMO, community living, ≥1 of 8 targeted risk factor(s) for falls, mean (SD) age intervention group 78.3 (5.3) years, control group 77.5 (5.3) years ●1 year	●Assessment and targeted intervention at home by nurse and physical therapist (n=153) *v* social visits (n=148) ●3 months (longer if necessary for exercise component), monthly phone calls to 6 months	●US dollars ●Enrolment 1990 to 1992 ●1 year	●Intervention costs (development, equipment, personnel, travel, overheads)	●Mean cost per intervention participant $891		●Intervention cost per fall prevented $1947 ●Intervention cost per fall resulting in medical care prevented $12 392
●Rizzo *et al*[29] (also reported in Tinetti *et al*[27]): ●Patients from an HMO, community living, ≥1 of 8 targeted risk factor(s) for falls, mean (SD) age 77.9 (5.3) years ●1 year	●Assessment and targeted intervention at home by nurse and physical therapist (n=148 of 153) *v* social visits (n=140 of 148) ●3 months, maintenance phase (contacted monthly) to 6 months	●US dollars ●1993 prices used ●1 year from study entry	●Intervention costs (developmental and training, enrollment of participants, overheads, equipment, staff related expenses, environmental modifications) ●Charges from relevant source assigned to hospitalisation and emergency department, outpatient, home care and skilled nursing facility use	●Mean cost per intervention participant $905 (range $588 to $1346)	●Mean for intervention group approximately $2000 less, median costs approximately $1000 more than control group	●Intervention cost per fall prevented $1772 (calculated using mean costs), $1815 (using median costs), $2668 (using total intervention costs) ●Incremental total costs per fall prevented <$0 (using mean costs), $2150 (using median costs)
●Buchner *et al*[24]: ●Patients from an HMO, community living, mild deficits in strength and balance, mean age 75 (range 68 to 85) years ●Up to 25 months	●Centre based endurance training and/or strength training (n=75) *v* no active intervention (n=30) ●Supervised for 24–26 weeks then self supervised	●US dollars ●Randomisation 1992–1993* ●Period 7 to 18 months after randomisation	●Hospital costs, ancillary outpatient costs from HMO computerised records		●Hospitalised control participants more likely to have >$5000 hospital costs ($p<0.05$)	

HMO, health maintenance organisation.
Note. None of the studies specified the perspective taken when measuring costs.
*Personal communication with authors.

training (n = 64; mean (SD) age 76.3 (5.1) years), or an education control group (n = 64; mean (SD) age 75.4 (4.1) years). Tai Chi classes concentrated on components of movement that often become limited with aging, including the standing base of support, body and trunk rotations, and reciprocal arm movements. The participants were encouraged to practise the movements at least twice a day at home for 15 minutes. Computerised balance training took place on a moveable platform and under one on one supervision. Participants practised moving their centre of mass without moving their feet with their eyes open and then closed and also during floor movement. Both were 15 week interventions. Tai Chi was most effective in reducing falls in people who fell recurrently, and, compared with controls, Tai Chi participants were less afraid of falling.

The Seattle FICSIT trial targeted men and women, mean age 75 years, with impairments in balance and strength.[24] Eligible participants were those unable to complete eight tandem steps without errors and those below the 50th percentile in knee extensor strength for the subject's height and weight. Only 7% from a random sample of 13 866 health maintenance organisation enrollees were eligible to take part. The intervention participants attended supervised exercise classes for 24–26 weeks and were then given a discharge plan to continue exercising in supervised or unsupervised settings for a further three months. The study reported no significant effect of either strength or endurance training on gait and balance measures. One mechanism proposed by the authors to explain why exercise did not reduce fall rates but the fall rate in the control group increased was that people with mild deficits in strength and balance may be at high risk for further deterioration and exercise delays this decline.

Campbell *et al*[10] targeted a group at high risk for falling, women aged 80 years and older. The women were invited by their general practitioner to participate. Participants were randomised to an exercise intervention group (n = 116; mean (SD) 84.1 (3.4) years of age) or a control group (n = 117; mean (SD) 84.1 (3.1) years of age). The exercise programme was designed as a public health intervention to prevent falls and injuries in older people. At six months there was a significant improvement in two measures of strength and balance in the intervention group compared with the control group, when assessed by an independent physiotherapist blind to group allocation. There were no significant differences between the two groups in six other tests of strength, gait, endurance, and function. Despite very modest improvements in physical functioning, falls and moderate injuries were reduced in the exercise group compared with the control group. Participants were invited to continue in the programme for a second year (summarised separately in table 1).[11] Of the 213 participants remaining at the end of one year, 71% agreed to continue for a second year. Those who continued were more active and less afraid of falling at the end of year one and took fewer medications at baseline compared with those who declined to take part. At the end of the second year, 31 (44%) of those remaining in the intervention group were still exercising at least three times a week. The year two follow up showed that the lower fall rate achieved in year one could be sustained over a second year. More frequent visiting from the physiotherapist and encouragement from the general practitioner to continue exercising may have improved exercise compliance. The intervention was designed for easy community implementation but has only been tested in women aged 80 years and older living at home.

In a companion study, Campbell and colleagues tested the same home based exercise programme and a second intervention, gradual withdrawal of psychotropic medication in men and women currently taking those medications.[25] Only 19% of eligible participants who were invited to take part by their general practitioner agreed to participate. The study compared the effects of exercise (n = 45) versus no exercise (n = 48), and psychotropic medication withdrawal (n = 48) versus continuing to take the original psychotropic medication (n = 45). Nearly half (45%) of the participants stopped taking the study capsules before the 44 week trial was completed. The exercise programme was modified so that there was no upper limit for the amount of ankle cuff weights used for leg strengthening exercises. The home based exercise programme was associated with significant improvements in tests of strength and balance at six months (unpublished). There was a 66% reduction in fall rate in the medication withdrawal group but no significant reduction in falls in the exercise group. The exercise programme was less effective in this study group than in the group of women 80 years and older.

MULTIPLE INTERVENTION TRIALS WITH AN EXERCISE COMPONENT

In a large community trial, participants were randomised by household to an intervention group (n = 1611) or minimal treatment control group (n = 1571).[26] Nearly a third of participants (32%) were 70–74 years of age. The intervention emphasised removal of home hazards, reducing risk taking behaviour, and improving physical fitness. The exercises selected for the intervention were designed to involve all body parts, maintain range of movement, provide strengthening, and improve posture and balance. After one supervised group session, the participants were given a manual and instructed to carry out the exercises at home. At one year, the odds of being a faller was significantly less in the intervention group. Statistical analysis did not address the fact that participants were randomised by household, but the unit of analysis was the individual. However, 75% of the households had only one participant.

At the New Haven FICSIT site, 301 community dwelling men and women aged 70 years and older with at least one risk factor for falling were studied (85% of the eligible study population).[27] The participants were

randomised to either a multiple risk factor intervention group (n = 153; mean (SD) age 78.3 (5.3) years) or a control group (n = 148; mean (SD) age 77.5 (5.3) years). The intervention participants received specific interventions depending on a baseline assessment of falls risk factors. Participants in the intervention group received a mean (SD) of 7.8 (4.0) home visits. The participants were instructed to perform the exercises often (twice a day for 15–20 minutes each session). The physical assessor and falls assessor were blind to group allocation. At one year there was a significant reduction in the percentage of intervention participants compared with controls still taking four medications or more, with balance impairments and with impairments in transfers at baseline. There was also a significant reduction in the proportion of fallers in the intervention group compared with the control group at one year. Muscle strength did not improve, and the authors suggest that manual muscle assessing may be insensitive to change, or alternatively their strength training regimen was of insufficient intensity. This well designed study provides good evidence for the effectiveness of a targeted multifactorial falls prevention programme in community dwelling older people.

A volunteer sample of 118 women, mean age 64.5 (range 60–73) years, were randomised to a calcium supplementation or calcium supplementation plus exercise group.[28] The exercise component of this two year trial involved weight bearing exercises to music in a centre. Bone mineral density showed a significant increase at one of three sites in the exercise plus calcium supplementation group. The method used for monitoring falls and injuries was not specified. There were fewer falls in the calcium plus exercise group than the calcium group between 12 and 18 months but the difference over the two year period was not significant. With no report of intermediate outcomes it is not known if the exercise programme was associated with improvements in balance and strength.

ECONOMIC EVALUATION WITHIN THE STUDIES

Two of the studies reviewed reported the cost of the intervention and three studies included total health care service costs as outcome measures in the trial (see table 3).[21 24 27] One study reported the charge for the physical therapy intervention delivered to nursing home residents and estimated health care costs for all participants during the four month trial.[21] Buchner *et al*[24] estimated health care use and costs after the first six months of the trial because exercise participants (but not controls) were asked to delay elective procedures until the end of the supervised exercise period. Hospital use was similar in both exercise and control groups, but control participants were more likely to spend more than three days in hospital.

There has been one report of a detailed economic evaluation of a falls prevention programme tested in these trials.[29] Rizzo *et al* investigated the cost effectiveness of the home based multifactorial programme which included an exercise component.[27] Table 3 shows a summary of results. The intervention was more cost effective for those at "high" risk, defined as having four or more of the eight targeted risk factors for falls. Health care costs resulting from falls during the study were also identified, and in each category, costs were lower for the intervention than the control group. No statistical comparisons were made for health care costs between the exercise and control groups. Sensitivity analyses indicated that cost effectiveness ratios were robust for minimum to maximum intervention costs, and for 25th to 75th percentile values of total health care cost distribution. The authors limited the time horizon to the year of the trial and did not attempt to forecast costs or consequences of the intervention into the future.

Discussion

SYNTHESIS

All 12 articles included in the review were reporting randomised controlled trials. Nine articles reported the effect of exercise only and one of these reported a second year of follow up. Three studies evaluated the effectiveness of exercise in combination with other interventions in preventing falls. Four studies investigated the effect of exercise in women only and all the studies, except one, involved independent, community dwelling older people rather than those in institutions. Five studies included people aged 60 years and older, two those aged 65 years and older, two those aged 70 years and older, one those aged 80 years and older, and one included participants aged between 68 and 85 years of age. The interventions included strengthening, endurance, balance and flexibility exercises, computerised balance training, Tai Chi, the stand up/step down procedure, and walking as well as combinations of these exercises. In five studies, the exercise intervention was delivered to a group,[18 20 22 24 28] and in another four studies exercises were carried out in the home.[10 25–27] In one study both a group and home based approach was incorporated in one of the exercise interventions, and the second exercise intervention was not home based but required one on one supervision.[23] In the rest home, trial exercises were delivered one on one.[21] Definitions of a fall and methods of measuring falls and testing effectiveness differed. Intention to treat analysis was stated in four studies.[10 21 24 25] Five studies showed a significant reduction in the rate of falls or risk of falling in the intervention group.[10 23 24 26 27]

EXERCISE PROGRAMME COMPONENTS

There is a need to identify which components of an exercise programme are most effective in lowering falls risk. A wide variety of exercise interventions have been tried using different exercise frequencies, intensities, and duration periods. Studies successfully lowering falls have used strength and balance retraining, endurance training, and Tai Chi. A meta-analysis of the seven FICSIT exercise trials suggests that balance may be more effective in lowering falls risk than the other exercise components.[17] Tinetti *et al*[30] investigated the effectiveness of a

multifactorial intervention programme on the number of falls risk factors and concluded that a change in balance score of 1 (possible scores ranged from 0 to 12) was associated with an 11% reduction in fall rate. It is probable that exercise would have had the greatest effect on balance in this multiple intervention study. Three successful programmes have required the participants to exercise regularly against resistance using either therabands or weights.[10 24 27]

- Five of the 12 studies reviewed successfully lowered falls by using strength and balance retraining, endurance training, or Tai Chi
- Factors resulting in negative studies included inadequate exercise intensity, inadequate power, and low study compliance
- All the trials reported, except one, targeted community dwelling rather than institutionalised older people

COMPLIANCE

Programmes should be acceptable to older people to ensure compliance, and this needs to be considered at the exercise programme design stage. Definitions of exercise compliance differed, and two studies failed to report exercise monitoring and compliance.[18 20] Exercise compliance at one and two years will provide a better indication of programme acceptability than measures after shorter time periods. One trial reported 27% (31 of 116) of participants from the original sample still carrying out exercise sessions at least three times a week at two years.[11] It is not known whether a home based or group approach is more acceptable to older people. Programmes offering both approaches may enhance compliance.

ADVERSE EFFECTS

Four studies addressed adverse events.[21 22 24 27] Ten participants (6.5%) reported self limiting musculoskeletal symptoms in one home based programme, which the investigators attributed to the exercises.[27] No medical incidents occurred in another trial during group exercise sessions.[22] One study reported that exercise related injuries were uncommon and not an important factor associated with dropout.[24] At the San Antonio FICSIT site, adverse effects were monitored by research assistants, blind to group assignment.[21] Intervention participants reported moderate muscle soreness at 7% of the physical therapy sessions but physical therapists reported no injuries during the exercises. There were no significant differences in severe soreness, bruising, and fatigue between participants receiving physical therapy and those receiving friendly visits. Exercise can be carried out safely in older people with moderate disability and intact cognitive functioning, and also in frail institutionalised older people with intact cognitive functioning under one on one supervision from a physical therapist.

STUDY FACTORS DIMINISHING BENEFIT

Six studies reported no change in falls after the exercise intervention.[18 20–22 25 28] We consider that the following factors contributed to this lack of effectiveness. Several studies used exercise of inadequate intensity to modify falls risk factors, and this was shown by the lack of change in intermediate variables.[18 20 26] Most negative studies lacked sufficient power to detect a reduction in falls, although reducing falls was not necessarily a primary outcome in some of these trials. Exercise may be less effective in fall prevention when there are other significant risk factors for falls present that are not influenced by exercise. For example, in a younger sample of men and women on psychotropic drugs, exercise was less effective in reducing falls than in an older frail population.[25] One exercise trial targeted frail rest home residents.[21] This study reported modest improvements in physical function following one on one physical therapy and no effect on falls. While intermediate outcomes improve in frail institutionalised elderly following high intensity strength training,[34] falls may not decrease because other risk factors may not improve. Lastly, study compliance may be too low for the intervention to be effective across the sample as a whole when analysed on an intention to treat basis.

FALL RELATED INJURIES AND COSTS

Owing to the low number of serious fall injury events such as fractures, the studies, even in meta-analyses, lacked sufficient power to determine whether exercise had a beneficial effect on serious fall injury risk.[17] One exercise study reported a significant reduction in moderate injuries in the exercise group compared with the control group at one[10] and two years.[11] Similarly, studies looking at health care costs lacked adequate power to show cost savings. However, some falls prevention intervention studies have reported a reduction in health care use as a result of the intervention.[24 31 32] Reductions in falls should reduce the number of fall related injuries but there may be a difference in the degree of reduction. An exercise programme may improve protective responses at the time of the fall. A long term exercise programme may improve bone mineral density. On the one hand a fitter quicker group of elderly people may fall at greater speed while about their daily activities.[33] On the other hand active older people may spend less time in hospital.[24]

- No falls prevention study has had sufficient power to show a reduction in serious fall injuries such as fractures
- Several falls prevention interventions, including one exercise intervention, have reported reduced health care use as a result of the intervention

CONCLUSIONS AND RECOMMENDATIONS

The wide variety of exercise interventions tried, some successful and others not, does enable us to draw some conclusions. Appropriate exercise

- Exercise programmes can be carried out safely in older people
- Exercise programmes must be regular and sustainable to be effective
- More trials are required to determine the exercise type, frequency, duration, and intensity that are most effective in lowering falls risk in different groups of older people

programmes can decrease the number of falls and fall risk in randomised controlled trials but certain conditions need to be met.

For maximum effect the population needs to be right—not too fit and not too frail. Exercise interventions in people in institutions have not yet been shown to lower the risk of falling.[21] The same exercises used in younger populations have not been as effective as in older groups.[10] With increasing age there is a progressive loss of muscle strength and stability, but the weakness needs to reach a certain point or threshold before daily functions are affected. It is possible that around this point small increases in strength have a disproportionate effect on function, and exercise programmes are most effective.

The exercises need to be of sufficient intensity to improve muscle strength. We suggest that most investigators, including ourselves, initially underestimated the capacity of older people to manage weights. Balance retraining should be an important component of any exercise programme designed to decrease falls. This may consist of specific dynamic balance retraining exercises or be a component of a movement form such as Tai Chi. The exercises need to be regular and sustainable. There is no evidence of benefit beyond the period of the exercises but continued participation can lead to sustained lower fall risk at least up to two years.[11]

The exercises may be performed at a centre or at home. Home exercises are suitable for a frail less mobile population without easy access to transport. They are safe if properly established by a trained therapist but the supervision is less than with a centre based programme. A centre based programme does have the additional value of social interaction which has important beneficial effects in its own right.[35]

If the exercises are part of a public health programme to be introduced widely in the community, they should be simple, easily instituted, and low cost. Elderly people involved in fall prevention exercise programmes are prone to intercurrent illness, accident, and social change. Programmes need to have the resources to reassess and restart. They should also be planned for long term use. Repetitive programmes with little variety are unlikely to be sustained. If the exercises are part of a programme of fall prevention in a person presenting with falls, then the exercises must be part of a full assessment of the person's risk factors and treatment. Exercises are of value in falls prevention when part of a comprehensive package.[27]

There is a need for further research on the most effective balance and strength retraining exercises, the groups most likely to benefit, the determinants of compliance, and the best ways to improve this.

Exercise programmes designed to prevent falls in older people have two important advantages. Falls are very common so programmes are likely to be cost effective when compared with other public health measures in this population. Exercise is also beneficial to the participants in additional ways such as decreasing fear of falling, improving functional reserve by increasing strength, and in improving other important health areas as varied as cardiovascular health,[36] sleep,[37] depression,[38] and mortality.[36]

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Take home message

Many different risk factors contribute to falls, but muscle weakness and poor balance underlie most falls. Strength training against resistance and dynamic balance retraining improve both strength and balance and in randomised controlled trials have been shown to decrease the risk of falls. Exercise programmes that are individually tailored and target those at high risk may be the most effective.

True or false?

1 Falls prevention exercise programmes work on which of the following premises:
(a) Muscle strength and balance are common risk factors for falls.
(b) Exercise must be continued to be effective.
(c) Only fit elderly people should take part.
(d) Strength training should be a gentle, optional extra exercise.

2 Proven benefits of falls prevention exercise programmes to date include:
(a) Decreased fear of falling.
(b) Reduced admissions to rest home.
(c) Improved functional independence.
(d) Reduced hip fractures.

3 In a systematic review on falls which electronic databases would be searched?
(a) Web of science
(b) Ovid
(c) Generator
(d) Cochrane database of systematic reviews

(Answers p 76.)