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Effective Health Care

Bulletin for decision makers on the effectiveness of health service interventions

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Preventing Falls and Subsequent Injury in Older People

- The risk of falls increases with age. Falls in older people often result in injury and death. Such injuries, frequently fractures, are a common and costly cause of hospital admission.
- There is some evidence to suggest that exercise, such as balance training, is effective in reducing the risk of falls in older people. Access to such interventions should be offered and ways of promoting uptake should be investigated. New programmes should be part of controlled evaluations.
- Home visits and surveillance to assess and where appropriate, modify environmental and personal risk factors can be effective in reducing falls. This can be carried out by nurses, health visitors, occupational therapists or trained volunteers.
- Soft hip protector pads have been shown to dramatically reduce hip fractures in frail older people in residential care. Their effect and acceptability in the community needs further research.
- High dose Vitamin D supplementation with or without calcium appears to be effective in reducing fractures. Research is needed to identify the most cost-effective strategy.

A. Accidental falls and older people

In the UK in 1991 about one in six people were over 65, and by 2021 this proportion is expected to be nearly one in five.[1] Within this, there is a relative increase in people over 75.

Accidents are a major health problem among older people.[2,3] Falls, traffic accidents and burns are the main causes of accidental death among older people.[4] Of these categories, falls are the leading cause of death from injury among people aged over 75 (Figure 1).[4] Over 85% of all fatal falls in the home in England and Wales are in people aged over 65.[5] Falls are also by far the most important cause of hospitalisation for older people (Fig 2).[6]

About one third of the population aged 65 and over, rising to more than half of the women aged over 85 living at home and a greater proportion in those in institutional settings, will fall at least once every year.[4,7,8] It has been estimated that between 5 and 10% of falls result in injury.[9,10] The most common serious injuries are fractures[11] which account for 40% of deaths from injury, over half of injury admissions to hospital, and two-thirds of bed days for injury.[6]

Reducing the death rate from accidents in people aged 65 and over by at least 33% by the year 2005 is a specific target in the Health of the Nation key area of accidents.[3] This *Effective Health Care* Bulletin provides a summary of the research evidence on the prevention of falls and subsequent injury which may be useful to Health Authorities seeking to make progress in this Health of the Nation area.

There are a large number of epidemiological studies exploring risk factors for falls[4,12-14] and a recent systematic review of the literature has identified over 400 variables investigated as potential risk factors.[15] However, comparison and synthesis of the studies to identify the most important independent risk factors is difficult for a number of methodological reasons. For example, a range of methods are used to define falls and fallers, and different populations are studied using a variety of study designs. There are additional problems when using retrospective study designs such as biases due to recurrent falls and innacuracies in recall.[16,17] Therefore, no agreed and reliable set of risk factors can be presented. Table 1 illustrates some of the most frequently cited potential risk factors associated with falls and fractures resulting from them.

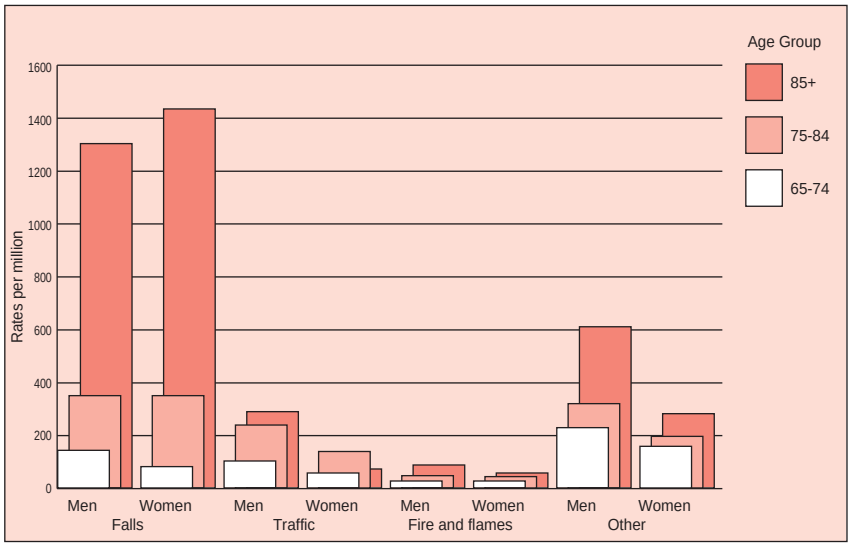

Fig. 1 Age-specific mortality rates from accidents among older people in 1992
Source: OPCS Mortality Statistics, 1992

B. Evaluating health promotion interventions to prevent falls and subsequent injury in older people

Searching the Literature: The relevant literature was identified by a search of computerised databases (Social Science Citation Index (BIDS), PSYCHLIT, EMBASE, RCN database, AMED and UNCOVER), citation in identified papers and previous reviews, and contributions from peer reviewers and other experts in the field. Papers were read and data extracted by two people. Only randomised controlled trials (RCTs) evaluating the effectiveness of preventive interventions and which measured the effect on falls, fall related injury or change in a risk factor for falls were included. Studies which reported falls or falls related injuries as outcomes are given more weight in this review than those reporting intermediate outcomes such as balance.

The importance of randomised controlled trials: Randomised controlled trials provide the most reliable evidence of the efficacy of interventions. By randomly allocating patients to treatment and control groups, the comparability of the groups is improved. This allows statistically significant outcomes to be more confidently attributed to the intervention.[18]

Few of the studies identified were carried out in the UK. This may be an important limitation

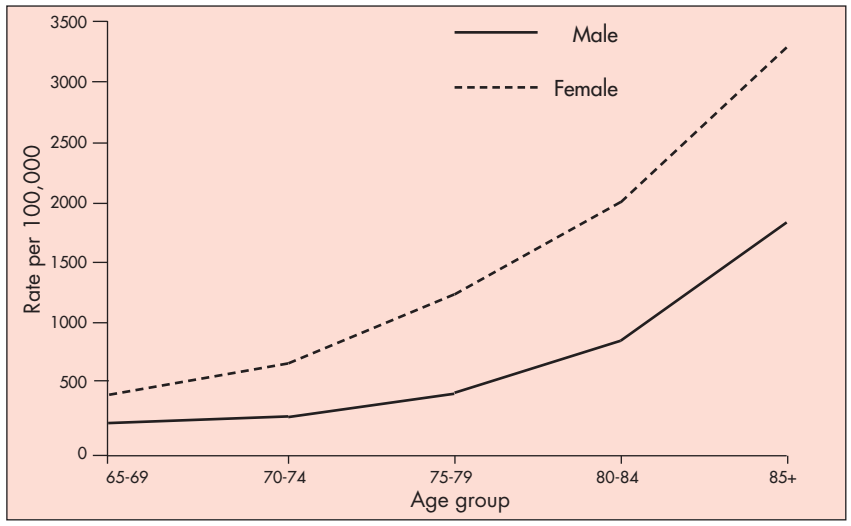

Fig. 2 Age-specific hospital admission rates for falls among residents of South Thames (East) in 1991/92 Source: Cryer et al., 1993

since socio-cultural factors can have an important influence in health promotion, particularly on the acceptability of and likely adherence to recommended interventions.

36 trials were identified which evaluated interventions to prevent falls [exercise (23), home assessment (9), type of shoe (1), interventions in institutional settings (3)] and interventions to reduce the likelihood of an injury resulting from a fall [nutritional supplementation (1) and hip protectors(1), 2 studies examined interventions covering more than one area]. Of these, seven make up a set of linked RCTs at separate sites examining exercise alone or with other interventions carried out under the 'Frailty and Injuries: Co-operative Studies of Intervention Techniques' (FICSIT) programme.[19-25] The vast majority of these 36 trials studied people with no previous history of a fall or fall-related injury. In addition the results of a newly completed Cochrane Collaboration meta-analysis of trials of vitamin D and calcium supplementation were made available to Effective Health Care.[26]

This bulletin does not examine the research literature on the more general issues of the prevention of osteoporosis (See *Effective Health Care* Vol 1 No 1, 1992) the effectiveness of hormone replacement therapy and the treatment of people who have had a fracture.

C. Reducing the risk of falling

C.1 *Exercise*

The FICSIT trials

The question of whether short-term exercise reduces falls and fall-related injuries in older people has been specifically addressed in seven of the FICSIT programme of RCTs in the United States.[27] All of these trials measured the effect of the intervention on the rate of falls. Two took place in nursing homes and five were community-based. All the interventions included an exercise component for 10-36 weeks, sometimes combined with other interventions, and follow up lasted 2-4 years. The exercise elements of the trials are summarised in Table 2.

Pooling the results of these studies showed, overall, that people assigned to an exercise group had an estimated 10% lower risk of falling than controls (adjusted fall incidence ratio [IR] = 0.90; 95% confidence interval [CI]: 0.81 - 0.99; p = 0.04).[27]

Some of the interventions contained non-exercise components, making it difficult to separate the effects of exercise from the other activities. When considering the subset of studies with only exercise interventions, a reduction in the risk of falls persists (though it is not statistically significant).

Table 1 Examples of potential risk factors for falls and injury

Nutritional Status	Environmental Hazards	Medication	Lack of Exercise	Ageing Changes and Medical Condition
Vitamin D and calcium deficiency Vitamin D is needed for optimal functioning of bone. Reduced calcium absorption by the gut is associated with ageing	Between a third and half of falls among older people living in the community are thought to be due to environmental hazards, including loose carpets, bathtubs without handles, poor lighting, unsafe stairways, etc. Also ill fitting shoes and thick shoe soles	Certain categories of prescribed drugs, especially anti depressants and hypnotics, have been found to be associated with increased risk of falling. Also: Benzodiazepine, analgesics sedatives tranquillizers, diuretics, laxatives	Insufficient exercise is associated with weak muscles, poor balance and gait as well as accelerated bone loss	It has been postulated that deterioration of vision with age may account for some of the increased falls. Also cognitive impairment has been associated with falls. However, it is not clear to what extent these are independent risk factors

Table 2 Exercise interventions of the FICSIT trials*

	Site 1 (Hornbrook et al, 1993)[19]	Site 2 (Tinetti et al, 1994)[20]	Site 3 (Buchner et al, 1993)[21]	Site 4 (Mulrow et al, 1994)[22]	Site 5 (Wolf et al, 1993)[23]	Site 6 (Fiatarone et al 1994)[24]	Site 8 (Wolfson et al, 1993)[25]
Number and age of participants	1323 participants aged at least 75, or 65 if they had fallen within the previous month	300 participants aged at least 70	100 participants aged 65-85	194 participants aged at least 60	180 participants aged at least 70	100 participants aged at least 70	120 participants aged at least 75
Exercise interventions	4 months of low level endurance followed by flexibility exercises	3 months of resistance, balance and flexibility exercises	6 months of flexibility training plus resistance and/or endurance exercises	16 weeks of resistance, flexibility and balance training.	15 weeks of static balance training on a balance platform or dynamic exercise training using Tai Chi	10 weeks of resistance training	13 weeks of balance and resistance training

* All participants, except those of site 4 and 6, were free living in the community. Some of the interventions were combined with other non-exercise interventions (sites 1, 2 and 6).

Pooling the results of studies evaluating a balance training only intervention showed a reduction in the risk of falling of 25% (IR = 0.75, p = 0.01). In one trial (Site 5) people offered the balancing exercise Tai Chi, had a 37% lower risk of falling than the non-intervention group (IR = 0.63; 95% CI: 0.44 - 0.89).[23]

Other exercise trials

16 other RCTs which evaluated exercise only interventions in the prevention of falls have been identified (Table 3).[28-43] These studies are difficult to synthesise because they examine different outcomes such as falls, postural stability, sway or balance, strength, and quality of life. They also vary according to the populations studied, the risk of falling, the type and duration of exercise intervention, how it was delivered and the length of follow up. Many had only a few months follow up.

Only two of these RCTs used the rate of falls in a 'natural' environment as an outcome.[33, 40] One other examined falls in response to platform tests in a controlled environment.[38] Reinsch *et al*, concentrated on improving lower extremity muscle strength and found that the rate of falls was higher (though not significantly) in groups receiving low intensity exercise.[33] Lord *et al*, found no statistically significant effect on falls overall, although there was a significant drop in falls due to loss of balance.[40] Hu and Woollacott however, found that balance training reduced the rate of falls in platform sensory tests.[38]

The thirteen studies (Table 3b) which report intermediate outcomes contribute little in the way of direct evidence for the prevention of falls. Seven showed a decrease in risk factors for falls with exercise,[28, 31, 32, 34, 36, 37, 43] four showed no significant effect other than improvements in strength,[30, 35, 41, 42] one showed an improvement in flexibility only[39] and one reported a deterioration in postural sway with exercise.[29] They do, however, provide evidence for the acceptability of various exercise programmes in this age group.

Overall, despite the variable quality of these studies, the results from these and the FICSIT trials provide reasonable evidence to suggest that exercise offers potential benefits in reducing the risk of falls and some risk factors for falls. Those interventions which use balancing exercise, strength training, and low impact aerobic exercise, appear to be the most promising.

An increase in physical activity is likely to have other benefits for older people. Most importantly, perhaps, it has been shown to reduce the risk of coronary heart disease.[44]

A recent review of the health care costs and benefits of exercise reported that in people over 45 years of age, exercise results in health care cost savings due to reductions in morbidity from coronary heart disease, falls etc.[45] These health benefits and consequent cost savings are likely to be experienced soon after exercise programmes are implemented and will exceed the costs due to injury from exercise.[45] However, the type of exercise must be appropriate to the level of health and fitness of the person. High levels of exercise-related injury have been reported when people over 70 participated in high-impact aerobic activities or high intensity, low repetition strength testing.[46] No reliable estimates of the costs of promoting or providing exercise for older people were found.

A recent review was published examining trials which evaluated the effectiveness of methods to promote exercise in community based adults.[47] Some studies were in people over 55 years of age. The review concluded that it is possible to increase and

maintain levels of activity and that this is best achieved when exercise is of moderate intensity, can be performed alone or with others, is enjoyable and convenient, and can be completed in three sessions a week. Professional support or interaction with a health care professional appears to be important in promoting exercise and adherence.

Trials to prevent falls in older people have reported levels of adherence to exercise regimes of 70% and above.[30, 32, 35-37, 40, 43, 46, 48, 49] Social support, convenience and leadership may be important factors in promoting uptake in this age group.[49] Most of these trials involved community dwelling older people in countries other than the UK. It is not obvious that these interventions will be acceptable in a British context, nor can we be confident of the degree to which the results may be generalizable to people at higher risk such as those with a history of fracture.

There is little evidence about the likely effectiveness of prescription for exercise schemes in the UK. However, a major RCT examining the overall benefits and costs of GP-based exercise prescription in unselected people over 65 is being conducted by the University of Sheffield, England. This will include 800 people randomised to exercise and 1,600 controls. The results should be reported in 1998.

C.2 *Home Assessments and Surveillance*

Nine RCTs were found which evaluated home assessments and surveillance interventions (Table 4).[20, 50-57] These all involve visiting older people at home, an assessment of the safety of the home environment, and a range of interventions such as safety checks, safety modifications, referral to care, and recommendations for exercise. Six of the studies had more than 100 people in the intervention group and over 1 year follow up.[20, 50-52, 56, 57]

In a study of over 2,000 people, Hornbrook found that those offered a home intervention to remove and repair safety hazards showed a reduction in falls compared with controls.[56] Similarly Carpenter and Demopoulos found that older people visited at home by trained volunteers reported one third of the number of falls as did controls.[51] Wagner in a multifactorial intervention involving home visits from nurses, reported reduced falls in the intervention group in the first year of follow up.[57] However, this effect was not sustained at 2 years, suggesting that the effects may be lost if the intervention is discontinued. In another multifactorial intervention, The FICSIT trial by Tinetti *et al*, evaluated a programme which tailored interventions to individual risk factors such as multiple drug use, use of sedative/hypnotics, postural hypotension, etc, and was implemented by nurses and physiotherapists.[20] This reduced the rate of reported falls by 21%. The two other large trials found no effect.[50, 52]

C.3 *Shoes*

Older peoples' footwear may be important in affecting their balance and stability. In some hospitals, footwear assessment by physiotherapists is routinely carried out.[58] However, no rigorous evaluation of such an intervention was identified. A trial looking at the effect of shoe type on balance found that stability was better with shoes with a thinner and harder mid-sole, compared with thicker, more comfortable trainer type shoes (Table 5).[59] This study was carried out in laboratory conditions. RCTs looking at the effect of the type of shoe and the effectiveness of interventions to improve the fit of shoes under natural conditions are needed.

C.4 *Interventions in Institutional Settings*

Six trials were identified which evaluated the effectiveness of interventions other than exercise and assessment in people who live in institutions (Table 5).[24, 60-64] The FICSIT trial by Fiatarone *et al*, used a 2x2 factorial design to assess the effect of multinutrient supplementation compared to a placebo drink in residents of a rehabilitation centre.[24] The nutritional supplement had no effect.

Frail people are at particularly high risk of falling when getting out of bed. The use of a bed alarm which alerts an assistant when a person tries to get out of bed was evaluated in a small trial.[60] This showed a reduction in falls which was not statistically significant. In contrast, evaluation of the use of identification bracelets given to high risk inpatients showed an increased rate of falls.[61]

Tai Chi class

Bowling found that people assessed to be in need of long term residential care, have half the risk of falling in hospital compared to nursing homes.[62-64] However, this could be accounted for by their reduced freedom to move about in

hospital, which was reflected in poorer ratings of their observed quality of life.

D. REDUCING INJURY FROM FALLS

D.1 *Dietary Interventions*

Studies have shown that body levels of vitamin D decline with age and that the lowest levels occur in winter when there is least sunlight[65] and in people who are artificially deprived of sunlight for an extended period of time, such as those who have been homebound.[66]

Reduced levels of vitamin D are associated with increased bone loss, an important risk factor for bone fractures especially in older women. Vitamin D is one of a number of agents which can reduce bone loss in healthy post-menopausal women, particularly in the winter[67] and which may therefore reduce the risk of fractures in those who fall.

Recently a systematic review of RCTs, completed within the Cochrane Collaboration, looked at the effectiveness of vitamin D and calcium supplementation in reducing fractures.[26] The results of this review are summarised below.

Two large RCTs assessed the effect of oral vitamin D and calcium supplementation on frail women in nursing homes[68] and oral vitamin D alone.[69] These showed that vitamin D given along with calcium in doses between a quarter to a third higher than the current UK recommended daily allowances, appears to reduce the number of people who have one or more fractures over a 3 year period by 20% ($p<0.02$).[68] However, when given in lower doses, Vitamin D by itself did not show a protective effect.[69] The only trial to evaluate Vitamin D provided as an annual injection reported a significant drop in the fracture rate.[70] This study was not included in the Cochrane review because it was not properly randomised but it points to the need for replication in a better trial.

The review also showed that calcium supplementation by itself, evaluated in small studies, may possibly be effective for reducing symptomatic fractures (odds ratio OR = 0.37; 95% CI: 0.4 - 0.97). There is some evidence from two small trials that calcitriol (a vitamin D analogue) is more effective than a placebo (OR 0.31; 95% CI: 0.11 - 0.83). In one large trial, calcitriol appeared more effective than calcium for reducing fractures of the bones of the upper and lower limbs (OR 0.44; 95% CI: 0.22 - 0.88).[71]

This review demonstrates that there is potential to prevent fractures in older people by vitamin D and/or calcium supplementation. One possible way to implement this intervention would be to promote exposure to sunlight and increased consumption of dairy products. However, dietary supplementation in older people at high risk of fractures is likely to be a better option.[72] There is not sufficient information to decide on the most cost-effective strategy.

D.2 *Hip Protectors*

A RCT of external hip protector pads in people over 69 years old in residential nursing homes found that the risk of a hip fracture in those randomly allocated the pads was more than halved (age adjusted relative risk RR = 0.4; 95% CI: 0.18 - 0.82).[73] No fractures occurred in anyone wearing the pads at the time of a fall. This appears a promising intervention in those at high risk of a fall. However, the extent to which protection pads are generally acceptable and would be worn in the community is not clear. An eighth FICSIT trial is designed to explore acceptability of hip protectors in community and residential settings.[74]

E. IMPLICATIONS FOR HEALTH CARE

There is limited evidence for any single intervention but:

E.1 Balancing, low impact aerobic or muscle strengthening exercise for older people may reduce the rate of falls. Therefore, older people should be offered access to exercise classes or home exercise routines which include for example, balance training such as Tai Chi. Little is known about the best way to implement such programmes and encourage attendance in the UK and so these should be carefully monitored and evaluated.

E.2 Home visiting to identify and remedy environmental and personal risks for falling may reduce the risk of falling. The type of safety changes could include removal of throw rugs and objects in pathways, and installation of improved night lights and bath non-skid mats. Visits could be carried out by health visitors, nurses, occupational therapists, or trained volunteers.

E.3 Introducing the use of hip pad protectors for high risk people in institutional care may significantly reduce injury due to falls. Their acceptability in various settings in the UK needs to be evaluated.

Given the limited research evidence, new programmes should, where possible, be developed as part of controlled evaluations.

Recommendations For Research

E.4 A programme of work designed to identify risk factors for defined populations of older people which suffer the highest number of injurious falls may help inform the optimal prevention strategy.

E.5 Research is needed to identify the most cost-effective exercise programmes for older people. This could, for example, explore ways of promoting uptake and long-term adherence, and evaluate the relative advantage of different types of exercise. Many studies are not large enough to show a statistically significant difference in outcomes and so any new research studies need to be large.

E.6 Research is needed to assess the most cost-effective ways of reducing home environmental and personal risks of falling. For example, it would be useful to know if information from the annual screening of older people and GP records is helpful.

E.7 Major trials to assess the cost-effectiveness of vitamin D/calcium supplementation in older people to reduce fracture risk are needed. In particular, the potential value of an annual Vitamin D injection and other cost-effective ways of delivering Vitamin D should be explored.

E.8 Trials to examine the potential effect of shoes on falls - taking into account both type of sole and whether they are well fitting - are needed.

E.9 During the planning, evaluation and implementation of interventions, the perspectives of older people should be taken into account.

Table 3a Summary of identified RCTs of exercise interventions where falls or related injuries are measured

Author, country and objectives	Population, setting and intervention	Design	Key result	Commentary
Hu & Woollacot (1994)[38] North America To determine the effects of 10 hour standing balance training on balance ability in a group of healthy older people	Older healthy people age 65-90 living in the community Setting: research centre I: a 10 hour training programme over a 15 day period delivered by a physical trainer (n = 12) C: no intervention (n = 12)	Method of randomisation: not stated Follow-up: 4 weeks	The I group showed significant improvement in stability in 5 of the 8 conditions ($p<0.006$) and fell less frequently during platform sensory tests and stood longer on one leg than the C group ($p<0.001$) Drop-outs: I = 17% C = 17%	The I group experienced a greater number of falls in the platform sensory tests at baseline which was adjusted for in the analysis Drop-outs were not included in any of the analyses
Lord et al (1995)[40] Australia To determine whether a 12-month programme of regular exercise can improve balance, reaction time, neuro-muscular control and muscle strength and reduce the rate of falling in older women	Women aged 60 to 85 years, living independently in one community I: a 1 hour exercise session, twice weekly for 10 to 12-week terms, run by exercise trainers (n = 100) C: no intervention (n = 97)	Method of randomisation: not stated Follow-up: 12 months	The I group showed improved performance in all 5 strength measures ($p<0.05$-<0.01), reaction time, neuro-muscular control ($p<0.01$) and body sway ($p<0.05$) There were no statistically significant differences between the I and C groups in the percentage of falls. However, the groups differed in types of falls (e.g. balance fall 5% v 17% for I and C groups respectively) Average attendance was 73% Drop-outs: I = 25% C = 22%	Slight differences in reported medical conditions, falls, instability, drug use and inactivity between C and I groups at baseline Drop-outs not included in any of the analyses
Reinsch et al (1992)[33] North America To assess the effectiveness of exercise and cognitive behavioural programmes in reducing falls and injuries and improving balance and strength in older people	Adults aged 60 years and over in senior centres Exercise (E): low intensity programme to prevent falls (n = 4 centres, 57 individuals) Cognitive behavioural (CB): health and safety education to prevent falls and relaxation training (n = 4 centres, 51 individuals) Exercise-cognitive behavioural (EC): combined programme of exercise, relaxation and discussion (n = 4 centres, 72 individuals) C: discussion of health related topics (n = 4 centres, 50 individuals)	Method of randomisation: not stated Randomised by senior centre Follow-up: 1 year	The rate of falling as identified by the first fall, was 25% in the E group, 19% in the CB group, 37% in the EC group and 19% in the C group The CB group had the highest proportion of repeat fallers (53%) and the C group had the lowest (29%) There were no statistically significant differences in the levels of injuries or on measures of balance and strength between groups Drop-outs: E = 23% CB = 27% EC = 15% C = 16%	The 2 groups (E) (EC) involved in exercise had the highest rates of falling Intention to treat analysis used

Table 3b Summary of identified RCTs of exercise interventions where modification of potential risk factors for falling are measured

Author, country and objectives	Population, setting and intervention	Design	Key result	Commentary
Crilly et al (1989)[29] North America To test whether an exercise programme would improve postural stability as reflected in postural sway in older women	Females aged 70 years and over (mean = 82 years) who were residents of sheltered apartments, rest homes or nursing homes Setting: classes were held at each of the centres I: exercise classes 3 times per week ranging from 15 min. to 35 min. duration given by a physiotherapist aimed at improving balance (n = 23) C: no intervention (n = 24)	Method of randomisation: random number tables Follow-up: 12 weeks	No statistically significant differences between I and C groups in postural sway In the I group there was a significant deterioration in lateral sway in the anteroposterior direction with eyes closed (p = 0.03) 35% of the I group attended at least 24 out of 36 classes Drop-outs: I = 4% C = 8%	Drop-outs not included in any of the analyses
Era (1988)[28] Finland To measure the effect of physical training on postural sway and maximal isometric strength in older men	Men aged 74-78 years Both programmes were carried out twice weekly for 8 weeks, supervised by a physiotherapist Muscle strengthening (MS): isometric and dynamic exercises to strengthen the limbs and trunk (n = 20) Gymnastics (G): weight bearing, flexibility and rhythmic exercises (n = 20) C: no intervention (n = 20)	Method of randomisation: not stated Follow-up: 8 weeks	Knee strength was significantly greater in the G group than in the MS group or C group ($p<0.05$) In both exercise groups anteroposterior sway was diminished after training ($p<0.05$) Drop-outs: MS = 35% G = 45% C = 10%	The G group had higher values in in maximal isometric strength of the muscles for grip strength and body flexion than the 2 other groups and had higher maximal body extension strength than the C group at baseline Drop-outs were not included in any of the analyses, and the drop-out rate in the 2 intervention groups was high
Hopkins et al (1990)[31] North America To determine the effects of a low impact aerobic dance class on the functional fitness of older women	Community living, sedentary women aged from 57 to 77 years I: three 50 minute exercise sessions per week for 12 weeks, including a low impact aerobic workout (n = 35) C: instructed to continue daily activities as usual and told they would join the exercise class at the end of the first 12 weeks (n = 30)	Method of randomisation: not stated Follow-up: 12 weeks	Statistically significant differences were found in strength/endurance ($p<0.01$), balance ($p<0.01$), flexibility ($p<0.05$) and agility ($p<0.01$) between the I and C groups Drop-outs: I = 14% C = 23%	Drop-outs not included in any of the analyses
Judge et al (1993)[34] North America To evaluate the effectiveness of a rigorous exercise programme in improving the balance of older women and reducing their risks of falls and falls-associated injuries	Older 'healthy' women (mean = 68 years) Setting: fitness centre Combined training (CT): knee extensions, sitting leg press machines, brisk walking for 20 mins, and postural control exercise which included Tai Chi like exercises 3 times per week for 20 minutes (n = 12 numbers after drop-outs) Flexibility training (FT): postural control exercises only (n = 9 numbers after drop-outs)	Method of randomisation: not stated Follow up: 6 months	Double stance balance remained unchanged in both groups Single stance improved by 17% in the CT and by 5% in the FT, this was not statistically significant Average attendance for both groups was 80% Drop-outs: 16% overall	Very small sample sizes Drop-outs not included in any of the analyses
Lichtenstein et al (1989)[30] North America To test the effect of exercise on balance in older women	Women, over 65 years of age living alone in a high-rise apartment building Setting: apartment building I: 1 hour of balance and response exercies, 3 times per week (n = 1 unit, 22 individuals) C: no intervention (n = 1 unit, 21individuals)	Method of randomisation: buildings were randomised by the toss of a coin Follow-up: 16 weeks	No statistically significant differences between the I and the C group in balance measures Compliamce with the programme was 85% Drop-outs: I = 8% C = 19%	Sample sizes were small and the I group had significantly better vision and was better educated than the C group. Multiple linear regression was used to adjust for baseline differences Drop-outs not included in any of the analyses

Table 3b continued Summary of identified RCTs of exercise interventions where modification of potential risk factors for falling are measured

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
McMurdo & Rennie (1993)[36] UK To evaluate whether regular seated exercise produced improvements in balance, flexibility, strength or functional capacity and was acceptable to residents of local authority homes	Residents of local authority homes aged 64-91 years (mean = 81 years) I: a twice weekly seated exercise programme was carried out by a physiotherapist (n = 2 homes, 20 individuals) C: reminiscence and music sessions twice weekly to promote social interaction (n = 2 homes, 29 individuals)	Method of randomisation: sealed envelopes, prepared from random number tables Randomised by residential home Follow-up: 7 months	Grip strength ($p<0.02$), spinal flexion ($p<0.001$), chair to stand time ($p<0.001$) and activities of daily living ($p<0.05$) improved in the I group Average attendance for I group was 91% and for C group 80% Drop-outs: I = 25% C = 10%	The C group had significantly better spinal flexibility at baseline than the I group Drop-outs were not included in any of the analyses
McMurdo & Johnstone (1995)[41] UK To evaluate the effects of 3 homebased programmes on mobility, strength, postural control and activities of daily living in older people	Adults (age 75+) with limited mobility, dependence in at least one activity of daily living (mean = 82 years) Setting: homes Each group was visited by a physiotherapist every 3-4 weeks and instructed about the programme Strength programme (SP): strength exercises using looped resistive elastic bands (Thermabands) (n = 25) Mobility programme (MP): 24 individual exercises to be completed on a daily basis (n = 31) Health Education (HE): discussions on exercise, diet, sleep, medication, footcare and safety in the home (n = 30)	Method of randomisation: sealed envelopes supplied in sequence containing computer generated random numbers Follow-up: 6 months	No statistically significant differences between groups on functional mobility, postural control, activities of daily living and quality of life measures Drop-outs: SP = 16% MP = 35% HE = 7%	Research assistant collected measurements blind to the intervention Drop-outs not included in any of the analyses
Mills (1994)[39] North America To determine if low intensity aerobic exercises would improve muscle stength, flexibility and balance among older people	Sedentary adults aged 65 to 88 years of age living in apartment complexes for older people I: low intensity aerobic exercises for 20 minutes, 3 times per week (n = 24) C: no intervention (n = 29)	Method of randomisation: not stated 2 apartment buildings were randomised to either I or C Follow-up: 8 weeks	The 1 group had significant improvements in flexibility ($p<0.05$, $p<0.001$) compared to the C group No statistically significant differences were found in balance, and muscle strength between the groups Drop-outs: I = 17% C = 7%	Randomisation was by building and analysis by individual Drop-outs not included in any of the analyses
Nelson et al (1994)[37] North America To evaluate the effects of a high intensity strength training programme on bone, muscle strength and balance in post-menopausal women	Community dwelling, postmenopausal women aged 50 to 70 years, who were sedentary and estrogen-deplete Setting: exercise laboratory I: high intensity strength training exercises using 5 different exercises, 2 days per week (n = 21) C: no intervention (n = 19)	Method of randomisation: not stated Follow-up: 1 year	A positive effect was found on bone density (0.9% ± 4.5%), muscle mass, muscle strength and dynamic balance ($p = 0.03$ to <0.001) in the I group Average attendance was 88%±2% Drop-outs: I = 5% C = 0%	Women in the C group were significantly younger than the exercisers and had a greater history of past smoking ($p = 0.03$) at baseline Intention to treat analysis used
Sauvage et al (1992)[32] North America To determine whether a moderate to high intensity strengthening and aerobic exercise programme can improve strength, exercise capacity, gait and balance in older men	Deconditioned male nursing home residents aged 60 and above I: progressive resistance lower extremity weight training and an aerobic conditioning programme, 3 days per week (n = 8) C: usual care (n = 6)	Method of randomisation: not stated Follow-up: 12 weeks	The I group had significant improvements in muscle strength ($p<0.01$), muscular endurance ($p<0.01$), left stride length and gait velocity ($p<0.05$) as compared with the C group Increases in balance related items in the I group approached statistical significance ($p<0.06$) Average attendance was 95% Drop-outs: I = 25% C = 0%	Sample sizes were very small Drop-outs not included in any of the analyses

Table 3b continued Summary of identified RCTs of exercise interventions where modification of potential risk factors for falling are measured

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
Skelton et al (1995)[42] UK To determine the effects of 12 weeks of progressive resistance strength training on the isometric strength, explosive power and functional abilities of older women	Women aged 75 years and over (median = 80 years) living in the community Setting: medical school and participants own homes I: one supervised and 2 unsupervised exercise sessions per week consisting of resistance training using elastic tubing (n = 24) C: no intervention (n = 23)	Method of randomisation: random number table Participants were matched for age and habitual physical activity Follow-up: 12 weeks	Significant improvements were found in the I group in strength (p = 0.03, p = 0.05) No statistically significant differences were found in explosive power and functional abilities between groups Drop-outs: I = 17% C = 13%	The C group were significantly heavier than the I group (p<0.05) at baseline Drop-outs not included in any of the analyses
Skelton & McLaughlin (1996)[43] UK To determine the feasibility, acceptibility and effects of 8 weeks of strength training exercises on strength, functional ability, flexibility and balance in older women	Women aged 70 years and over (median = 81 years) living in the community I1: one exercise class per week, for 8 weeks, run by a physiotherapist, plus 2 unsupervised home sessions per week following an exercise prescription (n = 10) I2: as above (controls participated after the first 8 weeks and acted as their own controls) (n = 10)	Method of randomisation: not stated Matched by age Follow-up: 8 weeks	The I group had improvements in strength (p = 0.03, p = 0.04), flexibility (p = 0.03, p = 0.01, p = 0.0001) and balance (p = 0.02) 78% of participants attended all classes and performed all home sessions Drop-outs: I1 = 10% I2 = 10%	No differences at baseline between the groups, therefore the results for I1 and I2 were combined Not clear that the changes found can be fully attributed to the intervention due to inadequate control
Topp et al (1993)[35] North America To test whether a 12 week dynamic resistance strength training programme can change gait velocity and improve measures of balance in older adults	Community dwelling adults aged 65 and over Setting: exercising took place both in a group setting and in the subjects homes I: a 12 week dynamic resistance strength training programme, using elastic tubing, 3 times per week (n = 31) C: two 3-hour group driver education classes per week, during which participants interacted with project staff (n = 32)	Method of randomisation: not stated Follow-up: 12 weeks	No statistically significant differences in gait velocity, dynamic balance or in static balance between the I and the C groups Average attendance at supervised sessions was 90% and for unsupervised sessions was 87% Drop-outs: I = 19% C = 6%	There were significant differences in age and gait velocity (p<0.05) at baseline between I and C groups Drop-outs were not included in any of the analyses

Table 4a Summary of identified RCTs of home assessment and surveillance interventions where falls or fall related injuries are measured

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
Carpenter & Demopoulos (1990)[51] UK To test the benefits of regular surveillance of older people at home over a 3 year period	Adults aged 75 and over from 2 general practices I: volunteers visited participants and completed activity of daily living questionnaires. Participants were re-visited at regular intervals and those with an increase of >5 in their activity of daily living score were referred to their GP (n = 272) C: subjects were visited at the beginning and end of the study (n = 267)	Method of randomisation: females allocated by random number tables, husbands allocated to same group, remaining men allocated by random number tables Follow-up: 3 years	94 people received interventions initiated as a result of the project In the C group 36 falls were reported in the month before the final interview. In the I group 12 falls were recorded at the final interview (p<0.05) 90% (of those completing a questionnaire) wished to continue with the scheme Drop-outs: I = 34% C = 31%	There were differences at baseline in the disability scores between C and I groups. Initial disability was not adjusted for in the analysis No information provided about the sorts of interventions that were initiated by GPs
El-Faizey & Reinsch (1994)[55] North America A preliminary study to evaluate compliance with recommended safety changes in the home and its effect on falls in older adults	Adults over 60 years of age living in the community who were members of a senior centre Setting: home I: home safety assessments and education about safety and home modifications carried out by researchers (n = 2 centres, 14 individuals) C: home visits, no safety information (n = 1 centre, 14 individuals)	Method of randomisation: not stated Randomised by senior centre and participants were volunteers Follow-up: 6 months	No statistically significant differences in the implementation of home safety changes between the I and the C groups In the I group 8 participants fell (38% of falls due to home hazards) and in the C group 4 participants fell (20% of falls due to home hazards) No drop-outs	Intention to treat analysis used This was a very small study in which the groups were self-selected from a much larger RCT of exercise and a cognitive behavioural intervention (see Reinsch et al 1992)

Table 4a continued Summary of identified RCTs of home assessment and surveillance interventions where falls or fall related injuries are measured

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
Fabacher et al (1994)[54] North America To evaluate the effectiveness of in-home geriatric assessments as a means of providing preventive health care and improving health and functional status in older adults	Community living adults aged 70 years and over I: a home visit by a physician's assistant or nurse to screen for medical, functional and psycho-social problems and follow-up visists every 4 months for 1 year (n = 131) C: telephone interviews every 4 months to collect outcome data (n = 123)	Method of randomisation: randomly generated assignement cards in sealed envelopes Follow-up: 1 year	Gait and balance were the most common disorders identified from screening (22%) 28 recommendations were made to modify the home to reduce the risk of falls of which 20 were followed up No statistically significant differences in self-reported fall rates between groups, although there was a trend for the I group to have fewer falls during the follow-up year (14% vs 23%) Drop-outs: I = 24% C = 23%	The I group differed significantly in age ($p<0.05$) and level of education ($p<0.05$) from the C group at baseline Drop-outs were not included in the analyses
Hornbrook et al (1994)[56] North America To evaluate the impact of a moderate intensity falls prevention programme on older adults	Adults living in the community aged 65 years and over Both groups had home assessment, and falls safety hazards were recorded I: participants encouraged to remove/repair safety hazards. Didactic approach (4 weekly, 90 minute group meetings) to dealing with falls and falls prevention and a group exercise component (isometric strengthening and range of movement for 20 minutes, encouraged to walk 3 times per week) (n = 1271 households, 1611 individuals) C: minimal treatment; no repair advice or group sessions (n = 1238 households, 1571 individuals)	Method of randomisation: not stated Randomised by household Follow-up: 2 years	There were 1730 falls in the I group and 2084 in the C group Participating in the intervention reduced the odds (0.85) of being a faller relative to the C group ($p<0.05$) No statistically significant effect on the probability of medical care falls 61% attended 3 or more group meetings Drop-outs: I = 10% C = no information given	The effect was strongest for men aged 75 years and above Drop-outs were not included in the analyses
Rubenstein et al (1990)[50] North America To measure the effects of a specialised post-fall assessment to detect causes and underlying risk factors for falls and to recommend preventive and therapeutic interventions in older adults in residential care	Ambulatory patients (mean = 87 years) in a long term residential care facility I: post fall assessment included a physical examination and environmental assessment by a nurse practitioner, coupled with referrals for specific treatment and preventive interventions (n = 79) C: usual care (n = 81)	Method of randomisation: computer generated, randomly sequenced cards in sealed envelopes Follow-up: 2 years	41% of I group received all recommended interventions (e.g treatment of active problems, minimizing of potential risks, correcting hazardous environments) The I group had 71% subjects with falls v 76% in the C group, at 1 year. At 2 years this was 81% v 84% respectively. This difference was not statistically significant No drop-outs	The I group had significantly more medical problems ($p<0.05$) and was taking more antibiotic medication ($p<0.01$) than the C group at baseline
Tinetti et al (1994)[20] North America To assess the effectiveness of a multifactorial targeted risk-abatement strategy in reducing the risk of falls in older people	Adults aged 70 and above living in the community with at least 1 risk factor for falling Setting: subject's homes I: a nurse practitioner assessed participants risk factors and targeted interventions accordingly; a physical therapist gave home exercise routines (balance and strengthening programmes) (n =153) C: usual health care plus social visits (n = 148)	Methom of randomisation: not stated Physicians were randomised and participants were assigned to the same group as their physician Follow-up: 1 year	35% of the I group had fallen at 1-year follow-up compared with 47% of the C group (p = 0.04) A significant reduction in risk factors at reassessment in the I vs C group: medications (63 vs 86%), balance impairement (21 vs 46%), gait impairement (45 vs 62%) and impairement in toilet transfer skills (49 vs 65%) Drop-outs: I = 4% C = 3%	The cost of the intervention was $891 per person, the cost per fall prevented was $1947 and the cost for preventing 1 fall requiring medical care was $12392 Blinded assessment was carried out I group had more impairement of leg strength than C group at baseline

Table 4a continued Summary of identified RCTs of home assessment and surveillance interventions where falls or fall related injuries are measured

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
Vetter et al (1992)[52] UK To assess whether a targeted intervention including assessment and correction of hazards in the home and assessment and improvement in fitness could reduce the incidence of fractures in older people	Adults living in the community aged 70 years and over I: assessment and correction of nutritional deficiencies and environmental hazards in the home, assessment and referral of medical conditions, assessment and improvement of fitness carried out by health visitors (n = 350) C: visited at the beginning and the end of the study (n = 324)	Method of randomisation: random numbers tables using participants' study numbers and without direct contact with participants Randomised by household Follow-up: 4 years	The rate of falls (with fractures) was 5% in the I group and 4% in the C group The rate of falls was 23% in the I group and 16% in the C group Drop-outs: 33% (over both groups)	There was more disability in the C group than in the I group at baseline Increase in falls in I group compared to C group is most significant in those with no initial disability Intention to treat analysis used
Wagner et al (1994)[57] North America To test whether a multicomponent intervention programme could prevent falls and disability in older adults	Enrollees of a Health Maintenance Organisation aged 65 years and over (mean = 73 years) Setting: health centre I1: nurse assessment visit, and follow-up targeted interventions (no active interventions during year 2) (n = 635) I2: general health promotion, nurse visit (n = 317) C: usual care (n = 607)	Method of randomisation: not stated Follow-up: 2 years	Significant differences were found between I1 and C in percentage falls at 1 year (28% vs 37%) but not at 2 years (31% vs 29%) respectively Significant differences found between I1 and C in percentage injurious falls (10% vs 15%) at year 1 but not at year 2 (13% vs 10%) respectively Drop-outs: 3% overall	Drop-outs were not included in the analyses

Table 4b Summary of identified RCTs of home assessment and surveillance interventions where modification of potential risk factors for falling are measured

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
Ploeg et al (1994)[53] Canada To evaluate the effectiveness of 2 health promotion programmes (safety promotion or influenza vaccination) with older people	Adults aged 65 years and over living in the community (mean = 77 years) Setting: home Safety Promotion (SP): during home visits a public health nurse used a checklist to discuss personal, home and community safety; and suggest strategies to improve safety (n = 148) Influenza Vaccination (IV): home visit by a public health nurse to discuss influenza vaccination (n = 211)	Method of randomisation: not stated Follow-up: 3 months	Both groups made safety changes with a slightly higher proportion of people making changes in the SP group (22% vs 18%) Changes included installing grab bars and using a cane 69% of safety changes were falls prevention strategies Drop outs: SP = 3% IV = 7%	Groups were not compared at baseline - post-intervention measures only Blinded assessment was carried out; with research assistants obtaining data over the telephone, blinded to the intervention groups Drop-outs were not included in the analyses

Table 5 Summary of identified RCTs of other interventions to reduce the risk of falls, falls and injury from falls

Author(s), country and objectives	Population, setting and intervention	Design	Key result	Commentary
Robbins et al (1992)[59] North America To compare the effects of different shoe midsole thickness on older peoples' balance and perceptions of comfort	Older ambulatory patients drawn from an internal medicine practice Setting: laboratory Different shoes (6 types) with varying thickness and hardness of midsole were tried on each subject (n = 25)	Matched randomised controlled trials. Each of 6 shoes types and bare feet in each of 25 persons	Midsole softness and thick mid soles were associated with poor stability ($p<0.0001$ and $p<0.01$ respectively) Worst outcomes were with bare feet. Higher comfort was inversly correlated with balance	The matched analysis is powerful. However, it is not clear that performance on a bar in artificial circumstances predicts incidence of falls in normal activity
Fiatarone et al (1994)[24] North America To assess whether a home based nursing intervention can improve muscle strength in older people	Institutionalised adults aged 70 to 100 years (mean = 87 years) Resistance exercise training (RT): high intensity resistance training of the hip and knee extensors, 3 days per week (n = 25) Multinutrient supplementation (MS): liquid supplying 360 kcal providing one third of the recommended daily allowances of vitamins and minerals (N = 24) Both interventions (B) (n = 25) Control: recreational therapy, minimally nutritive flavoured liquid (n = 26)	Method of randomisation: computer generated random assignement Follow-up: 10 weeks	Significant differences were found in muscle strength ($p<0.001$), gait velocity ($p=0.02$), stair-climbing power ($p=0.01$) between RT and the other groups The nutritional supplement had no statistically significant independent or additive effect on outcomes Compliance ranged from 97% (RT) to 100% (C) Drop-outs: RT = 12% MS = 8% B = 0% C = 4%	Participants assigned to B were significantly weaker than those assigned to RT ($p = 0.05$) at baseline. Baseline strength was included as a covariate in all analyses Intention to treat analysis used
Tideiksaar et al (1993)[60] North America To determine the efficacy of a bed alarm system in reducing the number of bed falls in older patients with poor mobility	Adults aged 67-97 years of age (mean = 84 years) in a geriatric evaluation and treatment unit who demonstrated poor bed mobility I: an Oncall bed monitoring system which alerts nursing staff that patients are leaving their beds (n = 35) C: usual care (n = 35)	Method of randomisation: not stated Follow-up: 9 months	In the I group there was 1 fall from bed and in the C group there were 4 falls from bed. This was not statistically significant Drop-outs: not stated	The low rate of bed falls and the small sample size may have resulted in a failure to detect a significant effect
Mayo et al (1994)[61] North America To evaluate the efffectiveness of using an identification bracelet to prevent falls among older hospitalised people	Newly admitted hospital patients who had a primary risk factor for falling, (mean = 70 years) to a facility specializing in physicial rehabilitation I: blue ID bracelet given by a nurse to identify individuals at risk of falling and increase patients' vigilance about falling (n = 65) C: usual hospital identification bracelet (n = 69)	Method of randomisation: not stated Follow-up: 1 year	Rates of falls in the I and C groups were 41% and 30% respectively, although the difference was not statistically significant No drop-outs	The groups differed at baseline in their ability to walk: in the I group 11% needed assistance, wheras in the C group 20% needed assistance (this was not tested statistically)
Bowling et al (1992a b c)[62 63 64] UK To compare the quality of life, satisfaction, physical and mental functioning, including falls in older people in long stay facilities	Older people (mean = 91 years) in need of long stay care with no mental illness and not in need of intensive nursing care Setting: long stay facilities in London Long stay state funded nursing home (n = 63) Long stay hospital ward (n = 59)	Method of randomisation: computer generated random numbers table Follow-up: 2 years, 6 months	Half the incidence of falls in the hospital ward compared to the nursing home. 3 falls100/month/ at least one accident per year versus 6 Quality of life was lower in hospital ward Drop-outs: 41% overall	The reduction of incidence of falls may be due to the reduction in flexibility and freedom to move about in the hospital ward Intention to treat analysis used
Lauritzen et al (1993)[73] Denmark To investigate the effect of external hip protectors on the prevention of fractures in older nursing home residents	Residents of a nursing home aged 69 years and over I: an external hip protector was worn to divert a direct impact away from the greater trochanter during falls. The protector was fixed in special underwear (n = 10 wards, 247 individuals) C: usual care (n = 18 wards, 418 individuals)	Method of randomisation: a ward was selected when its number was drawn by an independent doctor Randomised by ward Follow-up: 11 months	In the I group there were 8 hip and 15 non-hip fractures. In the C group there were 31 hip and 27 non-hip fractures People in the I group with fractures were not wearing hip protectors at the time of fracture The relative risk of hip fracture in the I group (adjusted for skewness in age) was 0.41 (95%CI 0.18 to 0.82) Drop-outs: not stated	The risk of hip fracture in the I group was reduced by 53% and 9 hip fractures were estimated to have been avoided

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