Primary care

Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomised clinical trials

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Abstract

Objective To assess the relative effectiveness of interventions to prevent falls in older adults to either a usual care group or control group.

Design Systematic review and meta-analyses.

Data sources Medline, HealthSTAR, Embase, the Cochrane Library, other health related databases, and the reference lists from review articles and systematic reviews.

Data extraction Components of falls intervention: multifactorial falls risk assessment with management programme, exercise, environmental modifications, or education.

Results 40 trials were identified. A random effects analysis combining trials with risk ratio data showed a reduction in the risk of falling (risk ratio 0.88, 95% confidence interval 0.82 to 0.95), whereas combining trials with incidence rate data showed a reduction in the monthly rate of falling (incidence rate ratio 0.80, 0.72 to 0.88). The effect of individual components was assessed by meta-regression. A multifactorial falls risk assessment and management programme was the most effective component on risk of falling (0.82, 0.72 to 0.94, number needed to treat 11) and monthly fall rate (0.63, 0.49 to 0.83; 11.8 fewer falls in treatment group per 100 patients per month). Exercise interventions also had a beneficial effect on the risk of falling (0.86, 0.75 to 0.99, number needed to treat 16) and monthly fall rate (0.86, 0.73 to 1.01; 2.7).

Conclusions Interventions to prevent falls in older adults are effective in reducing both the risk of falling and the monthly rate of falling. The most effective intervention was a multifactorial falls risk assessment and management programme. Exercise programmes were also effective in reducing the risk of falling.

Introduction

Falls are a major health problem among older adults. In the United States one in three people aged 65 or more living in the community fall at least once a year. This proportion increases to one in two for those over 80 years.[1–3] Worldwide, adults aged over 70 years, particularly females, have a significantly higher fall related mortality than younger people.[4] The severity of fall related complications also increases with age.[2 3]

The primary sequelae of falls include fall related injuries, such as fractures and head injuries, and post-fall anxiety.[5–7] These lead to loss of independence through disability and fear of falling. The reduction in mobility and independence are often serious enough to result in admission to hospital or a nursing home or even premature death.[8 9] In the United States in 1994 the total cost of fall injuries for older people was around $20.2bn and is projected to reach $32.4bn (in 1994 US dollars) by 2020.[10]

Although the extensive literature on interventions to prevent falls provides many insights, there is no clear message about how best to prevent falls in older adults. To identify effective interventions and their relative effectiveness in preventing such falls, we conducted a meta-analysis of relevant randomised controlled trials. This approach builds on earlier work, where beneficial interventions are identified by using separate estimates of absolute effectiveness in different study strata.[11] Our strategy provides additional insight by applying a global multivariate model, allowing for assessment of the relative effectiveness of each intervention component while controlling for the effect of other components in multifactorial interventions across all studies.

Methods

The categories we identified for intervention programmes to prevent falls were multifactorial falls risk assessment and management, exercise, environmental modifications, and education. A multifactorial falls risk assessment and management programme was defined as a focused post-fall assessment or systematic risk factor screening among individuals at risk tied to intervention recommendations and follow up for risks uncovered. Review of drugs was an important component of nearly all the programmes.

Exercise programmes included both general and specific physical activities. Examples of general physical activity included walking, cycling, aerobic movements, and other endurance exercises. Specific physical activity included training targeted towards balance, gait, and strength.

Environmental modification programmes often included a home visit by a professional, who would check for environmental hazards such as poor lighting or sliding carpets and recommend modifications. Some programmes would also assist with implementation of recommendations.

Educational interventions targeted individuals, groups, or communities. This could vary from pamphlets and posters at senior centres and nursing homes to more intensive interventions such as one to one counselling about risk factors.

To identify relevant literature, we checked the reference lists from 82 reviews (see bmj.com) and reference lists obtained from the American Physical Therapy Association, American Geriat-

Relevant articles, details of studies, and references in table 2 are on bmj.com

rics Society, and experts. The Cochrane Library was searched in 2002. We also searched Medline, Ageline, Embase, CINAHL, and PsycINFO databases from 1992 to 2002 using the search terms accidental falls, falling, or fall *and* aged, aging, elder care, elderly, elderly care, geriatric, geriatric assessment, older, or senior *and* clinical trial or randomised controlled trial. There was no restriction on language of publication.

Data collection

JTC and WAM independently reviewed the articles and extracted general information on objectives, design, participants' age, and outcomes. Detailed information was extracted only from studies that met the major inclusion criteria: focus on falls prevention, data on participants aged 60 or more, randomised controlled trial, and inclusion of a usual care or control group. Data were collected on study design; study quality with the Jadad score[12 13]; concealment of allocation; participants (number and characteristics); type, duration, and intensity of interventions; outcomes measured; time from intervention until outcome; and results, including falls outcomes. Each study could contain one or more intervention groups, and each intervention consisted of one or more components. Disagreements were resolved by consensus, and PGS resolved any remaining ones.

Each study intervention was classified independently by LZR (for content) and by PGS (for methods) as including up to two of the following components: multifactorial falls risk assessment and management, exercise, environmental modification, or education. If more than two components were described, each investigator chose the two judged to contribute most to the effectiveness of the intervention. Calculations were not performed for inter-rater reliability, but there were essentially no discrepancies in coding the interventions. To minimise detection bias, each investigator received only the methods sections for each article, retyped but with no identifiers. A debriefing showed that PGS correctly matched none of the deidentified methods sections to their respective article, whereas LZR correctly matched only two articles. Exercise components were further characterised as balance, endurance, flexibility, or strength, based on the description of the intervention. Walking programmes were classified as endurance exercise.

Statistical analyses

We considered two outcomes: falling at least once during a specified follow up period and the monthly rate of falling. Other clinically relevant outcomes were not reported sufficiently, often to justify pooling data. Each of these outcomes had its own analysis plan.

Our first analysis included studies that provided the number of patients in each group (intervention, control, or usual care) who fell at least once during follow up of six to 18 months. This interval was selected on the basis that a treatment effect at any time during this interval would be comparable. For studies with more than one follow up data point during this interval, we chose the one closest to 12 months. A risk ratio was estimated for most of the studies that compared an intervention group with a usual care or control group. For the few studies that contained more than one intervention group, we estimated multiple risk ratios, one for each intervention compared with the common usual care or control group, and performed a sensitivity analysis to assess the impact of correlation among these ratios. We estimated the DerSimonian and Laird random effects pooled log risk ratio of all studies, conducted a χ^2 test of heterogeneity, and calculated the I^2 statistic and its 95% uncertainty interval; this was also done for the second analysis of incidence rate ratios, including a DerSimonian and Laird random effects pooled log

incidence rate ratio of all included studies.[14–16] To adjust for the heterogeneity across interventions, we also fit in Stata two random effects meta-regressions of the log risk ratio for falling at least once as a function of different predictors.[17–19] The first model contained the intervention components as predictors in a main effects additive model, and the second contained exercise components as predictors in a main effects additive model. We also performed an exploratory analysis to determine the relative effectiveness of the components of the multifactorial falls risk assessment.

Our second analysis included studies that provided data on the total number of falls and the average follow up period in each group. For each group we calculated the monthly incidence rate of falling and the incidence rate ratio for each comparison between an intervention group and usual care or control group.[20] The same modelling approach was applied as that used for the outcome of falling at least once.[17–19]

We calculated the number needed to treat or number needed to harm for the statistically significant adjusted risk ratios.[21] We assumed the underlying risk of falling was equal to the simple average fall rate across the control groups of the modelled trials. Analogously for the incidence rate ratios, we calculated the number of additional falls per 100 patients per month by assuming the underlying monthly fall rate was equal to the simple average fall rate across the modelled trials.

We assessed funnel plots of the log risk ratios and the log incidence rate ratios for publication bias. Formal statistical testing included an adjusted rank correlation test and a regression asymmetry test.[22 23]

Sensitivity analyses

To assess the robustness of our findings, we undertook several sensitivity analyses. The first set of analyses included correcting for randomisation at the cluster level because several studies were randomised as such rather than at the individual patient level. All models were re-estimated using an adjustment in sample size, from the observed number of clusters within each group, and an intracluster correlation of 0.05 for those studies that were randomised at the cluster level. To correct for correlation across treatment arms within a single study, we performed a second set of analyses to examine whether correlation across multiple risk ratios or incidence rate ratios in the same study had an effect on model estimation. A third set of sensitivity analyses examined the effect on model estimation using data from the sites included in a pooled meta-analysis—the FICSIT trial (Frailty and Injuries: Cooperative Studies of Intervention Techniques).[24] In the last set of analyses we fit several additional meta-regressions that examined patient risk, provider setting, intensity level, Jadad score, and some limited interactions between these variables and intervention components.

Results

Ninety nine of 830 articles met the inclusion criteria for detailed data abstraction (fig 1). Sixty one were randomised controlled trials that included outcomes on falls. These were reviewed for potential inclusion in the meta-regression analyses. After excluding articles for being outside our specified follow up period, using idiosyncratic interventions that could not be pooled (for example, restraints, a bed alarm), or including duplicate study populations (see bmj.com), 40 trials contributed data to the meta-analyses (see table A on bmj.com). Using the Jadad tool for study quality (scores from 0 to 5), four trials scored 1, 22 scored 2, and 14 scored 3.[12] As this scoring system gives up to two points for double blinding, and double blinding is not conceptually
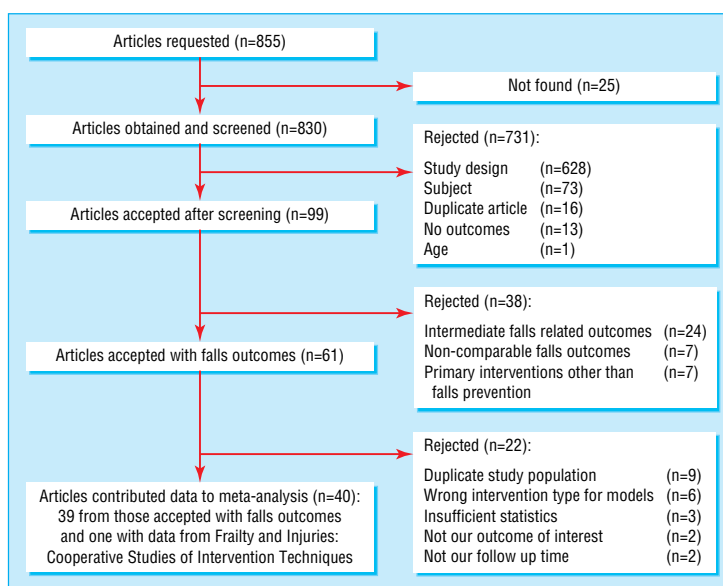
Fig 1 Flowchart of articles

possible for falls intervention studies, the maximum possible score for these studies is effectively 3. Nine studies described concealment of intervention allocation.

Data for the meta-analysis of participants who fell at least once came from 26 intervention groups in 22 studies. The combined data showed a significant reduction in the risk of falling (risk ratio 0.88, 95% confidence interval 0.82 to 0.95; P = 0.03; I^2 = 31%, 95% uncertainty interval, 0% to 61%; fig 2). Data for the meta-analysis on monthly rate of falling came from 30 intervention groups in 27 studies. The combined data showed a significant reduction in the

monthly rate of falling (incidence rate ratio 0.80, 0.72 to 0.88; P < 0.001; I^2 = 81%, 74% to 86%; fig 3).

None of the studies directly assessed the relative effectiveness of intervention components. To assess such effectiveness we therefore compared the magnitude of the effect of each of the components to a control group that received usual care. We entered all studies in the meta-regression model that assessed the effect of individual components while controlling for other components (table 1). A multifactorial falls risk assessment and management programme had a statistically significant beneficial
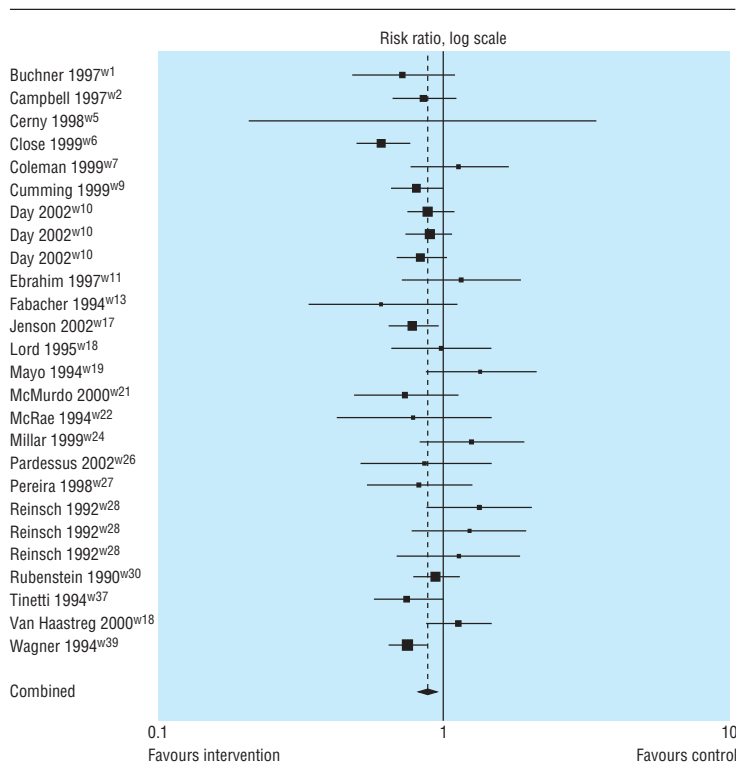

Fig 2 Pooled risk ratio of participants who fell at least once

Table 1 Meta-regression estimates of effect of individual intervention components controlling for other intervention components

Treatment component	Participants who fell at least once*			Monthly rate of falling†		
	No of studies (comparison pairs)	Adjusted risk ratio (95% CI)	Number needed to treat	No of studies (comparison pairs)	Adjusted incidence rate ratio (95% CI)	Fewer falls in treatment group‡
Multifactorial falls risk assessment and management programme	10 (10)	0.82 (0.72 to 0.94)	11	7 (7)	0.63 (0.49 to 0.83)	11.8
Exercise	13 (15)	0.86 (0.75 to 0.99)	16	19 (21)	0.86 (0.73 to 1.01)	2.7
Environmental modifications	5 (4)	0.90 (0.77 to 1.05)	NA	5 (6)	0.85 (0.65 to 1.11)	NA
Education	2 (3)	1.28 (0.95 to 1.72)	NA	1 (1)	0.33 (0.09 to 1.30)	NA

NA=not applicable.
*R^2=0.29.
†R^2=0.16.
‡Per 100 patients a month.

effect on both risk of falling (adjusted risk ratio 0.82, 0.72 to 0.94) and monthly rate of falling (adjusted incidence rate ratio 0.63, 0.49 to 0.83). The two models fit relatively well, explaining 29% and 16% of the variance, respectively. The risks assessed in multifactorial risk assessments varied among studies. The most commonly assessed risks were drugs, vision, environmental hazards, and orthostatic blood pressure (table 2). Exercise was an intervention in the largest number of studies. This also had a statistically significant beneficial effect on the risk of falls (adjusted risk ratio 0.86, 0.75 to 0.99), but on monthly rate of falling (adjusted incidence rate ratio 0.86, 0.73 to 1.01) did not reach conventional statistical significance. Environmental modification and education were primary components of a few studies, and the pooled estimates were not statistically significant.

In the second meta-regression analysis, we were not able to detect statistically significant differences or consistent trends in the efficacy between different types of exercises (table 3). Colinearity between balance and both flexibility and strength was problematic.

We observed some trends in the relative effectiveness of the major components of a multifactorial falls risk assessment and management programme, but no component was most or least effective.

In a post hoc analysis we attempted to see if the greater effectiveness of the multifactorial falls risk assessment and management programme was due to the preferential enrolment of people at higher risk. Therefore we classified each study according to population (general, community dwelling, or higher than average risk groups for falls—for example, living in a nursing home, recent history of falls) and repeated our meta-regression analyses stratified by population. No significant differences were found in effectiveness of the interventions by population studied.
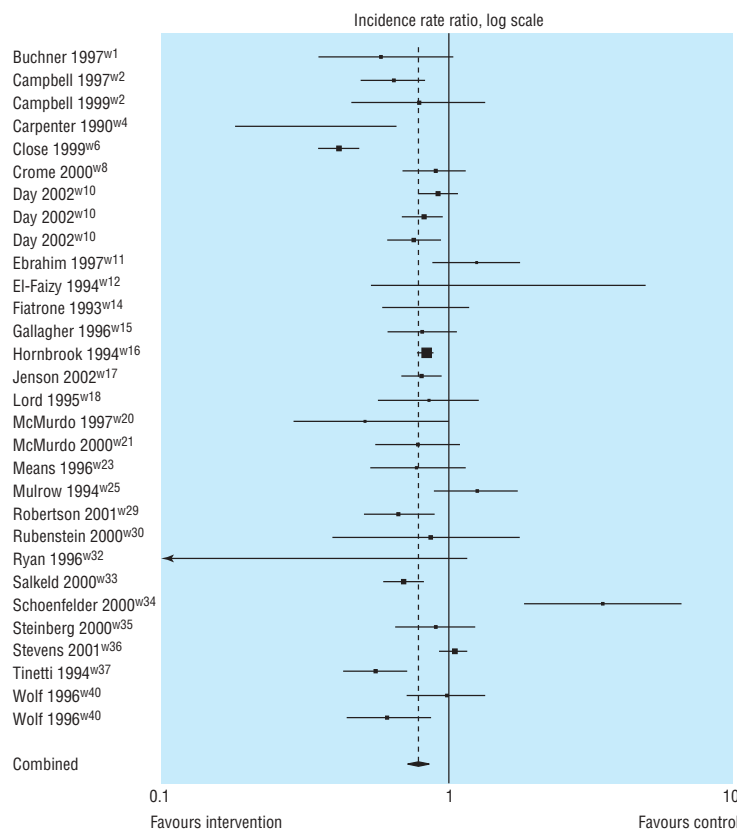

Fig 3 Pooled incidence rate ratio of monthly rate of falling

Table 2 Components of multifactorial falls risk assessment

Trial	Orthostatic blood pressure	Vision	Balance and gait	Drug review	Instrumental activities of daily living or activities of daily living	Cognitive evaluation	Environmental hazards	Other
Carpenter 1990[w4]	No	No	No	No	Yes	No	No	
Fabacher 1994[w13]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Assessment of hearing and depression
Rubenstein 1990[w30]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Neurological and musculoskeletal examination, laboratory tests, 24 hour heart monitor
Tinetti 1994[w37]	Yes	No	Yes	Yes	No	No	Yes	Muscle strength and range of motion
Wagner 1994[w39]	No	Yes	No	Yes	No	No	Yes	Hearing, assessment of alcohol misuse, assessment of physical activity
Gallagher 1996[w15]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	List of health problems
Coleman 1999[w7]	No	No	No	Yes	No	No	No	Self management skills, health assessment
Close 1999[w6]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Affect, carotid sinus studies (if clinical suspicion)
McMurdo 2000[w21]	Yes	Yes	No	Yes	No	No	No	Review of lighting in environment
Van Haastregt 2000[w38]	No	No	No	Yes	Yes	Yes	Yes	Physical health, psychosocial functioning
Millar 1999[w24]	Yes	Yes	No	Yes	No	No	No	Review of lighting in environment
Crome 2000[w8]*								
Jensen 2002[w17]	No	Yes	Yes	Yes	Yes	Yes	Yes	Hearing, review of lighting in environment, assistive device (for example, cane, walker), review of use of device, and repair of device if needed

See table A on bmj.com for details of references.
*No specific components stated.

A visual inspection of the funnel plots indicated no evidence of publication bias for all studies included in the meta-analyses for the risk ratio of falling at least once and for the falls incidence rate ratio. Although the adjusted rank correlation test indicated no evidence of publication bias, the regression asymmetry test did indicate some evidence for the falling at least once outcome.

None of the sensitivity analyses significantly changed the estimates of the meta-regression models, nor did the additional meta-regression models yield contrary conclusions.

Discussion

Interventions to prevent falls significantly reduce the proportion of older people who fall at least once and the monthly rate of falling. Among the interventions studied in our systematic review and meta-analyses, a multifactorial falls risk assessment and management programme was the most effective component. Exercise was also effective at reducing falls. We found no clear evidence for the independent effectiveness of environmental modification or education programmes.

Our results for exercise need to be put into context with those from the FICSIT trials, a preplanned meta-analysis of randomised controlled trials. FICSIT included seven trials that assessed a variety of exercise interventions, including endurance, flexibility, platform balance, t'ai chi, and resistance.[25–31] The meta-analysis included data at the individual patient level, which we did not have access to.[24] In one of our meta-analyses on participants who fell at least once we were only able to include data from two of the FICSIT trials because these were the only published results available on this outcome.[29 31] All but one FICSIT trial contributed data on monthly falling rate to the second meta-analysis. Despite this, our results on exercise agree with those of the central FICSIT meta-analysis, that exercise programmes help prevent falls (pooled effect for monthly rate of falling: FICSIT, adjusted incidence rate ratio 0.9, 0.81 to 0.99 v 0.86, 0.73 to 1.01), and there were no differences between types of exercise. Our meta-analysis goes beyond the FICSIT meta-analysis by providing evidence about the effectiveness of exercise relative to other falls prevention interventions.

Table 3 Meta-regression estimates of effect of individual exercise components controlling for other exercise components

Exercise type	Participants who fell at least once*		Monthly rate of falling†	
	No of studies (comparison pairs)	Adjusted risk ratio (95% CI)	No of studies (comparison pairs)	Adjusted incidence rate ratio (95% CI)
Balance	8 (10)	1.16 (0.67 to 2.01)	14 (16)	0.78 (0.60 to 1.01)
Endurance	7 (7)	0.86 (0.70 to 1.05)	5 (5)	1.53 (1.04 to 2.25)
Flexibility	5 (6)	0.87 (0.60 to 1.25)	6 (7)	1.03 (0.68 to 1.54)
Strength	9 (11)	0.82 (0.48 to 1.41)	14 (15)	1.04 (0.76 to 1.42)

*R^2=0.16.
†R^2=0.38.

Study limitations

One limitation of our study was the availability of original studies, common to all systematic reviews. Our efforts to locate original studies and advances in analytic capabilities allowed us to include more studies in our meta-analyses than in recent attempts.[11 32] Because of the larger number of studies, we were able to explore the relative effectiveness of intervention components. As none of the studies compared interventions directly, we used indirect methods to assess the relative effectiveness of the individual components. Although indirect comparisons are not as powerful as direct ones, the validity of our findings are strengthened by the convergence of results from two clinically important outcomes.

Assessing methodological quality with the Jadad scale and assessing the concealment of intervention allocation highlight the challenges in falls intervention trials, where double blinding is not conceptually possible and concealment of allocation is uncommon.[12] Better measures are needed to assess the quality of trials of complex interventions. To minimise the potential bias from low quality studies, we included only randomised controlled trials in our pooled analyses and made no further quality distinctions based on design or execution as there remains little consensus about what quality assessment criteria matter most.[33] We examined post hoc the impact of study quality on our results. Our findings were not changed by stratifying studies based on quality.

We also acknowledge that the outcome of monthly rate of falling is susceptible to correlation within patients. The distribution of the number of falls is skewed across individuals, with one individual potentially contributing a large number of falls than another. Falls within an individual are correlated and should not be treated as independent. Unfortunately the studies did not provide adequate information to allow us to adjust for this correlation and since the incidence rate ratio is the ratio of two possibly biased statistics, we cannot hypothesise whether it is biased and, if so, in what direction. The rate of falling, however, remains important because frequent falling is associated with more adverse outcomes, such as admission to hospital.[34] By examining both the risk and the rate of falling, and comparing and contrasting the effect of different intervention components on each, we were able to conduct a more thorough analysis than if we had focused only on the risk of falling.

Since the completion of our analysis, there have been six additional randomised controlled trials of falls intervention programmes with falls outcomes. Two studies included a multifactorial falls risk assessment and management programme but focused on examining the effect in participants with cognitive impairment. Both found that the intervention was not effective in older adults with significant cognitive impairment.[35 36] Three studies included exercise as an intervention; two were effective.[37–39] One study focused on an environmental modification component and reported a significant reduction in the rate of falls, particularly in a subgroup of frequent fallers.[40] The results of these trials may help future meta-analytic work examining the effectiveness of interventions in subgroups.

Our results indicate a two pronged approach to falls prevention. Implementing a multifactorial falls risk assessment and management programme would be most feasible by targeting selected people, such as those with a history of falls. Exercise programmes, however, could feasibly be implemented to a general population of older adults. Future research should focus on making these programmes most cost effective by directly assessing which components of a multifactorial falls risk assessment and what characteristics of exercise programmes, including level

What is already known on this topic

Many interventions have been developed to prevent falls

Systematic reviews have reached conclusions on the absolute effectiveness of individual components of these interventions

The relative effectiveness of different approaches to prevent falls is not known

What this study adds

Among current randomised clinical trials, a multifactorial falls risk assessment and management programme was the most effective component of a falls prevention programme

The next most effective component was exercise

of supervision and intensity, are essential. These steps should help older adults to preserve two of their most valuable assets, function and independence.

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