Best-practice recommendations for physical activity to prevent falls in older adults: a rapid review

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An ***Evidence Check*** Review
brokered by the Sax Institute for the
NSW Department of Health

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Suggested Citation:
Sherrington, C., Lord, SR., Close JCT. Best-practice recommendations for physical activity to prevent falls in older adults: An *Evidence Check* rapid review brokered by the Sax Institute (http://www.saxinstitute.org.au) for the Centre for Health Advancement, NSW Department of Health; 2008.

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EXECUTIVE SUMMARY

OVERVIEW

- Forty-seven randomised controlled trials have evaluated the effect of exercise as a single intervention to prevent falls – 33 trials have looked at prevention in the community setting and 14 in a range of residential aged care facilities.
- Exercise which specifically challenges balance is the most effective physical activity intervention in preventing falls.
- Exercise needs to be undertaken for at least 2 hours per week with the recommendation that exercise continues for life.
- Exercise can be undertaken in a group program or home-based program.
- There is strong evidence which supports exercise as a single intervention to prevent falls in community settings.
- There is limited evidence which supports exercise as a single intervention in residential aged care facilities.
- There is some evidence that exercise can be effective as part of a multifaceted approach to prevent falls in both community and residential aged care settings.

Question 1. What are the types, frequency and intensity of physical activity that are most effective in reducing the risk of falls in older adults?

- Exercise which has a focus on balance training has the greatest effect on falls.
- Programs of at least 2 hours of exercise per week for 6 months or more are more effective in preventing falls than lower dose programs.
- Walking or strength training programs as single interventions do not appear to prevent falls.
- More active people experience fewer falls but there is no evidence that we can prevent falls by simply encouraging older people to be more active.

Question 2. What are the most effective programs for delivering these recommended types and levels of physical activity?

- Falls can be prevented by a range of exercise programs which target balance and provide ongoing exercise - these include the Otago Exercise Program of home-based balance and strength training, group-based Tai Chi, and other group-based balance and strengthening exercise programs.
- Programs should be designed according to the needs of the target population to ensure they provide exercise that is challenging yet safe.

MAIN REVIEW

The Extent of the Evidence

Collating the evidence

Randomised controlled trials (RCTs) in clinical or public health settings and systematic reviews of RCTs are the optimal approach to assessing effectiveness of potential health care interventions (for both treatment and prevention)[1]. Clinical practice guidelines and health care decisions should be guided by randomised trials and systematic review findings where available. There have been many randomised controlled trials investigating the effect of exercise on falls.

A recently published systematic review of the literature in this area[2], the Cochrane collaboration review[3], the National Institute for Clinical Excellence (NICE) guideline[4] and a further updated search of the literature (up to October 2008, see Appendix 1) form the basis for the recommendations in this document. The systematic review recently published by the authors of this report is the most recent review of relevant randomised controlled trials and is included as Appendix 4[2]. Figure 1 in Appendix 4[2] shows its trial inclusion flow chart. The search criteria are available from the authors on request. The American College of Sports Medicine recommendation on “Physical Activity and Public Health in Older Adults”[5] was also consulted and its recommendations are given in Appendix 3 of this report.

A number of large methodologically-rigorous trials examining the effects of physical activity on falls are currently in progress. This highlights the need to review these recommendations on a regular basis.

Synthesising the evidence

Table 1 (Appendix 4[2]) summarises the characteristics of 44 trials investigating the effects of exercise on falls. The results of these studies were then pooled using meta-analysis and meta-regression to ascertain whether any features of study design, study population or exercise program components were associated with smaller or larger effects of exercise on preventing falls. Three recent trials (Appendix 1) published after the systematic review[2] was completed were reviewed separately for the present report with regard to their efficacy for preventing falls.

Methodological quality of included studies

Many of the trials of exercise for falls prevention have some design limitations. Twenty-eight trials in the systematic review did not report using a concealed process for allocating subjects to intervention or control groups and 22 did not use an intention to treat analysis. Both these features are likely to be associated with bias i.e. greater benefits from interventions are likely in trials which do not have these criteria[6-8]. However, our meta-regression analysis of the available exercise trials did not find that an absence of either concealed allocation to groups or the lack of an intention to treat analysis was associated with a larger effect on falls[2].

Comparing different programs

There have been few head-to-head trials directly comparing the effect of different approaches to exercise in preventing falls. The recommendations in this report are primarily from a meta-analysis of the size of the effect on falls reported in trials comparing an exercise intervention with no exercise (control group)[2].

Different settings

Fourteen of the 47 trials have been conducted in residential aged care facilities and only six of these have been conducted in high-care facilities (nursing homes). The trials in residential care settings have had fewer total participants (2463) than the trials conducted among community-dwellers (7538) and the trials in high-care residential settings have only had 1000 participants. Therefore, there is a stronger evidence base to guide practice in community settings than in residential care settings.

Single versus multiple interventions

Physical activity interventions are often a component of multifaceted fall prevention programs[3]. Exercise as a single intervention is the focus of the present review. In multifaceted interventions it is difficult to determine which components (or combination of components) are determinants of success or failure of the intervention.

SUMMARY OF THE EVIDENCE

Question 1 What are the types and intensity of physical activity that are most effective in reducing the risk of falls in older adults?

A. What types of physical activity are most effective in preventing falls in older people?

- Exercise which challenges balance is the most effective form of exercise for preventing falls.
- Walking or strength training programs as single interventions do not appear to prevent falls.

Physical activity, exercise and falls

Observational studies have shown that more active people experience fewer falls[9]. However, there is no evidence that falls can be prevented by simply encouraging older adults to be more active. It is likely that many people at risk of falls are less active as they are concerned about falling whilst undertaking physical activities. It is possible that a non-specific approach to increasing physical activity levels in frailer populations could lead to increased falls due to increased exposure to risk.

Balance training

Analysis of the existing studies shows that exercise programs which challenge balance have a 25% greater effect on preventing falls than programs which do not challenge balance[2]. The presence of balance training explained 19% of the difference between findings with regard to effectiveness in preventing falls of different trials. High level balance training for the purposes of this report means exercises conducted whilst standing in which participants aimed to:-

a) stand with their feet closer together or on one leg;

b) minimise use of their hands to assist; and

c) practice controlled movements of the body's centre of mass.

Combination of features

The greatest reduction in falls is seen from programs which include high level balance training, do not include a walking program and provide a higher dose of exercise. This combination of features resulted in a 42% reduction in the rate of falls (i.e. there were 42% fewer falls in the pooled intervention groups compared to the pooled control groups of studies which evaluated programs with these features, adjusted pooled rate ratio = 0.58, 95% confidence interval 0.48 to 0.69)[2].

Programs which included a high dose of exercise, a high challenge to balance and a walking program also resulted in a significant effect on falls (adjusted pooled rate ratio = 0.76, 95% confidence interval 0.66 to 0.88). However, programs which only provided a low to moderate challenge to balance and included a walking program did not significantly reduce falls (adjusted pooled rate ratio = 0.96, 95% confidence interval 0.80 to 1.16 for a high dose exercise and adjusted pooled rate ratio = 1.20, 95% confidence interval 1.00 to 1.44)[2].

Walking

The reason for the apparent lesser effect of exercise on fall rates when walking programs are included may be due to:

a) increased exposure to risk with walking;

b) walking taking time away from high level balance training; or

c) confounding of the results as there was some correlation between walking programs and high risk populations (e.g. in residential care).

Although walking appears not to be an effective fall prevention strategy there are other benefits of walking programs for older people[5,10]. Walking can be included in falls prevention programs if this component does not take time away from high level balance training. Programs should include a mechanism for assessing which participants would be able to safely undertake a walking program.

Strength training

The meta-regression[2] and two previous meta-analyses[11,12] revealed that the inclusion of strength training was not associated with smaller or larger effects of exercise in preventing falls. Therefore, strength training does not appear to be an effective single intervention for preventing falls. As with walking, there are other benefits of strength training for older people[5] and it is recommended that older people undertake strength training (see Appendix 3). Strength training could be included in falls prevention programs if combined with high-level balance training.

Risk status

A smaller relative effect of exercise on falls is seen when programs are delivered to those at increased risk of falls (based on age, history of falls, risk factors for falls on assessment, or living in a residential aged care facility). Programs conducted in populations where the control group fall rate was more than 2 falls per person year had a 30% smaller effect ($p<0.02$) and this factor explained 17% of the difference between findings with regard to effectiveness in preventing falls of different trials[2].

However as people at higher risk have more falls, the absolute numbers of falls prevented by exercise programs would still be larger when programs are delivered to people at an increased risk of falls (see Appendix 2 for a table that illustrates this point).

Residential care

Fewer trials have been conducted among people in residential aged care settings. A separate meta-analysis of trials conducted in residential care settings did not find evidence of a statistically significant effect of exercise in preventing falls in residential aged care facilities. In nursing homes there was a 10% reduction in the number of falls but this was not statistically significant (i.e. the 95% confidence interval was wide and crossed 1, pooled rate ratio 0.90, 95% CI 0.55 to 1.47). In all residential care settings (i.e. hostels and nursing homes) there was a non-significant 8% reduction in fall rates (pooled rate ratio 0.92, 95% CI 0.75 to 1.13). There was an indication that programs which provided a higher challenge to balance and a higher dose of exercise prevented more falls in these settings.

Additional interventions

Exercise can also be a component of a multifaceted falls prevention program (e.g. Tinetti, Baker, McAvay, et al.[13]). Investigation of multi-facetted interventions to prevent falls is beyond the scope of this review. However, the Stepping On program[14] warrants attention as it was developed in Sydney, has an emphasis on exercise and has been found to prevent falls. The program involves group exercise and education sessions which aim to enhance self-efficacy and encourage participants to learn about the risk of falls and steps they can take to maintain safety.

B. For these activities, what are the minimum requirements in terms of frequency (number of times per week) and intensity (number of minutes per session) that are likely to be effective in preventing falls?

- Programs of at least two hours of exercise a week for a six-month period have a bigger effect on falls.
- Ongoing exercise is likely to be the best way to prevent falls.

In the meta-analysis of exercise trials, a bigger effect of exercise on preventing falls was seen in programs which included more than 50 hours of exercise over the trial period. There was a 20% bigger effect of falls from the higher dose programs and this explained 22% of the variability between different trial results[2].

This total time was achieved in different ways in different trials and often included a combination of group and home exercise (e.g. once a week group exercise supplemented by a home program[15]. Examples of minimal weekly exercise doses would be two exercise sessions of one hour each, or three exercise sessions of 40 minutes each.

It is likely that any benefits of exercise would be lost when exercise is ceased[5]. Therefore programs would need to offer ongoing exercise, or encourage people to undertake ongoing exercise at the end of the program (see Appendix 3 for recommendation from the American College of Sports Medicine about ongoing exercise for older people).

Question 2 What are the most effective programs for delivering these recommended types and levels of physical activity?

- Falls can be prevented by a range of different exercise programs which target balance and provide ongoing exercise.
- These include: the Otago Programme of home-based balance and strength training; group based-Tai Chi; and other group-based balance and strengthening exercise programs.
- Programs should be designed according to the needs of the target population to ensure they provide exercise that is challenging yet safe.

The systematic review of exercise trials found that program design features were less important in predicting the efficacy of the program than the content of the program (i.e. the inclusion of balance training and the overall dose of exercise)[2].

Effective programs have:

- been both home and centre-based;
- recruited participants through GP referral and through general advertisement;
- targeted the general community and those at high risk.

A. What are the characteristics (including recruitment methods, intervention components, duration, and costs) of effective community-based programs?

The characteristics of some of the successful community-based fall prevention exercise programs are outlined in the table below.

Program	Recruitment methods	Intervention components	Duration/ frequency	Costs[a]
Otago Exercise Programme[16-18]. http://www.acc.co.nz/otagoexerciseprogramme).	Letter from General Practitioner, followed by a phone call.	Home-based balance and strength training set up in 4-5 home visits by a physiotherapist or trained nurse, plus phone calls in months where there was no visit.	12 months of home exercise, 3x/week plus a walk 2x/week if suitable.	NZ$1803 (1998 prices) when delivered by nurses[17]. Estimated current costs in Australia are $1091 per participant including travel time, staff training, program supervision by a physiotherapist and administration (using a rate of $72/hour for nurses which includes all on-costs and overheads)[b]. This equates to a monthly cost of $91 per participant. Note that this program may need to be repeated annually for ongoing effectiveness.
Tai Chi[19-22] (includes Voukelatos et al.,[21] Australia).	Advertisements and direct contact in an independent living facility[19]. Physician letter and follow-up phone call[20]. Advertisements in community newspaper[21]. Notices posted in community centres[22].	Group-based Tai Chi. "Gradual reduction of the base of standing support until single limb stance was achieved, increased body and trunk rotation, and reciprocal arm movements."[19] Classic "Yang" style[22] which "emphasizes multidirectional weight shifting, awareness of body alignment, and multisegmental movement coordination"[20]. A mixture of styles[21].	Classes 2x/week for 15 weeks plus encouragement to practice 30 mins per day (45 mins with instructor each week for each participant to individualise program)[19]. 1-hour classes weekly for 16 weeks[21]. 1-hour classes 3x/week for 6 [20] or 12 months[22].	Average current Australian cost of $115/class for Tai Chi instructors[c]. Thus 3x/weekly Tai Chi classes would cost $17,940 to run for 12 months and x1/weekly classes would cost $5980. One study had 8-15 participants per class[21] so with an average of 12 participants the cost for a 12 month program 3x/week would be $1495 per participant. If a 30% administration fee is added the cost is $1943 per participant. Total monthly cost of $162 per participant. Classes could also be delivered weekly with time devoted to individualise home programs at a monthly cost of $109 per participant.

Program	Recruitment methods	Intervention components	Duration/ frequency	Costs[a]
Group exercise: Example 1 (Barnett et al., Australia)[15].	General Practitioners and public hospital physiotherapists invited clients to join if they had falls risk factors which could be addressed by exercise.	Combination of group and home-based balance and strength exercises.	12 months duration, 1 class / week in school terms (37 classes) plus home exercises 1+ times per week.	Classes designed by a physiotherapist and delivered by a fitness leader (estimated costs $50[d] per hour). Mean class size = 9, 1 instructor / class. Excluding costs of program design, supervision and leader training, the estimated cost to deliver this program for 12 months is $1850 or $206 per participant. If a 30% administration fee is added the cost would be $267 per participant. It is estimated that this amount would need to be doubled to safely prescribe and progress the home exercise program. Thus total annual cost per participant is $534 which is a monthly cost per participant of $45 (assuming no travel costs to the venue).
Group exercise : Example 2 (Skelton et al., U.K.[23]).	Posters in emergency departments, fracture clinics, day centers and voluntary organizations, newspaper articles and interviews, radio interviews.	Falls Management Exercise (FaME) based on the Otago Programme with group sessions including more-challenging balance exercises. Al participants had previously had multiple falls.	1-hour classes x1/ week for 36 weeks. Plus home exercise 2x/week for 30 mins.	Led by exercise instructors with additional training. Excluding costs of leader training, the estimated cost to deliver this program for 12 months is $1800 or $300 per participant (assuming 6 participants per class). If a 30% administration fee is added the cost would be $390 per participant. It is estimated that this amount would need to be doubled to safely prescribe and progress the home exercise program. Total cost $780 per participant which is a monthly cost per participant of $65 (assuming no travel costs to the venue).

Key:

[a]Costs are reported here without reference to the outcomes of different programs. It is likely that the more intense programs will have bigger effects (e.g. the 3x/week Tai Chi programs actually prevent more falls than the 1x/week programs see Appendix 2). It may be possible to train less qualified staff to deliver these interventions but provision should be made for training and supervision of these staff members and this has not been factored into the costs. The costs of staff employment will also depend greatly on how they are employed e.g. a casual/contact staff member will cost more per hour than a full time staff member but on-costs would also need to be considered. In addition, we have not individually costed advertising, program administration, and costs of venue hire. Instead we have added a 30% administration fee to each of the programs. A fuller economic analysis would be required to cover each of the above aspects.

[b]This calculation includes travel to participants' homes, advertising and training and staff costs are fully-inclusive of on-costs and overheads (see the link: http://www.dhs.vic.gov.au/rrhacs/businessunits/primaryhealth/fundingapproach/faq).

This figure is from a draft report in: Day, et al. *Modelling the impact, costs and benefits of falls prevention measures to support policy-makers and program planners*, Monash University Accident Research Centre.

[c]The midpoint of a range ($80-$150) of different costs for Tai Chi instructors in Victoria from the draft of Day, et al. *Modelling the impact, costs and benefits of falls prevention measures to support policy-makers and program planners*, Monash University Accident Research Centre.

[d]Information from Sally Castell (Physical Activity Co-ordinator, Northern Sydney Central Coast Area Health Service) that the rate paid to trained fitness leaders to run classes for Northern Sydney Central Coast Area Health Service Healthy Lifestyle programs as at Nov 2008 is $40-44 per hour. Ms Castell estimates that private exercise leaders currently charge approximately $50 per hour.

[e]It is estimated by Jane Louis (Physiotherapy Services Manager, Anglican Retirement Villages) that the costs of a physiotherapist would be around $50 per hour if employed by an organization, or up to $150 per hour on a contract basis. The primary health care rate from Victoria including on-costs and overheads is $81 (see the link:http://www.dhs.vic.gov.au/rrhacs/businessunits/primaryhealth/fundingapproach/faq).

B. What are the characteristics (including recruitment methods, intervention components, duration, and costs) of effective programs in residential aged care settings?

As indicated above, the evidence to support exercise as a single approach in residential aged care settings is limited. However our meta-analysis revealed trends indicating that in residential aged care a) exercise can prevent falls; and b) programs which challenge balance and deliver ongoing exercise are more effective.

Three individual trials have found exercise to prevent falls in residential care settings. The remaining trials are smaller and/or involved interventions which did not prevent falls. Characteristics of the three successful trials are summarised below.

Program	Recruitment methods	Intervention components	Duration/ frequency	Costs
Hostel and retirement village, Lord et al.,(Australia)[24].	Information sessions held with each village/hostel plus individual invitations.	Group based balance and strength exercises.	12-months duration, 2 x 1-hour sessions / week.	Average class size is10-15, 1 trainer per class. Excluding costs of leader training, the estimated cost to deliver this program for 12 months is $5200 or $400 per participant if an average of 13 participants (using an instructor cost of $50). If a 30% administration fee is added, the cost would be $520 per participant. A monthly cost of $43 per participant. In frailer groups a smaller group size would be required, with a monthly cost of $93 per participant for groups of 6.
Low-intensity exercise and incontinence care (Schnelle et al., USA)[25].	Eligible residents identified by nursing home staff and then a direct approach was made to the resident or their designated representative.	Regular supervised sessions of 8x sit-to-stand and walks or wheelchair mobilisation to the toilet and upper body strengthening daily.	Each 2 hours between 8am and 4pm, 5 days a week for 8 months.	Unclear who provided the intervention in the study but if we use a rate of $50 per hour and a time of 20 mins per session, the intervention could cost $3333 per participant. This would be a monthly cost per participant of $417. However it may be possible to train cheaper staff to deliver such interventions. If 30% administration costs are added the costs would be $4333 per participant. This would be a monthly cost per participant of $541.

Program	Recruitment methods	Intervention components	Duration/ frequency	Costs
Individualised visual feedback-based balance training (Sihvonen et al., Finland)[26].	Meeting held at residential care home.	Visual feedback on movement of centre of pressure using a force platform balance measurement and training device.	20-30 minute individualised sessions 3 times a week for 4 weeks.	Unclear who conducted training in this study. Assuming a cost of $50[d] per hour cost for a 4 week program would be $250 per participant. If 30% administration costs are added the monthly cost would be $325 per participant.

Key:

[a]Information from Sally Castell (Physical Activity Co-ordinator) that the rate paid to trained fitness leaders to run classes for Northern Sydney Central Coast Area Health Service Healthy Lifestyle programs as at Nov 2008 is $40-44 per hour. Sally estimates that private exercise leaders currently charge approximately $50 per hour.

C. Are specific types of programs more likely to be effective with particular population sub-groups? (Sub-groups include: people aged 85+ years; people with chronic diseases or functional limitations; people from culturally and linguistically diverse backgrounds; and indigenous people).

People aged 85+ and those with chronic disease or functional limitations are at an increased risk of falls. Therefore, exercise programs must be prescribed carefully to ensure they do not cause the falls they are attempting to prevent. There is evidence that falls can be prevented in people at increased risk of falls through well-designed group exercise programs or by the Otago home-based program[2].

When delivering group programs in these populations, transport and access to venues needs to be considered. A "circuit" design where participants take turns at completing more challenging exercises with more supervision may be of use[27]. In addition, the use of more than one exercise class leader should be considered.

Home programs in this population also need to be carefully designed. The Otago Programme is carefully designed and clearly described in a published and readily available manual (http://www.acc.co.nz/otagoexerciseprogramme).

Many NSW hospitals and health services are already offering physiotherapy-led exercise for people at a high risk of falls[27]. As these usually safely challenge balance they would be expected to prevent falls.

Trials have not specifically investigated the role of exercise in people from culturally and linguistically diverse backgrounds or indigenous people. However, if offered in a culturally-sensitive manner, exercise should also be able prevent falls in these groups. An ongoing project in Sydney is currently evaluating the role of the Stepping On Program[14] which has been adapted for people from a range of ethnic backgrounds.

D. What does the evidence suggest would be the best bets for community based programs and residential aged care programs in NSW?

The best bet would be to deliver exercise programs which safely challenge balance to older people in the general community and community dwellers at an increased risk of falls. This can be done in a group or individual basis and can be delivered in different formats in different settings.

General community

Older people in the general community should be encouraged to undertake ongoing exercise which challenges balance (i.e. which requires participants to stand with their feet closer together or on one leg, minimise use of their hands to assist and practice controlled movements of the body's centre of mass).

Guidance will need to be given to exercise instructors and to the general community about how to safely carry out these exercises (e.g. gradually increase the challenge to balance, have your hand near something to steady yourself).

In order to maximise uptake of interventions which are evidence based, people should be given choice regarding exercise setting (e.g. home or group-based) and program type (e.g. Tai Chi or other group-based balance and strengthening exercise group exercises). It is likely that ongoing adherence and motivation would be better in a group setting but some individuals prefer to exercise alone.

Exercise designed to prevent falls is particularly beneficial for general populations of older people (i.e. not identified as high risk). A higher uptake of exercise in the general population of older people may also be associated with a reduction in falls in the longer term.

Community-dwellers at increased risk

For older people at an increased risk of falls, exercise needs to be carefully prescribed. It is more difficult to safely challenge balance in people at an increased risk of falls. Safe exercise prescription may require the involvement of health professionals in delivering or training others to deliver exercise.

We suggest that exercise designed to prevent falls should also be undertaken in people at an increased risk of falls. Although there is likely to be a lesser relative effect in this population, the absolute number of falls prevented is likely to be greater in this population (see Appendix 2).

Residential care

People in residential care are at a high risk of falls. However, programs which do not sufficiently challenge balance are unlikely to be effective.

Existing evidence indicates that:

- group exercise can be safely provided for residents in hostels or retirement villages; and that

- individual programs that encourage mobility may prevent falls in nursing homes.

We suggest that group programs could also prevent falls in nursing homes if they are delivered with sufficient staff/participant ratios to ensure safety. Several trials of multifaceted interventions in residential care have been conducted in other countries and have found that programs including group exercise can prevent falls[28].

Question 3. Additional interpretation of existing evidence

There is a likely role of mid-life exercise in the prevention of falls among older people. This is very difficult to evaluate in randomised trials due to the long follow-up periods required. Poor balance and impaired muscle strength are associated with falls in older people in observational studies[29]. Unfortunately, both balance and strength deteriorate with age and it is likely that mid-life exercise can offer some protection against this deterioration.

Therefore we suggest that middle-aged people and “younger” older people continue to be encouraged to be as active as possible. Activities such as dancing, golf, tennis, bowls, running, bush walking and group exercise challenge balance and co-ordination and may assist in maintaining these abilities. Strength training (using exercise machines or free weights) may also protect against age-related loss of strength.

Some of these activities could be continued into older age if they are carefully designed so as not to increase the risk of falls and injury. In some countries there are programs of adaptive physical activity which aim to safely offer a range of activities for people with a range of abilities. There is the international Federation of Adaptive Physical Activity (http://www.ifapa.biz/) but such programs are not widely available in NSW.

Summary of important papers, their findings and their relevance to Australia

Below are published abstracts from randomised controlled trials which found exercise programs to prevent falls. Each of these trials was well designed (included concealed allocation to groups and intention to treat analysis) and many were conducted in Australia and New Zealand. We have also included a US-based trial but we consider this to be relevant to Australia also. The published paper from our systematic review is included as Appendix 4.

1. Otago Programme meta-analysis.

This is an analysis of the 3 randomised trials evaluating the Otago home exercise Programme which were conducted in New Zealand[16,17,30]. In the first trial the intervention was delivered by a physiotherapist and in the second two trials the intervention was delivered by a nurse trained by a physiotherapist.

Robertson MC, Campbell AJ, Gardner MM, Devlin N: Preventing injuries in older people by preventing falls: a meta-analysis of individual-level data. *Journal of the American Geriatrics Society* 2002; 50(5): 905-11.

OBJECTIVES: Our falls prevention research group has conducted four controlled trials of a home exercise program to prevent falls in older people. The objectives of this meta-analysis of these trials were to estimate the overall effect of the exercise program on the numbers of falls and fall-related injuries and to identify subgroups that would benefit most from the program. DESIGN: We pooled individual level data from the four trials to investigate the effect of the program in those aged 80 and older, in those with a previous fall, and in men and women. SETTING: Nine cities and towns in New Zealand. PARTICIPANTS: One thousand sixteen community-dwelling women and men aged 65 to 97. INTERVENTION: A program of muscle strengthening and balance retraining exercises designed specifically to prevent falls and individually prescribed and delivered at home by trained health professionals. MEASUREMENTS: Main outcomes were number of falls and number of injuries resulting from falls during the trials. RESULTS: The overall effect of the program was to reduce the number of falls and the number of fall-related injuries by 35% (incidence rate ratio (IRR) = 0.65, 95% confidence interval (CI) = 0.57-0.75; and, respectively IRR = 0.65, 95% CI = 0.53-0.81.) In injury prevention, participants aged 80 and older benefited significantly more from the program than those aged 65 to 79. The program was equally effective in reducing fall rates in those with and without a previous fall, but participants reporting a fall in the previous year had a higher fall rate (IRR = 2.34, 95% CI = 1.64-3.34). The program was equally effective in men and women. CONCLUSION: This exercise program was most effective in reducing fall-related injuries in *those aged 80 and older and resulted in a higher absolute reduction in injurious falls when offered to those with a history of a previous fall.*

2. Tai Chi

The Central Sydney Tai Chi study by Voukelatos et al [21] found a significant effect on falls from weekly Tai Chi classes. However, larger effects were seen in this US-based study of Tai Chi conducted three times per week by Li et al [20].

Voukelatos A, Cumming RG, Lord SR, Rissel C: A randomized, controlled trial of Tai Chi for the prevention of falls: the Central Sydney Tai Chi trial*. Journal of the American Geriatrics Society 2007; 55(8): 1185-91.*

OBJECTIVES: To determine the effectiveness of a 16-week community based Tai Chi program in reducing falls and improving balance in people aged 60 and older. DESIGN: Randomized, controlled trial with waiting list control group. SETTING: Community in Sydney, Australia. PARTICIPANTS: Seven hundred and two relatively healthy community-dwelling people aged 60 and older (mean age 69). INTERVENTION: Sixteen-week program of community-based Tai Chi classes of 1 hour duration per week. MEASUREMENTS: Falls during 16 and 24 weeks of follow-up were assessed using a calendar method. Balance was measured at baseline and 16-week follow-up using six balance tests. RESULTS: Falls were less frequent in the Tai Chi group than in the control group. Using Cox regression and time to first fall, the hazard ratio after 16 weeks was 0.72 (95% confidence interval (CI)=0.51-1.01, P=.06), and after 24 weeks it was 0.67 (95% CI=0.49-0.93, P=.02). There was no difference in the percentage of participants who had one or more falls. There were statistically significant differences in changes in balance favouring the Tai Chi group on five of six balance tests. CONCLUSION: Participation in once per week Tai Chi classes for 16 weeks can prevent falls in relatively healthy community-dwelling older people.

Li F, Harmer P, Fisher KJ, et al.: Tai Chi and fall reductions in older adults: a randomized controlled trial. *Journals of Gerontology Series A-Biological Sciences & Medical Sciences.* 2005; 60(2): 187-94.

BACKGROUND: The authors' objective was to evaluate the efficacy of a 6-month Tai Chi intervention for decreasing the number of falls and the risk for falling in older persons. METHODS: This randomized controlled trial involved a sample of 256 physically inactive, community-dwelling adults aged 70 to 92 (mean age, 77.48 years; standard deviation, 4.95 *years) who were recruited through a patient database in Portland, Oregon. Participants were randomized to participate in a three-times-per-week Tai Chi group or to a stretching control group for 6 months. The primary outcome measure was the number of falls; the secondary outcome measures included functional balance (Berg Balance Scale, Dynamic Gait Index, Functional Reach, and single-leg standing), physical performance (50-foot speed walk, Up&Go), and fear of falling, assessed at baseline, 3 months, 6 months (intervention termination), and at a 6-month post intervention follow-up. RESULTS: At the end of the 6-month intervention, significantly fewer falls (n=38 vs 73; p=.007), lower proportions of fallers (28% vs 46%; p=.01), and fewer injurious falls (7% vs 18%; p=.03) were observed in the Tai Chi group compared with the stretching control group. After adjusting for baseline covariates, the risk for multiple falls in the Tai Chi group was 55% lower than that of the stretching control group (risk ratio,.45; 95% confidence interval, 0.30 to 0.70). Compared with the stretching control participants, the Tai Chi participants showed significant improvements (p<.001) in all measures of functional balance, physical performance, and reduced fear of falling. Intervention gains in these measures were maintained at a 6-month post intervention follow-up in the Tai Chi group. CONCLUSIONS: A three-times-per-week, 6-month Tai Chi program is effective in decreasing the number of falls, the risk for falling, and the fear of falling, and it improves functional balance and physical performance in physically inactive persons aged 70 years or older.*

3. Group-based balance and strengthening exercise

This study was conducted in South West Sydney. The intervention comprised weekly 1-hour group-based exercise sessions for 12 months combined with home exercises.

Barnett A, Smith B, Lord SR, Williams M, Bauman A: Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. *Age & Ageing.* 2003; 32(4): 407-14.

BACKGROUND: Recent studies have found that moderate-intensity exercise is an effective intervention strategy for preventing falls in older people. However, research is required to determine whether supervised group exercise Tai Chimes, conducted in community settings with at-risk older people referred by their health care practitioner are also effective in improving physical functioning and preventing falls in this group. OBJECTIVES: to determine whether participation in a weekly group exercise program with ancillary home exercises over one year improves balance, muscle strength, reaction time, physical functioning, health status and prevents falls in at-risk community-dwelling older people. METHODS: the sample comprised 163 people aged over 65 years identified as at risk of falling using a standardised assessment screen by their general practitioner or hospital based physiotherapist, residing in South

Western Sydney, Australia. Subjects were randomised into either an exercise intervention group or a control group. Physical performance and general health measures were assessed at baseline and repeated 6-months into the trial. Falls were measured over a 12-month follow-up period using monthly postal surveys. RESULTS: At baseline both groups were well matched in their physical performance, health and activity levels. The intervention subjects attended a median of 23 exercise classes over the year, and most undertook the home exercise sessions at least weekly. At retest, the exercise group performed significantly better than the controls in three of six balance measures; postural sway on the floor with eyes open and eyes closed and coordinated stability. The groups did not differ at retest in measures of strength, reaction time and walking speed or on Short-Form 36, Physical Activity Scale for the Elderly or fear of falling scales. Within the 12-month trial period, the rate of falls in the intervention group was 40% lower than that of the control group (IRR=0.60, 95% CI 0.36-0.99). CONCLUSIONS: These findings indicate that participation in a weekly group exercise program with ancillary home exercises can improve balance and reduce the rate of falling in at-risk community-dwelling older people.

This study was conducted in 20 retirement village and hostels in the Greater Sydney and Illawarra regions. The intervention comprised a 12-month program of twice-weekly 1-hour group-based balance and strength training.

Lord SR, Castell S, Corcoran J, et al.: The effect of group exercise on physical functioning and falls in frail older people living in retirement villages: a randomized, controlled trial. *Journal of the American Geriatrics Society. 2003; 51(12): 1685-92.*

OBJECTIVES: To determine whether a 12-month program of group exercise can improve physical functioning and reduce the rate of falling in frail older people. DESIGN: Cluster randomized, controlled trial of 12 months duration. SETTING: Retirement villages in Sydney and Wollongong, Australia. PARTICIPANTS: Five hundred fifty-one people aged 62 to 95 (mean+/-standard deviation=79.5+/-6.4) who were living in self- and intermediate-care retirement villages. MEASUREMENTS: Accidental falls, choice stepping reaction time, 6-minute walk distance postural sway, leaning balance, simple reaction time, and lower-limb muscle strength. RESULTS: Two hundred eighty subjects were randomized to the weight-bearing group exercise (GE) intervention that was designed to improve the ability of subjects to undertake activities for daily living. Subjects randomized to the control arm (n=271) attended flexibility and relaxation (FR) classes (n=90) or did not participate in a group activity (n=181). In spite of the reduced precision of cluster randomization, there were few differences in the baseline characteristics of the GE and combined control (CC) subjects, although the mean age of the GE group was higher than that of the CC group, and there were fewer men in the GE group. The mean number of classes attended was 39.4+/-28.7 for the GE subjects and 31.5+/-25.2 for the FR subjects. After adjusting for age and sex, there were 22% fewer falls during the *trial in the GE group than in the CC group (incident rate ratio=0.78, 95% confidence interval (CI)=0.62-0.99), and 31% fewer falls in the 173 subjects who had fallen in the past year (incident rate ratio=0.69, 95% CI=0.48-0.99). At 6-month retest, the GE group performed significantly better than the CC group in tests of choice stepping reaction time, 6-minute walking distance, and simple reaction time requiring a hand press. The groups did not differ at retest in tests of strength, sway, or leaning balance. CONCLUSION: These findings show that group exercise can prevent falls and maintain physical functioning in frail older people.*

Conclusions

1 What are the types, frequency and intensity of physical activity that are most effective in reducing the risk of falls in older adults?

Exercise programs which included highly challenging balance training are the most effective in preventing falls. These programs include: exercises conducted whilst standing in which participants aim to: a) stand with their feet closer together or on one leg b) minimise use of their hands to assist balance; and c) practice controlled movements of the body's centre of mass.

There are bigger effects of exercise on falls from programs which included a higher dose of exercise (e.g. a dose of more than 50 hours of exercise). It is likely that exercise needs to be ongoing to have a lasting effect on fall rates.

2 What are the most effective programs for delivering these recommended types and levels of physical activity?

Falls can be prevented by a range of exercise programs which target balance and provide ongoing exercise.

These include: the Otago Programme of home-based balance and strength training, group based Tai Chi and other group-based balance and strengthening exercise.

Programs should be designed according to the needs of the target population to ensure they provide exercise that is challenging yet safe.

3 Main gaps in research in this area

The main research gaps in this area relate to a paucity of trials investigating dance, organized activities (bowls, golf etc.), walking and strength training as single interventions. There are also gaps regarding direct comparisons of different exercise interventions. It has not been demonstrated prospectively whether mid-life exercise can prevent falls in older age or whether exercise can prevent fall-related fractures in an appropriately designed and powered randomised controlled trial. There have also been few large scale trials of exercise in residential care. The relative benefit of exercise as a single intervention versus multiple interventions also requires further investigation.

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Appendix 1.

Updated Search Results

Our updated search (October 08) found three extra randomised controlled trials investigating the effect of exercise on falls. The inclusion of these in the meta-analysis would not have significantly altered the findings.

1. Ashburn A, Fazarkarley L, Ballinger C, Pickering R, McLellan LD, and Fitton C. A randomized controlled trial of a home-based exercise programme to reduce the risk of falling among people with Parkinson's disease. *J. Neurol. Neurosurg. Psychiatry*. 2007; 78:68-684.

2. Beyer N, Simonsen L, Bulow J, Lorenzen T, Jensen DV, Larsen L, Rasmussen U, Rennie M, and Kjaer M. Old women with a recent fall history show improved muscle strength and function sustained for six months after finishing training. *Aging Clin. Exp. Res*. 2007; 19: 300-309.

3. Rosendahl, E., et al., A randomized controlled trial of fall prevention by a high-intensity functional exercise program for older people living in residential care facilities. *Aging Clin Exp Res.* 2008. 20(1): p. 67-75

Appendix 2.

Calculation regarding falls per 100 person years prevented in trials with different combinations of features in different population.

↓Falls per 100 person yr	Balance + high dose	Balance	Balance + high dose + walking	Dose
General older population	**Tai Chi** 27 Woo[22] 42 Li[20] 155 Wolf[19]	**Tai Chi** 25 Voukelatos[21] **Group** 30 Suzuki[31]	**Group** 47 Madureira[32]	**Group** 15 McMurdo[33]
Study population at increased risk	**Group** 100 Skelton[23]	**Balance** 97 Sihvonen[26]	**Otago Home Exercise** 43 Campbell[16] 47 Robertson[17] **Group** 19 Lord[34] 39 Barnett[15]	**Strength/endurance** 32 Buchner[35]

Appendix 3.

Extract from the American College of Sports Medicine recommendations (2007 update: adapted)[5]

1. To promote and maintain good health, older adults should maintain a physically active lifestyle. I (A) (See box below).

2. They should perform moderate-intensity aerobic (endurance) physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic activity for a minimum of 20 min on three days each week. I (A) Moderate-intensity aerobic activity involves a moderate level of effort relative to an individual's aerobic fitness. On a 10-point scale, where sitting is 0 and all-out effort is 10, moderate-intensity activity is a 5 or 6 and produces noticeable increases in heart rate and breathing. On the same scale, vigorous-intensity activity is a 7 or 8 and produces large increases in heart rate and breathing. For example, given the heterogeneity of fitness levels in older adults, for some older adults a moderate-intensity walk is a slow walk, and for others it is a brisk walk.

3. Combinations of moderate- and vigorous-intensity activity can be performed to meet this recommendation. IIa (B) These moderate- or vigorous-intensity activities are in addition to the light-intensity activities frequently performed during daily life (e.g. self care, washing dishes) or moderate-intensity activities lasting 10 min or less (e.g. taking out trash, walking to parking lot at store or office).

4. In addition, at least twice each week older adults should perform muscle strengthening activities using the major muscles of the body that maintain or increase muscular strength and endurance. IIa (A) It is recommended that 8–10 exercises be performed on at least two nonconsecutive days per week using the major muscle groups. To maximize strength development, a resistance (weight) should be used that allows 10–15 repetitions for each exercise. The level of effort for muscle-strengthening activities should be moderate to high.

5. Because of the dose-response relationship between physical activity and health, older persons who wish to further improve their personal fitness, reduce their risk for chronic diseases and disabilities, or prevent unhealthy weight gain will likely benefit by exceeding the minimum recommended amount of physical activity. I (A)

6. To maintain the flexibility necessary for regular physical activity and daily life, older adults should perform activities that maintain or increase flexibility on at least two days each week for at least 10 min each day. IIb (B)

7. To reduce risk of injury from falls, community-dwelling older adults with substantial risk of falls should perform exercises that maintain or improve balance. IIa (A)

8. Older adults with one or more medical conditions for which physical activity is therapeutic should perform physical activity in a manner that effectively and safely treats the condition(s). IIa (A)

9. Older adults should have a plan for obtaining sufficient physical activity that addresses each recommended type of activity. IIa (C) Those with chronic conditions for which activity is therapeutic should have a single plan that integrates prevention and treatment. For older adults who are not active at recommended levels, plans should include a gradual (or stepwise) approach to increase physical activity over time. Many months of activity at less than recommended levels is appropriate for some older adults (e.g. those with low fitness) as they increase activity in a stepwise manner. Older adults should also be encouraged to self-monitor their physical activity on a regular basis and to reevaluate plans as their abilities improve or as their health status changes.

Box: ACC/AHA approach to assigning the classification of recommendations and level of evidence.

Classifications of recommendation (COR) I, II, and III are used to summarize indications (suggested phrases for writing recommendations)

Class I: Conditions for which there is evidence and/or general agreement that a given procedure or treatment is useful and effective (should; is recommended; is indicated; is useful/effective, beneficial)

Class II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment

IIa: Weight of evidence/opinion is in favor of usefulness/efficacy (is reasonable; can be useful, effective or beneficial; is probably recommended or indicated)

IIb: Usefulness/efficacy is less well established by evidence/opinion (may/might be considered, may/might be reasonable, usefulness/effectiveness is unknown, unclear/uncertain or not well established)

Class III: Conditions for which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful

(is not recommended; is not indicated; should not; is not useful/effective, beneficial; may be harmful)

Levels of evidence (LOE) for individual class assignments (with suggested language to be used with each level)

A: Data derived from multiple randomized clinical trials

B: Data derived from a single randomized trial or from nonrandomized studies

C: Consensus opinion of experts

Effective Exercise for the Prevention of Falls: A Systematic Review and Meta-Analysis

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OBJECTIVES: To determine the effects of exercise on falls prevention in older people and establish whether particular trial characteristics or components of exercise programs are associated with larger reductions in falls.

DESIGN: Systematic review with meta-analysis. Randomized controlled trials that compared fall rates in older people who undertook exercise programs with fall rates in those who did not exercise were included.

SETTING: Older people.

PARTICIPANTS: General community and residential care.

MEASUREMENTS: Fall rates.

RESULTS: The pooled estimate of the effect of exercise was that it reduced the rate of falling by 17% (44 trials with 9,603 participants, rate ratio (RR) = 0.83, 95% confidence interval (CI) = 0.75–0.91, $P < .001$, $I^2 = 62\%$). The greatest relative effects of exercise on fall rates (RR = 0.58, 95% CI = 0.48–0.69, 68% of between-study variability explained) were seen in programs that included a combination of a higher total dose of exercise (> 50 hours over the trial period) and challenging balance exercises (exercises conducted while standing in which people aimed to stand with their feet closer together or on one leg, minimize use of their hands to assist, and practice controlled movements of the center of mass) and did not include a walking program.

CONCLUSION: Exercise can prevent falls in older people. Greater relative effects are seen in programs that include exercises that challenge balance, use a higher dose of exercise, and do not include a walking program. Service providers can use these findings to design and implement exercise programs for falls prevention. **J Am Geriatr Soc 56:2234–2243, 2008.**

Key words: falls; exercise; meta-analysis

The development and implementation of effective and cost-efficient strategies to prevent falls in older people is an urgent global health challenge. In developed countries, life expectancy for people aged 65 years old is approximately 17 years for men and 21 years for women. At least one-third of people aged 65 and older fall at least once annually,[1] and falls account for more than half of the injury-related hospitalizations for older people.[2] Fall rates in the general older population are reported to be 1.2 falls per person year.[3]

Falls in older people are not purely random events but can be predicted by assessing a number of risk factors.[4,5] Some of these risk factors (e.g., reduced muscle strength and impaired balance and gait) can be modified using exercise, whereas others (e.g., poor vision, psychoactive medication use) require different intervention approaches. Exercise can be used as a stand-alone falls prevention intervention or as a component of a multifaceted program. Multifaceted interventions can prevent falls in the general community, in those at greater risk of falls, and in residential care facilities.[4,6]

Many trials have sought to establish the specific effect of exercise on fall rates, but a large proportion of these trials have been underpowered. The best way to interpret these trials may be to pool their data in a meta-analysis, but trials of the effects of exercise on fall rates vary in their quality, have been conducted on a range of populations, and employ exercise programs that differ greatly in their aims and content. Meta-analysis should therefore involve exploration of whether these factors "explain" (are associated with) estimates of the effect of exercise programs.[7,8]

A Cochrane review of fall prevention strategies[6] conducted separate meta-analyses on different forms of exercise and concluded that some exercise programs can prevent falls in community dwellers (e.g., home exercise program of balance and strength training, a Tai Chi group program) but

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DOI: 10.1111/j.1532-5415.2008.02014.x

0002-8614/08/$15.00

that others are unlikely to be beneficial (brisk walking in women with an upper limb fracture in the previous 2 years) or require further investigation (untargeted group-based exercise interventions and individual lower-limb strength training). A limitation to this approach is that it combines programs that may be different (e.g., group programs that are of low and high intensity) and separates programs that share key features (e.g., balance training).

This study sought to establish the effect of exercise on fall rates, with a major aim of explaining between-trial variability. Meta-regression methods were used to investigate whether particular features of study populations, exercise programs, and study design were associated with the size of estimates of effects of exercise on fall rates.

METHODS

Data Sources and Searches

A literature search was conducted in May 2007. OVID was used to search MEDLINE, EMBASE, and CINAHL. Search filters developed by the Scottish Intercollegiate Guidelines Network (SIGN; http://www.sign.ac.uk/methodology/filters.html) to identify randomized trials were combined with a strategy to identify studies of the effects of exercise (available from the authors on request) and search terms from the relevant Cochrane review[6] (to identify studies of falls prevention). The search was supplemented with searches of PubMed, the Physiotherapy Evidence Database (http://www.pedro.fhs.usyd.edu.au), SafetyLit (http://www.safetylit.org/archive.htm), and Prevention of Falls Network Europe (ProFaNE; http://www.profane.eu.org/). The reference list of the Cochrane review[6] and other reviews and the updated search results provided by the trial search coordinator of the Cochrane Bone, Joint and Muscle Trauma Group were also checked.

Study Selection

Published randomized trials conducted in older people in which the primary intervention being evaluated was exercise and the outcome was number of falls, number of fallers, or rate of falls were reviewed. Trials were ineligible if nonexercise interventions were a major (>25% of time) component of the intervention being evaluated.

To determine eligibility of identified trial reports, two investigators (CS, RDH) independently scanned titles and abstracts. If it was clear that the control group received exercise or the intervention program involved substantial (>25% of time) additional nonexercise interventions, the study was excluded. The full articles were obtained for the remaining titles. Differences of opinion of the two investigators about study eligibility were resolved by discussion.

Data Extraction and Quality Assessment

Two of the authors (CS and SRL or JCTC) extracted data on study characteristics and estimates of effect of exercise from each study. Differences were resolved by discussion with a third investigator (SRL or JCTC).

The quality of study design was assessed by noting whether allocation to groups was concealed and analysis was according to intention to treat.[9]

The studies were described in terms of population (dwelling situation and risk status), presence and intensity of different exercise program components (addressing strength, balance, endurance, flexibility, and walking), broad aspects of the exercise program (amount of supervision, progression of exercises, modifying in type or intensity of exercise, adherence to program and overall dose of exercise), and study design (concealed allocation to groups and intention-to-treat analysis). Criteria for coding are summarized in Table 1. The majority of characteristics were coded on 3- to 5-point scales, but all were dichotomized a priori for the analysis. For several variables, analyses were conducted using two different cutpoints for dichotomization. The cutpoint that explained the most variability was used and is reported in the tables.

Five of the trials had two exercise groups and one control group. For these trials, estimates of the effects of each exercise intervention were obtained. To avoid "double counting" of control subjects from these trials, the total falls and subject numbers in the control group were allocated in proportion to the participant numbers in each intervention group. There were thus 49 comparisons in the meta-analysis.

Estimates of the effect of exercise were extracted from each trial. Where possible, estimates of incidence rate ratios (IRRs) from negative binomial regression models (6 studies), person-time analyses (1 study), or hazard ratios from proportional hazards models that allowed for multiple falls per person (6 trials) were used. Alternatively, data on the total number of falls (n = 20) or number of falls per person (n = 6) and exposure times (person-years of follow-up using actual follow-up times and number of participants providing data where reported) were used to calculate IRRs. Three trials reported only the incidence proportions of fallers in intervention and control groups, and two trials reported only the hazard ratios for time to first fall. For these trials, the ratio of incidence proportions or the hazard ratio was used as an estimate of the IRR. Where possible, unadjusted falls rates and longer follow-up times were used (e.g., in an article such as[10], which presented 6- and 12-month falls data, the 12-month data were used).

Four of the trials were cluster-randomized. Two of these accounted for the effect of clustering. For the other two, the variance of estimates for clustering was adjusted by assuming an intracluster correlation of 0.01.[11,12]

Data Synthesis and Analysis

A random-effects meta-analysis was conducted. Comprehensive Meta-Analysis software (Version 2, Biostat, Englewood NJ) was used to calculate a pooled IRR. Statistical heterogeneity was quantified with the I[13] and Q statistics. Publication bias was assessed using Egger's test. The pooled effect was also calculated in STATA (Stata Corp., College Station, TX) using the "metan" command.[14] Influence was assessed in STATA using the "metaninf" command.[14]

Sensitivity analyses were conducted to assess the effect of excluding the trials for which only risk ratios or hazard ratios were available and excluding the cluster randomized trials.

Appendix 4: Published systematic review on exercise to prevent falls

Table 1. Summary of Included Trials (n = 44) and Comparisons (n = 49) Showing Control Group Fall Rate over Follow-Up Period, Sample Size, Length of Follow-Up, Estimate of Effect of Intervention, and Number and Percentage of Trials with Each Population, Program, or Study Quality Descriptor

First Author, Year, and Program Type If Two Intervention Groups	Control Group Falls/ Person-Year or % Who Fell During Follow-Up Period	Data Extracted	Sample Size at Randomization	Follow-Up (Months)	Estimate of Fall Rate Ratio (95% CI)	High-Support Residential Care[a]	Population at Greater Risk[b]	Average Age 75 and Older	Moderate-to High-Intensity Strength Training[c]	High-Challenge Balance Training[d]	Moderate-to High-Intensity Endurance Training[e]	Stretching Program[f]	Walking Program[g]	Moderatly to Highly Supervised Exercise[h]	Exercises Progressed Weekly or More[i]	Exercises Modified in Type or Intensity[j]	Good Adherence[k]	50+Total Hours of Exercise[l]	Concealed Allocation to Groups[m]	Intention to Treat Analysis[n]
Barnett, 2003[30]	0.97	IRR	163	12	0.60 (0.36–0.99)	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y
Bunout, 2005[31]	0.18	F/PY	298	12	1.22 (0.70–2.14)	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	N
Buchner, 1997[32]	0.81	Rate Ratio	105	25	0.61 (0.39–0.93)	N	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	N	Y
Campbell, 1997[33]	1.34	HR-4	233	12	0.68 (0.52–0.90)	N	Y	Y	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	Y
Campbell, 1999[34]	0.97	HR-M	93	10	0.87 (0.36–2.09)	N	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y
Campbell, 2005[35]	1.13	IRR	391	12	1.15 (0.82–1.61)	N	Y	Y	Y	Y	Y	N	Y	N	N	Y	N	Y	Y	Y
Carter, 2002[36]	0.52	F/PY	93	5	0.88 (0.32–2.41)	N	N	N	N	N	N	Y	N	N	N	Y	Y	N	N	N
Cerny, 1998[37]	0.46	F/PY	28	6	0.87 (0.17–4.29)	N	N	N	Y	N	Y	Y	Y	N	N	N	N	Y	N	N
Day, 2002[38]	64%	HR-M	1090	18	0.82 (0.70–0.97)	N	N	Y	N	N	N	N	N	N	N	N	Y	N	Y	Y
Ebrahim, 1997[39]	0.55	F/PY	165	24	1.29 (0.90–1.83)	N	Y	N	N	N	Y	N	Y	N	N	Y	Y	Y	Y	N
Faber, 2006[40] "Functional walking"	2.50	FR	278	12	1.32 (1.03–1.69)	N	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	N	N	N
Tai Chi					0.96 (0.76–1.22)	N	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	N	N	N
Green, 2002[41]	31%	Risk ratio	170	9	1.34 (0.87–2.07)	N	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	Y	Y
Hauer, 2001[42]	60%	Risk ratio	57	6	0.75 (0.46–1.25)	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Korpelainen, 2006[43]	0.53	F/PY	160	30	0.79 (0.59–1.05)	N	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Latham, 2003[44]	2.7	F/PY	243	6	1.08 (0.87–1.35)	N	Y	Y	Y	N	N	Y	N	N	Y	Y	Y	N	Y	Y
Li, 2005[10]	0.76	F/PY	256	12	0.45 (0.33–0.62)	N	N	Y	N	Y	N	N	N	N	N	N	Y	Y	N	Y
Lin, 2007[45]	0.88[j]	FR	150	6	0.67 (0.32–1.41)j	N	Y	Y	N	Y	N	Y	Y	N	Y	Y	N	N	N	N
Lord, 1995[46]	0.63	F/PY	197	12	0.85 (0.57–1.27)	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	N	N
Lord, 2003[47]	0.85	IRR (cl)	551	12	0.78 (0.62–0.99)	N	Y	Y	N	Y	Y	Y	Y	N	N	N	N	Y	N	Y
Liu-Ambrose, 2004[48] strength	0.65	F/PY	104	6	1.8 (0.67–4.85)	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	Y
Agility					1.03 (0.36–2.98)	N	N	Y	N	Y	Y	N	N	Y	N	N	Y	N	N	Y
Luukinen, 2007[49]	1.23	HR-M	486	16	0.93 (0.80–1.09)	N	Y	Y	N	N	N	N	Y	N	N	Y	N	Y	N	Y
McMurdo, 1997[50]	0.32	F/PY	118	24	0.53 (0.28–0.98)	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
Madureira, 2007[51]	0.90	FR	66	12	0.48 (0.25–0.93)	N	N	N	N	Y	N	Y	Y	N	N	N	Y	Y	N	N
Means, 2005[52]	1.18	FR	338	6	0.41 (0.21–0.77)	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	N
Morgan, 2004[53]	31%	HR	294	12	1.05 (0.66–1.68)	N	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	N	N	Y
Mulrow, 1994[54]	2.05	F/PY	194	4	1.26 (0.90–1.76)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	Y	N
Nowalk, 2001[55] strength/endurance	75%	Risk ratio	112	24	0.96 (0.63–1.46)	N	Y	Y	Y	N	Y	N	Y	N	N	Y	Y	N	N	N
Tai Chi					0.77 (0.46–1.28)	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
Protas, 2005[56]	37.6	F/PY	18	0.5	0.62 (0.26–1.48)	N	Y	N	N	Y	Y	N	Y	Y	N	Y	Y	N	N	Y
Reinsch, 1992[57]	40%	HR (cl)	230	12	1.24 (0.77–1.98)	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
Resnick, 2002[58]	0.56	FR	20	6	0.71 (0.04–11.58)	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	N	N	N
Robertson, 2001[59]	1.01	IRR	240	12	0.54 (0.32–0.91)	N	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y

(Continued)

Table 1. (Contd.)

First Author, Year, and Program Type If Two Intervention Groups	Control Group Falls/Person-Year or % Who Fell During Follow-Up Period	Data Extracted	Sample Size at Randomization	Follow-Up (Months)	Estimate of Fall Rate Ratio (95% CI)	High-Support Residential Care[a]	Population at Greater Risk[b]	Average Age 75 and Older	Moderate-to High-Intensity Strength Training[c]	High-Challenge Balance Training[d]	Moderate-to High-Intensity Endurance Training[e]	Stretching Program[f]	Walking Program[g]	Moderatly to Highly Supervised Exercise[h]	Exercises Progressed Weekly or More[i]	Exercises Modified in Type or Intensity[j]	Good Adherence[k]	50+Total Hours of Exercise[l]	Concealed Allocation to Groups[m]	Intention to Treat Analysis[n]
Rubenstein, 2000[60]	2.25	F/PY	59	3	0.90 (0.42–1.91)	N	Y	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	N
Sakamoto, 2006[61]	1.14	F/PY	553	6	0.82 (0.64–1.04)	Y	Y	Y	N	N	N	N	N	Y	N	N	Y	N	N	N
Schoenfelder, 2000[62]	3.43	F/PY	16	6	3.06 (1.61–5.82)	Y	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N
Schnelle, 2003[63]	0.69	F/PY	190	8	0.62 (0.38–0.98)	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N
Sihvonen, 2004[64]	1.57	F/PY	27	12	0.38 (0.17–0.87)	Y	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y	N
Skelton, 2005[21]	3.21	IRR	100	20	0.69 (0.50–0.96)	N	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y
Steinberg, 2000[65]	0.85	FR (cl)	252	17	0.90 (0.79–1.03)	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Suzuki, 2004[66]	0.46	F/PY	52	20	0.35 (0.14–0.90)	N	N	Y	Y	Y	N	N	N	N	N	N	Y	N	N	Y
Toulotte, 2003[67]	1.95	F/PY	20	4	0.08 (0.00–1.37)	Y	Y	Y	N	Y	N	N	Y	Y	N	N	Y	N	N	N
Voukelatos, 2007[68]	0.74[j]	IRR	702	6	0.67 (0.46–0.97)	N	N	N	N	Y	N	N	N	N	N	N	Y	N	Y	Y
Wolf, 1996[69] Tai Chi	3.18	HR-M	200	20	0.51 (0.36–0.73)	N	N	Y	N	Y	N	N	N	N	N	N	Y	Y	N	N
Balance					0.98 (0.71–1.34)	N	N	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N
Wolf, 2003[70]	60%	HR-M (cl)	311	11	0.75 (0.52–1.08)	N	Y	Y	N	Y	N	N	N	N	N	N	Y	Y	N	Y
Woo, 2007[22] Tai Chi	0.52	F/PY	180	12	0.49 (0.24–0.99)	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	Y	N
Strength					0.78 (0.41–1.48)	N	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	N
Total, n (%)						6 (12)	29 (59)	32 (65)	19 (39)	25 (51)	20 (41)	12 (24)	27 (55)	23 (47)	14 (29)	28 (57)	41 (84)	25 (51)	16 (33)	22 (45)

[a] Mainly high-support care facility (nursing home) residents.
[b] The presence of a particular falls risk factor was used as inclusion criteria to the study, or the entire population was known to be at greater risk (e.g., aged care facility residents, aged ≥75, impaired strength or balance, previous falls).
[c] Moderate intensity (40–60% of the one repetition maximum (1RM; i.e., a weight so heavy that it can only be lifted once) or high intensity (>60% 1RM).
[d] Moderately challenging = two of the following criteria or highly challenging = all three criteria: movement of the center of mass, narrowing of the base of support, and minimizing upper limb support.
[e] Moderate intensity = 40% to 60% of maximum heart rate, some increase in breathing or heart rate, or perceived exertion of 11 to 14 on the Borg scale; high intensity = >60% of maximum heart rate or heart rate reserve, large increase in breathing or heart rate (conversation is difficult or broken), or perceived exertion of ≥15 on the Borg scale.
[f] Short- or long-duration stretches were specifically mentioned.
[g] Walking program or practice was specifically mentioned.
[h] 10 or fewer participants per instructor.
[i] Most exercises progressed at least weekly.
[j] Type or intensity of most exercises was designed for each individual based on an assessment.
[k] ≥75% participants attended 50% or more sessions or >50% attendance rate.
[l] ≥50 hours of exercise with instructor plus prescribed home exercise over study period.
[m,n] Coded using PEDro rating scale[71] http://www.pedro.fhs.usyd.edu.au.
[j] Additional data provided by the author.
IRR = incidence rate ratios from analysis with negative binomial models from trial reports; F/PY = Falls per person-year (by group) were used to calculate rate ratio; rate ratio = rate ratio from trial reports ; FR = fall rates (by group) were used to calculate rate ratios; HR = hazard ratio from Cox models or survival analyses considering time to first fall in trial reports; HR-M = hazard ratio from extensions to Cox models that allow for multiple events from trial reports; HR-4 = hazard ratio from extensions to Cox models that allow for up to four events from trial reports; Risk ratio = risk ratio was calculated from the proportion of fallers in each group; cl = cluster randomized trials; N = no; Y = yes.

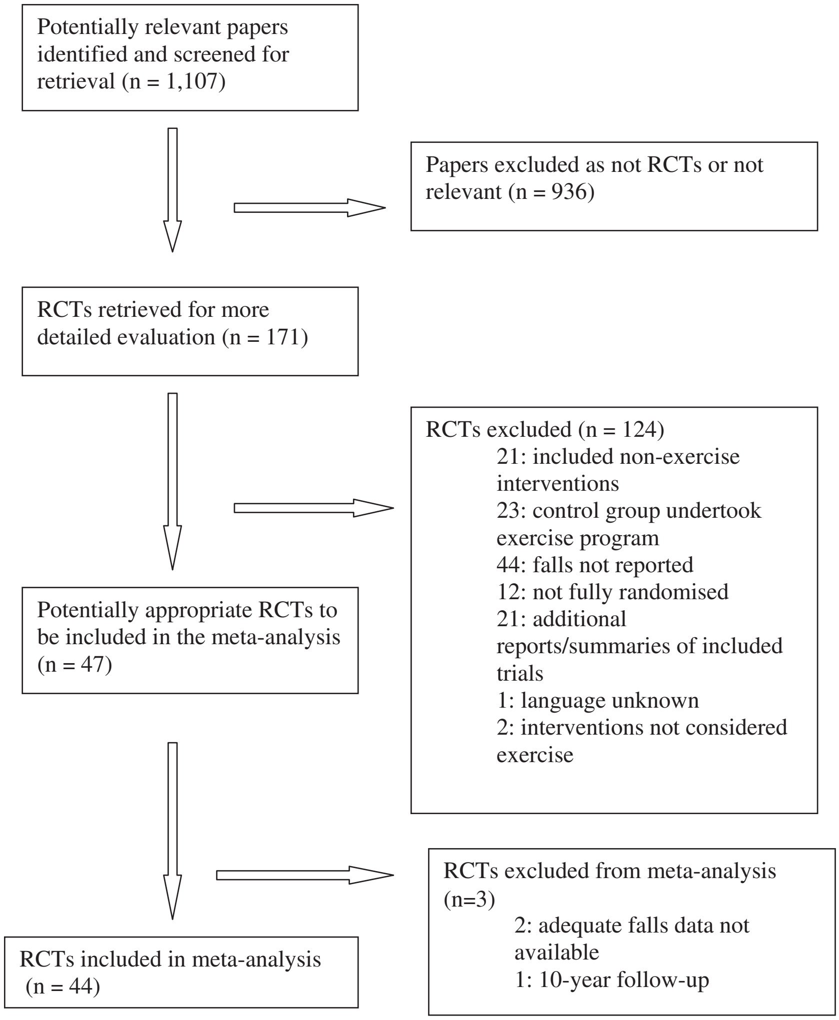

Figure 1. QUOROM statement[16] flow diagram.

Heterogeneity was investigated with random effects meta-regression using the "metareg" command in STATA.[14] Univariate meta-regressions were conducted to assess the associations between each study characteristic and estimates of the effect of exercise. The five strongest predictors were then entered into a multivariate model, and a backwards elimination approach was used to remove those that did not contribute significantly to the model.[15] The best model was identified by examining the proportion of overall between-trial variability explained by each model (as assessed using the τ^2 statistic). Subsequent models were then assessed to determine whether other combinations of the five variables that explained the most variance in the univariate analyses could account for similar variability in exercise effect. The exponentiated coefficients of the meta-regression models were the "ratio of rate ratios," which estimate of the effect of each variable or combination of variables on the effect of exercise on fall rates. The "lincom" command in STATA was used to assess the effect of specific combinations of variables from the multivariate models on the pooled effect of exercise on fall rates.

To assess the extent of correlation between variables, phi coefficients were calculated for each pair of variables in the models using SPSS (SPSS, Inc., Chicago, IL). Pairs of variables were not included in the same models if they had phi correlation coefficients greater than 0.6.

RESULTS

Trial Flow and Study Characteristics

Searching yielded 171 trials, of which 47 were potentially appropriate for inclusion in the meta-analysis (Figure 1).[16] Two trials were then excluded, because they did not report sufficient data to estimate effects of exercise on falls, and one trial was excluded because it presented only 10-year follow-up data. Five trials had two intervention groups, so the 44 included trials yielded 49 estimates of the effects of exercise. The included trials involved a total of 9,603 participants. Characteristics of the trials are summarized in Table 1. The majority of trials were conducted in older people living in the general community; six trials were conducted in residents of high care residential facilities (nursing homes). Twenty-nine trials included only participants who could be defined as being at greater risk of falls. Most of the exercise programs (n = 23) evaluated in the trials were conducted under supervision, with fewer than 10 participants per instructor. In most of the programs, the intensity or type of exercise was tailored to the individual (n = 28).

Effects of Exercise on Fall Rates

The pooled estimate of the incidence rate ratio (the effect of exercise on fall rates) was 0.83 (95% confidence interval (CI) = 0.75–0.91, $P < .001$). There was a moderate to high level of heterogeneity in estimates of the effects of exercise ($I^2 = 62\%$, Q = 125.5, degrees of freedom (df) = 48, $P < .001$; Figure 2). No study exerted excessive influence, because omission of any single study had little effect on the pooled estimate (the 95% CIs remained between 0.74 and 0.92). There was no conclusive evidence of small sample bias (Egger's Test of the Intercept $B0 = -0.675$, 95% CI = -4.10–0.06, $t = 1.544$, $df = 47$, $P = .13$, and the funnel plot of standard error and log rate ratio was quite symmetrical). Sensitivity analysis revealed similar effects when the meta-analysis was conducted without the five trials for which only proportion of fallers or time to first fall were available (pooled RR = 0.80, 95% CI = 0.73–0.89, 43 comparisons) and when the four cluster randomized trials were omitted (pooled RR = 0.82, 95% CI = 0.73–0.91, 44 comparisons).

Trial-Level Determinants of Effects of Exercise

The proportion of between-study variability in effect sizes (effects of exercise on fall rates) explained by each of the study and program characteristics is shown in Table 2. The total dose of exercise (22%, dichotomized as ≤50 hours over the trial period) and the presence of highly challenging balance training in exercise programs (19%) explained the most variability. The presence of either of these features in the exercise programs tested in the included trials was associated with a greater reduction in fall rates (ratio of rate ratios = 0.80, 95% CI = 0.65–0.99, $P = .04$ for dose; ratio of rate ratios = 0.76, 95% CI = 0.62–0.93, $P = .009$ for balance training).

There was an indication of a lesser effect of exercise on fall rates in the trials that were conducted in higher-risk populations; this variable explained 12% of between-study variability ($P = .09$). To explore this finding, a post hoc analysis was undertaken using the control rate of falls during the follow-up period dichotomized at 1 (close to the median) and 2 falls per person-year. In the 41 comparisons for which these data were available, there was a lesser effect of exercise on falls in the trials in which the control groups had an average fall rate of 2 or more per person-year (ratio of rate ratios = 1.36, 95% CI = 1.05–1.77, $P = .02$, 17% between-study variability explained).

A meta-regression model with three variables explained 68% of the between-study variability of the effect

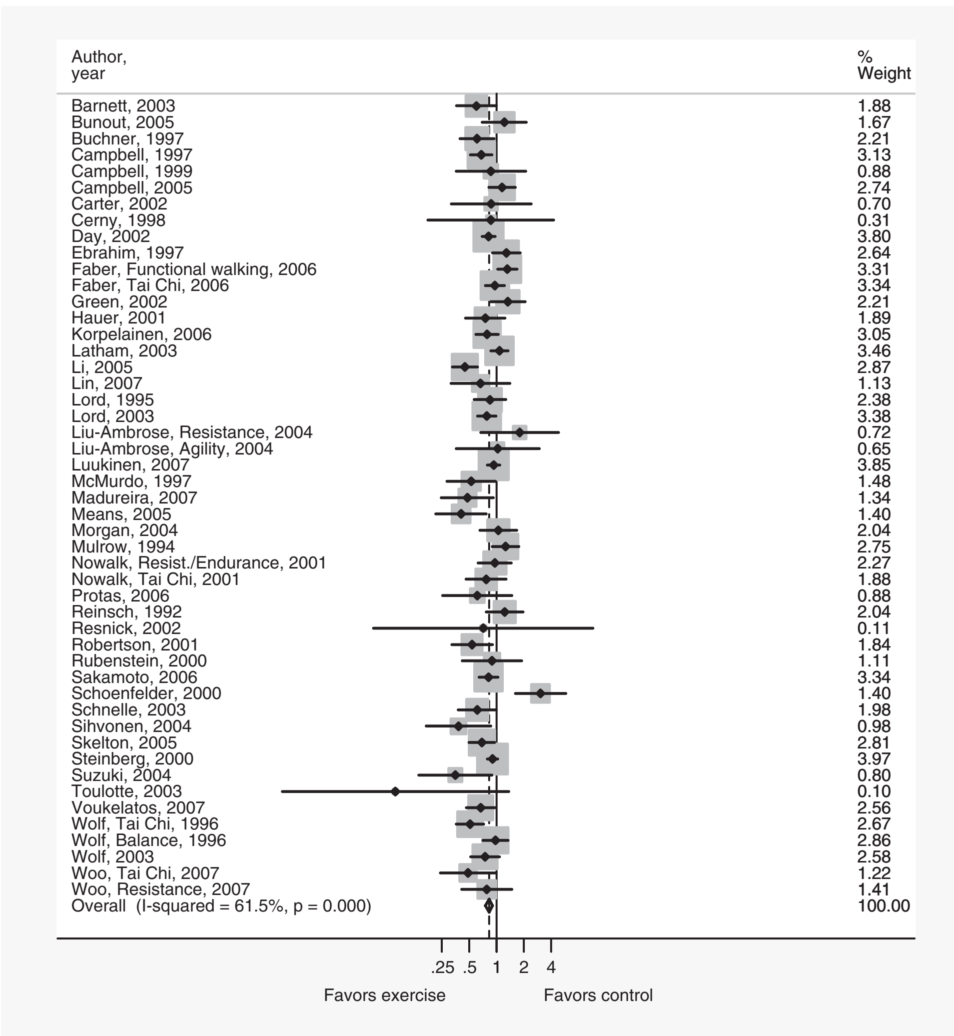

Figure 2. Forest plot from the meta-analysis of exercise on fall rates showing estimates of effect of exercise on falls with 95% confidence intervals and relative weight for each trial.

Table 2. Trial-Level Determinants of Effects of Exercise: Univariate and Multivariate Associations

Characteristic	Comparisons with This Feature, n	Ratio of Rate Ratios (95% Confidence Interval)*	P-Value	Variance Explained, %†
Study population				
Mainly care facility residents	13	1.17 (0.92–1.49)	.19	4
Mainly high-support care facility residents	6	1.16 (0.81–1.65)	.41	0
Study population at high risk	29	1.21 (0.97–1.50)	.09	12
Average age ≥75	32	1.05 (0.83–1.33)	.66	0
Control group fall rate >2 per person per year during follow-up period (p1)	10	1.36 (1.05–1.77)	.02	17
Type and intensity of exercise				
Moderate- or high-intensity strength training	19	1.09 (0.87–1.36)	.47	0
High-intensity strength training	5	1.16 (0.81–1.67)	.40	0
Moderate- or high-challenge balance training	34	0.75 (0.60–0.94)	.01	14
High-challenge balance training	25	0.76(0.62–0.93)	.009	19
Moderate- or high-intensity endurance training	20	0.94 (0.75–1.18)	.58	0
Stretching program	12	0.89 (0.69–1.15)	.37	0
Walking program (any)	27	1.19 (0.96–1.46)	.11	9
Longer walking program (≥20 minutes)	8	1.07 (0.79–1.45)	.67	0
Exercise program features				
Supervised exercise	41	0.89 (0.68–1.17)	.40	0
Moderately to highly supervised exercise (10 or fewer participants per instructor)	23	1.16 (0.93–1.44)	.18	3
Progressive (monthly or more)	32	1.12 (0.89–1.40)	.34	0
More progressive (weekly or more)	14	1.01 (0.79–1.28)	.96	0
Intensity or type modified (most exercises)	28	1.21 (0.98–1.49)	.08	15
Good adherence	41	0.97 (0.73–1.27)	.80	0
Dose with instructor ≥30 hours	25	0.95 (0.77–1.19)	.67	0
Dose of prescribed home program ≥30 hours	12	0.84 (0.66–1.07)	.15	2
Total (instructor and home program) dose ≥50 hours over trial	25	0.80 (0.65–0.99)	.04	22
Total dose ≥8 hours per month (p2)	19	1.04 (0.83–1.30)	.72	0
Total length of exercise program ≥12 months (p2)	20	0.98 (0.78–1.22)	.83	0
Study design features				
Concealed allocation to groups	16	1.05 (0.83–1.32)	.69	0
Intention to treat analysis	22	0.91 (0.73–1.12)	.36	3
Multivariate (adjusted)				68
High-challenge balance training	25	0.79 (0.66–0.95)	.01	
Total dose ≥50 hours	25	0.80 (0.67–0.96)	.02	
Walking program (any)	27	1.32 (1.11–1.58)	.003	

* The "ratio of rate ratios" is the estimate of the effect of each variable or combination of variables on the effect of exercise on fall rates.
† The proportion of between-trial variability (as assessed using the τ^2 statistic) of the model with no covariates that is explained by model with these variable(s) included.
(p1) post hoc analyses undertaken to explore importance of not being at high risk. This analysis includes only the 41 trials for which control fall rate data were available. The percentage variance explained was calculated from the variance in a meta-analysis with these 41 trials only.
(p2) post hoc analyses undertaken to explore importance of total dose.

of exercise on fall rates. In this model, each of the predictor variables (exercise program descriptors) was independently and significantly ($P < .05$) associated with the effect of exercise on falls (Table 2). The regression model was used to obtain adjusted estimates of the effects of exercise on fall rates in studies with and without each of the three predictive characteristics (Table 3). The greatest effects of exercise on falls (RR = 0.58, 95% CI = 0.48–0.69) were obtained from programs that challenged balance to a high extent, included a higher total dose of exercise, and did not include a walking program.

A sensitivity analysis found that excluding the six comparisons from studies undertaken in nursing homes had little effect on the results. The same three variables were retained in the model, and the model explained 65% of intertrial variability.

Models were also developed in which the other two variables that explained more than 10% of between-study variability in univariate analyses (a high-risk population and a tailored exercise program) replaced the variable regarding the inclusion of walking in an exercise program, but these models explained less than 50% of between-study variability.

Table 3. Adjusted Effects of Exercise on Falls

Program	High Balance Challenge	Mod-Low Balance Challenge
	Adjusted Pooled Rate Ratios (95% Confidence Interval)	
High dose and walking	0.76 (0.66–0.88)	0.96 (0.80–1.16)
High dose, no walking	0.58 (0.48–0.69)	0.73 (0.60–0.88)
Low dose and walking	0.95 (0.78–1.16)	1.20 (1.00–1.44)
Low dose, no walking	0.72 (0.60–0.87)	0.91 (0.79–1.05)

The adjusted pooled rate ratios estimate the effects of exercise on fall rates in trials with different combinations of exercise program components.

DISCUSSION

This systematic review provides strong evidence that exercise programs can reduce fall rates in older people. The overall reduction of 17% based on 44 trials involving 9,603 participants provides confidence that these findings are robust and generalizable to a broad section of older people. Furthermore, the meta-regression analysis model revealed that three factors (balance training, exercise dose, and the absence of a walking program) are associated with the efficacy of exercise programs.

The inclusion of balance training in exercise programs appears to be important. This finding is consistent with the Frailty and Injuries: Cooperative Studies of Intervention Techniques prospective meta-analysis of individual participant data from eight trials, which found a pooled estimate of a 17% lower falls risk from exercise programs that included balance training but not from other forms of exercise.[17]

Inclusion of balance training may help to explain why several intervention strategies that appear to be different are similarly effective in substantially reducing fall rates. For example, effective programs, such as Tai Chi[10] conducted in a group setting and the home-based Otago Exercise Programme,[18] primarily include balance training. These trials also show that, with appropriate prescription and supervision, exercise that challenges balance can be administered safely. For example, it has been demonstrated that the Otago Exercise Programme is feasible and safe for older people to undertake at home and produced a 35% reduction in falls and falls-related injury.[18]

Total exercise dose also explained a significant and independent amount of variability with regard to the effectiveness of the exercise trials. This finding is consistent with trials of stroke rehabilitation, which have found better outcomes with more-intense exercise.[19] The measure of exercise dose combined frequency of exercise on a weekly basis with program length, and this measure proved to be superior in discriminating between less-effective and more-effective trials than weekly exercise frequency or program length when analyzed separately. Although programs varied markedly with regard to these factors, the criterion for a minimal effective exercise dose would equate to a twice-weekly program running over 25 weeks. This finding has important implications for service delivery, because many programs are offered for shorter periods than this, typically for 10 weeks. Strategies for achieving long-term exercise participation could include combining supervised group exercise with interspersed or follow-on home exercise programs.

Exercise programs that did not include walking reduced fall rates more than exercise programs that involved walking. One explanation might be that participants are exposed to greater risk of falls while walking, although the published trials do not indicate that many falls occurred when participants were undertaking the prescribed walking programs. An alternative explanation is that time spent walking takes the place of time spent undertaking balance training (the most effective exercise) in time-limited programs. Falls are not the only important outcome for exercise trials in older people, and other studies have shown that walking programs have health benefits including improved fitness, weight loss, and lower blood pressure.[20] For these reasons, walking programs could be included in exercise programs for older people, but if fall prevention is the primary aim, walking programs should be included only if they are in addition to a balance training program of adequate intensity and duration. Ideally, there should also be some assessment of whether a walking program will unduly increase the risk of falls for individual participants. Further research into the relationship between walking programs and falls is required.

There is an indication that lesser relative reductions in fall rates were seen in studies of exercise that included people at a high risk of falls. This provides support for a population-based approach to falls prevention with appropriate exercise. However the absolute effects of exercise may be greater in high-risk populations, such as nursing home residents or those with previous falls. For example, one trial[21] found a 31% difference between fall rates in the intervention and control groups in a sample of multiple fallers in which the control group fall rate was 3.2 falls per person-year. This equates to the prevention of 1 fall per person-year. A trial in a lower-risk population in which the control group rate was 0.52 falls per person-year[22] found a 51% between-group difference, which represented the prevention of 0.27 falls per person-year. It could also be argued that the consequences of falls (e.g., fracture rates, hospital admissions, and moves to institutional care) may also be more significant in higher-risk populations. For these reasons, exercise for falls prevention should be undertaken in populations at high risk and in the general older community.

The studies that were conducted in high-risk populations were more likely to include walking programs (phi = 0.42, $P = .003$) and modified exercise (phi = 0.46, $P < .001$). No two of these three variables simultaneously made an independent contribution to the models. Thus it is possible that risk status confounds the effect of walking and modifying of exercise on falls.[9]

Although poorer muscle strength is a risk factor for falls,[23] the presence of moderate- or high-intensity strength training was not found to be associated with a greater effect of exercise on falls. This finding is more definitive than previous meta-analysis findings. One previous study[7] found some indication of an effect of strength training on the proportion of fallers (pooled adjusted risk ratio from 9 studies was 0.82, 95% CI = 0.48–1.41) but not on the rate of falls (pooled adjusted incidence RR from 14 studies was 1.04, 95% CI = 0.76–1.42), and another[17] found the pooled effect of resistance training on falls to be 0.96 ($P = .59$). It is likely that impaired balance is a stronger risk factor for falls than poor muscle strength and that this finding is in keeping with previous findings that strength training increases strength but has less-clear effects on balance abilities.[24,25] Nevertheless, the relationship between strength and falls may be nonlinear. This may mirror the nonlinear relationship between strength and gait speed[26] (i.e., once a person has sufficient strength to avoid falling, further strength training may not be of additional benefit). Like walking programs, strength training is likely to provide many older people with other health benefits,[25,27] but it does not seem to be the optimal intervention for falls prevention.

This systematic review had certain limitations. First, because a meta-regression of trial-level characteristics was used, some caution is warranted when interpreting the findings.[28] The analysis permits inference only about the effects of trial-level characteristics (e.g., whether the trial included high-risk participants or average exercise dose) on trial-level estimates of effects of exercise. Inferences cannot be made about the effects of the characteristics of individuals (e.g., presence of risk factors in individual participants) or of participant-specific features of the intervention (e.g., the dose of exercise given to an individual) on the effects of exercise on falls risk in individual participants.[29] Despite multivariate adjustment, there is the possibility that the conclusions are subject to confounding by unmeasured variables or by failure to adjust completely for measured variables. There is also a possibility that the coding of program content does not reflect the real nature of the program, because the coding was based on the short descriptions of often-complex programs in the published articles. Nonetheless, the findings are consistent with the little that is known about optimal exercise protocols from analyses at the level of individual participants.[17]

In conclusion, this analysis confirms that exercise can reduce fall rates in older people and identifies the important components of effective exercise intervention strategies. It confirms the importance of balance training in falls prevention and the need for exercise to be sustained over time. Service providers can use these findings to design and implement exercise programs for preventing falls.

ACKNOWLEDGMENTS

This review was undertaken as part of the work of ProFaNE, of which J. C. T. Close is a principal contractor and J. C. Whitney, C. Sherrington, S. R. Lord, and R. G. Cumming are network associates. C. Sherrington, S. R. Lord, and R. D. Herbert are funded by Australian National Health and Medical Research Council Fellowships. Lesley Gillespie, trial search coordinator of the Cochrane Bone, Joint and Muscle Trauma Group Field, was most helpful in providing updated search results, and Clare Roberston provided valuable comments on the draft manuscript. Elizabeth Barraclough and Sandra O'Rourke provided valuable assistance with data checking, as did Esther Vance with literature searching.

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this manuscript.

Author Contributions: C. Sherrington participated in protocol development, literature searching, data extraction, data analysis, and manuscript preparation. J. C. Whitney participated in protocol development, literature searching, data extraction, and manuscript preparation. S. R. Lord and J. C. T. Close participated in protocol development, data extraction, data analysis, and manuscript preparation. R. D. Herbert participated in protocol development, literature searching, data extraction, data analysis, and manuscript preparation. R. G. Cumming participated in protocol development, data analysis, and manuscript preparation.

Sponsor's Role: None.

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Appendix 4: Published systematic review on exercise to prevent falls

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