

Exercise for preventing falls in older people living in the community: Update of Cochrane Systematic Review

Prepared for the Guideline Development Group for the
WHO Guidelines on physical activity and sedentary behaviour for children and adolescents, adults
and older adults



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EXECUTIVE SUMMARY

Objectives

The information provided in this report is intended to inform the WHO Guideline Development Group (GDG) update of the WHO Global Recommendations on Physical Activity for Health.

We assessed the effects of exercise interventions for preventing falls in older people living in the community.

Methods

We included randomised controlled trials evaluating the effects of any form of exercise as a single intervention on the rate of falls in people aged 60+ years living in the community. This is an update of a Cochrane Review, published in 2019 with additional analyses to explore dose-response relationships. GRADE was used to assess the certainty of the evidence.

Results

Exercise reduces the rate of falls by 23% (pooled rate ratio (RaR) 0.77, 95% confidence interval (CI) 0.71 to 0.83; 14,306 participants, 64 studies; high-certainty evidence). Subgroup analyses showed no evidence of a difference in effect on falls on the basis of risk of falling as a trial inclusion criterion, participant age 75 years+ or group versus individual exercise, or whether interventions were delivered by a health professional.

Different forms of exercise had different impacts on falls. Balance and functional exercises reduce the rate of falls by 24% compared with control (RaR 0.76, 95% CI 0.70 to 0.82; 7989 participants, 39 studies; high-certainty evidence). Multiple types of exercise (commonly balance and functional exercises plus resistance exercises) probably reduce the rate of falls by 28% (RaR 0.72, 95% CI 0.56 to 0.93; 2283 participants, 15 studies; moderate-certainty evidence). Tai Chi probably reduces the rate of falls by 23% (RaR 0.77, 95% CI 0.61 to 0.97; 3169 participants, 9 studies; moderate-certainty evidence). We are uncertain of the effects of programmes that primarily involve resistance training, dance or walking.

There was a suggestion of a dose-response relationship. There was a greater reduction in falls from exercise programmes that involved more hours per week although this did not reach statistical significance ($p=0.077$). Interventions that included an exercise dose of 3+ hours per week and included balance and functional exercises were particularly effective with an estimated 42% reduction in the rate of falls (IRR 0.58, 95% CI 0.45 to 0.76).

Conclusions and implications

Given the high certainty of evidence, effective programmes should now be implemented at a population-wide scale.

BACKGROUND

The information provided in this report is intended to inform the WHO Guideline Development Group (GDG) update the WHO Global Recommendations on Physical Activity for Health(1).

At least one-third of community-dwelling people over 65 years of age fall each year(2, 3) and the rate of fall-related injuries increases with age(4). Falls can have serious consequences, such as fractures and head injuries(4).

Falls are associated with reduced quality of life(5), and can have psychological consequences: fear of falling and loss of confidence that can result in self-restricted activity levels leading to a reduction in physical function and social interactions(6). Paradoxically, this restriction of activities may increase the risk of further falls by contributing to deterioration in physical capacity.

A previous Cochrane Review found exercise, as a single intervention, prevents falls(7) and is the most commonly tested single fall prevention intervention. Economic evaluations accompanying randomised trials have found exercise to be a cost effective falls-prevention strategy(8). Exercise interventions have been found to be effective when delivered in a group-based setting or on an individual basis. The optimal features of successful falls prevention exercise programmes are not yet clear, but programmes that are multicomponent (e.g. target both strength and balance(7)), and programmes that include balance training appear to be particularly effective(9).

Regular updates of the estimates of the effects of exercise interventions on falls are warranted given the number of new trials published, the increasing number of older people living in the community and the major long-term consequences associated with falls and fall-related injuries to both the individual and to society. Different exercise programmes may have different effects on falls and so careful analysis of the impact of different programmes is important to optimise the recommendation of exercise interventions to inform public health efforts for healthy ageing.

In 2019 we published a Cochrane Review of randomised controlled trials that assessed the effects of exercise interventions for preventing falls in older people living in the community when compared to controls. This report includes an update of this Cochrane Review, and focuses on the review's primary outcome, rate of falls. Please refer to the full Cochrane review(10) for reports of other outcomes as well as more detailed methods, descriptions of included studies and forest plots.

METHODS

Protocol

The protocol for the 2019 Cochrane review was published (Sherrington et al, 2016)(11), and is unchanged here.

Eligibility criteria

We included randomised controlled trials (RCTs), either individually or cluster randomised, evaluating the effects of exercise interventions on falls or fall-related fractures in older people living in the community. We included trials if they specified an inclusion criterion of 60 years of age or over. Trials that included younger participants were included if the mean age minus one standard deviation was more than 60 years. We included trials where the majority of participants were living in the community, either at home or in places of residence that, on the whole, do not provide residential health-related care or rehabilitative services; for example, retirement villages, or sheltered housing. We excluded studies that only included participants affected by particular clinical conditions that increase the risk of falls, such as stroke, Parkinson's disease, multiple sclerosis, dementia, previous hip fracture and severe visual impairment. Several of these topic areas are covered by other Cochrane Reviews(12),(13). We acknowledge that some individuals with these (and other) health conditions may be included in studies of the general community; these we included. This review comprised all exercise interventions tested in trials that measured falls in older people. Our focus was on trials where exercise was a single intervention as opposed to a component of a broader intervention. We considered trials where an additional low-contact intervention (e.g. information on fall prevention) was given to one or both groups if we judged that the main purpose of the study was to investigate the role of exercise.

Information sources and search

The present report updates the searches performed in the 2019 Cochrane Review(10), with this review extending studies published up to 7 November 2019. This review extended the searches performed up to February 2012 in the 2012 Cochrane Review(7). We searched: the Cochrane Bone, Joint and Muscle Trauma Group Specialised Register (2 May 2018 to 7 November 2019); the Cochrane Central Register of Controlled Trials. (CENTRAL) (Cochrane Register of StudiesOnline) (2018 Issue 1 to 7 November 2019); MEDLINE (including Epub Ahead of Print, In-Process & Other Non-Indexed Citations and MEDLINE Daily) (start 2018 to 7 November 2019); Embase (start 2018 to 7 November 2019); the Cumulative Index to Nursing and Allied Health Literature (CINAHL) (May 2018 to 7 November 2019); and the Physiotherapy Evidence Database (PEDro) (2018 to 2019), using tailored search strategies. We did not apply any language restrictions. In MEDLINE, we combined subject-specific search terms with the sensitivity- and precision-maximising version of the Cochrane Highly Sensitive Search Strategy for identifying randomised trials.(14) The search strategies for CENTRAL, MEDLINE, Embase, CINAHL and PEDro are shown in Appendix 1). We also searched the World Health Organisation International Clinical Trials Registry Platform (WHO ICTRP) and ClinicalTrials.gov for ongoing and recently completed trials (November 2019) (see Appendix 1). We checked reference lists of other systematic reviews as well as contacting researchers in the field to assist in the identification of ongoing and recently completed trials.

Study selection

Independent reviewers (NF, WK) screened the title, abstract and descriptors of identified studies for possible inclusion. From the full text, these review authors independently assessed potentially eligible trials for inclusion and resolved any disagreement through discussion with a third author. We contacted authors for additional information as necessary.

Data collection process

Pairs of reviewers (CS, NF, WK) independently extracted data using a pretested data extraction form (based on the one used in the Cochrane Review(15)). Disagreement was resolved by consensus or third party adjudication. Review authors were not blinded to authors and sources. Review authors did not assess their own trials.

Data items

Full details of data extracted (excluding the nine new trials included in this update) are shown in Sherrington 2019. The present publication focuses on the primary outcome, the rate of falls. We grouped similar exercise interventions using the fall prevention classification system (taxonomy) developed by the Prevention of Falls Network Europe (ProFaNE)(16). For simplicity the ProFaNE category gait, balance, co-ordination or functional task training was referred to as balance and functional exercises. Full details are shown in Appendix 2.

Risk of bias and certainty of evidence

One review author (NF) assessed risk of bias using Cochrane's Risk of bias tool as described in the Cochrane Handbook(17). We constructed and visually inspected funnel plots. We used The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach to assess the quality of evidence(18); we assessed the certainty of the evidence as 'high', 'moderate', 'low' or 'very low' depending on the presence and extent of five factors: risk of bias; inconsistency of effect; indirectness; imprecision; and publication bias. We prepared 'Summary of finding' tables. We used standardised qualitative statements to describe the different combinations of effect size and the certainty of evidence(19).

Synthesis of results

We reported the treatment effects for rate of falls as rate ratios (RaRs) with 95% confidence intervals (CIs). We assessed heterogeneity of treatment effects by visual inspection of forest plots and by using the Chi² test (with a significance level at $P < 0.10$) and the I² statistic. For our primary comparison, we pooled data from all relevant trials without stratification.

We undertook subgroup analyses to compare the effect of exercise on falls in trials that did and did not use an increased risk of falls as an inclusion criterion and in trials with predominantly older populations (defined by inclusion criteria 75 years or above, lower range limit more than 75 years, or mean age minus one standard deviation more than 75 years) compared with those with predominantly younger populations. We also assessed the impact of individual versus group-based exercise, exercise delivered by people with different qualifications (e.g. health professionals versus trained fitness leaders) and the different ProFaNE exercise intervention categories. We used the test for subgroup differences available

in Review Manager 2014 to determine whether there was evidence for a difference in treatment effect between subgroups.

We undertook meta-regression using the user-written Stata command 'metareg'(20) to explore the impact of hours of exercise intervention per week over the programme period (hours of intervention are shown for each study in Tables 5 and 6) and used the 'lincom' post-estimation command to estimate the impact of interventions that are of higher dose (3+ hours per week) and include exercises that target balance and function (i.e., balance and functional exercise, Tai Chi and multiple component exercise interventions that include balance and functional exercise). This analysis is an update of the one in our previous non-Cochrane review of exercise on the rate of falls (9).

RESULTS

Study selection

Figure 1 shows the flow of records. In brief, the search update identified 2396 potentially eligible new records and the full text was screened for 44 studies. Study selection resulted in the inclusion of nine studies not in the 2019 Cochrane Review and the exclusion of 35 studies. This update includes 116 studies; the 108 studies included in the 2019 Cochrane Review and the 9 new studies. One feasibility study(21) included in the 2019 Cochrane Review was replaced with the recently published full trial(22).

Study characteristics

The characteristics of the 116 included trials are summarised in 2. The 116 included studies were all randomised controlled trials (RCTs) and involved 25,160 participants. The majority of trials were individually randomised and ten were cluster randomised. The median number of participants randomised per trial was 131 (interquartile range (IQR) 66 to 249). The included trials were carried out in 25 countries, the most common being USA (21 trials), Australia (20 trials), Japan (11 trials) and the UK (7 trials). Overall, 73% of included participants were women. All participants were women in 28 trials and men in one trial. The average of average participant ages in the included trials was 76 years. Sixty-two included studies (53%) specified a history of falling or evidence of one or more risk factors for falling in their inclusion criteria. Seventy-nine trials (68%) excluded participants with cognitive impairment, either defined as an exclusion criterion or implied by the stated requirement to be able to give informed consent.

Risk of bias within studies

The summary of risk of bias in the individual trials is displayed in Table 3. We judged the risk of bias in generation of the allocation sequence as low in 68% (n = 79/116) of trials, unclear in 32% (n = 37/116) and high in zero trials. We assessed the methods of concealment of the allocation prior to group assignment as low risk of bias in 36% (n = 42/116), unclear in 59% (n = 69/116) and high in the remaining 5% (6/116) of trials. In the majority of studies (96%, n = 111/116) it was not possible to blind the personnel and participants to group allocation. As the likelihood of awareness of group allocation introducing performance bias was not clear, we assessed the risk of bias for non-blinding as unclear for these trials. We judged the impact

of performance bias as low in 4% (n = 5/116) of trials, unclear in 91% (105/116) of trials and high in 5% (6/116) of trials. We judged the risk of detection bias in relation to the methods of ascertainment of the rate of falls to be low in 41% (n = 48/116), high in 21% (n = 24/116) and unclear in 38% (n = 44/116) of the included trials. We judged the risk of bias due to incomplete outcome data to be low in 53% (n = 62/116), unclear in 18% (n = 21/116) and high in the remaining 28% of trials (n = 33/116). We assessed the risk of bias due to selective reporting of falls outcomes as low in 19% (n = 22/116) of studies, unclear in 36% (n = 42/116) and high in 45% (52/116). We assessed 59% of included studies (n = 68/116) as being at low risk of bias in the recall of falls (i.e. falls were recorded concurrently using recommended methods of monthly diaries or postcards). We judged the risk of bias to be high in 26% of trials (n = 30/116), in that ascertainment of falling episodes was by participant recall, at intervals during the study or at its conclusion. In 16% of trials (n = 18/116) the risk of bias was unclear, as retrospective recall was for a short period only, or details of ascertainment were not described.

Overall effects of exercise (all types)

Exercise (all types) reduces the rate of falls by 23% compared with control (rate ratio (RaR) 0.77, 95% confidence interval (CI) 0.71 to 0.83; 14,306 participants, 64 studies, $I^2 = 61\%$; high-certainty evidence). See Table 4: Summary of findings table.

Subgroup analysis by falls risk at baseline, found there was probably little or no difference in the effect of exercise (all types) on the rate of falls in trials where all participants were at an increased risk of falling (RaR 0.76, 95% CI 0.69 to 0.84; 7872 participants, 32 studies, $I^2 = 65\%$) compared with trials that did not use increased risk of falling as an entry criterion (RaR 0.78, 95% CI 0.68 to 0.89; 6434 participants, 32 studies, $I^2 = 57\%$); test for subgroup differences: $\text{Chi}^2 = 0.1$, $\text{df} = 1$, $P = 0.75$, $I^2 = 65\%$.

Subgroup analysis by participant age found there was probably little or no difference in the effect of exercise (all types) on the rate of falls in trials where participants were aged 75 years or older (RaR 0.85, 95% CI 0.73 to 1.0; 3841 participants, 14 studies, $I^2 = 61\%$) compared with trials where participants were aged less than 75 years (RaR 0.74, 95%CI 0.68 to 0.81; 10465 participants, 50 studies, $I^2 = 60\%$); test for subgroup differences: $\text{Chi}^2 = 2.29$, $\text{df} = 1$, $P = 0.13$, $I^2 = 56\%$.

Subgroup analyses found there may be no difference in the effect of exercise (all types) in trials where interventions were delivered by a health professional (usually a physiotherapist, RaR 0.73, 95% CI 0.64 to 0.82; 5099 participants, 28 studies, $I^2 = 53\%$) than in trials where the interventions were delivered by trained instructors who were not health professionals (RaR 0.79, 95%CI 0.72 to 0.88; 9207 participants, 36 studies, $I^2 = 65\%$); test for subgroup differences: $\text{Chi}^2 = 1.2$, $\text{df} = 1$, $P = 0.27$, $I^2 = 16\%$. Notably, both approaches resulted in reductions in the rate of falls.

Subgroup analyses found there may be no difference in the effect of exercise (all types) on the rate of falls where interventions were delivered in a group setting (RaR 0.74, 95%CI 0.67 to 0.83; 8909 participants, 43 studies, $I^2 = 66\%$) compared with trials where interventions

were delivered individually (RaR 0.81, 95%CI 0.72 to 0.91 5397 participants, 23 studies, $I^2=47\%$); test for subgroup differences: $\text{Chi}^2 = 1.3$, $\text{df} = 1$, $P = 0.31$, $I^2 = 3\%$.

Subgroup analysis by exercise type showed a variation in the effects of the different types of exercise on rate of falls, the visual impression being confirmed by the statistically significant test for subgroup differences: $\text{Chi}^2 = 18.91$, $\text{df} = 6$, $P = 0.004$, $I^2 = 68.3\%$.

Effects of different types of exercise

Exercise interventions that were classified as being primarily balance and functional reduce the rate of falls by 24% compared with control (RaR 0.76, 95% CI 0.70 to 0.82; 7989 participants, 39 studies, $I^2 = 31\%$, high-certainty evidence).

Exercise interventions that include multiple categories of the ProFaNE taxonomy (most commonly balance and functional exercises plus resistance exercises) probably reduce the rate of falls by 28% compared with controls (RaR 0.72, 95% CI 0.56 to 0.93; 2283 participants, 15 studies; $I^2 = 65\%$; moderate-certainty evidence). Sensitivity analyses revealed little difference in the results when we pooled only trials that include the most common two components (balance and functional exercises plus resistance exercises) (RaR 0.69, 95%CI 0.48 to 0.97; 1084 participants, 8 studies; $I^2 = 71\%$).

Exercise interventions that were classified as 3D (Tai Chi or similar) probably reduce the rate of falls by 23% compared with control (RaR 0.77, 95% CI 0.61 to 0.97; 3169 participants, 9 studies, $I^2=83\%$; moderate-certainty evidence).

We are uncertain whether exercises, classified as being primarily 3D (dance) using the ProFaNE taxonomy, reduce the rate of falls compared with control (RaR 1.34, 95% CI 0.98 to 1.83; 522 participants, 1 study; very low-certainty evidence).

We are uncertain whether interventions, classified as being primarily walking programmes using the ProFaNE taxonomy, reduce the rate of falls compared with control (RaR 1.14, 95% CI 0.66 to 1.97; 441 participants, 2 studies; $I^2 = 67\%$; very low-certainty evidence).

The characteristics of studies in categories of exercise intervention that significantly reduced falls are described in Table 5. The characteristics of studies in categories of exercise not found to be effective in preventing falls are outlined in 6.

Effect on number of people experiencing one or more falls

Exercise (all types) reduces the number of people experiencing one or more falls by 15% compared with control (risk ratio (RR) 0.85, 95% confidence interval (CI) 0.81 to 0.90; 14,776 participants, 67 studies, $I^2 = 30\%$; high-certainty evidence).

Effect of dose

Meta-regression analyses suggested a dose-response relationship. There was a greater reduction in falls from exercise programmes that involved more hours per week (Figure 2) although this did not reach statistical significance ($p=0.077$). Interventions that included an exercise dose of 3+ hours per week and included balance and functional exercises were

particularly effective with an estimated 42% reduction in the rate of falls (IRR 0.58, 95% CI 0.45 to 0.76). Table 1 shows the estimated impact of the separate and combined impact of dose and exercise type on falls. This suggests that attention to both type and dose of exercise is important.

Table 1. Estimated impact of dose and exercise type on falls.

Feature	Effect on falls, IRR (95% CI)
Higher dose, 3+ hours per week of total exercise	0.83 (0.60 to 1.15)
Inclusion of balance/ functional exercises ^a	0.76 (0.69 to 0.83)
Higher dose, 3+ hours per week of total exercise plus inclusion of balance/ functional exercises ^a	0.58 (0.45 to 0.76)
Lower dose, <3 hours per week of total exercise and no inclusion of balance/ functional exercises ^a	1.08 (0.84 to 1.38)

^abalance and functional exercise, Tai Chi and multiple component exercise interventions that include balance and functional exercise

Heterogeneity and risk of bias across studies

This review's analyses display minimal to substantial heterogeneity with $P < 0.05$ for the Chi² test and I^2 values up to 83%. This variability was not explained by our subgroup analyses. We consider this likely to represent between-study differences in the exact nature of programmes (e.g. dose, intensity, adherence) and target populations, which requires ongoing investigation. Given the overall positive impact of the programmes and the stability of results, we do not consider this to negate the findings of the meta-analyses we have undertaken. The funnel plots in did show some asymmetry but we did not consider the asymmetry sufficient to downgrade the level of evidence (see Figure 3, funnel plot for the comparison of exercise versus control on rate of falls).

DISCUSSION

There is high-certainty evidence from 64 randomised controlled trials that exercise reduces the rate of falls in older adults living in the general community.

Subgroup analyses did not reveal differences in effect according to whether trials were selected for high risk of falling or not but the absolute numbers of falls prevented will be greater in the higher risk populations. Subgroup analyses did not reveal differences in effect on falls according to whether trials included younger and older populations based on a 75 year cut-off, or whether interventions were delivered by a health professional versus trained instructors who were not health professionals. These findings suggest that exercise programs should be delivered to older/ higher risk individuals as well as to the general community. Overall, programmes delivered by health professionals are not more effective than programmes delivered by trained others, although it is likely that the provision of exercise to high risk people can be more safely and effectively undertaken by health professionals.

Subgroup analyses did not reveal differences in effect on falls according to whether interventions were delivered in a group setting or delivered individually. This suggests that either delivery mode can be effective and participants can choose which suits their preferences and other commitments.

When sub-grouped by exercise type there were significant subgroup differences for rate of falls, a finding that endorsed our prespecified intention to report separate analyses by primary exercise type. Exercise programmes that reduce falls primarily involve balance and functional exercises, while programmes that probably reduce falls include multiple exercise categories (typically balance and functional exercises plus resistance exercises). Tai Chi probably also prevents falls but we are uncertain of the effect of resistance exercise (without balance and functional exercises), dance, or walking on the rate of falls.

There was an indication of a dose-response relationship but, unlike type of exercise, this did not reach statistical significance. The estimated 42% reduction in the rate of falls from programmes that include a higher dose of exercise and include exercises that target balance/function suggests that attention to both type and dose of exercise is important.

Despite our thorough search strategy, we acknowledge the possibility that some relevant trials may have been missed, especially if they were published in languages other than English. Two review authors independently classified the exercise interventions using the ProFaNE guidelines(16), including assigning intervention categories to primary or secondary status. We recognise there is some subjectivity in this classification system, particularly for those interventions containing more than one category of exercise. In the published Cochrane Review(10), sensitivity analyses that tested the effects of re-categorising primary balance and functional exercise trials with a secondary component of strength training indicated that this did not importantly affect the results.

This update adds to the existing body of evidence and supports the findings of Gillespie 2012(7) and Sherrington 2019(10), whereby multiple component group-based exercise was found to reduce the rate of falls. In the recent work, we extended the findings of Gillespie 2012(7) by recoding intervention programmes, in an attempt to identify a primary exercise component for each included study and reserving the 'multiple component' category for trials in which the intervention programme had an equal focus on each of the multiple components. As a result, more studies in our review are classified as balance and functional exercises and fewer as multiple component programmes. The present review also adds to our previous non-Cochrane review(9), that used different methodology (multivariable meta-regression) yet reached similar conclusions about the importance of the inclusion of exercises that safely challenge balance in fall prevention exercise programmes. Other recent analyses have reached similar findings, including a large network meta-analysis(23).

Further work is needed to understand the relative impact of different exercise programmes. Such studies will need to be very large to be adequately powered to detect effects between interventions. Large studies are also needed to establish the impact of fall prevention interventions on fall-related fractures and falls requiring medical attention, as such falls are particularly costly to health systems and impactful for individuals. When developing priority topics for future research, the current evidence base should be considered in conjunction

with the areas studied in the ongoing trials. Individual participant data meta-analysis could contribute further to the investigation of differential effects of exercise in people of different ages and baseline fall risks, as these are individual-level rather than trial-level characteristics. We recommend researchers follow the Prevention of Falls Network Europe (ProFaNE) guidelines for the conduct of falls trials(24). Further research is required to establish the effectiveness of fall prevention programmes in emerging economies, where the burden of falls is increasing more rapidly than in high-income countries due to rapidly ageing populations(25). There is an urgent need to investigate strategies to enhance implementation of effective exercise-based fall prevention interventions into routine care of older people by healthcare professionals and community organisations. Future studies should use the consensus definition of a fall developed for trials in community-dwelling populations by ProFaNE(24), consistent methods of falls ascertainment, and consistent measurement of adverse events in both groups throughout the trial period. Future research should use the ProFaNE descriptors to categorise interventions(16), but should be clear how this was operationalised.

Current evidence about fall prevention suggests a targeted approach to exercise rather than more general promotion of physical activity. The importance of exercise in falls prevention suggests that greater attention be given to the widespread implementation of a life course approach to healthy ageing, i.e. lifelong exercise to maximise physical functioning in older age, as suggested by the World Health Organization(25). Although trial follow-up ranged from 3 to 18 months in the main comparison, there are likely to be longer-term benefits of introducing falls prevention exercise habits in people in the general community. Notably too, the duration of most of the exercise programmes was 12 weeks or over and nearly one-third lasted a year or more. These findings also highlight the importance of ongoing exercise. As it is possible that interventions designed to increase physical activity could increase falls due to increased exposure to risk, we suggest that those undertaking trials of physical activity interventions in older people consider monitoring falls.

In conclusion, this review provides high-certainty evidence that well-designed exercise programmes reduce the rate of falls amongst older people living in the community. Greater provision and population-wide implementation of these programmes is an urgent challenge for the global sport and exercise medicine community and broader health and social support systems.

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Figure 1. Flow of studies

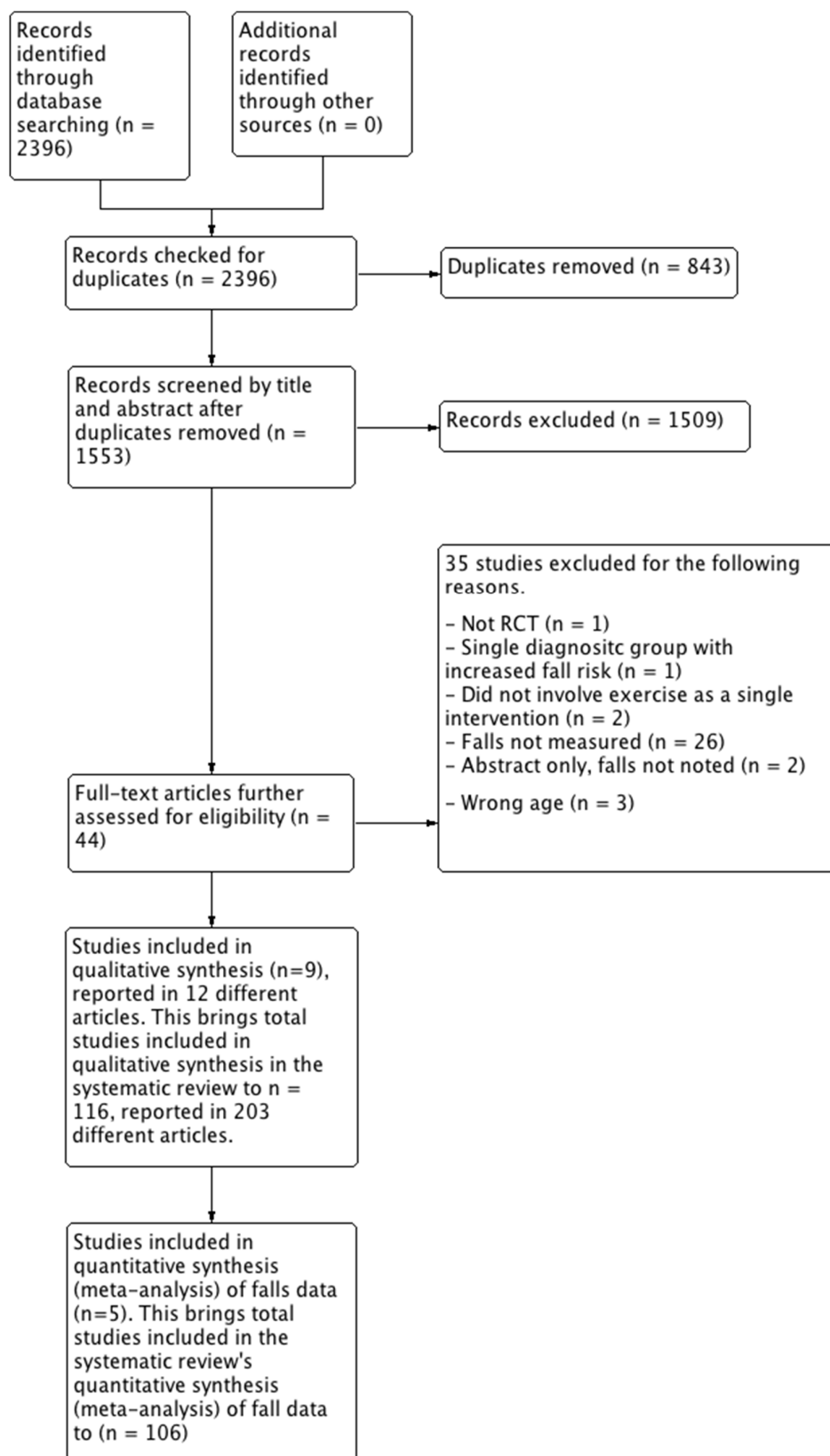


Figure 2. Relationship between effect of intervention on rate of falls and hours of exercise per week

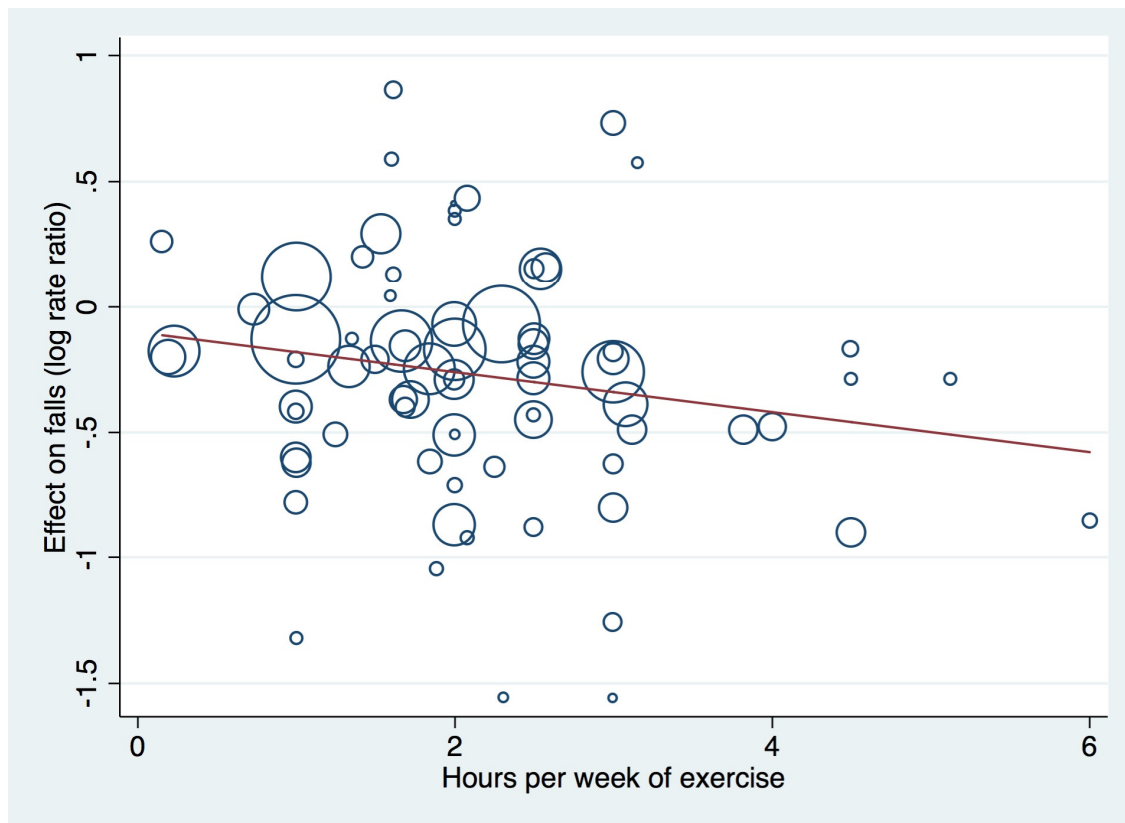


Figure 3. Funnel plot for the comparison of exercise versus control on rate of falls

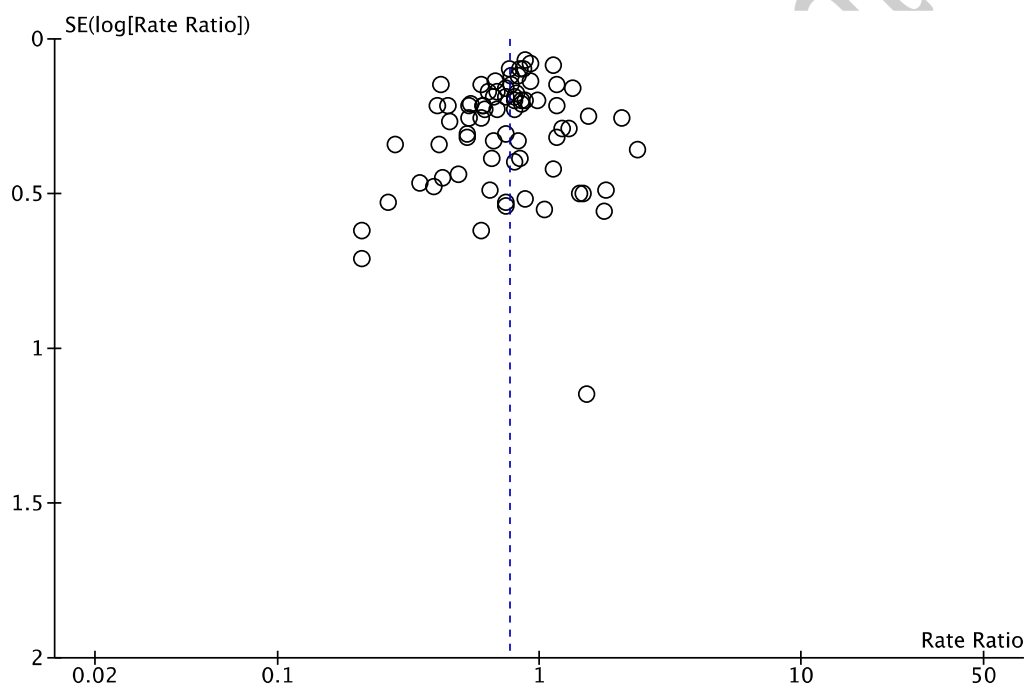


Table 2: Characteristics of the 116 included trials

First author, year	Sample size at randomisation	Trial location	Age	Gender (% women)	Falls risk at enrolment ^a	Inclusion criteria related to falls	Good adherence ^b
Almeida, 2013(26)	119	Brazil	79	83 ^c	1	Previous falls	NR
Ansai, 2015(27)	69	Brazil	82	68	1	All > 80 years	N
Arantes, 2015(28)	30	Brazil	73	100	1	Previous falls	Y
Arkkukangas, 2019(29)	175	Sweden	83	70	0		NR
Ballard, 2004(30)	40	USA	73	100	1	Previous falls	Y
Barclay, 2018(31)	9	Canada	76	78	0		Y
Barker, 2016(32)	53	Australia	69	88	1	Other assessment	Y
Barnett, 2003(33)	163	Australia	75	67	1	Poor balance or lower limb weakness or slow reaction time	Y
Bernardelli, 2019(34)	186	Italy	76	80	0		Y
Beyer, 2007(35)	65	Denmark	78	100	1	All > 80 years or previous falls	Y
Boongird, 2017(36)	439	Thailand	74	83	1	Poor balance	Y
Brown, 2002(37)	99	Australia	84 ^d	79	0	-	Y
Buchner, 1997(38)	105	USA	75	51	1	Lower limb weakness or impaired gait	Y
Bunout, 2005(39)	298	Chile	75	71	0	-	N
Campbell, 1997(40)	233	New Zealand	84	100	1	All > 80 years	NR
Carter, 2002(41)	93	Canada	69	100	0	-	Y
Cerny, 1998(42)	28	USA	71	NR	0	-	NR
Clegg, 2014(43)	84	UK	79	71	1	Recent rehabilitation	N
Clemson, 2010(44)	34	Australia	82	47	1	Previous falls	NR
Clemson, 2012(45)	317	Australia	83	58	1	Previous falls	Y
Cornillon, 2002(46)	303	France	71	83	0	-	Y
Dadgari, 2016(47)	551	Iran	71	49	1	Previous falls	NR
Dangour, 2011(48)	984	Chile	66	68	0	-	N
Davis, 2011(49)	155	Canada	70	100	0	-	NR
Day, 2002(50)	272	Australia	76	60	0	-	Y
Day, 2015(51)	503	Australia	70	70	1	Poor mobility	Y
Duque, 2013(52)	60	Australia	77	62	1	Previous falls or poor balance	Y
Ebrahim, 1997(53)	165	UK	67	100	0	-	Y
El-Khoury, 2015(54)	706	France	80	100	1	Poor balance	N

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Fiatarone, 1997(55)	34	USA	82	94	1	Functional limitation	NR
Freiberger, 2007(56)	134	Germany	76	44	1	Previous falls or fear of falling	Y
Gallo, 2018(57)	69	United States	79	46	0		NR
Gill, 2016(58)	1635	USA	79	67	1	Functional limitation	Y
Grahn Kronhed, 2009(59)	65	Sweden	71	100	0	-	Y
Gschwind, 2015(60)	153	Australia + Spain + Germany	75	61	0	-	Y
Haines, 2009(61)	53	Australia	81	60	1	Recent hospitalisation or use mobility aids	N
Halvarsson, 2013(62)	59	Sweden	77	71	1	Previous falls or fear of falling	Y
Halvarsson, 2016(63)	96	Sweden	76	98	1	Previous falls or fear of falling	Y
Hamrick, 2017(64)	43	USA	70	79	0	-	Y
Hauer, 2001(65)	57	Germany	82	100	1	Recent rehabilitation	Y
Helbostad, 2004(66)	77	Norway	81	81	1	Previous falls or use mobility aids	Y
Hirase, 2015(67)	93	Japan	82	70	1	Other assessment	Y
Huang, 2010(68)	115	Taiwan	72 ^c	30 ^c	0	-	NR
Hwang, 2016(69)	456	Taiwan	72	67	1	Previous falls	Y
Iliffe, 2015(70)	1254	UK	73	62	0	-	N
Irez, 2011(71)	60	Turkey	75	100	0	-	Y
Iwamoto, 2009(72)	68	Japan	76	90	0	-	Y
Kamide, 2009(73)	57	Japan	71	100	0	-	Y
Karinkanta, 2007(74)	149	Finland	72	100	0	-	Y
Kemmler, 2010(75)	246	Germany	69	100	0	-	Y
Kerse, 2010(76)	193	New Zealand	81	59	0	-	Y
Kim, 2014(77)	105	Japan	78	100	1	Previous falls	Y
Korpelainen, 2006(78)	160	Finland	73	100	0	-	Y
Kovacs, 2013(79)	76	Hungary	68	100	0	-	Y
Kwok, 2016(80)	80	Singapore	80	85	1	Functional limitation	Y
Kyrdalen, 2014(81)	125	Norway	83	73	1	Previous falls	Y
LaStayo 2017(82)	134	USA	76	65	1	Previous falls	Y
Latham, 2003(83)	243	Australia + New Zealand	79	53	1	Recent hospitalisation	Y
Lehtola, 2000(84)	131	Finland	72	80	0	-	Y
Li, 2005(85)	256	USA	77	70	0	-	Y
Li, 2018(86)	670	United States	78	65	1	Fall history/assessed risk of falls or reduced mobility	Y

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Lin, 2007(87)	100	Taiwan	77	51	1	Previous falls	NR
Lipsitz, 2019(88)	180	United States	75	67	0		Y
Liston, 2014(89)	21	UK	78	85	1	Previous falls	NR
Liu-Ambrose, 2004(90)	104	Canada	79	100	0	-	Y
Liu-Ambrose, 2008(91)	74	Canada	82	70	1	Previous falls	Y
Liu-Ambrose, 2019(92)	345	Canada	82	67	1	Previous fall	Y
Logghe, 2009(93)	269	Netherlands	77	71	1	Previous falls or poor balance or poor mobility or dizziness or diuretics use	Y
Lord, 1995(94)	197	Australia	72	100	0	-	Y
Lord, 2003(95)	551	Australia	80	86	0	-	N
Lurie, 2013(96)	64	USA	80	58	1	Other assessment	NR
Luukinen, 2007(97)	486	Finland	88	79	1	Previous falls	NR
Ma, 2019(98)	33	Hong Kong	70	84	0		NR
Madureira, 2007(99)	66	Brazil	74	100	0	-	Y
McMurdo, 1997(100)	118	UK	65	100	0	-	Y
Means, 2005(101)	338	USA	74	57	0	-	Y
Merom, 2016(102)	530	Australia	78	85	0	-	Y
Miko, 2016(103)	100	Hungary	79	100	0	-	NR
		Belgium + Israel + Italy + Netherlands +				Previous falls	
Mirelman, 2016(104)	152	UK	83	35	1		Y
Morgan, 2004(105)	294	USA	81	71	1	Prolong bed rest	Y
Morone, 2016(106)	38	Italy	69	100	1	Poor balance	NR
Morrison, 2018(107)	65	USA	67	48	0	-	NR
Ng, 2015(108)	98	Singapore	70	61	1	Frail	Y
Nitz, 2004(109)	73	Australia	76	92	1	Previous falls	NR
Okubo, 2016(110)	105	Japan	70	63	0	-	Y
Oliveira, 2019(111)	131	Australia	72	71	0		NR
Park 2008(112)	50	Korea	69	100	0	-	NR
Reinsch, 1992(113)	230	USA	74	80	0	-	Y
Resnick, 2002(114)	20	USA	88	100	0	-	Y
Robertson, 2001(115)	240	New Zealand	81	68	0	-	Y
Rubenstein, 2000(116)	59	USA	74	0	1	Previous falls or lower limb weakness or poor balance	Y

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Sakamoto, 2013(117)	1365	Japan	81	82	1	Poor balance	NR
Sales 2017(118)	66	Australia	73	69	1	Previous falls or fear of falling	Y
Sherrington, 2014(119)	340	Australia	81	74	1	Recent hospitalisation	Y
Shigematsu, 2008(120)	68	Japan	69	63	0	-	Y
Siegrist, 2016(121)	378	Germany	78	74	1	Poor balance or fear of falling	Y
Skelton, 2005(122)	81	UK	73	100	1	Previous falls	Y
Smulders, 2010(123)	96	Netherlands	71	94	1	Previous falls	Y
Steadman, 2003(124)	199	UK	83	82	1	Poor balance	Y
Suzuki, 2004(125)	52	Japan	78	100	0	-	Y
Taylor, 2012(126)	684	New Zealand	75	73	1	Previous falls	Y
Trombetti, 2011(127)	134	Switzerland	76	96	1	Previous falls or poor balance	Y
Uusi-Rasi, 2015(128)	205	Finland	74	100	1	Previous falls	Y
Verrusio, 2017(129)	150	Italy	65	53	1	Poor balance	NR
Vogler, 2009(130)	180	Australia	80	83	1	Recent hospitalisation	Y
Voukelatos, 2007(131)	702	Australia	69	84	0	-	Y
Voukelatos, 2015(132)	386	Australia	73	74	0	-	NR
Weerdesteyn, 2006(133)	58	Netherlands	74	77	1	Previous falls	Y
Wolf, 1996(134)	200	USA	76	81	0	-	Y
Wolf, 2003(135)	311	USA	81	94	1	Previous falls	Y
Woo, 2007(136)	180	China	69	50	0	-	Y
Wu, 2010(137)	64	USA	76	84	1	Previous falls	Y
Yamada, 2010(138)	60	Japan	NR	NR	0	-	Y
Yamada, 2012(139)	157	Japan	86	81	0	-	Y
Yamada, 2013(140)	264	Japan	77	57	0	-	Y
Yang, 2012(141)	165	Australia	81	44	1	Poor balance	N

^a Presence of a particular risk factor for falls was used as inclusion criteria of the trial (0= No specific risk; 1= Previous falls, poor balance, recent hospitalisation, reduced lower strength, poor mobility, use mobility aids, frail, prolong bed rest, recent rehabilitation, functional limitation, all participants greater than age 80); ^b Attendance rate exceeded 50% and/or 75% or more of the participants attended 50% or more sessions; ^c In people lost to follow-up; ^d Determined using numbers in each age group; N=No, Y=Yes, NR = not reported

Table 3: Risk of bias assessment of the 116 included trials

First author, year	Sequence generation ^a	Allocation concealment ^a	Blinding of participants and personnel ^a	Blinding of outcome assessment ^a	Incomplete outcome data ^a	Selective outcome data ^a	Ascertainment bias ^a
Almeida, 2013(26)	2	2	2	2	3	3	3
Ansai, 2015(27)	1	1	2	3	1	3	2
Arantes, 2015(28)	2	2	2	2	2	3	2
Arkkukangas, 2019(29)	1	1	2	1	1	1	1
Ballard, 2004(30)	2	2	2	3	1	3	3
Barclay, 2018(31)	1	2	2	1	1	1	1
Barker, 2016(32)	1	1	2	2	2	1	1
Barnett, 2003(33)	2	1	2	2	1	2	2
Bernardelli, 2019(34)	1	2	2	3	3	1	2
Beyer, 2007(35)	1	2	2	2	2	3	1
Boongird, 2017(36)	1	1	2	1	1	1	1
Brown, 2002(37)	1	1	2	2	3	3	1
Buchner, 1997(38)	1	2	2	2	2	2	1
Bunout, 2005(39)	1	2	2	2	2	3	2
Campbell, 1997(40)	1	1	2	3	1	2	1
Carter, 2002(41)	1	2	2	1	1	3	1
Cerny, 1998(42)	1	3	2	2	1	3	3
Clegg, 2014(43)	1	1	2	2	2	1	2
Clemson, 2010(44)	1	1	2	2	1	2	1
Clemson, 2012(45)	1	1	2	1	2	1	1
Cornillon, 2002(46)	1	2	2	2	1	2	1
Dadgari, 2016(47)	2	2	2	2	3	2	3
Dangour, 2011(48)	1	3	2	3	3	3	3
Davis, 2011(49)	1	1	1	1	1	3	1
Day, 2002(50)	1	1	2	1	1	2	1

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Day, 2015(51)	1	1	2	1	1	1	1
Duque, 2013(52)	2	2	2	1	1	3	3
Ebrahim, 1997(53)	1	2	3	3	3	2	2
El-Khoury, 2015(54)	1	1	2	1	1	1	1
Fiatarone, 1997(55)	2	2	2	2	2	3	2
Freiberger, 2007(56)	1	2	2	2	1	3	1
Gallo, 2018(57)	2	2	2	2	3	1	2
Gill, 2016(58)	1	1	2	2	2	3	3
Grahn Kronhed, 2009(59)	1	1	2	1	1	3	1
Gschwind, 2015(60)	1	2	2	1	1	3	1
Haines, 2009(61)	1	1	2	1	1	1	1
Halvarsson, 2013(62)	1	2	2	3	2	3	3
Halvarsson, 2016(63)	1	2	3	3	2	3	3
Hamrick, 2017(64)	2	2	2	1	1	2	3
Hauer, 2001(65)	2	2	2	1	1	2	1
Helbostad, 2004(66)	2	1	1	1	1	2	1
Hirase, 2015(67)	2	2	2	3	1	3	1
Huang, 2010(68)	2	3	2	2	3	3	2
Hwang, 2016(69)	1	1	2	1	3	2	1
Iliffe, 2015(70)	1	1	2	3	3	2	3
Irez, 2011(71)	2	2	2	3	1	3	1
Iwamoto, 2009(72)	2	2	2	3	1	3	3
Kamide, 2009(73)	1	2	3	2	3	3	3
Karinkanta, 2007(74)	1	1	2	2	1	3	3
Kemmler, 2010(75)	1	1	1	1	1	3	1
Kerse, 2010(76)	1	2	3	1	1	2	3
Kim, 2014(77)	1	2	2	1	1	3	2
Korpelainen, 2006(78)	1	1	2	1	1	3	3
Kovacs, 2013(79)	2	1	2	1	1	2	1
Kwok, 2016(80)	2	2	2	1	1	3	1

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Kyrdalen, 2014(81)	1	1	3	3	3	3	3
LaStayo 2017(82)	2	2	2	3	2	2	1
Latham, 2003(83)	1	1	1	1	2	2	2
Lehtola, 2000(84)	2	2	2	2	3	1	2
Li, 2005(85)	1	2	2	1	3	2	1
Li, 2018(86)	1	2	2	1	1	1	1
Lin, 2007(87)	2	2	2	2	3	3	1
Lipsitz, 2019(88)	1	2	2	1	3	1	1
Liston, 2014(89)	1	2	2	2	3	3	3
Liu-Ambrose, 2004(90)	2	2	2	2	1	3	1
Liu-Ambrose, 2008(91)	1	1	2	3	3	2	1
Liu-Ambrose, 2019(92)	1	1	2	2	1	1	1
Logghe, 2009(93)	1	1	2	1	1	2	1
Lord, 1995(94)	2	2	2	3	2	2	3
Lord, 2003(95)	2	3	2	3	3	2	1
Lurie, 2013(96)	1	2	2	3	2	3	3
Luukinen, 2007(97)	1	2	2	1	3	2	3
Ma, 2019(98)	2	1	2	1	3	1	3
Madureira, 2007(99)	2	2	2	1	1	3	2
McMurdo, 1997(100)	2	2	2	2	3	2	2
Means, 2005(101)	1	2	2	1	3	2	1
Merom, 2016(102)	1	2	2	1	1	1	1
Miko, 2016(103)	2	2	2	2	1	2	1
Mirelman, 2016(104)	1	1	2	1	1	3	1
Morgan, 2004(105)	2	2	2	2	3	3	1
Morone, 2016(106)	1	1	2	2	3	3	2
Morrison, 2018(107)	1	2	2	2	3	3	3
Ng, 2015(108)	1	1	2	1	1	3	3
Nitz, 2004(109)	1	2	2	1	3	3	1
Okubo, 2016(110)	1	2	2	3	2	3	1

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Oliveira, 2019(111)	1	1	2	1	1	1	1
Park 2008(112)	1	2	2	2	1	3	3
Reinsch, 1992(113)	2	3	2	2	1	3	1
Resnick, 2002(114)	1	2	2	2	3	3	2
Robertson, 2001(115)	1	1	2	1	1	2	1
Rubenstein, 2000(116)	1	2	2	3	1	2	2
Sakamoto, 2013(117)	1	2	2	2	3	2	1
Sales 2017(118)	1	2	2	3	3	1	1
Sherrington, 2014(119)	1	1	2	1	1	1	1
Shigematsu, 2008(120)	1	2	1	3	1	2	1
Siegrist, 2016(121)	1	2	2	1	1	1	1
Skelton, 2005(122)	1	2	2	1	1	2	1
Smulders, 2010(123)	2	2	2	1	1	2	1
Steadman, 2003(124)	1	2	2	1	3	3	3
Suzuki, 2004(125)	2	2	2	2	2	2	3
Taylor, 2012(126)	1	1	2	1	1	2	1
Trombetti, 2011(127)	1	1	2	2	1	2	1
Uusi-Rasi, 2015(128)	1	2	2	2	2	2	1
Verrusio, 2017(129)	1	2	2	2	1	3	1
Vogler, 2009(130)	1	1	2	1	1	3	1
Voukelatos, 2007(131)	1	2	2	1	1	2	1
Voukelatos, 2015(132)	1	1	2	2	2	2	1
Weerdesteyn, 2006(133)	2	2	2	3	1	2	1
Wolf, 1996(134)	1	2	2	2	1	3	1
Wolf, 2003(135)	2	2	2	1	1	2	1
Woo, 2007(136)	1	2	2	3	3	3	3
Wu, 2010(137)	2	2	2	2	1	3	3
Yamada, 2010(138)	2	1	2	2	2	2	1
Yamada, 2012(139)	2	1	3	2	1	2	1
Yamada, 2013(140)	2	2	2	2	2	1	1

Yang, 2012(141)	1	2	2	1	3	3	3
Total low risk (%)	79 (68%)	42 (36%)	5 (4%)	48 (41%)	62 (53%)	22 (19%)	68 (59%)
Total unclear risk (%)	37 (32%)	69 (59%)	105 (91%)	44 (38%)	21 (18%)	42 (36%)	18 (16%)
Total high risk (%)	0 (0%)	5 (4%)	6 (5%)	24 (21%)	33 (28%)	52 (45%)	30 (26%)

^a Assessed using the Cochrane Risk of Bias tool(17) (1 = Low risk; 2 = unclear risk; 3 = high risk)

Table 4. Summary of findings. Rate of falls outcome (falls per person-years) for types of exercise

Type of exercise	Follow-up range	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No. of participants (studies)	Certainty of the evidence (GRADE)	Comments
		Assumed risk	Corresponding risk				
Exercise ^a (all types) versus control ^b (e.g. usual activities)	3 to 30 months	Control	Exercise (all types)	Rate ratio 0.77 (0.71 to 0.83) ^d	14,306 (64 RCTs)	High ^e	Overall, there is a reduction of 23%(95%CI 17% to 29%) in the number of falls Guide to the data: If 1000 people were followed over 1 year, the number of falls in the overall population would be 655 (95% CI 604 to 706) compared with 850 in the group receiving usual care or attention control. In the unselected population, the corresponding data are 466 (95%CI 430 to 503) compared with 605 in the group receiving usual care or attention control. In the selected higher-risk population, the corresponding data are 993 (95%CI 915 to 1071) compared with 1290 in the control group
		All studies population					
		850 per 1000 ^c	655 per 1000 (604 to 706)				
		Not selected for high risk population					
		605 per 1000 ^c	466 per 1000 (430 to 503)				
		Selected for high risk population					
		1290 per 1000 ^c	993 per 1000 (915 to 1071)				
Balance, and functional exercises ^f versus control ^b (e.g. usual activities)	3 to 30 months	Control	Exercise (gait, balance, and functional training)	Rate ratio 0.76 (0.70 to 0.82)	7989 (39 RCTs)	High ^h	Overall, there is a reduction of 24% (95%CI 18% to 30%) in the number of falls Guide to the data based on the all-studies estimate. If 1000 people were followed over 1 year, the number of falls would be 646 (95% CI 595 to 689) compared with 850 in the group receiving usual care or attention control
		All studies population					
		850 per 1000 ^g	646 per 1000 (595 to 689)				
		Specific exercise population					
		865 per 1000 ^g	657 per 1000 (606 to 709)				

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Resistance exercises ⁱ versus control ^b (e.g. usual activities)	4 to 12 months	Control	Exercise (resistance training)	Rate ratio 1.14 (0.67 to 1.97)	327 (5 RCTs)	Very low ^k	The evidence is of very low certainty, hence we are uncertain of the findings of an increase of 14% (95% CI 33% reduction to 97% increase) in the number of falls. Guide to the data based on the all-studies estimate. If 1000 people were followed over 1 year, the number of falls would be 969 (95% CI 570 to 1675) compared with 850 in the group receiving usual care or attention control
		All studies population					
		850 per 1000 ^j	969 per 1000 (570 to 1675)				
		Specific exercise population					
		630 per 1000 ^j	719 per 1000 (423 to 1242)				
3D (Tai Chi) exercise ⁱ versus control ^b (e.g. usual activities)	6 to 17 months	Control	Exercise (3D (Tai Chi))	Rate ratio 0.77 (0.61 to 0.97)	3169 (9 RCTs)	Moderate ⁿ	Overall, there is probably be a reduction of 23% (95% CI 3% to 39%) in the number of falls. Guide to the data based on the all-studies estimate. If 1000 people were followed over 1 year, the number of falls is probably 655 (95% CI 519 to 825) compared with 850 in the group receiving usual care or attention control
		All studies population					
		850 per 1000 ^m	655 per 1000 (519 to 825)				
		Specific exercise population					
		1290 per 1000 ^m	993 per 1000 (787 to 1251)				
3D (dance) exercise ^o versus control ^b (e.g. usual activities)	12 months	Control	Exercise (3D [dance])	Rate ratio 1.34 (0.98 to 1.83)	522 (1 RCT)	Very low ^q	The evidence is of very low certainty, hence we are uncertain of the findings of an increase of 34% (95% CI 2% reduction to 83% increase) in the number of falls. Guide to the data based on the all-studies estimate. If 1000 people were followed over 1 year, the number of falls may be 1139 (95% CI 833 to 1556) compared with 850 in the group receiving usual care or attention control
		All studies population					
		850 per 1000 ^p	1139 per 1000 (833 to 1556)				
		Specific exercise population					
		800 per 1000 ^p	1072 per 1000 (784 to 1464)				
General physical activity (including walking) training ^r versus control ^b	12 to 24 months	Control	Exercise (general physical activity [including walking])	Rate ratio 1.14 (0.66 to 1.97)	441 (2 RCTs)	Very low ^t	The evidence is of very low certainty, hence we are uncertain of the findings of an increase of 14% (95% CI 34% reduction to 97% increase) in the number of falls

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(e.g. usual activities)		All studies population					Guide to the data based on the all-studies estimate If 1000 people were followed over 1 year, the number of falls may be 969 (95% CI 561 to 1675) compared with 850 in the group receiving usual care or attention control
		850 per 1000 ^s	969 per 1000 (561 to 1675)				
		Specific exercise population					
		670 per 1000 ^s	764 per 1000 (443 to 1320)				
Multiple categories of exercise (often including, as primary interventions: gait, balance, and functional (task) training plus resistance training ^u versus control ^b (e.g. usual activities)	2 to 25 months	Control	Exercise (multiple types (including, as primary interventions: gait, balance, and functional (task) training plus resistance training))	Rate ratio 0.72 (0.56 to 0.93) ^r	2283 (15 RCTs)	Moderate ^w	Overall, there is probably a reduction of 28% (95% CI 7% to 44%) in the number of falls Guide to the data based on the all-studies estimate If 1000 people were followed over 1 year, the number of falls would probably be 612 (95%CI 476 to 791) compared with 850 in the group receiving usual care or attention control
		All studies population					
		850 per 1000 ^v	612 per 1000 (476 to 791)				
		Specific exercise population					
		1205 per 1000 ^v	868 per 1000 (675 to 791)				

CI: confidence interval

GRADE Working Group grades of evidence

High certainty: We are very confident that the true effect lies close to that of the estimate of the effect

Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect

Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

^a Exercise is a physical activity that is planned, structured and repetitive and aims to improve or maintain physical fitness. There is a wide range of possible types of exercise, and exercise programmes of ten include one or more types of exercise. We categorised exercise based on the Prevention of Falls Network Europe (ProFaNE) taxonomy that classifies exercise type as: i) gait, balance, and functional training; ii) strength/ resistance (including power); iii) flexibility; iv) three- dimensional (3D) exercise (e.g. Tai Chi, Qigong, dance); v) general physical activity; vi) endurance; and vii) other kind of exercises. The taxonomy allows for more than one type of exercise to be delivered within a programme.

^b A control intervention is one that is not thought to reduce falls, such as general health education, social visits, very gentle exercise, or 'sham' exercise not expected to impact on falls.

^c The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 RCTs. We calculated the risk in the control group using the median falls per person-year for the subgroups of trials for which a) an increased risk of falls was not an inclusion criterion (32 RCTs, 6434 participants), or b) increased risk of falls was an inclusion criterion (32 RCTs, 7872 participants).

^d Subgroup analysis found no difference based on whether risk of falls was an inclusion criterion or not (test for subgroup differences: $\text{Chi}^2 = 0.1$, $\text{df} = 1$, $P = 0.75$, $I^2 = 0\%$).

^e There was no downgrading, including for risk of bias, as results were essentially unchanged with removal of the trials with a high risk of bias on one or more items.

^f Using Prevention of Falls Network Europe (ProFaNE) taxonomy, gait, balance, and functional training is: gait training = specific correction of walking technique, and changes of pace, level and direction; balance training = transferring bodyweight from one part of the body to another or challenging specific aspects of the balance systems; functional training = functional activities, based on the concept of task specificity. Training is assessment-based, tailored and progressed. Exercise programs included in this analysis contained a single primary exercise category (gait, balance, and functional training); these exercise programs may also include secondary categories of exercise.

^g The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 all-exercise types RCTs. The specific exercise population risk was based on the number of events and the number of participants in the control group for this outcome over the 39 RCTs.

^h We did not downgrade for risk of bias, as results were essentially unchanged with the removal of the trials with a high risk of bias in one or more items.

ⁱ Using Prevention of Falls Network Europe (ProFaNE) taxonomy, resistance training is any type of weight training (contraction of muscles against resistance to induce a training effect in the muscular system). Resistance is applied by body weight or external resistance. Training is assessment-based, tailored and progressed. Exercise programmes included in this analysis had resistance training as the single primary exercise category; these exercise programmes may also include secondary categories of exercise.

^j The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 all-exercise types RCTs. The specific exercise population risk was based on the number of events and the number of participants in the control group for this outcome over the 5 RCTs.

^k Downgraded by three levels due to risk of inconsistency (there was substantial heterogeneity ($I^2 = 67\%$)), imprecision (wide CI due to small sample size), and risk of bias (removing studies with high risk of bias in one or more items had a marked impact on results).

^l Using Prevention of Falls Network Europe (ProFaNE) taxonomy, 3D (Tai Chi) training uses upright posture, specific weight transferences and movements of the head and gaze, during constant movement in a fluid, repetitive, controlled manner through three spatial planes. Exercise programmes included in this analysis had 3D (Tai Chi) training as the single primary exercise category; these exercise programmes may also include secondary categories of exercise.

^m The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 all-exercise types RCTs. The specific exercise population risk was based on the number of events and the number of participants in the control group for this outcome over the nine RCTs.

ⁿ Downgraded by one level due to inconsistency (there was substantial heterogeneity ($I^2 = 83\%$). There was no downgrading for risk of bias, as results were essentially unchanged with removal of the trials with a high risk of bias on one or more items.

^o Using Prevention of Falls Network Europe (ProFaNE) taxonomy, 3D (dance) training uses dynamic movement qualities, patterns and speeds whilst engaged in constant movement in a fluid, repetitive, controlled manner through three spatial planes. Exercise programmes included in this analysis had 3D (dance) training as the single primary exercise category; these exercise programmes may also include secondary categories of exercise.

^p The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 all-exercise types RCTs. The specific exercise population risk was based on the number of events and the number of participants in the control group for this outcome in the sole RCT.

^q Graded very low due to serious imprecision (only one cluster-RCT, with a wide CI due to small sample size).

^r Using Prevention of Falls Network Europe (ProFaNE) taxonomy, physical activity is any movement of the body, produced by skeletal muscle, that causes energy expenditure to be substantially increased. Recommendations regarding intensity, frequency and duration are required in order to increase performance. Exercise programmes included in this analysis had general physical activity (including walking) training as the single primary exercise category; these exercise programmes may also include secondary categories of exercise.

^s The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 all-exercise types RCTs. The specific exercise population risk was based on the number of events and the number of participants in the control group for this outcome in the two RCTs.

^t Downgraded by three levels due to inconsistency (there was substantial heterogeneity ($I^2 = 67\%$)), imprecision (wide CI), and risk of bias (removing studies with high risk of bias on one or more items had a marked impact on results).

^u Exercise programmes included in this analysis had more than one primary exercise category. We categorised exercise based on the Prevention of Falls Network Europe (ProFaNE) taxonomy that classifies exercise type as: i) gait, balance, and functional (task) training; ii) strength/ resistance (including power); iii) flexibility; iv) three-dimensional (3D) exercise (e.g. Tai Chi, Qigong, dance); v) general physical activity; vi) endurance; and vii) other kind of exercises. The programmes of ten included, as the primary intervention, gait, balance, and functional (task) training plus resistance training. The exercise programmes may also include secondary categories of exercise.

^v The all-studies population risk was based on the number of events and the number of participants in the control group for this outcome over the 64 all-exercise types RCTs. The specific exercise population risk was based on the number of events and the number of participants in the control group for this outcome over the 15 RCTs.

^w Downgraded by one level due to inconsistency (there was substantial heterogeneity ($I^2 = 71\%$)). We did not downgrade for risk of bias, as results were essentially unchanged with removal of the trials at a high risk of bias in one or more items

Table 5: Components of studies in categories of exercise found to prevent falls(10)

First author, year and interventions	Type of exercise according to ProFaNE classification ^{16 a}							Duration of intervention (weeks)	Hours of intervention	Delivery mode ^b	Participants per instructor ^c	Tailored to the individual initially	Progressed based on individual assessment	Tailored in intensity or type	
	Balance or functional training	Strength or resistance training	Flexibility training	3D exercise	General physical activity	Endurance exercise	Other exercise								
Gait/Balance/functional training															
Almeida 2013 Fully supervised group-based balance and strength training(26)	P	S	S	-	-	-	-	16	40	1	NR	N	NR	N	
Almeida 2013 Minimally supervised group-based balance and strength training(26)	P	S	S	-	-	-	-	16	32	4	NR	N	NR	N	
Arantes 2015 Group-based balance training(28)	P	-	-	-	-	-	-	12	12	1	NR	Y	Y	Y	
Arkkukangas 2019 Individual Otago Exercise Program(29)	P	S	-	-	S	-	-	52	84	3	None	Y	Y	Y	
Barnett 2003 Group-based balance, strength and aerobic training(33)	P	S	-	-	-	S	-	52	65	4	NR	N	N	N	
Boongird 2017 Individual Otago Exercise Program(36)	P	S	-	-	S	-	-	52	104	3	None	Y	Y	Y	
Campbell 1997 Individual Otago Exercise Program(40)	P	S	-	-	S	-	-	52	160	3	None	Y	Y	Y	
Clegg 2014 Individual balance and strength training(43)	P	S	-	-	-	-	-	12	54	3	None	Y	Y	Y	
Clemson 2010 LiFE (Lifestyle approach to reducing Falls through Exercise) programme- balance and strength training embedded in daily life activities(44)	P	S	-	-	-	-	-	26	60	3	None	Y	Y	Y	
Clemson 2012 LiFE (Lifestyle approach to reducing Falls through Exercise) programme- balance and strength training embedded in daily life activities(45)	P	S	-	-	-	-	-	52	87	3	None	Y	Y	Y	
Cornillon 2002 Group-based balance and gait training(46)	P	-	-	-	-	-	-	52	10	1	NR	N	N	N	
Dadgari 2016 Individual Otago Exercise Program(47)	P	S	-	-	S	-	-	24	72	3	None	Y	Y	Y	

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Dangour 2011 Group-based balance and strength(48)	P	S	-	-	S	-	-	104	104	1	NR	N	N	N
Day 2002 Group-based balance and strength(50)	P	S	S	-	-	-	-	18	30	1	NR	N	N	N
Duque 2013 Virtual reality balance training(52)	P	-	-	-	-	-	S- visual-vestibular rehab	6	6	2	1	N	Y	Y
El-Khoury 2015 Group-based balance and strength plus home practice(54)	P	S	S	-	-	-	-	104	104	4	NR	Y	Y	Y
Gschwind 2015 Individual balance and strength training using exergames(60)	P	S	-	-	-	-	-	16	12	3	None	Y	Y	Y
Halvarsson 2013 Group-based progressive balance training(62)	P	-	-	-	-	-	-	12	27	1	3-3.5	Y	Y	Y
Halvarsson 2016 Group-based progressive balance training(63)	P	-	-	-	-	-	-	12	27	1	6-10	Y	Y	Y
Hamrick 2017 Home exercise group(64)	P	-	S	-	-	-	-	8	41	4	11-13	Y	Y	Y
Hirase 2015 Group-based balance training on foam rubber(67)	P	-	-	-	-	-	-	16	16	4	10	N	N	N
Hirase 2015 Group-based balance training on stable surface(67)	P	-	-	-	-	-	-	16	16	4	10	N	N	N
Iliffe 2015 Group-based FaME plus home training based on Otago Exercise Program(70)	P	S	-	-	S	-	-	24	72	4	9-10	Y	Y	Y
Iliffe 2015 Individual Otago Exercise Program(70)	P	S	-	-	S	-	-	24	60	3	None	Y	Y	Y
Iwamoto 2009 Group-based balance and gait training(72)	P	-	-	-	-	-	-	20	30	4	NR	N	N	N
Karinkanta 2007 Group-based balance and agility training(74)	P	-	-	-	-	-	-	52	104	1	NR	N	N	N
Kerse 2010 Individual Otago Exercise Program(76)	P	S	-	-	S	-	-	26	67	3	None	Y	Y	Y
Korpelainen 2006 Group-based balance and strength training plus home practice(78)	P	S	-	-	-	-	-	130	173	4	5-8	Y	N	Y
Kovacs 2013 Group-based balance and strength based on Otago Exercise Program(79)	P	S	-	-	S	-	-	25	52	1	30-38	Y	Y	Y
Lin 2007 Individual balance, strength and flexibility training(87)	P	S	S	-	-	-	-	16	27	2	1	Y	Y	Y
Liu-Ambrose 2004 Supervised agility training(90)	P	-	-	-	-	-	-	25	40	1	3	N	N	N
Liu-Ambrose 2008 Individual Otago Exercise Program(91)	P	S	-	-	S	-	-	26	65	3	None	Y	Y	Y
Lord 1995 Group-based balance, strength, gait training(94)	P	S	S	-	-	-	-	52	88	1	NR	N	N	N
Lord 2003 Group-based balance, strength, gait training(95)	P	S	S	-	-	-	-	52	96	1	NR	N	N	N
Luukinen 2007 Individual balance and gait training(97)	P	-	-	-	S	-	-	70	161	3	None	Y	N	Y
Madureira 2007 Group-based balance training and walking plus home practice(99)	P	-	-	-	S	-	-	40	100	4	NR	N	N	N
McMurdo 1997 Group-based balance training(100)	P	-	-	-	-	-	-	60	135	1	NR	N	N	N
Miko 2017 Individual, partially supervised balance training(103)	P	-	-	-	-	-	-	52	312	4	NR	N	Y	Y

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Morgan 2004 Group-based strength, balance and gait training(105)	P	S	S	-	-	-	-	8	18	1	5	Y	Y	Y
Nitz 2004 Group-based balance(109)	P	-	-	-	-	-	-	10	10	1	6	N	Y	Y
Reinsch 1992 Group-based balance and strength training(113)	P	S	-	-	-	-	-	52	156	1	NR	N	N	N
Robertson 2001 Individual Otago Exercise Program(115)	P	S	-	-	S	-	-	52	96	3	None	Y	Y	Y
Sakamoto 2013 One leg stand balance training(117)	P	-	-	-	-	-	-	26	6	3	None	Y	Y	Y
Sales 2017 Group-based strength, balance, co-ordination, mobility and flexibility(118)	P	S	-	-	-	-	-	18	45	1	6-8	Y	Y	Y
Siegrist 2016 Group-based balance, strength, power and gait training plus home practice(121)	P	S	-	-	-	-	-	16	16	4	4-12	Y	Y	Y
Skelton 2005 Group-based FaME balance and strength training plus home practice(122)	P	S	-	-	S	-	-	36	62	4	NR	Y	Y	Y
Smulders 2010 Group-based balance and gait training using an obstacle avoidance course(123)	P	-	-	-	S	-	S-training in fall techniques, lifting techniques	5.5	21	1	NR	N	N	N
Trombetti 2011 Group-based balance and gait training(127)	P	-	-	-	-	-	-	26	26	1	NR	N	N	N
Weerdesteyn 2006 Group-based balance and gait training using an obstacle avoidance course(133)	P	-	-	-	S	-	-	5	15	1	NR	N	N	N
Wolf 1996 Individual, computerised balance training on force platform.(134)	P	-	-	-	-	-	-	15	11	2	1	Y	Y	Y
Yang 2012 Individual Otago Exercise Program(141)	P	S	-	-	S	-	-	26	87	3	None	Y	Y	Y
3D														
Day 2015 Group-based Tai Chi(51)	-	-	-	P	-	-	-	48	96	1	12-16	N	N	N
Huang 2010 Group-based Tai Chi(68)	-	-	-	P	-	-	-	22	40	1	NR	N	N	N
Li 2005 Group-based Tai Chi(85)	-	-	-	P	-	-	-	26	78	1	NR	N	N	N
Li 2018 Tai Ji Quan(86)	-	-	-	P	-	-	-	24	48	1	9-21	N	N	Y
Lipsitz 2019 Group-based Tai Chi(88)	-	-	-	P	-	-	-	52	164	1	NR	N	NR	N R
Logghe 2009 Group-based Tai Chi(93)	-	-	-	P	-	-	-	13	33	4	7-14	N	N	N
Merom 2016 Group-based social dancing(102)	-	-	-	P	-	S	-	52	80	1	13-43	N	N	N
Taylor 2012 Group-based Tai Chi, 2x/ week(126)	-	-	-	P	-	-	-	20	40	1	15	N	N	N
Taylor 2012 Group-based Tai Chi, 1x/ week(126)	-	-	-	P	-	-	-	20	20	1	15	N	N	N
Voukelatos 2007 Group-based Tai Chi(131)	-	-	-	P	-	-	-	16	16	1	NR	N	N	N
Wolf 1996 Group-based Tai Chi(134)	-	-	-	P	-	-	-	15	60	4	NR	N	Y	Y

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Wolf 2003 Group-based Tai Chi(135)	-	-	-	P	-	-	-	48	120	1	NR	N	N	N
Woo 2007 Group-based Tai Chi(136)	-	-	-	P	-	-	-	52	156	1	NR	N	N	N
Wu 2010 Individual, supervised Tai Chi delivered via video conferencing(137)	-	-	-	P	-	-	-	15	45	2	1	N	N	N
Wu 2010 Group-based Tai Chi(137)	-	-	-	P	-	-	-	15	45	1	NR	N	N	N
Wu 2010 Individual Tai Chi with DVD instruction(137)	-	-	-	P	-	-	-	15	45	3	None	N	N	N
Multiple primary exercise categories														
Ansai 2015 Group-based balance, strength and aerobic training(27)	P	P	-	-	-	P	-	16	48	1	NR	Y	Y	Y
Arkkukangas 2019 Individual Otago Exercise Program + motivational interviewing(29)	P	S	-	-	S	-	P	52	84	3	None	Y	Y	Y
Barclay 2018(31)	P	-	-	-	P	-	-	9	18	1	3	Y	Y	Y
Beyer 2007 Group-based balance, strength and flexibility training(35)	P	P	P	-	-	-	-	26	52	1	5-7	Y	Y	Y
Brown 2002 Group-based balance, strength and aerobic training(37)	P	P	-	-	-	S	S - co-ordination activities	16	32	1	NR	Y	Y	Y
Buchner 1997 Group-based strength training(38) (combined with endurance and combined groups in analysis)*	-	P	-	-	-	P	-	25	78	1	NR	Y	Y	Y
Bunout 2005 Group-based balance, strength and walking(39)	P	P	-	-	-	P	-	52	74	1	NR	Y	Y	Y
Cerny 1998 Group-based balance, strength, flexibility, aerobic training and brisk walking(42)	P	P	P	-	-	P	-	24	108	1	NR	NR	NR	N R
Clemson 2012 Individual balance and strength training(45)	P	P	-	-	-	-	-	52	78	3	None	Y	Y	Y
Gill 2016 Group and home-based balance, strength, flexibility and walking training(58)	P	P	S	-	P	-	-	96	180	4	NR	Y	Y	Y
Haines 2009 Home strength and balance program with DVD/workbook(61)	P	P	-	P	-	-	-	8	48	3	None	Y	N	Y
Halvarsson 2016 Group-based progressive balance training plus walking(63)	P	-	-	-	P	-	-	12	45	4	6-10	Y	Y	Y
Hauer 2001 Group-based progressive strength and balance training(65)	P	P	-	-	P	-	-	12	87	1	4-6	Y	Y	Y
Irez 2011 Group-based pilates(71)	P	P	-	-	-	-	-	12	36	1	NR	Y	Y	Y
Kamide 2009 Individual balance and strength training(73)	P	P	-	-	-	-	-	26	39	3	None	N	N	N
Karinkanta 2007 Combined group-based balance, agility and resistance training(74)	P	P	-	-	-	-	-	52	104	1	NR	Y	Y	Y
Kim 2014 Group-based balance and strength training(77)	P	P	-	-	-	-	-	52	54	1	NR	Y	Y	Y
Lehtola 2000 Group-based balance and flexibility training plus walking and home practice(84)	P	-	P	-	P	-	-	26	78	4	NR	N	N	N

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Li 2018 Group-based balance, gait, resistance and flexibility training(86)	P	P	P	-	-	-	-	24	48	1	9-21	Y	Y	Y
Liu-Ambrose 2019 Individualised Otago Exercise Program(92)	P	P	-	-	P	-	-	52	130	3	None	Y	Y	Y
Means 2005 Group-based balance, strength, flexibility, gait training and walking(101)	P	P	P	-	S	-	-	6	27	1	6-8	Y	Y	Y
Ng 2015 Group-based strength and balance training plus home practice(108)	P	P	-	-	-	-	-	12	24	4	8-10	Y	Y	Y
Park 2008 Strength and balance and endurance training(112)	P	S	S	-	-	P	-	48	144	1	NR	N	N	N
Rubenstein 2000 Group-based balance, strength and endurance(116)	S	P	-	-	-	P	-	12	54	1	8-10	N	N	N
Sherrington 2014 home-based strength and balance programme(119)	P	P	-	-	-	-	-	52	138	3	None	Y	Y	Y
Suzuki 2004 Group-based strength, balance and gait training plus home practice(125)	P	P	P	P	-	-	-	26	49	4	NR	N	N	N
Uusi-Rasi 2015 Group-based balance and strength training plus home practice(128)	P	P	-	-	-	-	-	104	260	4	NR	Y	Y	Y
Vogler 2009 home-based strength training with weight-bearing, functional tasks(130)	P	P	-	-	-	-	-	12	22	3	None	Y	Y	Y

^a Classification (P = Primary; S = Secondary); ^b Delivery mode (1 = Group; 2 = Individual supervised; 3 = Individual unsupervised; 4 = Group + Home exercise); ^c 1 if delivery mode was individual supervised, None if delivery mode was individual unsupervised; * An a priori decision was made to combine three intervention arms of Buchner 1997(38) as falls data were not available for individual intervention arm; N = No, Y = Yes, NR = Not reported

Table 6: Components of studies in categories of exercise not found to prevent falls(10)

First author, year and interventions	Type of exercise according to ProFaNE classification ^{16 a}							Duration of intervention (weeks)	Hours of intervention	Delivery mode ^b	Participants per instructor ^c	Tailored to the individual initially	Progressed based on individual assessment	Tailored in intensity or type	
	Balance or functional training	Strength or resistance training	Flexibility training	3D exercise	General physical activity	Endurance exercise	Other exercise								
Strength/resistance (including power)															
Ansai 2015 Group-based progressive strength training(27)	-	P	-	-	-	-	-	16	48	1	NR	Y	Y	Y	
Carter 2002 Group-based Osteofit strength training(41)	S	P	-	-	-	-	-	20	27	1	NR	N	N	N	
Fiatarone 1997 Individual high-intensity progressive resistance training(55)	-	P	-	-	-	-	-	16	30	3	None	NR	Y	Y	
Grahn Kronhed 2009 Group-based strength and balance training(59)	S	P	S	-	-	S	-	16	32	1	NR	Y	Y	Y	
Karinkanta 2007 Group-based resistance training(74)	-	P	-	-	-	-	-	52	104	1	NR	N	Y	Y	
Latham 2003 Resistance exercise(83)	-	P	-	-	-	-	-	10	16	3	None	Y	Y	Y	
Liu-Ambrose 2004 Supervised, high-intensity resistance training(90)	-	P	-	-	-	-	-	25	40	1	2	Y	Y	Y	
Vogler 2009 home-based seated lower limb strength exercises(130)	-	P	-	-	-	-	-	12	22	3	None	Y	Y	Y	
Woo 2007 Group-based resistance training(136)	S	P	-	-	-	-	-	52	156	1	NR	N	N	N	
General Physical activity															
Ebrahim 1997 Brisk walking(53)	-	-	-	-	P	-	-	104	216	3	None	N	Y	Y	
Resnick 2002 Individual or group-based walking(114)	-	-	-	-	P	-	-	26	39	4	NR	Y	Y	Y	
Voukelatos 2015 Individual walking programme(132)	-	-	-	-	P	-	-	48	120	3	None	N	N	N	
Other															

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Oliveira 2019(111)	-	-	-	-	-	-	Health coaching, pedometer	26	4	1	None	Y	Y	Y
Exercise vs exercise														
Ballard 2004 Group-based balance, strength and aerobic training for 15 weeks(30)	P	S	-	-	-	S	-	15	45	1	5	NR	NR	NR
Ballard 2004 Group-based balance, strength and aerobic training for 2 weeks(30)	P	S	-	-	-	S	-	2	6	1	5	NR	NR	NR
Barker 2016 Group-based Pilates focused on balance and strength plus home practice(32)	P	S	-	-	-	-	-	12	54	4	4-6	Y	Y	Y
Barker 2016 Individual strength and balance(32)	P	S	-	-	-	-	-	12	30	3	None	Y	Y	Y
Davis 2011 Group-based progressive high intensity resistance training once weekly(49)	-	P	-	-	-	-	-	52	52	1	NR	Y	Y	Y
Davis 2011 Group-based progressive high intensity resistance training twice weekly(49)	-	P	-	-	-	-	-	52	104	1	NR	Y	Y	Y
Davis 2011 Group-based balance and tone(49)	P	-	S	-	-	-	-	52	104	1	NR	N	N	N
Freiberger 2007 Group-based psychomotor programme(56)	P	P	-	-	-	-	P- perceptual training	16	32	4	7.5	N	Y	Y
Freiberger 2007 Group-based balance, strength, flexibility, endurance(56)	P	P	P	-	-	P	-	16	32	4	7.5	N	Y	Y
Helbostad 2004 Combined group and home-based balance and strength training(66)	P	S	-	-	-	-	-	12	51	4	5-8	Y	Y	Y
Helbostad 2004 Individual home balance and strength training(66)	P	S	-	-	-	-	-	12	27	3	None	N	N	N
Hwang 2016 Individually supervised Tai Chi(69)	-	-	-	P	-	-	-	24	48	2	1	Y	Y	Y
Hwang 2016 Individually supervised balance and strength training(69)	P	S	S	-	-	-	-	24	24	2	1	Y	Y	Y
Kemmler 2010 Group-based balance, gait flexibility and strength training plus home practice(75)	P	P	P	-	-	S	-	78	108 6	4	NR	Y	Y	Y
Kemmler 2010 Group-based low intensity, low frequency balance and endurance training(75)	P	-	P	-	-	S	-	78	10	1	NR	N	N	N
Kwok 2016 Group-based balance, strength and aerobic training plus home practice(80)	P	P	-	-	-	P	-	12	24	1	6-8	Y	Y	Y
Kwok 2016 Balance, strength and aerobic training using the Nintendo WiiActive(80)	P	P	-	-	-	P	-	12	24	1	6-8	Y	Y	Y
Kyrdalen 2014 Group-based Otago Exercise Program(81)	P	S	-	-	S	-	-	12	16	4	4-8	Y	Y	Y
Kyrdalen 2014 Individual Otago Exercise Program(81)	P	S	-	-	S	-	-	12	16	3	None	Y	Y	Y
LaStayo 2017 Resisted lower limb exercise in standing and leg press(82)	P	P	S	-	S	-	-	12	36	1	2-5	Y	Y	Y

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LaStayo 2017 Resisted lower limb exercise using recumbent stepper-ergometer(82)	P	P	S	-	S	-	-	12	36	1	2-6	Y	Y	Y
Liston 2014 Group-based modified Otago Exercise Program plus individual, partially supervised multisensory balance training(89)	P	S	-	-	S	-	-	8	28	4	NR	Y	Y	Y
Liston 2014 Group-based modified Otago Exercise Program plus individual, partially supervised flexibility training(89)	P	S	S	-	S	-	-	8	28	4	NR	Y	N	Y
Lurie 2013 Standard Physical Therapy programme + surface perturbation treadmill training(96)	P	S	S	-	-	-	S- slip and trip training	Variable	Variable	2	1	Y	Y	Y
Lurie 2013 Standard Physical Therapy programme(96)	P	S	-	-	-	-	-	Variable	Variable	2	1	Y	Y	Y
Mirelman 2016 Individual, supervised treadmill training(104)	P	-	-	-	-	P	-	6	14	2	1	Y	Y	Y
Mirelman 2016 Individual, supervised treadmill training plus virtual reality(104)	P	-	-	-	-	S	-	6	14	2	1	Y	Y	Y
Morone 2016 Group-based balance training using Wii-Fit(106)	P	-	-	-	S	-	-	8	16	1	NR	N	N	N
Morone 2016 Group-based balance training(106)	S	-	P	-	-	-	-	8	16	1	NR	N	N	N
Morrison 2018 Group-based balance training(107)	P	-	-	-	-	-	-	12	22	1	3-5	N	N	N
Morrison 2018 Home-based strength, balance and aerobic Wii Fit programme(107)	P	-	-	-	-	S	-	12	22	2	1	Y	Y	Y
Okubo 2016 Group-based Tai Chi and Otago Exercise Program plus home practice(110)	S	S	-	P	S	-	-	64	88	1	NR	N	Y	Y
Okubo 2016 Group-based brisk walking(110)	-	-	-	-	P	-	-	64	120	1	NR	Y	Y	Y
Shigematsu 2008 Group-based stepping training on felt mat(120)	P	-	-	-	-	-	-	12	56	1	NR	N	Y	Y
Shigematsu 2008 Group-based walking(120)	P	-	-	-	P	-	-	12	16	1	NR	N	Y	Y
Steadman 2003 Standard, individualised physiotherapy focused on functional training plus balance training(124)	P	-	-	-	-	-	-	6	9	2	1	Y	Y	Y
Steadman 2003 Standard, individualised physiotherapy focused on functional training(124)	P	-	-	-	-	-	-	4	6	2	1	Y	N	Y
Verrusio 2017 Individual, supervised balance and gait training using exoskeleton human body posturizer(129)	P	-	-	-	-	-	-	52	156	2	1	Y	NR	Y
Verrusio 2017 Individual, supervised balance and gait training(129)	P	-	-	-	-	-	-	52	157	2	1	Y	NR	Y
Yamada 2010 Group-based indoor walking(138)	S	S	S	-	P	-	-	16	24	1	NR	Y	Y	Y
Yamada 2010 Group-based trail walking(138)	P	S	S	-	S	-	-	16	24	1	NR	Y	Y	Y
Yamada 2012 Group-based balance, strength, flexibility and gait training involving complex obstacle course(139)	P	S	S	-	S	-	-	24	24	1	NR	N	N	N
Yamada 2012 Group-based balance, strength, flexibility and gait training involving simple obstacle course(139)	P	S	S	-	S	-	-	24	24	1	NR	N	N	N

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Yamada 2013 Group-based balance, strength, flexibility and gait training including stepping mat(140)	P	S	S	-	S	-	-	24	18	1	NR	N	N	N
Yamada 2013 Group-based balance, strength, flexibility and gait training plus indoor walking(140)	P	S	S	-	S	-	-	24	18	1	NR	N	N	N

^a Classification (P = Primary; S = Secondary); ^b Delivery mode (1 = Group; 2 = Individual supervised; 3 = Individual unsupervised; 4 = Group + Home exercise); ^c 1 if delivery mode was individual supervised, None if delivery mode was individual unsupervised; * An a priori decision was made to combine three intervention arms of Buchner 1997(38) as falls data were not available for individual intervention arm; N = No, Y = Yes, NR = Not reported

Appendix 1. Search strategy

CENTRAL (CRS Online)

#1 MESH DESCRIPTOR Accidental Falls EXPLODE ALL TREES
#2 (falls or faller*):TI,AB,KY
#3 #1 or #2
#4 MESH DESCRIPTOR Aged EXPLODE ALL TREES
#5 (senior* or elder* or old* or aged or ag?ing or postmenopausal or community dwelling):TI,AB,KY
#6 #4 or #5
#7 #3 and #6

MEDLINE (Ovid Interface)

1 Accidental Falls/
2 (falls or faller*1).tw.
3 or/1-2
4 exp Aged/
5 (senior*1 or elder* or old* or aged or ag?ing or postmenopausal or community dwelling).tw.
6 or/4-5
7 3 and 6
8 Randomized controlled trial.pt.
9 Controlled clinical trial.pt.
10 randomized.ab.
11 placebo.ab.
12 Clinical trials as topic/
13 randomly.ab.
14 trial.ti.
15 8 or 9 or 10 or 11 or 12 or 13 or 14
16 exp Animals/ not Humans/
17 15 not 16
18 7 and 17

Embase (Ovid Interface)

1 Falling/
2 (falls or fallers).tw.
3 or/1-2
4 exp Aged/
5 (senior*1 or elder* or old* or aged or ag?ing or postmenopausal or community dwelling).tw.
6 or/4-5
7 3 and 6
8 exp Randomized Controlled Trial/ or exp Single Blind Procedure/ or exp Double Blind

Procedure/ or Crossover Procedure/

9 (random* or RCT or placebo or allocat* or crossover* or 'cross over' or trial or (doubl*
adj1 blind*) or (singl* adj1 blind*)).ti,ab.

10 8 or 9

11 (exp Animal/ or animal.hw. or Nonhuman/) not (exp Human/ or Human cell/ or (human
or humans).ti.)

12 10 not 11

13 7 and 12

CINAHL (Ebsco)

S1 (MH "Accidental Falls")

S2 TI (falls or faller*) OR AB (falls or faller*)

S3 S1 OR S2

S4 (MH "Aged+")

S5 TI (senior* or elder* or old* or aged or ag?ing or postmenopausal or community
dwelling) OR AB (senior* or elder* or old* or aged or ag?ing or postmenopausal or
community dwelling)

S6 S4 OR S5

S7 S3 AND S6

S8 PT Clinical Trial

S9 (MH "Clinical Trials+")

S10 TI clinical trial* OR AB clinical trial*

S11 TI ((single blind* or double blind*)) OR AB ((single blind* or double blind*))

S12 TI random* OR AB random*

S13 S8 OR S9 OR S10 OR S11 OR S12

S14 S7 AND S13

PEDro

Advanced search option selected

Abstract and Title: fall*

Method: clinical trial

Sub discipline: gerontology

New record added since: (date of last review entered here)

ClinicalTrials.gov

(prevent OR reduce OR reduction OR risk) AND (fall OR fallers) AND (exercise OR training)

WHO ICTRP

prevent* AND fall* AND exercise* OR reduc* AND fall* AND exercise* OR risk* AND fall*
AND exercise* OR prevent* AND fall* AND train* OR reduc* AND fall* AND train* OR risk*
AND fall* AND exercise*

Appendix 2. Categories of exercise (ProFaNE): definitions and applications

Exercise category	ProFaNE description	How the category criteria were applied in this review ^a
Gait, balance, and functional training	Gait training involves specific correction of walking technique (e.g. posture, stride length and cadence) and changes of pace, level and direction. Balance training involves the efficient transfer of bodyweight from one part of the body to another or challenges specific aspects of the balance systems (e.g. vestibular systems). Balance retraining activities range from the re-education of basic functional movement patterns to a wide variety of dynamic activities that target more sophisticated aspects of balance. Functional training uses functional activities as the training stimulus, and is based on the theoretical concept of task specificity. All gait, balance and functional training should be based on an assessment of the participant's abilities prior to starting the programme; tailoring of the intervention to the individuals abilities; and progression of the exercise programme as ability improves	Selected as exercise category if the intervention met the baseline assessment, tailoring and progression criteria. Selected as primary category for interventions where most exercises were conducted standing and where the intervention focus and most time spent was on exercise in this category
Strength/resistance (including power)	The term 'resistance training' covers all types of weight training i.e. contracting the muscles against a resistance to 'overload' and bring about a training effect in the muscular system. The resistance is an external force, which can be one's own body placed in an unusual relationship to gravity (e.g. prone back extension) or an external resistance (e.g. free weight). All strength/resistance training should be based on an assessment of the participant's abilities prior to starting the programme; tailoring the intervention to the individual's abilities; and progression of the exercise programme as ability improves	Selected as exercise category if the intervention met the baseline assessment, tailoring and progression criteria. Selected as primary category for interventions where additional resistance was used or where it was clear that overload was sufficient without external resistance and where the intervention focus and most time spent was on exercise in this category

Flexibility	Flexibility training is the planned process by which stretching exercises are practised and progressed to restore or maintain the optimal range of movement (ROM) available to a joint or joints. The ranges of motion used by flexibility programmes may vary from restoration/maintenance of the entire physiological range of motion, or alternatively, maintenance of range that is essential to mobility or other functions	Selected as exercise category if the intervention met the progression of stretching criterion. Selected as primary category for interventions where flexibility training was a stated aim of the intervention and where the intervention focus and most time spent was on exercise in this category
3D	3D training involves constant movement in a controlled, fluid, repetitive way through all three spatial planes or dimensions (forward and back, side to side, and up and down). Tai Chi and Qi Gong incorporate specific weight transferences and require upright posture and subtle changes of head position and gaze direction. Dance involves a wide range of dynamic movement qualities, speeds and patterns	Selected as exercise category if the intervention involved Tai Chi or dance. Selected as primary category for interventions where the intervention focus and most time spent was on exercise in this category
General physical activity	Physical activity is any bodily movement produced by skeletal muscle contraction resulting in a substantial increase in energy expenditure. Physical activity has both occupational, transportation and recreational components and includes pursuits like golf, tennis, and swimming. It also includes other active pastimes like gardening, cutting wood, and carpentry. Physical activity can provide progressive health benefits and is a catalyst for improving health attitudes, health habits, and lifestyle. Increasing habitual physical activity should be with specific recommendations as to duration, frequency and intensity if a physical or mental health improvement is indicated	Selected as exercise category if the intervention included unstructured physical activity. We classed programmes that included unstructured walking as this category. Selected as primary category for interventions where the intervention focus and most time spent was on exercise in this category
Endurance	Endurance training is aimed at cardiovascular conditioning and is aerobic in nature and simultaneously increases the heart rate and the return of blood to the heart	Selected as exercise category if the intervention focused on structured aerobic training. We classed programmes that included treadmill walking as this category. Selected as primary category for

		interventions where the intervention focus and most time spent was on exercise in this category
Other	Other kinds of exercises not described	Selected as exercise category if the intervention did not meet the other categories listed and where the intervention focus and most time spent was on exercise in this category
^a Interventions were allocated a secondary category if some but not all criteria were met by the intervention or where the category was not the primary focus of the intervention, or both		

References

1. World Health Organization. Global Strategy on Diet, Physical Activity and Health 2010.
2. Campbell AJ, Borrie MJ, Spears GF, Jackson SL, Brown JS, Fitzgerald JL. Circumstances and consequences of falls experienced by a community population 70 years and over during a prospective study. *Age Ageing*. 1990;19(2):136-41.
3. Tinetti ME SM, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med*. 1988;319(26):1701-7.
4. Peel NM, Kassulke DJ, McClure RJ. Population based study of hospitalised fall related injuries in older people. *Inj Prev*. 2002;8(4):280-3.
5. Stenhagen M, Ekstrom H, Nordell E, Elmstahl S. Accidental falls, health-related quality of life and life satisfaction: a prospective study of the general elderly population. *Arch Gerontol Geriatr*. 2014;58(1):95-100.
6. Yardley L SH. A prospective study of the relationship between feared consequences of falling and avoidance of activity in community-living older people. *Gerontologist*. 2002;42(1):17-23.
7. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, et al. Interventions for preventing falls in older people living in the community. The Cochrane database of systematic reviews. 2012(9):CD007146.
8. Davis JC RM, Ashe MC, Liu-Ambrose T, Khan KM, Marra CA. Does a home-based strength and balance programme in people aged > or =80 years provide the best value for money to prevent falls? A systematic review of economic evaluations of falls prevention interventions. *Br J Sports Med*. 2010;44(2):80-9.
9. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, et al. Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. *Br J Sports Med*. 2017;51(24):1750-8.
10. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community. The Cochrane database of systematic reviews. 2019;1:CD012424.
11. Sherrington C, Tiedemann A, Fairhall NJ, Hopewell S, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community. *Cochrane Db Syst Rev*. 2016;2016(11).
12. Canning CG AN, Bloem BR, Keus SH, Munneke M, Nieuwboer A, et al. Interventions for preventing falls in Parkinson's disease. *Cochrane Db Syst Rev*. 2015(3).
13. Verheyden GS, Weerdesteyn V, Pickering RM, Kunkel D, Lennon S, Geurts AC, et al. Interventions for preventing falls in people after stroke. The Cochrane database of systematic reviews. 2013(5):CD008728.
14. Lefebvre C, Manheimer E, Glanville J. Chapter 6: Searching for studies. In: Higgins JP, Green S, editor(s). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 (updated March 2011). The Cochrane Collaboration, 2011. Accessed: 2011. Available from: Available from www.handbook.cochrane.org.
15. Sherrington C, Fairhall N, Wallbank G, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community: an abridged Cochrane systematic Review. *Br J Sports Med*. 2019.

16. Lamb SE, Becker C, Gillespie LD, Smith JL, Finnegan S, Potter R, et al. Reporting of complex interventions in clinical trials: development of a taxonomy to classify and describe fall-prevention interventions. *Trials*. 2011;12:125.
17. Higgins JPT, Green S, Cochrane Collaboration. *Cochrane handbook for systematic reviews of interventions*. Chichester, England ; Hoboken, NJ: Wiley-Blackwell; 2011. xxi, 649 p. p.
18. Schünemann HJ OA, Higgins JP, Vist GE, Glasziou P, Akl E, et al. on behalf of the Cochrane GRADEing Methods Group (formerly Applicability and Recommendations Methods Group) and the Cochrane Statistical Methods Group. Chapter 11: Completing 'Summary of findings' tables and grading the confidence in or quality of the evidence. 2017. In: *Cochrane Handbook for Systematic Reviews of Interventions* [Internet]. The Cochrane Collaboration.
19. Norway C. How to write a plain language summary of a Cochrane intervention review Accessed: 15 November: 2017. Available from: <https://www.cochrane.no/how-write-plain-language-summary>.
20. Harbord RM, Higgins JP. Meta-regression in Stata. *Stata J*. 2008;8:493–1519.
21. Arkkukangas M, Johnson ST, Hellstrom K, Soderlund A, Eriksson S, Johansson AC. A feasibility study of a randomised controlled trial comparing fall prevention using exercise with or without the support of motivational interviewing. *Prev Med Rep*. 2015;2:134-40.
22. Arkkukangas M, Johnson ST, Hellstrom K, Anens E, Tonkonogi M, Larsson U. Fall Prevention Exercises With or Without Behavior Change Support for Community-Dwelling Older Adults: A Two-Year Follow-Up of a Randomized Controlled Trial. *Journal of Aging & Physical Activity*. 2019:1-26.
23. Tricco AC, Thomas SM, Veroniki AA, Hamid JS, Cogo E, Strifler L, et al. Comparisons of Interventions for Preventing Falls in Older Adults: A Systematic Review and Meta-analysis. *JAMA*. 2017;318(17):1687-99.
24. Lamb SE, Jorstad-Stein EC, Hauer K, Becker C, Prevention of Falls Network E, Outcomes Consensus G. Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. *J Am Geriatr Soc*. 2005;53(9):1618-22.
25. Organization WH. World Report on Ageing and Health Accessed: January 25: World Health Organization; 2015. Available from: www.who.int/ageing/events/world-report-2015-launch/en/.
26. Almeida TL, Alexander NB, Nyquist LV, Montagnini ML, Santos ACS, Rodrigues GHP, et al. Minimally supervised multi-modal exercise to reduce falls risk among economically and educationally disadvantaged older adults. *Journal of aging and physical activity*. 2013;21(3):241-59.
27. Ansai JH, Aurichio TR, Goncalves R, Rebelatto JR. Effects of two physical exercise protocols on physical performance related to falls in the oldest old: A randomized controlled trial. *Geriatrics & gerontology international*. 2015;16(4):492-9.
28. Arantes PMM, Dias JMD, Fonseca FF, Oliveira AMB, Oliveira MC, Pereira LSM, et al. Effect of a Program Based on Balance Exercises on Gait, Functional Mobility, Fear of Falling, and Falls in Prefrail Older Women: A Randomized Clinical Trial. *Topics in Geriatric Rehabilitation*. 2015;31(2):113-20.
29. Arkkukangas M, Johnson ST, Hellstrom K, Anens E, Tonkonogi M, Larsson U. Fall Prevention Exercises With or Without Behavior Change Support for Community-

- Dwelling Older Adults: A Two-Year Follow-Up of a Randomized Controlled Trial. *J Aging Phys Act.* 2019;1-26.
30. Ballard JE, McFarland C, Wallace LS, Holiday DB, Roberson G. The effect of 15 weeks of exercise on balance, leg strength, and reduction in falls in 40 women aged 65 to 89 years. *J Am Med Womens Assoc.* 2004;59(4):255-61.
 31. Barclay R, Webber S, Ripat J, Grant T, Jones CA, Lix LM, et al. Safety and feasibility of an interactive workshop and facilitated outdoor walking group compared to a workshop alone in increasing outdoor walking activity among older adults: a pilot randomized controlled trial. *Pilot Feasibility Stud.* 2018;4:179.
 32. Barker AL, Talevski J, Bohensky MA, Brand CA, Cameron PA, Morello RT. Feasibility of Pilates exercise to decrease falls risk: a pilot randomized controlled trial in community-dwelling older people. *Clin Rehabil.* 2016;30(10):984-96.
 33. Barnett A, Smith B, Lord SR, Williams M, Baumand 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.
 34. Bernardelli G, Roncaglione C, Damanti S, Mari D, Cesari M, Marcucci M. Adapted physical activity to promote active and healthy ageing: the PoliFIT pilot randomized waiting list-controlled trial. *Aging Clin Exp Res.* 2019;31(4):511-8.
 35. Beyer N, Simonsen L, Bülow J, Lorenzen T, Jensen DV, Larsen L, et al. 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(4):300-9.
 36. Boongird C, Keesukphan P, Phiphadthakusolkul S, Rattanasiri S, Thakkinstian A. Effects of a simple home-based exercise program on fall prevention in older adults: A 12-month primary care setting, randomized controlled trial. *Geriatrics & gerontology international.* 2017;17(11):2157-63.
 37. Brown A. Functional adaptation to exercise in elderly subjects. Perth: Curtin University of Technology; 2002.
 38. Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *J Gerontol A Biol Sci Med Sci.* 1997;52(4):M218-24.
 39. Bunout D, Barrera G, Avendaño M, de la Maza P, Gattas V, Leiva L, et al. Results of a community-based weight-bearing resistance training programme for healthy Chilean elderly subjects. *Age Ageing.* 2005;34(1):80-3.
 40. Campbell AJ, Robertson MC, Gardner MM, Norton RN, Tilyard MW, Buchner DM. Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *BMJ.* 1997;315(7115):1065-9.
 41. Carter ND, Khan KM, McKay HA, Petit MA, Waterman C, Heinonen A, et al. Community-based exercise program reduces risk factors for falls in 65- to 75-year-old women with osteoporosis: randomized controlled trial. *Can Med Assoc J.* 2002;167(9):997-1004.
 42. Cerny K, Blanks R, Mohamed O, Schwab D, Robinson B, Russo A, et al. The effect of a multidimensional exercise program on strength, range of motion, balance and gait in the well elderly. *Gait Posture.* 1998;7(2):185-6.
 43. Clegg A, Barber S, Young J, Iliffe S, Forster A. The Home-based Older People's Exercise (HOPE) trial: a pilot randomised controlled trial of a home-based exercise intervention for older people with frailty. *Age Ageing.* 2014;43(5):687-95.

44. Clemson L, Singh MF, Bundy A, Cumming RG, Weissel E, Munro J, et al. LiFE Pilot Study: A randomised trial of balance and strength training embedded in daily life activity to reduce falls in older adults. *Aust Occup Ther J.* 2010;57(1):42-50.
45. Clemson L, Fiatarone Singh MA, Bundy A, Cumming RG, Manollaras K, O'Loughlin P, et al. Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): randomised parallel trial. *BMJ.* 2012;345:e4547.
46. Cornillon E, Blanchon MA, Ramboatsisetraina P, Braize C, Beauchet O, Dubost V, et al. Effectiveness of falls prevention strategies for elderly subjects who live in the community with performance assessment of physical activities (before-after). *Ann Readapt Med Phys.* 2002;45(9):493-504.
47. Dadgari A, Aizan Hamid T, Hakim MN, Chaman R, Mousavi SA, Poh Hin L, et al. Randomized control trials on Otago Exercise Program (OEP) to reduce falls among elderly community dwellers in Shahroud, Iran. *Iranian Red Crescent Medical Journal.* 2016;18(5):e26340.
48. Dangour AD, Albala C, Allen E, Grundy E, Walker DG, Aedo C, et al. Effect of a nutrition supplement and physical activity program on pneumonia and walking capacity in Chilean older people: a factorial cluster randomized trial. *PLoS Med.* 2011;8(4):e1001023.
49. Davis JC, Robertson MC, Ashe MC, Liu-Ambrose T, Khan KM, Marra CA. Does a home-based strength and balance programme in people aged > or =80 years provide the best value for money to prevent falls? A systematic review of economic evaluations of falls prevention interventions. *Br J Sports Med.* 2010;44(2):80-9.
50. Day L, Fildes B, Gordon I, Fitzharris M, Flamer H, Lord S. Randomised factorial trial of falls prevention among older people living in their own homes. *BMJ.* 2002;325(7356):128.
51. Day L, Hill KD, Stathakis VZ, Flicker L, Segal L, Cicuttini F, et al. Impact of tai-chi on falls among preclinically disabled older people. A randomized controlled trial. *J Am Med Dir Assoc.* 2015;16(5):420-6.
52. Duque G, Boersma D, Loza-Díaz G, Hassan S, Suarez H, Geisinger D, et al. Effects of balance training using a virtual-reality system in older fallers. *Clin Interv Aging.* 2013;8:257-63.
53. Ebrahim S, Thompson PW, Baskaran V, Evans K. Randomized placebo-controlled trial of brisk walking in the prevention of postmenopausal osteoporosis. *Age Ageing.* 1997;26(4):253-60.
54. El-Khoury F, Cassou B, Latouche A, Aegerter P, Charles M-A, Dargent-Molina P. Effectiveness of two year balance training programme on prevention of fall induced injuries in at risk women aged 75-85 living in community: Ossébo randomised controlled trial. *BMJ : British Medical Journal.* 2015;351:h3830.
55. Fiatarone M, O'Neill E, Doyle R, Clements K, editors. Efficacy of home-based resistance training in frail elders. Abstracts of the 16th Congress of the International Association of Gerontology; 1997; Bedford Park, South Australia: World Congress of Gerontology Inc.
56. Freiburger E, Menz HB, Abu-Omar K, Rutten A. Preventing falls in physically active community-dwelling older people: a comparison of two intervention techniques. *Gerontology.* 2007;53(5):298-305.
57. Gallo E, Stelmach M, Frigeri F, Ahn D-H. Determining Whether a Dosage-Specific and Individualized Home Exercise Program With Consults Reduces Fall Risk and Falls in

- Community-Dwelling Older Adults With Difficulty Walking: A Randomized Control Trial. *J Geriatr Phys Ther.* 2018;41(3):161-72.
58. Gill TM, Pahor M, Guralnik JM, McDermott MM, King AC, Buford TW, et al. Effect of structured physical activity on prevention of serious fall injuries in adults aged 70-89: randomized clinical trial (LIFE Study). *BMJ.* 2016;352:i245.
 59. Grahn Kronhed A-C, Hallberg I, Ödkvist L, Möller M. Effect of training on health-related quality of life, pain and falls in osteoporotic women. *Advances in Physiotherapy.* 2009;11(3):154-65.
 60. Gschwind YJ, Eichberg S, Ejupi A, de Rosario H, Kroll M, Marston HR, et al. ICT-based system to predict and prevent falls (iStopFalls): results from an international multicenter randomized controlled trial. *European Review of Aging and Physical Activity.* 2015;12:10.
 61. Haines TP, Russell T, Brauer SG, Erwin S, Lane P, Urry S, et al. Effectiveness of a video-based exercise programme to reduce falls and improve health-related quality of life among older adults discharged from hospital: a pilot randomized controlled trial. *Clin Rehabil.* 2009;23(11):973-85.
 62. Halvarsson A, Franzen E, Faren E, Olsson E, Oddsson L, Ståhle A. Long-term effects of new progressive group balance training for elderly people with increased risk of falling - a randomized controlled trial. *Clin Rehabil.* 2013;27(5):450-8.
 63. Halvarsson A, Oddsson L, Franzén E, Ståhle A. Long-term effects of a progressive and specific balance-training programme with multi-task exercises for older adults with osteoporosis: a randomized controlled study. *Clin Rehabil.* 2016;30(11):1049-59.
 64. Hamrick I, Mross P, Christopher N, Smith PD. Yoga's effect on falls in rural, older adults. *Complement Ther Med.* 2017;35:57-63.
 65. Hauer K, Rost B, Rutschle K, Opitz H, Specht N, Bartsch P, et al. Exercise training for rehabilitation and secondary prevention of falls in geriatric patients with a history of injurious falls. *J Am Geriatr Soc.* 2001;49(1):10-20.
 66. Helbostad JL, Sletvold O, Moe-Nilssen R. Effects of home exercises and group training on functional abilities in home-dwelling older persons with mobility and balance problems. A randomized study. *Aging Clin Exp Res.* 2004;16(2):113-21.
 67. Hirase T, Inokuchi S, Matsusaka N, Okita M. Effects of a balance training program using a foam rubber pad in community-based older adults: a randomized controlled trial. *J Geriatr Phys Ther.* 2015;38(2):62-70.
 68. Huang H-C, Liu C-Y, Huang Y-T, Kernohan WG. Community-based interventions to reduce falls among older adults in Taiwan – long time follow-up randomised controlled study. *J Clin Nurs.* 2010;19(7-8):959-68.
 69. Hwang HF, Chen SJ, Lee-Hsieh J, Chien DK, Chen CY, Lin MR. Effects of Home-Based Tai Chi and Lower Extremity Training and Self-Practice on Falls and Functional Outcomes in Older Fallers from the Emergency Department—A Randomized Controlled Trial. *J Am Geriatr Soc.* 2016;64(3):518-25.
 70. Iliffe S, Kendrick D, Morris R, Masud T, Gage H, Skelton D, et al. Multicentre cluster randomised trial comparing a community group exercise programme and home-based exercise with usual care for people aged 65 years and over in primary care. *Health Technol Assess.* 2014;18(49):vii-xxvii, 1-105.
 71. Irez GB, Ozdemir RA, Evin R, Irez SG, Korkusuz F. Integrating pilates exercise into an exercise program for 65+ year-old women to reduce falls. *J Sports Sci Med.* 2011;10(1):105-11.

72. Iwamoto J, Suzuki H, Tanaka K, Kumakubo T, Hirabayashi H, Miyazaki Y, et al. Preventative effect of exercise against falls in the elderly: a randomized controlled trial. *Osteoporos Int.* 2009;20(7):1233-40.
73. Kamide N, Shiba Y, Shibata H. Effects on balance, falls, and bone mineral density of a home-based exercise program without home visits in community-dwelling elderly women: a randomized controlled trial. *J Physiol Anthropol.* 2009;28(3):115-22.
74. Karinkanta S, Heinonen A, Sievanen H, Uusi-Rasi K, Pasanen M, Ojala K, et al. A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. *Osteoporos Int.* 2007;18(4):453-62.
75. Kemmler W, von Stengel S, Engelke K, Häberle L, Kalender WA. Exercise effects on bone mineral density, falls, coronary risk factors, and health care costs in older women: the randomized controlled senior fitness and prevention (SEFIP) study. *Arch Intern Med.* 2010;170(2):179-85.
76. Kerse N, Hayman KJ, Moyes SA, Peri K, Robinson E, Dowell A, et al. Home-based activity program for older people with depressive symptoms: DeLLITE--a randomized controlled trial. *Ann Fam Med.* 2010;8(3):214-23.
77. Kim H, Yoshida H, Suzuki T. Falls and fractures in participants and excluded non-participants of a fall prevention exercise program for elderly women with a history of falls: 1-year follow-up study. *Geriatrics & gerontology international.* 2014;14(2):285-92.
78. Korpelainen R, Keinanen-Kiukaanniemi S, Heikkinen J, Vaananen K, Korpelainen J. Effect of exercise on extraskeletal risk factors for hip fractures in elderly women with low BMD: a population-based randomized controlled trial. *J Bone Miner Res.* 2006;21(5):772-9.
79. Kovacs E, Prokai L, Meszaros L, Gondos T. Adapted physical activity is beneficial on balance, functional mobility, quality of life and fall risk in community-dwelling older women: a randomized single-blinded controlled trial. *Eur J Phys Rehabil Med.* 2013;49(3):301-10.
80. Kwok BC, Pua YH. Effects of WiiActive exercises on fear of falling and functional outcomes in community-dwelling older adults: a randomised control trial. *Age Ageing.* 2016;45(5):621-7.
81. Kyrdaalen IL, Moen K, Røysland AS, Helbostad JL. The Otago Exercise Program performed as group training versus home training in fall-prone older people: a randomized controlled Trial. *Physiother Res Int.* 2014;19(2):108-16.
82. LaStayo P, Marcus R, Dibble L, Wong B, Pepper G. Eccentric versus traditional resistance exercise for older adult fallers in the community: a randomized trial within a multi-component fall reduction program. *BMC Geriatr.* 2017;17(1):149.
83. Latham NK, Anderson CS, Lee A, Bennett DA, Moseley A, Cameron ID. A randomized, controlled trial of quadriceps resistance exercise and vitamin D in frail older people: the Frailty Interventions Trial in Elderly Subjects (FITNESS). *J Am Geriatr Soc.* 2003;51(3):291-9.
84. Lehtola S, Hanninen L, Paatalo M. The incidence of falls during a six month exercise trial and four month follow-up among home dwelling persons aged 70–75 years. *Liikunta Tiede.* 2000;6:41-7.
85. Li F, Harmer P, Fisher KJ, McAuley E, Chaumeton N, Eckstrom E, et al. Tai Chi and Fall Reductions in Older Adults: A Randomized Controlled Trial. *The Journals of Gerontology: Series A.* 2005;60(2):187-94.

86. Li F, Harmer P, Fitzgerald K, Eckstrom E, Akers L, Chou L-S, et al. Effectiveness of a Therapeutic Tai Ji Quan Intervention vs a Multimodal Exercise Intervention to Prevent Falls Among Older Adults at High Risk of Falling. *JAMA Internal Medicine*. 2018;178(10):1301-10.
87. Lin MR, Wolf SL, Hwang HF, Gong SY, Chen CY. A randomized, controlled trial of fall prevention programs and quality of life in older fallers. *J Am Geriatr Soc*. 2007;55(4):499-506.
88. Lipsitz LA, Macklin EA, Trivison TG, Manor B, Gagnon P, Tsai T, et al. A Cluster Randomized Trial of Tai Chi vs Health Education in Subsidized Housing: The MI-WiSH Study. *J Am Geriatr Soc*. 2019;67(9):1812-9.
89. Liston MB, Alushi L, Bamiou DE, Martin FC, Hopper A, Pavlou M. Feasibility and effect of supplementing a modified OTAGO intervention with multisensory balance exercises in older people who fall: a pilot randomized controlled trial. *Clin Rehabil*. 2014;28(8):784-93.
90. Liu-Ambrose T, Khan KM, Eng JJ, Janssen PA, Lord SR, McKay HA. Resistance and agility training reduce fall risk in women aged 75 to 85 with low bone mass: a 6-month randomized, controlled trial. *J Am Geriatr Soc*. 2004;52(5):657-65.
91. Liu-Ambrose T, Donaldson MG, Ahamed Y, Graf P, Cook WL, Close J, et al. Otago home-based strength and balance retraining improves executive functioning in older fallers: a randomized controlled trial. *J Am Geriatr Soc*. 2008;56(10):1821-30.
92. Liu-Ambrose T, Davis JC, Best JR, Dian L, Madden K, Cook W, et al. Effect of a Home-Based Exercise Program on Subsequent Falls Among Community-Dwelling High-Risk Older Adults After a Fall: A Randomized Clinical Trial. *JAMA*. 2019;321(21):2092-100.
93. Logghe IH, Zeeuwe PE, Verhagen AP, Wijnen-Sponselee RM, Willemsen SP, Bierma-Zeinstra SM, et al. Lack of effect of Tai Chi Chuan in preventing falls in elderly people living at home: a randomized clinical trial. *J Am Geriatr Soc*. 2009;57(1):70-5.
94. Lord SR, Ward JA, Williams P, Strudwick M. The effect of a 12-month exercise trial on balance, strength, and falls in older women: a randomized controlled trial. *J Am Geriatr Soc*. 1995;43(11):1198.
95. Lord SR, Castell S, Corcoran J, Dayhew J, Matters B, Shan A, et al. The effect of group exercise on physical functioning and falls in frail older people living in retirement villages: a randomized, controlled trial. *J Am Geriatr Soc*. 2003;51(12):1685-92.
96. Lurie JD, Zagaria AB, Pidgeon DM, Forman JL, Spratt KF. Pilot comparative effectiveness study of surface perturbation treadmill training to prevent falls in older adults. *BMC Geriatr*. 2013;13:49.
97. Luukinen H, Lehtola S, Jokelainen J, Vaananen-Sainio R, Lotvonen S, Koistinen P. Pragmatic exercise-oriented prevention of falls among the elderly: a population-based, randomized, controlled trial. *Prev Med*. 2007;44(3):265-71.
98. Casas-Herrero A, Anton-Rodrigo I, Zambom-Ferraresi F, Saez de Asteasu ML, Martinez-Velilla N, Elexpuru-Estomba J, et al. Effect of a multicomponent exercise programme (VIVIFRIL) on functional capacity in frail community elders with cognitive decline: study protocol for a randomized multicentre control trial. *Trials [Electronic Resource]*. 2019;20(1):362.
99. Madureira MM, Takayama L, Gallinaro AL, Caparbo VF, Costa RA, Pereira RM. Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial. *Osteoporos Int*. 2007;18(4):419-25.

100. McMurdo MET, Mole PA, Paterson CR. Controlled trial of weight bearing exercise in older women in relation to bone density and falls. *BMJ*. 1997;314(7080):569.
101. Means KM, Rodell DE, O'Sullivan PS. Balance, mobility, and falls among community-dwelling elderly persons: effects of a rehabilitation exercise program. *Am J Phys Med Rehabil*. 2005;84(4):238-50.
102. Merom D, Mathieu E, Cerin E, Morton RL, Simpson JM, Rissel C, et al. Social Dancing and Incidence of Falls in Older Adults: A Cluster Randomised Controlled Trial. *PLoS Med*. 2016;13(8):e1002112.
103. Miko I, Szerb I, Szerb A, Poor G. Effectiveness of balance training programme in reducing the frequency of falling in established osteoporotic women: a randomized controlled trial. *Clin Rehabil*. 2017;31(2):217-24.
104. Mirelman A, Rochester L, Maidan I, Del Din S, Alcock L, Nieuwhof F, et al. Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial. *Lancet*. 2016;388(10050):1170-82.
105. Morgan RO, Virnig BA, Duque M, Abdel-Moty E, Devito CA. Low-intensity exercise and reduction of the risk for falls among at-risk elders. *J Gerontol A Biol Sci Med Sci*. 2004;59(10):1062-7.
106. Morone G, Paolucci T, Luziatelli S, Iosa M, Piermattei C, Zangrando F, et al. Wii Fit is effective in women with bone loss condition associated with balance disorders: a randomized controlled trial. *Aging Clin Exp Res*. 2016;28(6):1187-93.
107. Morrison S, Simmons R, Colberg SR, Parson HK, Vinik AI. Supervised balance training and Wii Fit-based exercises lower falls risk in older adults with type 2 diabetes. *J Am Med Dir Assoc*. 2018;19(2):185.e7-13.
108. Ng TP, Feng L, Nyunt MS, Feng L, Niti M, Tan BY, et al. Nutritional, physical, cognitive, and combination interventions and frailty reversal among older adults: a randomized controlled trial. *Am J Med*. 2015;128(11):1225-36.e1.
109. Nitz JC, Choy NL. The efficacy of a specific balance-strategy training programme for preventing falls among older people: a pilot randomised controlled trial. *Age Ageing*. 2004;33(1):52-8.
110. Okubo Y, Osuka Y, Jung S, Rafael F, Tsujimoto T, Aiba T, et al. Walking can be more effective than balance training in fall prevention among community-dwelling older adults. *Geriatrics & gerontology international*. 2016;16(1):118-25.
111. Oliveira JS, Sherrington C, Paul SS, Ramsay E, Chamberlain K, Kirkham C, et al. A combined physical activity and fall prevention intervention improved mobility-related goal attainment but not physical activity in older adults: a randomised trial. *J Physiother*. 2019;65(1):16-22.
112. Park H, Kim KJ, Komatsu T, Park SK, Mutoh Y. Effect of combined exercise training on bone, body balance, and gait ability: a randomized controlled study in community-dwelling elderly women. *J Bone Miner Metab*. 2008;26(3):254-9.
113. Reinsch S, MacRae P, Lachenbruch PA, Tobis JS. Attempts to prevent falls and injury: a prospective community study. *Gerontologist*. 1992;32(4):450-6.
114. Resnick B. Testing the effect of the WALC intervention on exercise adherence in older adults. *J Gerontol Nurs*. 2002;28(6):40-9.
115. Robertson MC, Devlin N, Gardner MM, Campbell AJ. Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 1: Randomised controlled trial. *BMJ*. 2001;322(7288):697-701.

116. Rubenstein LZ, Josephson KR, Trueblood PR, Loy S, Harker JO, Pietruszka FM, et al. Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. *The Journals of Gerontology: Series A*. 2000;55(6):M317-M21.
117. Sakamoto K, Endo N, Harada A, Sakada T, Tsushita K, Kita K, et al. Why not use your own body weight to prevent falls? A randomized, controlled trial of balance therapy to prevent falls and fractures for elderly people who can stand on one leg for ≤ 15 s. *J Orthop Sci*. 2013;18(1):110-20.
118. Sales M, Polman R, Hill KD, Levinger P. A novel exercise initiative for seniors to improve balance and physical Function. *J Aging Health*. 2017;29(8):1424-43.
119. Sherrington C, Lord SR, Vogler CM, Close JC, Howard K, Dean CM, et al. A post-hospital home exercise program improved mobility but increased falls in older people: a randomised controlled trial. *PLoS One*. 2014;9(9):e104412.
120. Shigematsu R, Okura T, Nakagaichi M, Tanaka K, Sakai T, Kitazumi S, et al. Square-stepping exercise and fall risk factors in older adults: a single-blind, randomized controlled trial. *Journals of gerontology Series A, Biological sciences and medical sciences*. 2008;63(1):76-82.
121. Siegrist M, Freiburger E, Geilhof B, Salb J, Hentschke C, Landendoerfer P, et al. Fall prevention in a primary care setting: The effects of a targeted complex exercise intervention in a cluster randomized trial. *Deutsches Ärzteblatt International*. 2016;113(21):365-72.
122. Skelton D, Dinan S, Campbell M, Rutherford O. Tailored group exercise (Falls Management Exercise — FaME) reduces falls in community-dwelling older frequent fallers (an RCT). *Age Ageing*. 2005;34(6):636-9.
123. Smulders E, Weerdesteyn V, Groen BE, Duysens J, Eijssbouts A, Laan R, et al. Efficacy of a short multidisciplinary falls prevention program for elderly persons with osteoporosis and a fall history: a randomized controlled trial. *Arch Phys Med Rehabil*. 2010;91(11):1705-11.
124. Steadman J, Donaldson N, Kalra L. A randomized controlled trial of an enhanced balance training program to improve mobility and reduce falls in elderly patients. *J Am Geriatr Soc*. 2003;51(6):847-52.
125. Suzuki T, Kim H, Yoshida H, Ishizaki T. Randomized controlled trial of exercise intervention for the prevention of falls in community-dwelling elderly Japanese women. *J Bone Miner Metab*. 2004;22(6):602-11.
126. Taylor D, Hale L, Schluter P, Waters DL, Binns EE, McCracken H, et al. Effectiveness of tai chi as a community-based falls prevention intervention: a randomized controlled trial. *J Am Geriatr Soc*. 2012;60(5):841-8.
127. Trombetti A, Hars M, Herrmann FR, Kressig RW, Ferrari S, Rizzoli R. Effect of music-based multitask training on gait, balance, and fall risk in elderly people: a randomized controlled trial. *Arch Intern Med*. 2011;171(6):525-33.
128. Uusi-Rasi K, Patil R, Karinkanta S, Kannus P, Tokola K, Lamberg-Allardt C, et al. Exercise and vitamin D in fall prevention among older women: a randomized clinical trial. *JAMA internal medicine*. 2015;175(5):703-11.
129. Verrusio W, Gianturco V, Cacciafesta M, Marigliano V, Troisi G, Ripani M. Fall prevention in the young old using an exoskeleton human body posturizer: a randomized controlled trial. *Aging Clin Exp Res*. 2017;29(2):207-14.

130. Vogler CM, Sherrington C, Ogle SJ, Lord SR. Reducing risk of falling in older people discharged from hospital: a randomized controlled trial comparing seated exercises, weight-bearing exercises, and social visits. *Arch Phys Med Rehabil.* 2009;90(8):1317-24.
131. 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. *J Am Geriatr Soc.* 2007;55(8):1185-91.
132. Voukelatos A, Merom D, Sherrington C, Rissel C, Cumming RG, Lord SR. The impact of a home-based walking programme on falls in older people: the Easy Steps randomised controlled trial. *Age Ageing.* 2015;44(3):377-83.
133. Weerdesteyn V, Rijken H, Geurts AC, Smits-Engelsman BC, Mulder T, Duysens J. A five-week exercise program can reduce falls and improve obstacle avoidance in the elderly. *Gerontology.* 2006;52(3):131-41.
134. Wolf SL, Barnhart HX, Kutner NG, McNeely E, Coogler C, Xu T. Reducing frailty and falls in older persons: an investigation of Tai Chi and computerized balance training. Atlanta FICSIT Group. Frailty and Injuries: Cooperative Studies of Intervention Techniques. *J Am Geriatr Soc.* 1996;44(5):489-97.
135. Wolf SL, Sattin RW, Kutner M, O'Grady M, Greenspan AI, Gregor RJ. Intense tai chi exercise training and fall occurrences in older, transitionally frail adults: a randomized, controlled trial. *J Am Geriatr Soc.* 2003;51(12):1693-701.
136. Woo J, Hong A, Lau E, Lynn H. A randomised controlled trial of Tai Chi and resistance exercise on bone health, muscle strength and balance in community-living elderly people. *Age Ageing.* 2007;36(3):262-8.
137. Wu G, Keyes L, Callas P, Ren X, Bookchin B. Comparison of telecommunication, community, and home-based Tai Chi exercise programs on compliance and effectiveness in elders at risk for falls. *Arch Phys Med Rehabil.* 2010;91(6):849-56.
138. Yamada M, Tanaka B, Nagai K, Aoyama T, Ichihashi N. Trail-walking exercise and fall risk factors in community-dwelling older adults: preliminary results of a randomized controlled trial. *J Am Geriatr Soc.* 2010;58(10):1946-51.
139. Yamada M, Aoyama T, Arai H, Nagai K, Tanaka B, Uemura K, et al. Complex obstacle negotiation exercise can prevent falls in community-dwelling elderly Japanese aged 75 years and older. *Geriatrics & gerontology international.* 2012;12(3):461-7.
140. Yamada M, Higuchi T, Nishiguchi S, Yoshimura K, Kajiwara Y, Aoyama T. Multitarget stepping program in combination with a standardized multicomponent exercise program can prevent falls in community-dwelling older adults: a randomized, controlled trial. *J Am Geriatr Soc.* 2013;61(10):1669-75.
141. Yang XJ, Hill K, Moore K, Williams S, Dowson L, Borschmann K, et al. Effectiveness of a targeted exercise intervention in reversing older people's mild balance dysfunction: a randomized controlled trial. *Phys Ther.* 2012;92(1):24-37.