Evidence on physical activity and osteoporosis prevention for people aged 65+ years

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

WHO Collaborating Centre for
Physical Activity, Nutrition and Obesity

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EXECUTIVE SUMMARY

Background

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

Aims

This review aimed to investigate the association between physical activity and osteoporosis prevention in older people (aged 65 years and above). The questions were: i) What is the association between physical activity and osteoporosis prevention in older people (>64 years old)? ii) Is there a dose response association (volume, duration, frequency, intensity) between physical activity and prevention of osteoporosis? iii) Does the association vary by type or domain of physical activity? The focus was on primary prevention studies i.e., studies in the general community rather than studies in those with existing osteoporosis.

Methods

A search for systematic reviews was conducted in PubMed (2008 to November 2019). Reviews were screened according to the following eligibility criteria: i) population: adults aged 65 years and older; ii) exposure: greater volume, duration, frequency, or intensity of physical activity; iii) comparison: no physical activity or lesser volume, duration, frequency, or intensity of physical activity; iv) outcome: osteoporosis related measures (e.g., bone mineral density); v) study design: systematic review and meta-analysis. We used GRADE to rate the certainty of the evidence.

Results

The search yielded 140 records but none of the 36 potentially eligible reviews met our eligibility criteria. Relevant individual studies were identified from 25 reviews and additional literature searching. We included 36 trials and observational studies in this evidence overview. A total of 30 trials compared physical activity with a control intervention. Evidence profiles are shown below (pages 13-17). Included studies suggest:

i) physical activity interventions probably improve bone health among older adults and thus prevent osteoporosis (23 studies, moderate-certainty evidence, main or most relevant outcome selected for each of the included studies). Physical activity interventions probably improve lumbar spine bone mineral density (13 studies, moderate-certainty evidence) and may improve hip (femoral neck) bone mineral density (14 studies, low-certainty evidence);
ii) greater impacts are evident from higher dose programmes. Typical programmes for which significant intervention impacts were detected in RCTs were undertaken for 60+ mins, 2-3 times/week for 7+ months;
iii) programmes involving multiple exercise types probably have significant effects on bone health and osteoporosis prevention (7 studies, moderate-certainty evidence). These programmes often involved balance and functional exercise with added resistance and/or endurance exercise. Programmes involving balance and functional exercises may have significant effects on bone health and osteoporosis prevention (11 studies, low-certainty evidence), especially when measured at the lumbar spine;
iv) observational studies suggested a positive impact of long-term leisure time physical activity (2 studies) and life-long sport (tennis) engagement (n=1) on bone health.

Conclusions

Physical activity probably plays a role in the prevention of osteoporosis. The level of evidence is higher for effects of physical activity on lumbar spine bone mineral density. Higher dose programmes and those involving multiple exercises types appear to be more effective. These results

should be interpreted with caution due to the lack of eligible systematic reviews identified and thus the use of sub-optimal search strategies to identify individual studies.

BACKGROUND

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

METHODS

The Guideline Development Group decided on the scope of the guideline and PICO (Population, Intervention, Comparison, Outcome) question.

Guiding Questions

What is the association between **physical activity** and **osteoporosis** prevention?
Is there a dose response association (volume, duration, frequency, intensity)?
Does the association vary by type or domain of physical activity?

Eligible studies

Studies were selected according to the criteria below. Additional details on the eligibility criteria are provided in Appendix 1.
Population: adults aged 65 years and older.
Exposure: Greater volume, duration, frequency, or intensity of physical activity.
Comparison: No physical activity or lesser volume, duration, frequency, or intensity of physical activity.
Outcome: Osteoporosis.
Study design: systematic review and meta-analysis.

Search and selection strategy

A search for existing systematic reviews was conducted in PubMed for reviews published from 2008 up to November 2019 (Appendix 2).

Two reviewers screened all titles and abstracts to identify existing systematic reviews that addressed the present research question. The full text of each review that potentially met the inclusion criteria was obtained and independently assessed for eligibility by two reviewers. Any disagreements were discussed and when consensus could not be reached, the eligibility of the study was decided following discussion with a third reviewer. We also searched reference lists of eligible papers and relevant systematic reviews known by the team for any additional studies. We screened the full text of any potentially eligible studies.

Since we did not find any eligible systematic review, we identified reviews that included potentially eligible studies and screened all included studies against our questions. We included individual studies (instead of reviews).

One reviewer extracted information into standardized forms and a second reviewer checked all data. We extracted all outcome measures relevant to osteoporosis reported by the included studies. We selected the most commonly reported outcomes across the included studies to overview the evidence.

Physical activity classification

We used the Prevention of Falls Network Europe (ProFaNE) taxonomy to classify the physical activity and exercise programmes in the included studies (Appendix 3).*(2)* The programmes were classified as primarily involving the following exercise categories: i) gait, balance, coordination and functional task training (referred to as 'balance and functional exercises' for simplicity); ii) strength/resistance training (including power training, using resistance so referred to as 'resistance exercises'); iii) flexibility; iv) three-dimensional (3D) exercise (with Tai Chi or dance subcategories); v) general physical activity (walking programmes); vi) endurance; vii) other kinds of exercise. The taxonomy allows for more than one type of exercise to be delivered within a programme. We also considered whether the exercise explicitly included bone loading (e.g., hopping or heel drops).

Grading the body of evidence

Using the Grading of Recommendations Assessment, Development and Evaluation GRADE framework,*(3)* we examined the quality of primary research and assessed the overall quality of evidence as 'high', 'moderate', 'low' or 'very low' in terms of presence and extent of five factors: risk of bias, inconsistency, imprecision, indirectness and publication bias. Details on the criteria used to apply the GRADE approach are provided in Appendix 4.

Exploratory meta-analysis and meta-regression

We undertook exploratory meta-analyses with meta-regression to investigate the impact of different doses and types of exercise using Comprehensive Metanalysis and Stata 14 metan and metareg commands. We used random effects meta-analysis models as we considered that a range of true effects was likely but also undertook sensitivity analyses using fixed effect models. For meta-regression, dose was coded as the total dose over the programme duration. Type of exercise was coded according to the presence of ProFaNE taxonomy categories outlined above: balance/function, resistance, bone loading and multiple exercise types. We explored the impact of study design by undertaking meta-regression to compare effects in trials with PEDro scores above and below 6.

INCLUDED EVIDENCE

Overview

The initial search for systematic reviews and meta-analysis did not identify sufficient evidence to answer the review questions. We screened the full texts of 36 reviews and no eligible reviews were found (Figure 1). The main reasons for exclusion were reviews including younger participants (n=34), participants with osteoporosis at baseline (management instead of prevention, n=12), and not investigating physical activity (e.g., whole body vibration, n=7). The reasons for exclusion for each review at full text assessment are reported in Appendix 5.

Amongst the 36 reviews which had their full text screened, 25 reviews included potentially eligible studies and their full texts were identified and assessed by two reviewers. We used the same eligibility criteria, but no restriction was applied for publication year of individual studies. We found 36 studies (trials and observational studies) investigating the association between physical activity and prevention of osteoporosis (34 identified from the reviews and 2 from hand searching).*(4-39)* The included studies were published between 1980 and 2015. There were 28 randomised controlled trials (RCT), 5 quasi-randomised trials and 3 observational studies.

Exposure

Within the included trials, 30 compared physical activity with a control intervention (Table 1), eight compared two physical activity programmes (Table 2), four trials (Table 3) and one observational study (Table 4) investigated different doses of physical activity; two investigated leisure-time physical activity and one sport (elite tennis) (Table 4).

The included studies investigated a wide range of physical activity and exercise modalities. Following the ProFaNE taxonomy, most studies (n=14) investigated more than one category of exercise (classified as multiple); 10 studies investigated balance and functional exercises, eight resistance; five endurance, three balance and functional exercise including bone loading and two 3D exercises (Tai Chi).

Participant characteristics

Most included studies recruited from the general older population. Studies in which all participants had already been diagnosed with osteoporosis were excluded. One study excluded participants with osteoporosis at baseline.*(16)* Three studies included participants with some level of frailty and one study included participants who had had surgical repair of a hip fracture no more than 16 weeks prior to study entry. One study investigated lifelong tennis athletes. Eighteen studies included only women whereas three investigated only men.

Outcomes

The included studies reported results for a range of different outcomes (n=28), and the most common ones were measures of bone mineral density (BMD) and bone mineral content (BMC). We performed an overall assessment of the evidence according to the study's main outcome (Table 5). If the study did not specify a main outcome, we selected the outcome we considered to be most relevant to the intervention. If multiple outcomes were reported we selected the outcome used commonly in other studies. We undertook two additional assessments according to the two most commonly reported outcomes across the included studies, which were measures of femoral neck BMD (Table 6) and lumbar spine BMD (Table 7). These two sites are the major diagnostic criteria for osteoporosis.*(40)*

Methodological quality of trials

We assessed the methodological quality of the RCTs and quasi-randomised trials using the PEDro scale with total scores ranging from 0 to 10.*(41, 42)* The overall quality of included studies was moderate (median 5, range 1 to 7). The PEDro total scores are reported for all relevant studies in tables 1-9 and the scores for each item are reported in Appendix 6.

Results

<u>Question 1. What is the association between physical activity and osteoporosis prevention?</u>

Studies investigating physical activity vs control interventions

A total of 30 studies (25 RCT and 5 quasi-randomised trials) investigated physical activity interventions compared with a control group (Table 1). Overall the sample size for the trials was small (median: 50, range: 16 to 283) and the median follow-up length was 11 months (range 3 to 36). We assessed the evidence for 23 RCTs according to the main outcome of each trial (Table 5). The quasi-randomised trials (n=5) and the studies that did not report intervention effects (n=2) were not considered. Since some studies included more than one intervention group, there were 35 relevant comparisons between physical activity and control groups and 24 (69%) were in the same direction of physical activity having a positive effect on bone health. Exploratory meta-analysis confirmed a significant but relatively small overall effect of exercise on BMD when the results of the main outcome from each study were pooled (pooled standardised effect size 0.21, 95% CI 0.06 to 0.36, n=18 trials; Figure 2). The overall results suggest that physical activity interventions probably improve bone health and prevent osteoporosis in older adults. The quality of evidence was moderate as per GRADE system, meaning that the true effect is likely to be close to the estimated results (Appendix 7).

We also summarised the evidence for the two most commonly reported outcome measures across the included studies. Fourteen RCTs investigated the effects of physical activity on femoral neck BMD and only 9/18 comparisons showed a positive effect for physical activity (Table 6). However, exploratory meta-analysis found a significant but relatively small overall effect of physical activity on femoral neck BMD (pooled standardised effect size 0.34, 95% CI 0.05 to 0.62, n=12 trials; Figure 3). Overall, these results suggest that physical activity interventions may improve BMD of the femoral neck in older adults. The quality of the evidence was low, suggesting limited confidence in the results (Appendix 8).

Thirteen RCTs investigated lumbar spine BMD and they showed that physical activity interventions probably improve BMD of the lumbar spine in older adults (Table 7). Most comparison (14/18) showed a positive effect of physical activity on bone health. These results were confirmed by the exploratory meta-analysis that found a significant but relatively small overall effect of physical activity on lumbar spine BMD (pooled standardised effect size 0.27, 95% CI 0.06 to 0.47, n=11 trials; Figure 4). The overall results suggest that physical activity interventions probably improve bone mineral density of the lumbar spine in older adults. The quality of the evidence was moderate, suggesting that the true effect is likely to be close to the estimated results (Appendix 9).

We included 3 observational studies. Since the studies varied in terms of design, statistical approach and measures of physical activity we did not review the evidence and apply the GRADE approach. All three studies showed a positive effect of physical activity on bone health (Table 4).

<u>Question 2. Is there a dose response association (volume, duration, frequency, intensity)?</u>

Studies investigating physical activity vs control interventions

As the Tables show, programmes which had significant impacts were generally of a higher dose. Typical programmes for which significant intervention impacts were detected in RCTs were undertaken for 60+ mins, 2-3 times/week for 7+ months.*(8, 15, 22, 26, 34)*

Studies investigating different doses of physical activity

The RCTs (n=4) investigating different doses of physical activity on bone health did not suggest a clear dose-response relationship (Table 3) but were probably too small (i.e., lacked statistical power) to detect differences between different doses of physical activity. The only longitudinal study investigating different doses of leisure physical activity on bone health found that higher levels of physical activity were associated with better bone health (Table 4).

Exploratory meta-regression

Exploratory meta-analysis found that studies with a higher overall intervention dose (i.e., session time x weekly frequency x programme duration) had greater effects (impact of dose on intervention effect p=0.04, Figure 5). To illustrate the size of the difference in impacts of programmes of different doses we dichotomised dose at 7800 total minutes (i.e., 150 mins x 52 weeks) and found the impact of higher dose interventions (7800+ mins) to be moderate and significant with a standardised effect size of 0.41 (95% CI 0.06 to 0.76, p=0.02) and of lower dose interventions (<7800 mins) to be small and not significant 0.15 (-0.04 to 0.34, p=0.12).

<u>Question 3. Does the association vary by type or domain of physical activity?</u>

Studies investigating physical activity vs control interventions by physical activity type
An assessment of the evidence was performed for the most common types of exercise: balance (including bone loading exercises, Table 8) and multiple (programmes including more than one type of exercise, Table 9). Most comparisons (11/14) showed a positive effect of balance and functional exercises on bone health when the main outcome of the study was considered (n=11 RCTs). Exploratory meta-analysis revealed that the effects of balance and functional exercises did not reach significance when the main outcome from each study was pooled (Figure 2), or when femoral neck BMD (Figure 3) and lumbar spine BMD (Figure 4) were analysed. However, the effects of balance and functional exercises approached significance for all outcomes and there was consistency in the direction of effects with all included studies showing a positive effect of balance and functional exercise on all outcomes considered. Overall, these results suggest that balance and functional exercises may improve bone health and prevent osteoporosis in older adults, although the effect seems to be small. The quality of the evidence was low, suggesting limited confidence in the results (Appendix 10).

When we considered the studies investigating a combination of multiple exercise types, most (6/7) showed a positive effect on bone health when the main outcome of the study was considered. Exploratory meta-analysis revealed that programmes including multiple exercise types had a significant impact on bone when the main outcome from each study was pooled (n=7 trials; Figure 2), as well as on a pooled analysis of femoral neck BMD (n=5 trials; Figure 3) and lumbar spine BMD outcomes (n=5; Figure 4). Overall, these results suggest that interventions involving a combination of multiple exercise types probably improve bone health and prevent osteoporosis in older people. The quality of the evidence was moderate, suggesting that the true effect is likely to be close to the estimated results (Appendix 11).

Exploratory meta-analysis also revealed that the pooled effects of resistance training as a single exercise component were not significant for the overall analysis (Figure 2), or for femoral neck BMD (Figure 3) and lumbar spine BMD outcomes (Figure 4).

Studies comparing different forms of physical activity interventions
There were 8 studies (6 RCTs and 2 quasi-randomised trials) comparing two or more forms of physical activity interventions (Table 2). The comparisons investigated by the studies included: balance vs resistance,*(5,13,16)* balance vs endurance,*(7)* multiple vs resistance,*(16)* 3D vs resistance,*(32, 38)* multiple vs balance,*(16)* endurance vs multiple*(30)* and multiple vs multiple.*(18)* None of the studies found a statistically significant difference between the groups and there was no clear pattern of superiority of one form of physical activity in relation to the others. Overall the studies investigated a small sample of participants (median=58; range 23 to 176 participants

analysed) and may have lacked statistical power to detect differences between forms of physical activity interventions.

Shading in Tables 1 to 9 indicates the studies which detected statistically significant intervention impacts on the relevant outcomes. The programmes used in the RCTs that detected such impacts involved weight-bearing exercises that challenged balance and function, plus additional components (such as added resistance and/or endurance training) and were of a relatively high dose (60+ mins, 2+ times per week) and duration (1+ years) and. For example the study by Bunout *(8)* involved a 1 hour session of: chair stands, squats, step-ups in a stair, arm pull-ups, respiratory muscle training with 15-min walking periods before and after these exercises, and was undertaken twice a week, with the intensity graded by a specialised coach using the Borg scale and lasted for 72 weeks. The study by Jessup *(15)* also involved multiple components, was undertaken 3 times a week with 60-90 minutes per session plus 30-45 minutes of walking and involved resistance training using a weighted vest.

Exploratory meta-regression

Exploratory meta-regression was undertaken to investigate whether the inclusion of any particular component in a programme was associated with greater overall effects. There were greater effects of programmes that included multiple exercise types (p=0.02 for the difference in effects) with significant effects for the programmes that involved multiple exercise types (standardised effect size 0.45, 95% CI 0.20 to 0.71, p = 0.001) but not for programmes that did not (standardised effect size 0.09, 95% CI -0.09 to 0.27, p = 0.33). There was a trend to greater effects for programmes than included resistance training (p=0.16) with significant effects for the programmes that involved resistance training (standardised effect size 0.32, 95% CI 0.09 to 0.55, p = 0.008) but not for programmes that did not (standardised effect size 0.09, 95% CI -0.14 to 0.32, p = 0.42). There was no evidence of differential effects by the inclusion of bone loading exercises (p=0.70) or balance exercises (p=0.45).

Exploration of the impact of study quality

Exploratory meta-regression did not reveal a differential effect of studies that scored less or more than 6 on the PEDro scale (p= 0.72).

Appendix 12 provides the abstracts for all included studies.

CONSIDERATIONS

The initial aim of this review was to summarise the evidence of physical activity on prevention of osteoporosis in older people by conducting a review of systematic reviews. However, since no reviews were found we included the relevant studies that were included in the reviews found. Since the search was targeted at reviews, it is possible that we have missed important studies, particularly recently-published studies (the most recent included study was published in 2015). More recent studies may have been identified with a literature search strategy that was designed to identify individual trials rather than reviews. Additionally, the search only included PubMed and it is possible that we might have missed relevant studies that are not indexed in this database.

We only included studies investigating the effects of physical activity for the prevention of osteoporosis and therefore excluded studies where all participants had been diagnosed with osteoporosis. Most studies did not use the absence of osteoporosis at baseline as an inclusion criterion. Therefore, it is likely that the studies investigated samples of people with mixed bone health status. Since bone health is a continuum, the inclusion of studies of people with existing osteoporosis would provide additional understanding of the effect of physical activity on osteoporosis but was beyond the scope of this review.

We used an adapted version of the GRADE approach considering the number of studies that showed a positive, neutral or negative effect as well as the exploratory meta-analysis results. The results from our exploratory meta-analysis should be interpreted with caution given the limitations of the search strategy used and the possibility that important trials might have been missed.

One review author classified the exercise interventions using the ProFaNE guidelines *(43)* and a second one checked the classification. We recognise there is some subjectivity in this classification system, particularly for those interventions containing more than one category of exercise.

The studies investigating exercises programmes had a median duration of 11 months. It is likely that longer exercise programmes would have greater effects on bone health, as suggested by the only longitudinal study.

In summary, while the results need to be treated with some caution, the studies included in this review suggest that physical activity is likely to play a role in the prevention of osteoporosis. The level of evidence is higher for lumbar spine BMD (than for femoral neck BMD) and for higher dose programmes and those involving multiple exercises types.

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EVIDENCE PROFILE 1. The relationship between physical activity and osteoporosis prevention in older people: exercise vs control

No. of Studies overall / meta-analysis	Design	Quality assessment					No. of Participants /No. meta-analysis	Effects	Quality
		Risk of bias	Inconsistency	Indirectness	Imprecision	Other			
Exercise vs control on the main outcome of the included studies									
A total of 30 studies (25 RCT and 5 quasi-randomised trials) investigated physical activity interventions compared with a control group (Table 1). Overall the sample size for the trials was small (median: 50, range: 16 to 283) and the median follow-up length was 11 months (range 3 to 36). Most included studies recruited from the general older population. Studies in which all participants had already been diagnosed with osteoporosis were excluded. One study excluded participants with osteoporosis at baseline. Three studies included participants with some level of frailty and one study included participants who had had surgical repair of a hip fracture no more than 16 weeks prior to study entry. Eighteen studies included only women whereas three investigated only men. The included studies reported results for a range of different outcomes (n=28), and the most common ones were measures of bone mineral density (BMD) and bone mineral content (BMC). We undertook two additional assessments according to the two most commonly reported outcomes across the included studies, which were measures of femoral neck bone mineral density and lumbar spine bone mineral density.									
23 / 18	RCTs[a]	Serious risk of bias[b]	No serious inconsistency[c]	No serious indirectness[d]	No serious imprecision[e]	None	1,915 / 1,331	24/35 comparisons showed a positive effect and 11/35 showed a negative effect for physical activity. Exploratory meta-analysis results: pooled standardised effect size 0.21, 95% CI 0.06 to 0.36. Physical activity interventions probably improve bone health and prevent osteoporosis in older adults.[f]	Moderate[g]
Exercise vs control on femoral neck bone mineral density (BMD)									
A total of 17 studies (14 RCTs and 3 quasi-randomised trials) investigated the effects of physical activity on femoral neck bone mineral density									
14 / 12	RCTs[h]	Serious risk of bias[i]	Serious inconsistency[j]	No serious indirectness[d]	No serious imprecision[k]	None	976 / 877	9/18 comparisons showed a positive effect for physical activity, 1/18 showed a neutral effect, and 8/18 showed negative effect for physical activity for on femoral neck bone mass density. Exploratory meta-analysis results: 0.34, 95% CI 0.05 to 0.62. Physical activity interventions may improve bone mineral density of the femoral neck in older adults.[l]	Low[m]
Exercise vs control on lumbar spine bone mineral density (BMD)									
A total of 17 studies (14 RCTs and 3 quasi-randomised trials) investigated the effects of physical activity on lumbar spine bone mineral density									
13 / 11	RCTs[n]	Serious risk of bias[o]	No serious inconsistency[p]	No serious indirectness[d]	No serious imprecision[q]	None	1,092 / 903	Most studies (14/18) showed a positive effect for physical activity on lumbar spine bone mass density. Exploratory meta-analysis results: pooled standardised effect size 0.27, 95% CI 0.06 to 0.47. Physical activity interventions probably	Moderate[s]

								improve bone mineral density of the lumbar spine in older adults.[r]	

a Includes 23 RCTs.*(4-6, 8-17, 20-22, 24-29, 31, 32, 34, 35, 37-39)* The quasi-randomised trials (n=5)*(18, 19, 30, 33, 36)* and the studies that did not report intervention effect (n=2)*(7, 23)* were not considered. Since some studies included more than one intervention group, there were 35 relevant comparisons between physical activity and control groups. There were 18 RCTs in the exploratory meta-analysis.*(4, 6, 9-11, 13, 15, 16, 21, 22, 25-28, 34, 35, 37, 39)*

b We downgraded the evidence by one level as 18/23 studies (78%) had a PEDro score <6/10. Additionally, 15/18 (83%) of studies in the meta-analysis had a PEDro score <6/10.

c We did not downgraded the evidence by one level due to heterogeneity of included studies. Although only 69% of comparisons were in the same direction (24/35 comparisons showed a positive effect and 11/35 showed a negative effect for physical activity), most of the comparisons in the meta-analysis were in the same direction (80%, 20/25).

d Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.

e The 23 included studies had a total of 1,915 participants analysed and the meta-analysis had 1,331 participants analysed. Therefore, we did not downgrade the evidence.

f The effects for each individual study can be found in Table 5 and exploratory meta-analysis results can be found in Figure 2.

g Quality of the evidence was downgraded from high to moderate because of serious risk of bias.

h Includes 14 RCTs.*(4, 10, 11, 13, 15, 20-22, 26-28, 31, 37, 39)* The quasi-randomised trials (n = 3)*(18, 19, 36)* were not considered. Since some studies included more than one intervention group, there were 18 relevant comparisons between physical activity and control groups. There were 12 RCTs in the exploratory meta-analysis.*(4, 10, 11, 15, 21, 22, 26-28, 34, 35, 37)*

i We downgraded the evidence by one level as 13/14 studies (93%) had a PEDro score <6/10. Additionally 11/12 studies (92%) included in the meta-analysis had a PEDro score <6/10.

j We downgraded the evidence by one level due to heterogeneity of included studies (9/18 comparisons showed a positive effect for physical activity, 1/18 showed a neutral effect, 8/18 showed negative effect for physical activity). Inconsistency was also found in the studies included in the meta-analysis where 5/15 comparisons showed a negative effect, 1/15 showed a neutral effect and 9/15 a positive effect.

k The 14 included studies had a total of 976 participants analysed. There were 877 participants included in the meta-analysis. Therefore, we did not downgrade the evidence.

l The effects for each individual study can be found in Table 6 and exploratory meta-analysis results can be found in Figure 3.

m Quality of the evidence was downgraded from high to low because of serious risk of bias and serious inconsistency.

n includes 13 RCTs.*(10, 11, 15, 20-22, 24, 26-28, 34, 35, 37)* The quasi-randomised trials (n=3)*(18, 19, 36)* and one study*(23)* that did not report intervention effect were not considered. Since some studies included more than one intervention group, there were 18 relevant comparisons between physical activity and control groups. There were 11 RCTs in the exploratory meta-analysis.*(10, 11, 15, 21, 22, 26-28, 34, 35, 37)*

o We downgraded the evidence by one level as 11/13 studies (76%) had a PEDro score <6/10. Additionally 8/11 studies (73%) included in the meta-analysis had a PEDro score <6/10.

p We did not downgrade the evidence due to heterogeneity of included studies as most comparisons (14/18) showed a positive effect for exercise. Similarly, in the meta-analysis most comparisons were in the same direction (80%, 12/15).

q The 13 included studies had a total of 1,092 participants analysed. There were 903 participants included in the exploratory meta-analysis. Therefore, we did not downgrade the evidence.

r The effects for each individual study can be found in Table 7 and exploratory meta-analysis results can be found in Figure 4.

s Quality of the evidence was downgraded from high to moderate because of serious risk of bias.

EVIDENCE PROFILE 2. The relationship between physical activity and osteoporosis prevention in older people: exercise vs control by physical activity type on the main outcome of the study

No. of studies	Design	Quality assessment					No. of participants	Effects	Quality
		Risk of bias	Inconsistency	Indirectness	Imprecision	Other			
The included studies investigated a wide range of physical activity and exercise modalities. Following the ProFaNE taxonomy, most studies (n=14) investigated more than one category of exercise (classified as multiple); 10 studies investigated balance and functional exercises, eight resistance, five endurance, three balance and functional exercise including bone loading and two 3D exercises (Tai Chi). An assessment of the evidence was performed for the most common types of exercise: balance (including bone loading exercises, and multiple programmes including more than one type of exercise.									
Balance and functional exercise vs control on the main outcome of the included studies									
11 / 7	RCT [a]	Serious risk of bias[b]	No serious inconsistency[c]	No serious indirectness[d]	Serious imprecision[e]	None	1,150 / 636	Most studies (11/14) showed a positive effect for physical activity. Exploratory meta-analysis results: pooled standardised effect size 0.13, 95% CI -0.03 to 0.28; n=7 trials. Balance and functional exercises may improve bone health and prevent osteoporosis in older adults.[f]	Low[g]
Multiple vs control on the main outcome of the included studies									
7	RCT[h]	Serious risk of bias[i]	No serious inconsistency[j]	No serious indirectness[d]	No serious imprecision[k]	None	440	Most studies (6/7) showed a positive effect for physical activity. Exploratory meta-analysis results: pooled standardised effect size 0.47, 95% CI 0.17 to 0.77. Interventions involving a combination of multiple exercise types probably improve bone health and prevent osteoporosis in older people.[l]	Moderate[m]

a Includes 11 RCTs.*(4, 8-10, 13, 16, 20-22, 24, 31)* Since some studies included more than one intervention group, there were 14 relevant comparisons between physical activity and control groups. There were 7 RCTs in the exploratory meta-analysis.*(4, 9, 10, 13, 16, 21, 22)*
b We downgraded the evidence by one level as 9/11 studies (82%) had a PEDro score <6/10. Additionally 5/7 studies (71%) included in the meta-analysis had a PEDro score <6.
c We did not downgrade the evidence due to heterogeneity of included studies as most studies (11/14) showed a positive effect for exercise. Additionally, all studies included in the exploratory meta-analysis were in the same direction.
d Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.
e The 11 included studies had a total of 1,150 participants analysed. There were 636 participants included in the exploratory meta-analysis. The confidence intervals were relatively wide so we downgraded the evidence.
f The effects for each individual study can be found in Table 8 and exploratory meta-analysis results can be found in Figure 2.
g Quality of the evidence was downgraded from high to low because of serious risk of bias and wide confidence intervals.
h Includes 7 RCTs*(6, 11, 15, 16, 26, 34, 37)* comparing multiple exercise types with control on the main outcome of the included studies. The quasi-randomised trials (n=4)*(18, 19, 30, 36)* were not considered. All trials were included in the exploratory meta-analysis.

i We downgraded the evidence by one level as 4/7 studies (57%) had a PEDro score <6/10. Similarly, in the exploratory meta-analysis 4/7 studies (57%) had a PEDro score <6/10.
j We did not downgrade the evidence due to heterogeneity of included studies as most studies (6/7) showed a positive effect for exercise. Similarly, in the exploratory meta-analysis 6/7 studies showed a positive effect.
k The 7 included studies had a total of 440 participants analysed (all included in the exploratory meta-analysis). Therefore, we did not downgrade the evidence.
l The effects for each individual study can be found in Table 9 exploratory meta-analysis results can be found in Figure 2.
m Quality of the evidence was downgraded from high to moderate because of serious risk of bias.

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FIGURE 1. Flow of studies

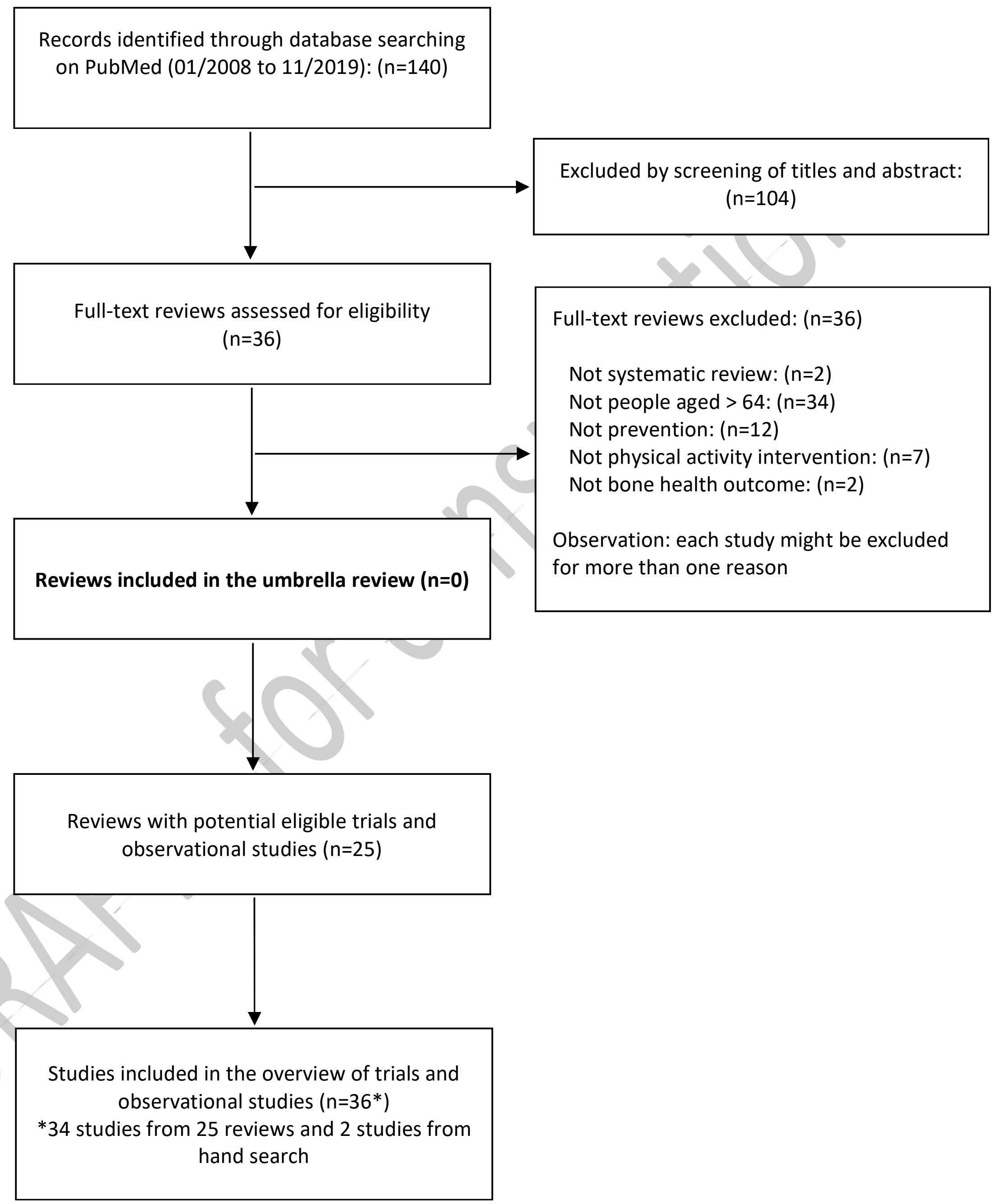

FIGURE 2. Effect of physical activity interventions on osteoporosis-related outcomes

Effect size (95% confidence interval) of physical activity interventions on the main outcome reported by pooling data from 18 trials comparing physical activity versus control using random-effects meta-analysis (n=1331)

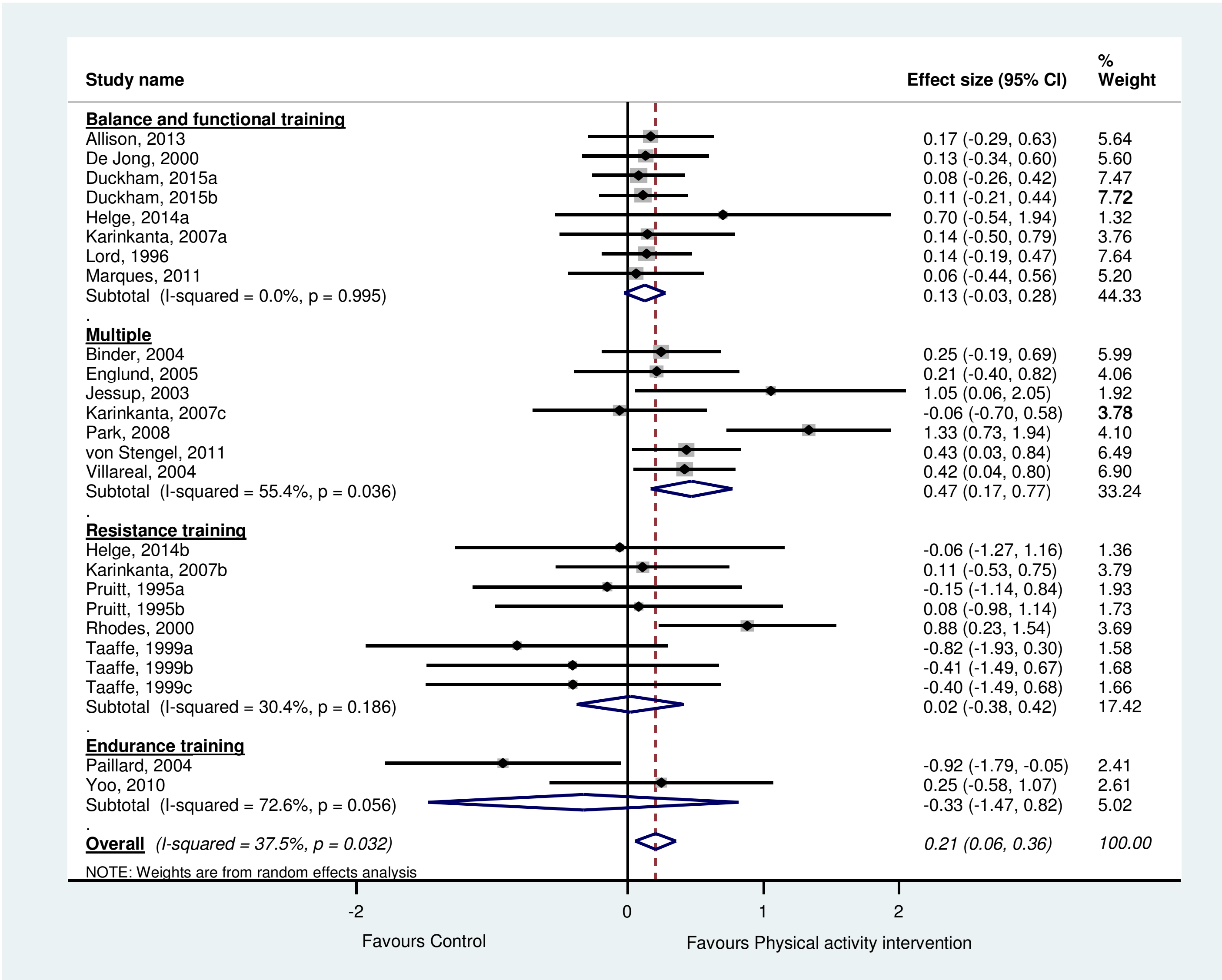

FIGURE 3. Effect of physical activity interventions on femoral neck bone mineral density

Effect size (95% confidence interval) of physical activity interventions on the femoral neck bone mineral density by pooling data from 12 trials comparing physical activity versus control using random-effects meta-analysis (n=877)

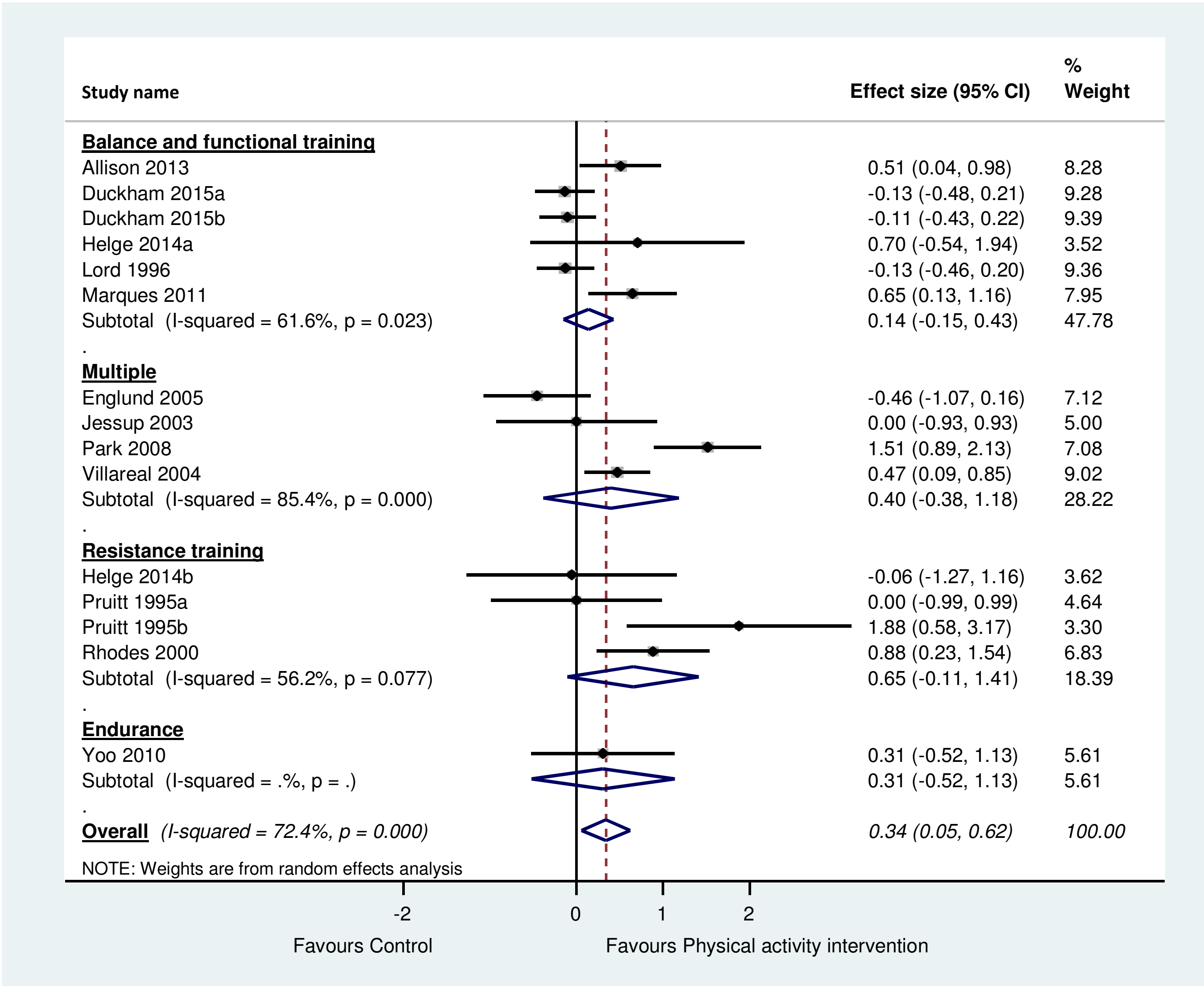

FIGURE 4. Effect of physical activity interventions on lumbar spine bone mineral density

Effect size (95% confidence interval) of physical activity interventions on lumbar spine bone mineral density by pooling data from 11 trials comparing physical activity versus control using random-effects meta-analysis (n=903)

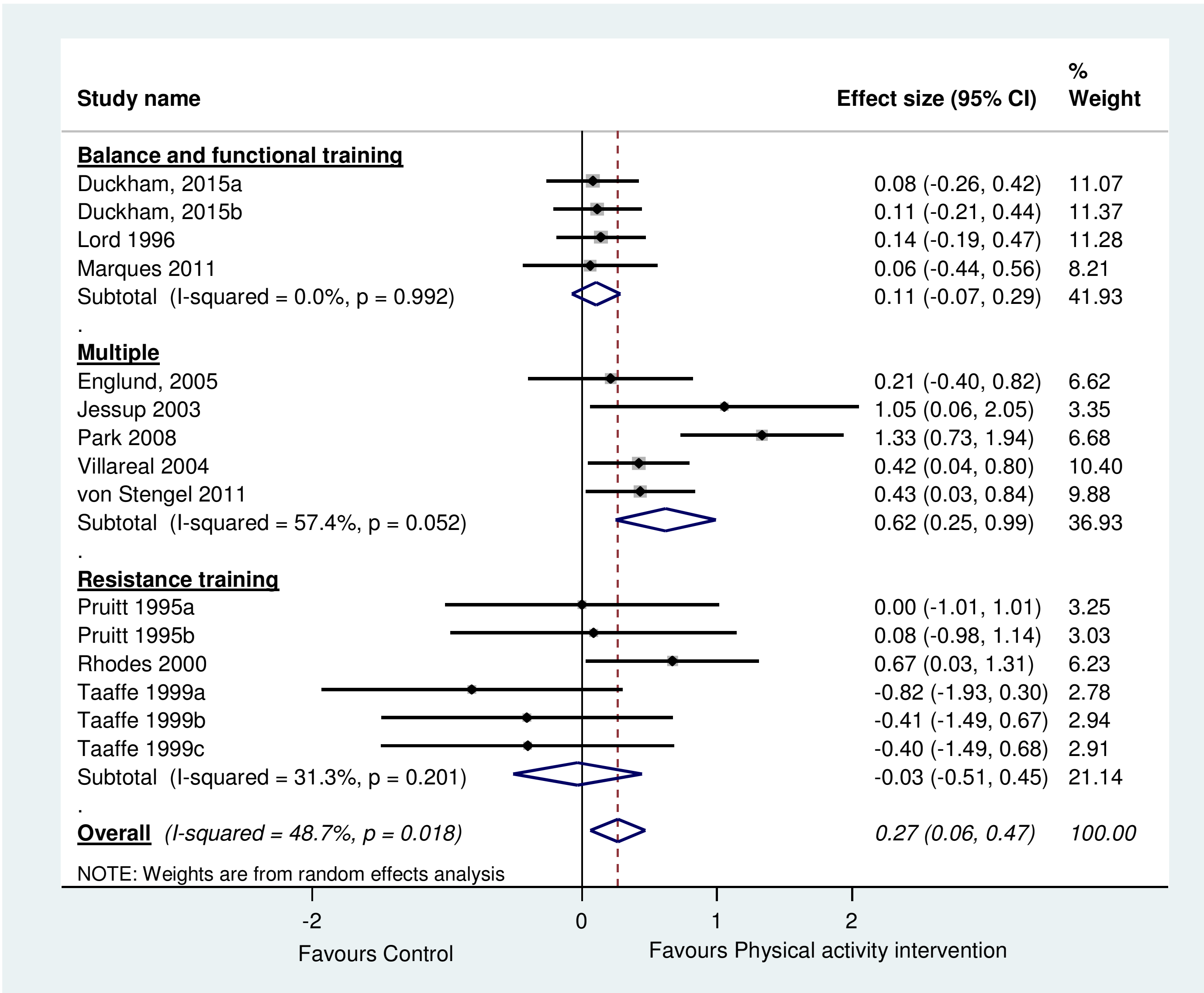

FIGURE 5. Relationship between overall intervention dose and size of effect on bone

Relationship between higher overall intervention dose (i.e., session time x weekly frequency x programme duration) and size of effect on bone (between group differences in trials) from meta-regression.

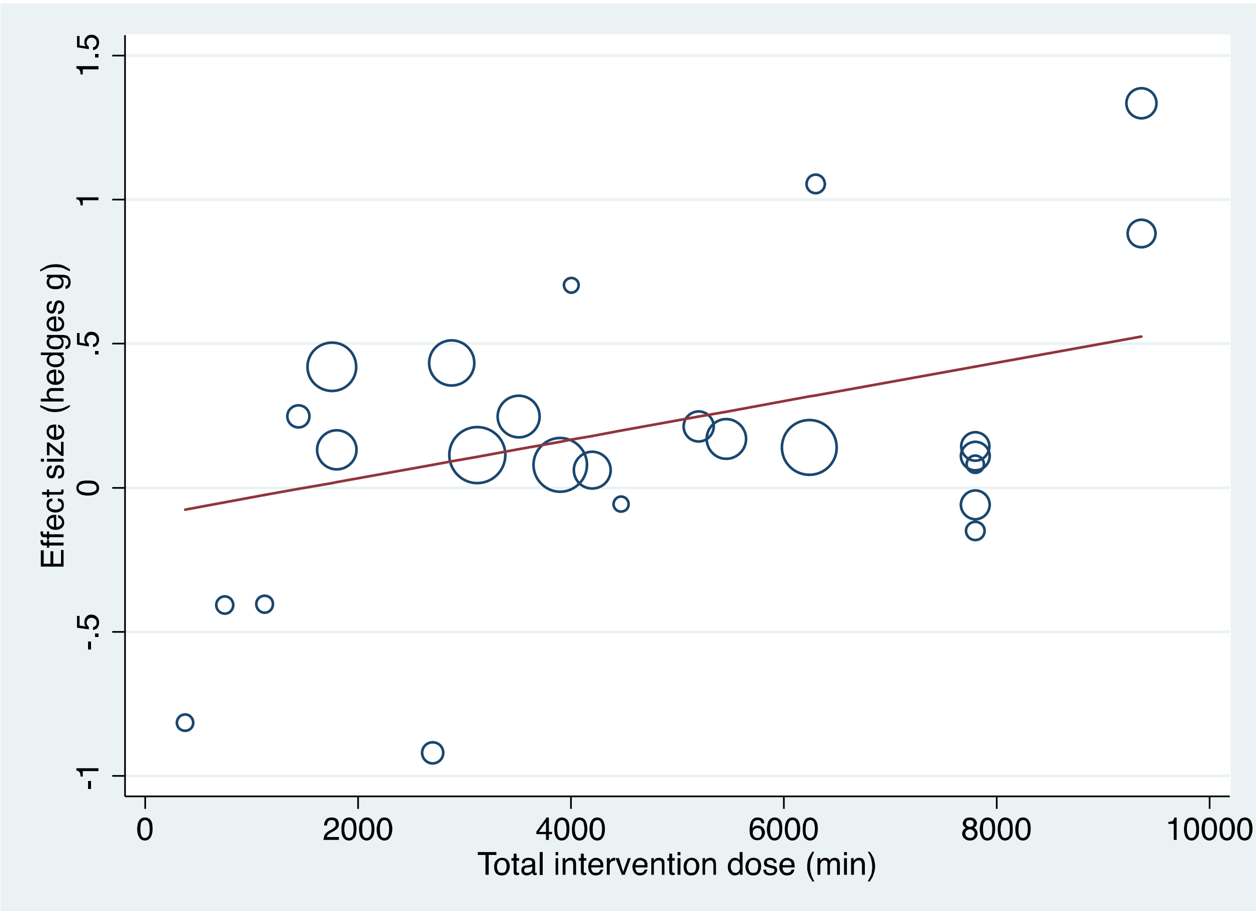

TABLE 1. Description of included studies comparing physical activity with a control intervention

Reference PEDro score	Study design Allocated/ Analysed	Participants (n, age mean (SD), % women, setting, health status)	Intervention Primary exercise type according to ProFANE[a]	Control[b]	Outcomes	Follow up (mo)	Results
Allison 2013 5/10	RCT 50/35	**Setting**: Community; United Kingdom **Health status**: Healthy **A. High impact exercise** **n**= 50 (randomised); 35 (analysed) **Age**: 69.9(4.0) **Female**: 0% **B. No exercise** Contralateral leg of each participant was used as control	**A.** High impact unilateral exercise programme (brief hopping exercise sessions) **Frequency**: 7 times/week **Intensity**: 5 sets of 10 multidirectional hops with a 15s rest period. Encouraged participants to continue to hop as high and as fast as they could. **Session duration**: ~15 mins/session **Delivered by**: NR **Duration of the intervention (wks):** 52 **Primary exercise type**: Balance and function including bone loading (multidirectional hopping)	**B.** No exercises performed with the control leg	1. Femoral neck BMD 2. Trochanter BMD 3. Total hip BMD 4. Femoral neck BMC 5. Trochanter BMC 6. Total hip BMC	12	Final score (mean ± SD) 1. Femoral neck BMD[¥] A. Exercise: 0.954 ± 0.017 B. Control: 0.945 ± 0.018 2. Trochanter BMD A. Exercise: 0.923 ± 0.017 B. Control: 0.923 ± 0.018 3. Total hip BMD A. Exercise: 1.030 ± 0.017 B. Control: 1.027 ± 0.018 4.Femoral neck BMC[¥] A. Exercise: 5.54 ± 0.13 B. Control: 5.49 ± 0.14 5. Trochanter BMC A. Exercise: 16.45 ± 0.54 B. Control: 16.49 ± 0.57 6. Total hip BMC: A. Exercise: 40.49 ± 0.91 B. Control: 40.35 ± 0.97
Binder 2004 7/10	RCT 90/78	**Setting**: Hospital, home care programme and community; United States **Health Status**: People with a recent proximal femur fracture **A. Physical Therapy and exercise training** **n**=46 (randomised); 46 (analysed) **Age**: 80 (7) **Female**: 72% **B. Control - Home exercise**	**A.** Supervised physical therapy and exercise training involving flexibility, balance, coordination, movement speed and progressive resistance exercises. **Frequency:** 3 times/week **Intensity**: the resistance training started from 1-2 sets of 6-8 reps each exercise at 65% of 1RM; progressed to 8-12 reps 3 sets at 85%-100% of initial 1-RM. **Session duration**: 45-90 min **Delivered by**: Physical therapist	**B.** Low-intensity home exercise programme	1. Whole body BMD 2. Hip BMD	6	Final score (mean ± SD) 1. Whole body BMD A. Physical therapy and exercise training: 1.03 ± 0.13 B. Home exercise programme: 1.00 ± 0.11 2. Hip BMD A. Physical therapy and exercise training: 0.64 ± 0.18 B. Home exercise programme: 0.69 ± 0.12 No significant group x time effects

		n= 44 (randomised); 44 (analysed) **Age**: 81 (8) **Female**: 77%	**Duration of the intervention (wks)**: 26 **Primary exercise type**: Multiple, (balance/function plus resistance)				
Blumenthal 1991 6/10	RCT 101/84	**Setting**: NR, United States **Health status**: Healthy **A. Aerobic Training** **n**= 33 (randomised) **B. Yoga and flexibility** **n**= 34 (randomised) **C. Control** **n**= 34 (randomised) **Age** (whole sample): 67 (range: 60-83) **Female**: NR	**A. Aerobic training:** Endurance training involving bicycle ergometry, brisk walking/jogging, and arm ergometry. **Frequency**: 3 times/week **Intensity**: 70% heart rate reserve **Session duration**: 60 min **Delivered by**: NR **Duration of intervention (wks):** 16 **Primary exercise type:** Endurance training **B. Yoga:** Supervised non-aerobic yoga programme. **Frequency**: at least 2 times/week **Intensity**: NR **Session duration**: 60 min **Delivered by:** NR **Duration of intervention (wks):** 16 **Primary exercise type**: Balance and function	**C.** Waiting list control: did not receive any form of treatment and were instructed not to change their physical activity habits and specifically not to engage in any aerobic exercise for the 4-month period.	1. Distal radius BMD	14	1. Distal radius BMD: no between-group differences. Quantitative estimates not reported for between-group comparisons. Sub-analysis was performed comparing participants who decided to continue to exercise or not for men and women separately (randomisation was broken for this analysis): -Men who continued the programme (mean ± SD): 1.4± 0.4 mg/cm²) -Men who discontinued the programme (mean ± SD): 1.0 ± 0.3 Between-group difference: $p<0.05$
Bunout 2001 4/10	RCT 149/98	**Setting**: Outpatient clinic; Chile **Health Status**: Healthy **A. Resistance training** **n**= 28 randomised; 16 (analysed) **Age**: 74.4 (3.3) **Female**: 75% **B. Control** **n**=31 (randomised); 25 (analysed) **Age**: 74.0 (3.7) **Female**: 48% **C. Supplementation + Resistance training** **n**= 42 (randomised) 31 (analysed) **Age**: 73.7(3.0) **Female**: 40% **D. Supplementation**	**A.** Endurance training consisting of exercise for upper and lower body, respiratory muscle training and walking. **Frequency**: 2 times/week **Intensity**: Graded by a coach using the Borg scale **Session duration**: 60 min **Delivered by**: Specialised coach **Duration of the intervention (wks)**: 78 **Primary exercise type**: Multiple (balance and function plus endurance)	**B.** No training	1. Whole body BMD 2. Whole body BMC	18	1. Whole body BMD Decreased significantly in all groups ($p = 0.006$), but the decline was less marked in the strength training combined with nutritional supplements compared with the other groups (statistically significant). Results reported in a graph and not possible to extract quantitative estimates. 2. Whole body BMC: NR

		n= 42 (randomised); 26 (analysed) **Age**: 74.7(3.7) **Female**: 62%					
De Jong 2000 5/10	RCT 217/143	**Setting**: Community; Netherlands **Health status**: People with frailty and BMI ≤ 25 **A. Exercise** **n**= 55 (randomised); 36 (analysed) **Age**: 76.5 (4.6) **Female**: 69% **B. Control** **n**= 44 (randomised); 33 (analysed) **Age**: 78.8 (6.7) **Female**: 67% **C. Exercise + nutrition** **n**= 60 (randomised); 39 (analysed) **Age**:79.8 (5.8) **Female**: 74% **D. Nutrition** **n**= 58 (randomised); 35 (analysed) **Age**:79.6 (5.0) **Female**: 69%	**A.** Supervised group-based exercise programme involving muscle strength, coordination, flexibility, speed, endurance with use of ropes, weights and elastic bands. **Frequency**: 2 times/week **Intensity**: Moderate to high; 7 of a 10-point Borg scale **Session duration**: 45 min **Delivered by**: Skilled teachers and supervisor **Duration of the intervention (wks)**: 17 **Primary exercise type**: Balance and function	**B.** Social programme involving creative and social activities as well as educational sessions.	1. Whole body BMD	4.5	Change score (mean change ± SD) 1. Whole body BMD A. Exercise: 0.000±0.022 B. Control: −0.003±0.018 C. Combination group: 0.003±0.023 D. Nutrition group: 0.006±0.014 No between-group differences in the relevant comparisons to this review (ie, exercise vs control and combination vs nutrition)
Duckham 2015 6/10	RCT 319/283	**Setting**: General practice; United Kingdom **Health status**: Healthy **A. Home based exercise (OEP)** **n**= 88 (randomised); 75 (analysed) **Age**: 71.4 (4.9) **Female**: 68% **B. Community based exercise (FaME)** **n**= 105 (randomised); 94 (analysed) **Age**: 71.8 (5.5) **Female**: 60% **C. Control: Usual care** **n**= 126 (randomised); 114 (analysed) **Age**: 72.2 (5.5) **Female**: 54	**A. OEP**: Home exercise programme consisting of leg strengthening, balance exercise, and walking. **Frequency**: 3 sessions/week of home exercise; at least 2 sessions/week of walking **Intensity**: Walking moderate pace **Session duration:** 30 min home exercise session, and 30 min walking session **Delivered by**: Trial research staff in the one-off training **Duration of the intervention (wks)**: 24 **Primary exercise type**: Balance and function **B. FaME:** Falls and exercise management programme involving progressive resistance training, flexibility training, functional floor	**C.** Usual care Participants not offered the FaME or OEP programmes	1. Femoral neck BMD 2. Trochanter BMD 3. Total hip BMD 4. Upper neck BMD 5. Lumbar spine BMD 6. Distal radius BMD 7. Whole body BMD 8. Whole body BMC	6	Mean difference (95% CI) 1. Femoral neck BMD A. OEP: −0.003 (−0.011 to 0.005) B. Community based: −0.002 (−0.010 to 0.005) 2. Trochanter BMD A. OEP: −0.005 (−0.032 to 0.022) B. Community based: 0.000 (−0.025, 0.026) 3. Total hip BMD A. OEP: −0.008 (−0.034 to 0.019) B. Community based: 0.003 (−0.022 to 0.028) 4. Upper neck BMD A. OEP: 0.003 (−0.018 to 0.023) B. Community based: 0.006 (−0.013 to 0.026) 5. Lumbar spine BMD A. OEP: 0.003 (−0.012 to 0.019) B. Community based: 0.005 (−0.010 to 0.020)

			skill and adapted Tai Chi. Additionally, FaME intervention included home exercise based on EOP and walking. **Frequency**: 3-5 times/week [One exercise class, two home exercise session and at least two sessions of walking per week] **Intensity**: walking at moderate pace **Session duration**: 60 min exercise class; 30 min home exercise session; 30 min walking session **Delivered by**: Postural stability instructor **Duration of the intervention (wks)**: 24 **Primary exercise type**: Balance and function				6. Distal radius A. OEP: 0.001 (−0.008, 0.010) B. Community based: −0.009 (−0.018 to −0.000)[¥] 7. Whole body BMD A. OEP: 0.003 (−0.002 to 0.008) B. Community based: −0.003 (−0.007 to 0.002) 8. Whole body BMC A. OEP: 0.8 (−22.0 to 23.6) B. Community based: −6.6 (−27.9 to 14.7)
Englund 2005 5/10	RCT 48/40	**Setting**: Community; Sweden **Health status**: Healthy **A. Exercise (COMB)** **n**= 24 (randomised); 21 (analysed) **Age**: 72.8 (3.6) **B. Control** **n**= 24 (randomised); 19 (analysed) **Age**:73.2 (4.9) **Female**: 100%	**A.** Supervised exercise programme involving a combination of strengthening, aerobic, balance and coordination exercises **Frequency**: 2 times/week **Intensity**: 2 sets of 8-12 reps (strengthening exercise) **Session duration**: 50 min **Delivered by**: Physiotherapist **Duration of the intervention (wks)**: 47 **Primary exercise type**: Multiple, balance and function plus resistance plus endurance	**B.** No training	1. Lumbar Spine BMD 2. Femoral neck BMD 3. Trochanter BMD 4. Ward's triangle BMD 5. Whole body BMD 6. Arms BMD 7. Whole body BMC	12	Mean difference (95% CI) (on % changes) 1. Lumbar spine BMD: 2.1 (-0.4 to 3.4) 2. Femoral neck BMD: 0 (-3.8 to 2.6) 3. Trochanter BMD: 3.4 (-1.2 to 7.3) 4. Ward's triangle BMD: 2.2 (1.8 to 12.9)[¥] 5. Whole body BMD: 0.1 (-1.3 to 2.2) 6. Arms BMD: 0 (-1.9 to 2.8) 7. Whole body BMC: 1.3 (-0.3 to 3.1)
Helge 2014 5/10	RCT 27/23	**Setting**: Community; Denmark **Health status**: Healthy **A. Football group** **n**= 9 (randomised); 9 (analysed) **Age**: 68.0 (4.0) **B. Resistance training** **n**= 9 (randomised); 8 (analysed) **Age**: 69.1 (3.1) **C. Control** **n**= 8 (randomised); 6 (analysed)	**A. Football group:** Supervised progressive football training **Frequency**: 1.7 (0.3) times/week (range: 1.2-2.2) **Intensity**: 82% of maximum heart rate (range 64 to 90%) **Session duration**: 45-60 min **Delivered by**: NR **Duration of the intervention (wks)**: 52 **Primary exercise type**: Balance and function (football)	**C.** Inactive control	1. Whole body BMD 2. Right femoral neck BMD 3. Left femoral neck BMD 4. Right femoral shaft BMD 5. Left femoral shaft BMD 6. Total right proximal femur 7. Total left proximal femur	12	Final score (mean ± SD) 1. Whole body BMD A. Football: 1.211 ± 0.036 B. Resistance: 1.225 ± 0.024 C. Control: 1.268 ± 0.030 2. Right femoral neck BMD A. Football: 0.921 ± 0.034 B. Resistance: 1.000 ± 0.042 C. Control: 1.008 ± 0.063 3. Left femoral neck BMD A. Football: 0.939 ± 0.034

		Age: 67.4 (2.7) **Female**: 0%	**B. Resistance training:** Progressive resistance training for core and upper and lower body **Frequency**: 1.9 (0.2) times/week (range: 1.4-2.2) **Intensity**: started from 3 sets of 16-20 RM to 4 sets of 8 RM **Session duration**: 45-60 min **Delivered by**: NR **Duration of the intervention (wks)**: 52 **Primary exercise type**: Resistance (seated)				B. Resistance: 1.006 ± 0.036 C. Control: 1.018 ± 0.043 4. Right femoral shaft BMD A. Football: 1.156 ± 0.042 B. Resistance: 1.229 ± 0.056 C. Control: 1.254 ± 0.059 5. Left femoral shaft BMD A. Football: 1.143 ± 0.043 B. Resistance: 1.229 ± 0.057 C. Control: 1.282 ± 0.045 6. Total right proximal femur A. Football: 0.982 ± 0.031 B. Resistance: 1.066 ± 0.048 C. Control: 1.083 ± 0.048 7. Total left proximal femur A. Football: 0.989 ± 0.031 B. Resistance: 1.069 ± 0.048 C. Control: 1.117 ± 0.041
Jessup 2003 5/10	RCT 18/16	**Setting**: Retirement Community; United States **Health Status**: Healthy **A. Multi-component intervention** **n**= 9 (randomised); 8 (analysed) **Age**: 69.1 (2.8) **B. Control** **n**= 9 (randomised); 8 (analysed) **Age**: 69.4 (4.2) **Female**: 100%	**A.** Supervised exercise programme involving resistance training, load-bearing walking with use of weights vest, stair-climbing, and balance training. **Frequency**: 3 times/week **Intensity**: 8-10 reps of 50% of 1RM, progressed to 75% of 1RM (resistance training **Session duration**: 60-90 min exercise training session; 30-45min walking **Delivered by:** Co-investigator and/or research assistant **Duration of the intervention (wks)**: 32 weeks **Primary exercise type**: Multiple (balance and function plus resistance plus endurance)	**B.** Control	1. Femoral neck BMD 2. Lumbar spine BMD	8	Change score (ANCOVA, p-value) 1. Femoral neck BMD A. Exercise: 1.7 B. Control: -0.04 F (1, 15) = 7.38, P = 0.016 2. Lumbar spine BMD A. Exercise: 0.11 B. Control: -0.003 F (1, 15) = 2.70, P = 0.121 Final score (mean ± SD) 1. Femoral neck BMD A. Exercise: 0.74 ± 0.05 B. Control: 0.74 ± 0.13 2. Lumbar spine BMD A. Exercise: 0.88 ± 0.08 B. Control: 1.14 ± 0.32
Karinkanta 2007 7/10	RCT 149/144	**Setting**: Community; Finland	**A. Balance-jumping training:** Balance training including static and dynamic balance exercise,	**D.** Control: Maintain their pre-study level of physical activity during the 12-month trial	1. Femoral neck BMC	12	Final score (mean ± SD) 1. Femoral neck BMC A. Balance: 2.73 ± 0.40

		Health Status: healthy and excluded participants with osteoporosis **A. Balance-jumping training** **n**= 37(randomised); 35 (analysed) **Age**: 72.9 (2.3) **B. Resistance training** **n**= 37 (randomised); 37(analysed) **Age**: 72.7 (2.5) **C. Combined Balance-jumping and resistance training** **n**= 38 (randomised); 36 (analysed) **Age**: 72.9 (2.2) **D. Control** **n**= 37 (randomised); 36 (analysed); **Age**: 72.0 (2.1) **Female**: 100%	agility training, impact exercises and changes of direction exercise. **Intensity**: NR **Primary exercise type**: Balance and function including bone loading (jumps) **B. Resistance training:** Tailored progressive resistance training programme for large muscle groups. **Intensity**: Initially 2 sets of 10-15 reps at intensity 50-60% of 1RM, progressed to 3 sets of 8-10 reps at 75-80% of 1RM. Rate of perceived exertion: above 18 out of 20 **Primary exercise type**: Resistance **C. Combined Balance-jumping and resistance training**: A combination of A & B on alternate weeks. **Primary exercise type**: Multiple (balance and function plus resistance) For all exercise groups: **Frequency**: 3 times per week **Session duration**: 50 min **Delivered by:** Exercise leaders **Duration of the intervention (wks)**: 52		2. Distal tibia trabecular density (mg/cm³)		B. Resistance: 2.71 ± 0.33 C. Combined: 2.65 ± 0.29 D. Control: 2.67 ± 0.44 2. Distal tibia trabecular density (mg/cm³) A. Balance: 224 ± 34 B. Resistance: 219 ± 26 C. Combined: 215 ± 39 D. Control: 226 ± 33
Kohrt 1997 3/10	Quasi-randomised trial 39/30	**Setting:** United States **Health Status**: Healthy **A. Ground reaction forces training** **n**= 14 (randomised); 12 (analysed) **Age**: 66.0 (1.0) **B. Joint reaction forces training** **n**= 13 (randomised); 9 (analysed) **Age**: 65.0 (1.0) **C. Control** **n**= 12 (randomised); 9 (analysed) **Age**: 68.0 (1.0) **Female**: 100%	**A. Ground reaction forces training:** Individualised exercise training focusing on activities that involved ground-reaction forces, such as walking, jogging and/or stair climbing. **Frequency**: 3 to 5 times/week **Intensity**: 60-70% to 80-85% maximum heart rate **Session duration:** 30-45 minutes/day **Delivered by**: NR **Duration of the intervention (wks)**: 36 **Primary exercise type**: Multiple (balance and function plus endurance plus flexibility)	**C.** No exercise	1. Whole body BMD 2. Lumbar spine L2–L4 BMD 3. Femoral neck BMD 4. Trochanter BMD 5. Ward's BMD 6. Ultra-distal wrist BMD 7. One-third distal wrist BMD	12	Between-group analysis relative to control 1. Whole body BMD A. Ground reaction: p < 0.05 B. Joint reaction: p < 0.01 2. Lumbar spine L2–L4 BMD A. Ground reaction: p < 0.05 B. Joint reaction: p < 0.01 3. Femoral neck BMD A. Ground reaction: p < 0.01 B. Joint reaction: no difference 4. Trochanter BMD A. Ground reaction: no difference B. Joint reaction: no difference

			B. Joint reaction forces training: Individualised exercise training including activities that involved joint-reaction forces, such as weightlifting and rowing. **Frequency**: 3 to 5 sessions/week **Intensity**: Weightlifting: 2-3 sets of 8-12 reps; Rowing: 60-70% to 80-85% of maximum heart rate **Session duration:** NR for the total session duration; however; rowing took 15-20 mins **Delivered by**: NR **Duration of the intervention (wks)**: 36 **Primary exercise type**: Multiple (resistance plus endurance plus flexibility)				5. Ward's BMD A. Ground reaction: $p < 0.01$ B. Joint reaction: $p < 0.05$ 6. Ultra-distal wrist BMD A. Ground reaction: no difference B. Joint reaction: no difference 7. One-third distal wrist BMD A. Ground reaction: no difference B. Joint reaction: no difference Quantitative estimates were not reported (chance scores are provided in a graph)
Kwon 2008 3/10	Quasi-randomised trial 40/NR	**Setting:** Community; Korea **Health status:** Healthy **A. Multicomponent intervention** **n**= 20 (randomised) **Age**: 77.4 (2.56) **B. Control** **n**= 20 (randomised) **Age**: 77.0 (3.33) **Female**: 100%	**A. Multicomponent intervention:** Combined training programme consisting of aerobic exercise, resistance training (free weights) and balance exercise . **Frequency:** 3 times/week **Intensity**: Aerobic exercises: started with 40-55% and up to 65-75% heart rate reserve; Resistance exercise: 8-12 reps at 75% of 1RM **Session duration:** 60 min **Delivered by:** NR **Duration of the intervention (wks)**: 24 **Primary exercise type**: Multiple (balance and function plus endurance plus resistance)	**B.** Control	1. Whole body BMD 2. Lumbar (L2-L4) spine BMD 3. Femoral neck BMD 4. Ward's triangle BMD 5. Greater trochanter BMD	6	Final score (mean ± SD) 1. Whole body BMD A. Exercise: 0.92 ± 0.07 B. Control: 0.88 ± 0.05 2. Lumbar (L2-L4) spine BMD A. Exercise: 0.85 ± 0.15 B. Control: 0.85 ± 0.10 3. Femoral neck BMD A. Exercise:0.68 ± 0.12 B. Control: 0.70 ± 0.07 4. Ward's triangle BMD A. Exercise: 0.48 ± 0.10 B. Control: 0.46 ± 0.08 5. Greater trochanter BMD[¥] A. Exercise: 0.59 ± 0.05 B. Control: 0.58 ± 0.12
Lau 1992 4/10	RCT 60/50	**Setting**: Hostel; Hong Kong **Health Status**: Healthy **A. Exercise group and placebo calcium supplementation** **n**= 11 (analysed) **Age**: mean age (range): 79 (76-81)	**A.** Supervised exercise involving moving the upper trunk while standing. **Frequency**: 4 times/week **Intensity**: Submaximal exertion effort **Session duration**: 15 min **Delivered by**: NR	Control	1. Femoral neck BMD 2. Wards triangle BMD 3.Intertrochanteri c area BMD 4. Lumbar spine (L2-L4) BMD	10	Change score (%; mean, 95% CI) 1. Femoral neck BMD A. Exercise: -6.6 (-12 to 0.8) B. Control: -1.1 (-7.4 to 5.3) C. Supplement: -3.5 (-9 to 1.8) D. Supplement and exercise: 5.0 (-0.77 to 10)

		B. Calcium supplementation **n**= 12 (analysed) **Age**: mean age(range): 75 (72-79) **C. Calcium supplementation and exercise** **n**= 15 (analysed) **Age**: mean age(range): 76 (73-80) **D. Control** **n**= 12 (analysed) **Age**: mean age (range): 75 years (71-78) **Female**: 100%	**Duration of the intervention (wks)**: 40 **Primary exercise type**: Balance and function				2. Wards triangle BMD A. Exercise: -6.0 (-15 to 3.2) B. Control: -2.4 (-10 to 5.9) C. Supplement: 2.5 (-5.9 to 11) D. Supplement and exercise: 17 (3 to 31) 3.Intertrochanteric area BMD A. Exercise: 0.1 (-6.5 to 6.7) B. Control: 0.25 (-3.3 to 3.8) C. Supplement: 2 (-1.6 to 5.7) D. Supplement and exercise: 11 (1.3 to 22) 4. Lumbar spine BMD A. Exercise: -1.9 (-6.7 to 2.8) B. Control: -2.5 (-6.5 to 1.4) C. Supplement: -0.08 (-5.2 to 5.1) D. Supplement and exercise: -1.1 (-3.7 to 1.4)
Lord 1996 4/10	RCT 179/138	**Setting**: Community, Australia **Health Status**: Healthy **A. Multicomponent exercise** **n**= 90 (randomised); 68 (analysed) **Age**: 71.7 (5.4) **B. Control** **n**= 89 (randomised); 70 (analysed) **Age**: 71.5 (5.3) **Female**: 100%	**A.** Supervised group-based exercise programme involving aerobic exercise, balance training, strengthening exercise, and stretching. **Frequency**: 2 times/week **Intensity**: NR **Session duration**: 60 min **Delivered by**: Instructors trained to provide the programme **Duration of the intervention (wks)**: 52 (only 42 weeks for exercise as there were breaks in between) **Primary exercise type**: Balance and function	No exercise	1. Femoral neck BMD 2. Trochanter BMD 3. Lumbar spine (L2-L4) BMD	12	Final score (mean ± SD) / Change score (mean % change ± SD) 1. Femoral neck BMD A. Exercise: 0.791 ± 0.122 / 1.52 ± 5.19 B. Control: 0.776 ± 0.110 / 3.12 ± 6.52 2. Trochanter BMD A. Exercise: 0.707 ± 0.127 / 0.69 ± 4,64 B. Control: 0.672 ± 0.123 / 0.73 ± 5.28 3. Lumbar spine (L2-L4) BMD A. Exercise: 1.036 ± 0.209 / 1.07 ± 2.59 B. Control: 1.008 ± 0.189 / 0.36 ± 3.91
Marques 2011 5/10	RCT 60/60	**Setting**: Community; Portugal **Health Status**: Healthy **A. Multi-component training** **n**= 30 (randomised and analysed) **Age**: 70.1 (5.4) **B. Control** **n**= 30 (randomised and analysed) **Age**: 68.2 (5.7) **Female**: 100%	**A.** Progressive multicomponent exercise training consisting of moderate to high impact weight-bearing activities, endurance, balance exercise, and agility training. **Frequency**: 2 times/week **Intensity**: Stepping exercise: at 120-125 beats/min. Weight bearing and strength exercise: from 2 sets of 8 reps to 3 sets of 15 reps **Session duration:** 60 min	**B.** Control	1. Femoral neck BMD 2. Total femur BMD 3. Trochanter BMD 4. Intertrochanteric BMD 5. Lumbar spine (L1-L4) BMD	8	Final score (mean ± SD) 1. Femoral neck BMD[¥] A. Exercise: 0.717 ± 0.085 B. Control: 0.671 ± 0.051 2. Total femur BMD A. Exercise: 0.832 ± 0.104 B. Control: 0.823 ± 0.058 3. Trochanter BMD A. Exercise: 0.628 ± 0.081 B. Control: 0.628 ± 0.034 4. Intertrochanteric BMD

			Delivered by: Physical education instructors specialised in physical activity for older adults **Duration of the intervention (wks)**: 32 **Primary exercise type**: Balance and function with bone loading (heel drops)				A. Exercise: 0.989 ± 0.148 B. Control: 0.977 ± 0.075 5. Lumbar spine (L1-L4) BMD A. Exercise: 0.868 ± 0.094 B. Control: 0.863 ± 0.065
McCartney 1995 3/10	RCT 68/NR	**Setting**: NR; Canada **Health status**: Healthy **A. Exercise** **n**= 37 (randomised) **Age**: 73(3) **Female**: 54% **B. Control** **n**= 31(randomised) **Age**: 72 (3) **Female**: 74%	**A.** Progressive resistance training for upper and lower body, and abdominals. Completed in as a circuit. **Frequency**: 2 sessions/week **Intensity**: 2 sets of each exercise at 50% of 1RM to 3 sets of 80% 1RM **Session duration:** NR **Delivered by:** NR **Duration of the intervention (wks)**: 42 weeks **Primary exercise type**: Resistance	**B.** Control Offered a supervised walking programme. **Frequency:** 2 sessions/week **Intensity**: low **Session duration:** NR **Delivered by:** NR **Duration of the intervention (wks)**: 42 weeks	1. Lumbar spine (L2-4) BMD 2. Whole body BMD 3. Lumbar spine (L2-4) BMC 4. Whole body BMC	10.5	No significant changes in BMD and BMC as a result of the training programme. Quantitative estimates not reported.
McMurdo 1997 4/10	RCT 118/92	**Setting**: Community; United Kingdom **Health status**: Healthy **A. Exercise and calcium supplementation** **n**= 44 (analysed) **B. Calcium supplementation** **n**= 48 (analysed) **Age**: 64.5 (range 60-73) **Female**: 100%	**A.** Exercise programme involving weight bearing exercise to music and calcium supplementation (1000 mg calcium daily, as calcium carbonate) **Frequency**: 3 times/week **Intensity**: NR **Session duration**: 45 min **Delivered by:** NR **Duration of the intervention (wks)**: 30 (three 10-week terms) **Primary exercise type**: Balance and function	**B.** Taking calcium supplementation (1000 mg calcium daily, as calcium carbonate)	1. Lumbar BMD 2. Distal forearm (non-dominant) BMC 3. Ultra distal forearm (non-dominant) BMC	24	Change score (mean % change ± 95% CI) 1. Lumbar BMD A. Exercise and calcium: -0.91 (-6.8 to 5.0) B. Calcium: -2.65 (-5.7 to 0.4) 2. Distal forearm (non-dominant) BMC A. Exercise and calcium: -2.18 (-3.0 to -1.4) B. Calcium: -1.38 (-2.2 to -0.6) 3. Ultra distal forearm BMC¥ A. Exercise and calcium: 1.14 (-0.8 to 3.1) B. Calcium: -2.6 (-4.6 to -0.6)
Paillard 2004 5/10	RCT 21/21	**Setting**: Community; France **Health status**: Healthy **A. Walking group** **n**= 11 (randomised and analysed) **Age**: 65.5(2) **B. Control**	**A.** Individualised brisk walking programme **Frequency**: 5 times/week **Intensity**: Lactate threshold (minimum heart rate: 131 beats/minute; maximum heart rate: 156 beats/minute) **Session duration**: 45-60 min **Delivered by**: NR	**B.** Control	1. Hip BMD 2. Whole body BMD	3	Final score (mean ± SD) 1. Hip BMD A. Walking: 0.84 ± 0.11 B. Control: 0.95 ± 0.12 2. Whole body BMD A. Walking: 1.06 ± 0.11 B. Control: 1.02 ± 0.13

		n= 10 (randomised and analysed) **Age**: 66.8(2) **Female**: 0%	**Duration of the intervention (wks)**: 12 **Primary exercise type**: Endurance (walking)				
Park 2008 5/10	RCT 50/50	**Setting**: Community; Korea **Health status**: Healthy **A. Multi-component training** **n**= 25 (randomised and analysed) **Age**: 68.3 (3.6) **B. Control** **n**= 25 (randomised and analysed) **Age**: 68.4 (3.4) **Female**: 100%	**A.** Exercise training including stretching, strength training, weight-bearing exercise, balance and posture correction training. **Frequency**: 3 times/week **Intensity**: 65%-75% of the maximum heart rate **Session duration**: 60 min **Delivered by**: NR **Duration of the intervention (wks)**: 48 **Primary exercise type**: Multiple balance/ function plus endurance (weight-bearing)	**B.** Control	1. Femoral neck BMD 2. Ward's triangle BMD 3. Trochanter BMD 4. Lumbar spine (L2 to L4) BMD	12	Final score (mean ± SD) 1. Femoral neck BMD[¥] A. Exercise: 0.857 ± 0.078 B. Control: 0.748 ± 0.063 2. Ward's triangle BMD A. Exercise: 0.659 ± 0.086 B. Control: 0.576 ± 0.079 3. Trochanter BMD[¥] A. Exercise: 0.725 ± 0.081 B. Control: 0.677 ± 0.062 4. Lumbar spine (L2 to L4) BMD A. Exercise: 1.059 ± 0.082 B. Control: 0.891 ± 0.155
Pruitt 1995 4/10	RCT 40/26	**Setting**: Community; America **Healthy status**: Healthy **A. High intensity resistance training** **n**= 15 (randomised); 8 (analysed) **Age**: 67.0 (0.5) **B. Low intensity resistance training** **n**= 13 (randomised); 7 (analysed) **Age**: 67.6 (1.4) **C. Control** **n**= 12(randomised); 11 (analysed) **Age**: 69.6 (4.2) **Female**: 100%	**A. High intensity resistance training:** High intensity supervised resistance training comprising exercises for upper and lower extremities with the use of equipment. **Intensity:** 2 sets of 7 reps at 80% 1RM **Primary exercise type**: Resistance **B. Low intensity resistance training:** Supervised resistance training comprising exercises for upper and lower extremities using equipment. **Intensity:** 3 sets of 14 reps at 40% 1RM For both A and B: **Frequency**: 3 times/week **Session duration**: 50 -55min **Delivered by**: NR **Duration of the intervention (wks)**: 52 **Primary exercise type**: Resistance	**C.** No training	1. Total hip BMD 2. Femoral neck BMD 3. Ward's triangle BMD 4. Lumbar spine (L2-L4) BMD	12	Change score (mean ± SD) 1. Total hip BMD A. High intensity: 0.005 ± 0.014 B. Low intensity: 0.008 ± 0.012 C. Control: 0.007 ± 0.010 2. Femoral neck BMD A. High intensity: -0.002 ± 0.154 B. Low intensity: 0.025 ± 0.008 C. Control: 0.005 ± 0.019 3. Ward's triangle BMD A. High intensity: 0.018 ± 0.032 B. Low intensity: 0.022 ± 0.045 C. Control: 0.008 ± 0.036 4. Lumbar spine (L2-L4) BMD A. High intensity: 0.007 ± 0.018 B. Low intensity: 0.005 ± 0.027 C. Control: 0.000 ± 0.020

Rhodes 2000 5/10	RCT 44/38	**Setting**: Community; Canada **Health Status**: Healthy **A. Resistance training** **n**= 22 (randomised); 20 (analysed) **Age**: 68.8 (3.2) **B. Control** **n**= 22 (randomised); 18 (analysed) **Age**: 68.2 (3.5) **Female**: 100%	**A**. Supervised progressive resistance training comprising exercises for large muscle groups. **Frequency**: 3 times/week **Intensity:** 3 sets of 8 reps at 75 % 1 RM **Session duration**: 60 min **Delivered by**: Professional lifestyle and fitness consultants **Duration of the intervention (wks)**: 52 **Primary exercise type**: Resistance	**B.** No exercise programme and were instructed to maintain their normal lifestyle throughout the study duration.	1. Femoral neck BMD 2. Ward's triangle BMD 3. Trochanter BMD 4. Lumbar spine (L2-L4) BMD 5. Femoral neck BMC 6. Ward's triangle BMC 7. Trochanter BMC 8. Lumbar spine (L2-L4) BMC	12	Final score (mean ± SD) 1. Femoral neck BMD A. Exercise: 0.83 ± 0.12 B. Control: 0.73 ± 0.10 2. Ward's triangle BMD A. Exercise: 0.70 ± 0.11 B. Control: 0.59 ± 0.12 3. Trochanter BMD A. Exercise: 0.75 ± 0.11 B. Control: 0.67 ± 0.11 4. Lumbar spine (L2-L4) BMD A. Exercise: 1.13 ± 0.18 B. Control: 1.01 ± 0.17 5. Femoral neck BMC A. Exercise: 4.02 ± 0.22 B. Control: 3.48 ± 0.19 6. Ward's triangle BMC A. Exercise: 1.85 ± 0.19 B. Control: 1.51 ± 0.18 7. Trochanter BMC A. Exercise: 9.04 ± 0.33 B. Control: 8.83 ± 0.36 8. Lumbar spine (L2-L4) BMC A. Exercise: 45.86 ± 2.7 B. Control: 42.50 ± 2.6
Rikli 1990 1/10	Quasi-randomised trial 37/31	**Setting**: Local retirement community; United States **Health Status**: Healthy **A. General exercise** **n**= 13 (randomised); 10 (analysed) **Age**: 72.2 (5.57) **B. General exercise + weight** **n**= 13 (randomised); 10 (analysed) **Age**: 71.6 (5.66) **C. Control** **n**= 11 (randomised); 11 (analysed)	**A. General exercise:** Group-based aerobic exercise training for large muscle groups. **Frequency**: 3 times/week **Intensity**: 60-70% maximum heart rate **Session duration**: 30-50 min **Delivered by**: NR **Duration of the intervention (wks)**: 40 **Primary exercise type:** endurance **B. General exercise + weight:** Group-based aerobic exercise training plus upper body	**C**. No exercise	1. Distal radius BMC/BW 2. Distal radius BMC	10	Change score (%) 1. Distal radius BMC/BW¥ A. General exercise: 0.921 B. General exercise and weight: 1.734 C. Control: -2.577 2. Distal radius BMC¥ A. General exercise: 1.023 B. General exercise and weight: 1.743 C. Control: -2.499

		Age: 70.8 (8.43) **Female**: 100%	progressive resistance training. The resistance training was performed without supervision. **Frequency**: 3 times/week **Intensity**: 60-70% maximum heart rate for aerobic activities **Session duration**: 50-70 min **Delivered by**: Assistants **Duration of the intervention (wks)**: 40 **Primary exercise type**: Multiple resistance plus endurance				
Sakai 2010 4/10	RCT 94/84	**Setting**: Community, Japan **Health Status**: Healthy **<u>A. Exercise</u>** **n**= 49 (randomised); 47 (analysed) **Age**: 68.3 (0.8) **<u>B. Control</u>** **n**= 45 (randomised); 37 (analysed) **Age**: 68.2 (0.5) **Female**: 100%	**A.** Home balance exercises involving unipedal standing exercise with their eyes open (single leg standing) **Frequency**: 3 sets/day; 7 days/week **Intensity**: NA **Session duration**: 2 mins/set **Delivered by**: NA (home exercise) **Duration of the intervention (wks)**: 26 **Primary exercise type**: Balance/function	**B.** Usual activity	1. Femoral neck BMD 2. Trochanter BMD 3. Intertrochanter BMD 4. Ward's triangle BMD 5. Total hip BMD	6	% mean difference (p-value) 1. Femoral neck: p=0.993 2. Trochanter: p=0.801 3. Intertrochanter: p=0.968 4. Ward's triangle p=0.096 5. Total hip: p=0.889 Change score reported in a graph
von Stengel 2011 7/10	RCT 151/141	**Setting**: Community; Germany **Health Status**: Healthy **<u>A. Conventional multicomponent training</u>** **n**= 50 (randomised); 47 (analysed) **Age**: 68.6 (3) **<u>B. Wellness control</u>** **n**= 51 (randomised); 48 (analysed) **Age**: 68.1 (2.7) **Female**: 100%	**A**. Training sessions consisting of aerobic dancing; progressive coordination and balance training; functional gymnastics and isometric strength training; and progressive upper body exercises. Additionally, participants were requested to carry out a home training session. **Frequency**: 4 times/week [i.e. 2 controlled training session/week; 2 home exercise/week] **Intensity**: Dance aerobic: 70–80% maximum heart rate; Functional gymnastics and isometric strength: 6-10s of maximum exertion and 20-30s of active rest; Upper body exercise: 3 sets 15 reps	**B:** Low intensity wellness programme that includes light physical exercises and a relaxation programme **Frequency**: 1 time/week **Intensity**: Light **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 72 (10 weeks of training were intermitted by a	1. Total hip BMD 2. Lumbar spine (L1-L4) BMD	18	Mean difference (95% CI): 1. Total hip BMD: 0.002 (−0.007 to 0.012) 2. Lumbar spine: 0.015 (0.001 to 0.029)[¥]

			Session duration: 60 min training session; 20 min home training session **Delivered by**: Certified instructors **Duration of the intervention (wks)**: 72 **Primary exercise type**: Multiple (balance/function, plus flexibility plus resistance plus endurance (dance)	break of 10 weeks and the training cycle was repeated throughout 72 weeks)			
Smith 1981 2/10	Quasi-randomised trial 80/51	**Setting**: Nursing home; United States **Health Status**: Healthy **<u>A. Physical activity group + placebo tablets</u>** **n**= 19 (randomised); 12 (analysed) Age: 82.9 (6.1) **<u>B. Control (placebo tablet)</u>** **n**= 26 (randomised); 18 (analysed) **Age**: 81.9 (7.4) **<u>C. Calcium and vitamin D</u>** **n**= 17 (randomised); 10 (analysed) **Age**: 80.7 (4.8) **<u>D. Physical activity + calcium and vitamin D</u>** **n**= 18 (randomised); 11 (analysed) **Age**: 84.3 (5.1) **Female**: 100%	**A.** Light-to-mild seated exercises including sideward leg spread, leg walk, running in place, arm cross, sideward bend and chair pull. **Frequency**: 3 times/week **Intensity**: 70% of the sampled VO_2 max **Session duration**:30 min/ day **Delivered by**: NR **Duration of the intervention (wks)**: 156 **Primary exercise type**: Endurance (seated)	**B.** Placebo tablets Received 360 mg of lactose, 5mg of magnesium stearate and 80 mg of microcrystalline cellulose in the placebo tablets	1. Radius BMC	36	Change score (%) Radius BMC[¥] A. Exercise: 2.29% D. Control: - 3.29%
Taaffe 1999 5/10	RCT 53/46	**Setting**: Community; United States **Health status**: Healthy **<u>A. High-intensity resistance training (1 day per week)</u>** **n**= 14 (randomised); 11(analysed) **Age**: 68.5 (3.6) **Female**: 36% **<u>B. High-intensity resistance training (2 days per week)</u>** **n**= 14 (randomised); 12 (analysed) **Age**: 69.4 (3.0)	**A, B & C.** Supervised resistance training targeting the major upper and lower body muscle groups. **A. Frequency**: 1 time/week **B. Frequency**: 2 times/week **C. Frequency**: 3 times/week **Intensity**: Started at 60% of the 1RM and gradually increase in intensity to 3 sets of 8 reps at 80% of 1 RM **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 24	**D**. Control	1. Lumbar spine (L2-L4) BMD 2. Total hip BMD 3. Midradius BMD 4. Total body BMC	6	Final score (mean ± SD) 1. Lumbar spine (L2-L4) BMD A. Resistance 1x/week: 1.025 ± 0.006 B. Resistance 2x/week: 1.033 ± 0.006 C. Resistance 3x/week: 1.032 ± 0.007 D. Control: 1.041 ± 0.006 2. Total hip BMD A. Resistance 1x/week: 0.865 ± 0.010 B. Resistance 2x/week: 0.866 ± 0.006 C. Resistance 3x/week: 0.864 ± 0.010 D. Control: 0.873 ± 0.010

		Female: 29% **C. High-intensity resistance training (3 days per week)** **n**= 11(randomised & analysed) **Age**: 71.0 (4.1) **Female**: 36% **D. Control** **n**= 14 (randomised); 12 (analysed) **Age**: 68.9 (3.6) **Female**: 43%	**Primary exercise type**: Resistance				3. Midradius BMD A. Resistance 1x/week: 0.605 ± 0.003 B. Resistance 2x/week: 0.604 ± 0.003 C. Resistance 3x/week: 0.608 ± 0.003 D. Control: 0.601 ± 0.003 4. Total body BMC A. Resistance 1x/week: 2552 ± 15 B. Resistance 2x/week: 2530 ± 14 C. Resistance 3x/week: 2525 ± 14 D. Control: 2536 ± 14
Villareal 2003 4/10	Quasi-randomised trial 28/28	**Setting**: Community; United States **Health status**: Mild to moderate physical frailty on hormone replacement therapy **A. Supervised multi-component training** **n**= 14 (randomised and analysed) **Age**: 81 (3) **B. Control: Home exercise** **n**= 14 (randomised and analysed) **Age**: 81 (3) **Female**: 100%	**A.** Supervised exercise programme involving flexibility and balance exercises, resistance training and endurance exercises. **Frequency**: 3 times/week **Intensity**: Resistance training: from 1-2 sets of 8-12 reps at 65% of 1RM to 2-3 sets of 6-8reps at 75–85% of 1RM Endurance: from 65–75 to 85–90% peak heart rate **Session duration**: 90–120 min **Delivered by**: Exercise physiologists **Duration of the intervention (wks)**: 36 weeks **Primary exercise type**: Multiple (resistance plus balance/function plus endurance)	**B**. Home exercise programme focusing on flexibility **Frequency**: 2-3 times/week	1. Total hip BMD 2. Femoral neck BMD 3. Trochanter BMD 4. Lumbar spine BMD 5. Whole body BMD	9	Change score (mean ± SD) 1. Total hip BMD A. Exercise: 0.003 ± 0.011 B. Control: 0.009 ± 0.011 4. Lumbar spine BMD¥ A. Exercise: 0.034 ± 0.022 B. Control: 0.015 ± 0.022 5. Whole body BMD A. Exercise: 0.015 ± 0.015 B. Control: 0.002 ± 0.015 No quantitative estimates reported for: 2. Femoral neck BMD 3. Trochanter BMD (There were no significant group-by-time interaction effects) Results reported in a graph
Villareal 2004 4/10	RCT 119/112	**Setting**: Community; United States **Health status**: mild-to-moderate physical frailty **A. Exercise training (ET)** **n**= 69 (randomised); 65 (analysed) **Age**: 83 (4) **Female**: 52% **B. Home exercise (HOME)** **n**= 50 (randomised); 47 (analysed) **Age**: 83 (4)	**A.** Supervised exercise programme involving flexibility and balance exercises, resistance training and endurance exercises. **Frequency**: NR **Intensity:** Resistance training: started from 1-2 sets of 6-8 reps at 65-75% of 1RM to 3 sets of 8-12 reps at 85-100% 1RM Endurance training*:* started from 15 mins at 65-75% of peak heart rate	**B.** Home exercise programme focusing on flexibility	1. Total hip BMD 2. Femoral neck BMD 3. Trochanter BMD 4. Lumbar spine (L2-L4) BMD 5. Whole Body BMD	9	Final score (mean ± SD) 1. Total hip BMD A. Exercise: 0.85 ± 0.19 B. Control: 0.75 ± 0.15 2. Femoral neck BMD A. Exercise: 0.70 ± 0.17 B. Control: 0.63 ± 0.11 3. Trochanter BMD A. Exercise: 0.65 ± 0.17 B. Control: 0.58 ± 0.12

		Female: 55%	to 30 mins at 85-90% of peak heart rate **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 36 **Primary exercise type**: Multiple (resistance plus balance/function plus endurance)				4. Lumbar spine (L2-L4) BMD A. Exercise: 1.08 ± 0.28 B. Control: 0.97 ± 0.23 5. Whole Body BMD A. Exercise: 1.09 ± 0.18 B. Control: 1.03 ± 0.17
Woo 2007 6/10	RCT 180/176	**Setting**: Community; Hong Kong **Heath status**: Healthy **A. Tai Chi** **n**=60 (randomised); 58 (randomised) **Age**: 68.2 years **B. Resistance training** **n**= 60 (randomised); 59 (randomised) **Age**: 68.7 years **C. No Treatment** **n**= 60 (randomised); 59 (randomised) **Age**: 68.1 years **Female**: 50%	**A. Tai Chi:** 24-forms of Tai Chi using Yang style **Frequency:** 3 times/week **Intensity**: NR **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 52 weeks **Primary exercise type**: 3D (Tai Chi) **B. Resistance training:** Resistance training with the use of medium strength TheraBand **Frequency:** 3 times/week **Intensity**: 30 times with medium strength TheraBand **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 52 weeks **Primary exercise type**: Resistance	**C.** No intervention	1. Total hip BMD 2. Total spine BMD	12	Change score (mean % change ± SE) Men 1. Total hip BMD A. Tai Chi: −0.48 ± 0.37 B. Resistance: −1.20 ± 0.38 C. Control: −0.15 ± 0.38 2. Total spine BMD A. Tai Chi: 1.35 ± 0.40 B. Resistance: 1.27 ± 0.42 C. Control: 0.54 ± 0.42 Women 1. Total hip BMD A. Tai Chi: 0.07 ± 0.64¥ B. Resistance: 0.09 ± 0.62¥ C. Control: −2.25 ± 0.60 2. Total spine BMD A. Tai Chi: 0.10 ± 0.50 B. Resistance: 1.98 ± 0.48 C. Control: 0.98 ± 0.47
Yoo 2010 4/10	RCT 28/21	**Setting**: Community; Korea **Health status**: Healthy **A. Exercise** **n**=14 (randomised); 11 (analysed) **Age**: 70.9 (2.7) **B. Control** **n**= 14 (randomised); 10 (analysed) **Age**: 71.1 (2.7) **Female**: 100%	**A**. Supervised walking exercise programme involving walking ankle weights. **Frequency**: 3 times/week **Intensity**: Maintained at 60% of heart rate reserve **Session duration**: 60 mins/session **Delivered by**: NR **Duration of the intervention (wks)**: 12 **Primary exercise type**: Endurance (walking with ankle weights)	**B**. Control	1. Femoral neck BMD 2. Femoral Ward's BMD 3. Femoral trochanter BMD 4. Spine BMD 5. Whole body BMD	3	Final score (mean ± SD) 1. Femoral neck BMD A. Exercise: 0.770 ± 0.132 B. Control: 0.729 ± 0.124 2. Femoral Ward's BMD A. Exercise: 0.580 ± 0.158 B. Control: 0.584 ± 0.164 3. Femoral trochanter BMD A. Exercise: 0.708 ± 0.105 B. Control: 0.687 ± 0.136 4. Spine BMD

							A. Exercise: 1.056 ± 0.188 B. Control: 1.010 ± 0.167 5. Whole body BMD A. Exercise: 1.057 ± 0.077 B. Control: 1.028 ± 0.109

BMC: bone mineral content (g); BMD: bone mineral density (g/cm^2); BMI: body mass index (kg/m^2); BW: bone width; NR: not reported; RCT: randomised controlled trial.
In studies where other groups or other outcomes not of interest to this study were included (example supplement, or whole-body vibration) we only included and extracted information for the groups and for the comparisons that were relevant to this study (i.e., those where the effect of physical activity could be evaluated). When data was available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score.
[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 often include one or more types of exercise. We categorised exercise based on a modification of 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. We also considered whether the exercise explicitly included bone loading eg hopping or heel drops
[b] A control intervention is one that is not thought to improve bone health, such as general health education, social visits, very gentle exercise, or 'sham' exercise not expected to impact on bone health.
Shading indicates studies which detected a statistically significant between-group difference for at least one outcome. ¥ indicates statistically significant between-group differences at $p < 0.05$.

TABLE 2. Description of included studies comparing two or more forms of physical activity

Reference PEDro score	Study design Allocated / Analysed	Participants (n, age mean (SD), % women, setting, health status)	Intervention Primary exercise type according to ProFANE[a]	Relevant comparison	Outcomes	Follow up (mo)	Results
Ashe 2013	RCT 155/ 135	**Setting**: Community; Canada **Health status**: Healthy **A. Balance and tone (BT)** **n**=49 (randomised); 42 (analysed) **Age**: 69.9 (3.1) **B. Once a week resistance training (RT1)** **n**= 54 (randomised); 47 (analysed) **Age**: 69.4 (3.0)	**A. BT:** Group-based supervised intervention consisting of balance and tone training with the use of body weight. **Frequency**: 2 times/week **Intensity**: NR **Session duration:** NR **Primary exercise type**: Balance and functional **B. RT1:** Low-frequency, group-based supervised resistance training for upper and lower body with the use of resistance equipment. **Frequency**: 1 time/week **Intensity**: 2 sets of 8 RM **Session duration:** NR **Primary exercise type**: Resistance	A vs B A vs C	1. Tibial volumetric cortical density (CovBMD) 2. Total area (ToA) midtibia 3. Tibial bone strength	12	Adjusted mean difference (95% CI) 1. Tibial CovBMD B – A 0.76 (−5.32 to 6.85) C – A −2.09 (−8.22 to 4.05) 2. Total area (ToA) midtibia B – A 0.10 (−2.72 to 2.92) C – A −0.49 (−3.34 to 2.35)

		<u>C. Twice a week resistance training (RT2)</u> n= 52 (randomised); 46 (analysed) **Age**: 69.2 (3.0) **Female**: 100%	**C. RT2**: High-frequency, group-based supervised resistance training for upper and lower body with the use of resistance equipment. **Frequency**: 2 times/week **Intensity**: 2 sets of 8 RM **Primary exercise type**: resistance **Duration of the interventions (wks)**: 52 weeks **Delivered by**: Certified fitness instructors				3. Tibial bone strength B – A 23.32 (−248.86 to 295.5) C – A −91.56 (−366.5 to 183.28)
Shen 2007 6/10	RCT 28/24	**Setting**: Local senior living campus; United States **Health Status**: Healthy **<u>A. Tai chi</u>** **n**= 14 (randomised); 12 (analysed) **Age**: 78.8 (1.3); **Female**: 79% **<u>B. Resistance exercise</u>** **n**= 14 (randomised); 12 (analysed) **Age**: 79.4 (2.2) **Female**: 71%	**<u>A. Tai chi</u>**: 24-form simplified Yang style Tai Chi. **Frequency:** 3 times/week **Intensity**: NR **Delivered by**: Experienced Tai Chi instructor **Session duration**: 40 min **Duration of the intervention (wks)**: 24 **Primary exercise type:** 3D Tai Chi **<u>B. Resistance exercise:</u>** Low-intensity resistance training for lower and upper extremities using equipment and dumbbells. **Frequency:** 3 times/week **Intensity**: 1 set of 10-12 reps at 50% of the 1RM **Delivered by**: Certified fitness trainer **Session duration**: 40 min **Duration of the intervention (wks)**: 24 **Primary exercise type**: Resistance	A vs B	1) Bone specific alkaline phosphatase (BAP), concentration change (%) 2) Pyridinoline (PYD), concentration change (%) 3) Parathyroid hormone (PTH), concentration change (%)	6	1. BAP No between-group difference (positive effect towards Tai chi) 2. PYD No between-group difference (positive effect towards Resistance training) 3) PTHP No between-group difference (positive effect towards Resistance training) Quantitative results not provided. Results reported in a graph
**Blumenthal 1991* 6/10	RCT 101/85	**Setting**: NR **Health status**: Healthy **<u>A. Aerobic Training</u>** **n**= 33 (randomised) **<u>B. Yoga and flexibility</u>** **n**= 34 (randomised) **<u>C. Control:</u>** Not relevant for this comparison. **Age**: (whole sample) 67 (min-max: 60-83) **Female**: NR	**A. <u>Aerobic training:</u>** Endurance training involving bicycle ergometry, brisk walking/jogging, and arm ergometry. **Frequency**: 3 times/week **Intensity**: 70% heart rate reserve **Session duration**: 60 min **Delivered by**: NR **Duration of intervention (wks):** 16 **Primary exercise type:** Endurance training **B. <u>Yoga:</u>** Supervised non-aerobic yoga programme. **Frequency**: at least 2 times/week **Intensity**: NR **Session duration**: 60 min **Delivered by:** NR **Duration of intervention (wks):** 16 **Primary exercise type**: Balance and function	A vs B	1. Distal radius BMD	14	1. Distal radius BMD: no between-group differences. Quantitative estimates not reported for between-group comparisons.
**Helge 2014* 5/10	RCT 27/23	**Setting**: Community; Denmark **Health status**: Healthy	**A. <u>Football group:</u>** Supervised progressive football training **Frequency**: 1.7 (0.3) times/week (range: 1.2-2.2)	A vs B	1. Whole body BMD	12	Final score (mean ± SD) 1. Whole body BMD

		A. Football group **n**= 9 (randomised); 9 (analysed) **Age**: 68.0 (4.0) **B. Resistance training** **n**= 9 (randomised); 8 (analysed) **Age**: 69.1 (3.1) **C. Control:** Not relevant for this comparison.	**Intensity**: 82% of maximum heart rate (range 64 to 90%) **Session duration**: 45-60 min **Delivered by**: NR **Duration of the intervention (wks)**: 52 **Primary exercise type**: Balance and function (football) **B. Resistance training:** Progressive resistance training for core and upper and lower body **Frequency**: 1.9 (0.2) times/week (range: 1.4-2.2) **Intensity**: Started from 3 sets of 16-20 RM to 4 sets of 8 RM **Session duration**: 45-60 min **Delivered by**: NR **Duration of the intervention (wks)**: 52 **Primary exercise type**: Resistance (seated)		2. Right femoral neck BMD 3. Left femoral neck BMD 4. Right femoral shaft BMD 5. Left femoral shaft BMD 6. Total right proximal femur 7. Total left proximal femur		A. Football: 1.211 ± 0.036 B. Resistance: 1.225 ± 0.024 2. Right femoral neck BMD A. Football: 0.921 ± 0.034 B. Resistance: 1.000 ± 0.042 3. Left femoral neck BMD A. Football: 0.939 ± 0.034 B. Resistance: 1.006 ± 0.036 4. Right femoral shaft BMD A. Football: 1.156 ± 0.042 B. Resistance: 1.229 ± 0.056 5. Left femoral shaft BMD A. Football: 1.143 ± 0.043 B. Resistance: 1.229 ± 0.057 6. Total right proximal femur A. Football: 0.982 ± 0.031 B. Resistance: 1.066 ± 0.048 7. Total left proximal femur A. Football: 0.989 ± 0.031 B. Resistance: 1.069 ± 0.048
**Karinkanta 2007* 7/10	RCT 149/144	**Setting**: Community; Finland **Health Status**: healthy and excluded participants with osteoporosis **A. Balance-jumping training** **n**= 37(randomised); 35 (analysed) **Age**: 72.9 (2.3) **B. Resistance training** **n**= 37 (randomised); 37(analysed) **Age**: 72.7 (2.5) **C. Combined Balance-jumping and resistance training** **n**= 38 (randomised); 36 (analysed)	**A. Balance-jumping training:** Balance training including static and dynamic balance exercise, agility training, impact exercises and changes of direction exercise. **Intensity**: NR **Primary exercise type**: Balance and function including bone loading (jumps) **B. Resistance training:** Tailored progressive resistance training programme for large muscle groups. **Intensity**: Initially 2 sets of 10-15 reps at intensity 50-60% of 1RM, progressed to 3 sets of 8-10 reps at 75-80% of 1RM. Rate of perceived exertion: above 18 out of 20 **Primary exercise type**: Resistance **C. Combined Balance-jumping and resistance training**: A combination of A & B on alternate weeks. **Primary exercise type**: Multiple (balance and function plus resistance) For all exercise groups: **Frequency**: 3 times per week **Session duration**: 50 min	A vs B A vs C B vs C	1. Femoral neck BMC 2. Distal tibia trabecular density (mg/cm^3)	12	Final score (mean ± SD) 1. Femoral neck BMC A. Balance: 2.73 ± 0.40 B. Resistance: 2.71 ± 0.33 C. Combined: 2.65 ± 0.29 2. Distal tibia trabecular density (mg/cm^3) A. Balance: 224 ± 34 B. Resistance: 219 ± 26 C. Combined: 215 ± 39

		Age: 72.9 (2.2) **D. Control:** Not relevant for this comparison	**Delivered by:** Exercise leaders **Duration of the intervention (wks)**: 52				
**Kohrt 1997* 3/10	Quasi-randomised trial 39/30	**Setting:** United States **Health Status**: Healthy **A. Ground reaction forces training** **n**= 14 (randomised); 12 (analysed) **Age**: 66.0 (1.0) **B. Joint reaction forces training** **n**= 13 (randomised); 9 (analysed) **Age**: 65.0 (1.0) **C. Control:** Not relevant for this comparison	**A. Ground reaction forces training:** Individualised exercise training focusing on activities that involved ground-reaction forces, such as walking, jogging and/or stair climbing. **Frequency**: 3 to 5 times/week **Intensity**: 60-70% to 80-85% maximum heart rate **Session duration:** 30-45 minutes/day **Delivered by**: NR **Duration of the intervention (wks)**: 36 **Primary exercise type**: Multiple (balance and function plus endurance plus flexibility) **B. Joint reaction forces training:** Individualised exercise training including activities that involved joint-reaction forces, such as weightlifting and rowing. **Frequency**: 3 to 5 sessions/week **Intensity**: Weightlifting: 2-3 sets of 8-12 reps; Rowing: 60-70% to 80-85% of maximum heart rate **Session duration:** NR for the total session duration; however; rowing took 15-20 mins **Delivered by**: NR **Duration of the intervention (wks)**: 36 **Primary exercise type**: Multiple (resistance plus endurance plus flexibility)	A vs B	1. Whole body BMD 2. Lumbar spine L2–L4 BMD 3. Femoral neck BMD 4. Trochanter BMD 5. Ward's BMD 6. Ultra distal wrist BMD 7. One-third distal wrist BMD	12	Quantitative estimates not reported (chance scores are provided in a graph) 1. Whole body BMD Positive effect towards "A" 2. Lumbar spine L2–L4 BMD Positive effect towards "A" 3. Femoral neck BMD Positive effect towards "A" 4. Trochanter BMD Positive effect towards "A" 5. Ward's BMD Positive effect towards "A" 6. Ultra distal wrist BMD Positive effect towards "B" 7. One-third distal wrist BMD Positive effect towards "B"
**Rikli 1990* 1/10	Quasi-randomised trial 37/31	**Setting**: Local retirement community; United States **Health Status**: Healthy **A. General exercise** **n**= 13 (randomised); 10 (analysed) **Age**: 72.2 (5.57) **B. General exercise + weight** **n**= 13 (randomised); 10 (analysed) **Age**: 71.6 (5.66) **C. Control**: Not relevant for this comparison **Female**: 100%	**A. General exercise:** Group-based aerobic exercise training for large muscle groups. **Frequency**: 3 times/week **Intensity**: 60-70% maximum heart rate **Session duration**: 30-50 min **Delivered by**: NR **Duration of the intervention (wks)**: 40 **Primary exercise type:** Endurance **B. General exercise + weight:** Group-based aerobic exercise training plus upper body progressive resistance training. The resistance training was performed without supervision. **Frequency**: 3 times/week **Intensity**: 60-70% maximum heart rate for aerobic activities **Session duration**:50-70 min **Delivered by**: Assistants **Duration of the intervention (wks)**: 40	A vs B	1. Distal radius BMC/BW 2. Distal radius BMC	10	Change score (%) 1. Distal radius BMC/BW A. General exercise: 0.921 B. General exercise and weight: 1.734 2. Distal radius BMC A. General exercise: 1.023 B. General exercise and weight: 1.743 Statistical test not performed between the two intervention groups

			Primary exercise type: Multiple (resistance plus endurance)				
**Woo 2007* 6/10	RCT 180/176	**Setting**: Community; Hong Kong **Heath status**: Healthy **A. Tai Chi** **n**=60 (randomised); 58 (randomised) **Age**: 68.2 years **B. Resistance training** **n**= 60 (randomised); 59 (randomised) **Age**: 68.7 years **C. No Treatment**: Not relevant for this comparison **Female**: 50%	**A. Tai Chi:** 24-forms of Tai Chi using Yang style **Frequency:** 3 times/week **Intensity**: NR **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 52 weeks **Primary exercise type**: 3D (Tai Chi) **B. Resistance training:** Resistance training with the use of medium strength TheraBand **Frequency:** 3 times/week **Intensity**: 30 times with medium strength TheraBand **Session duration**: NR **Delivered by**: NR **Duration of the intervention (wks)**: 52 weeks **Primary exercise type**: Resistance	A vs B	1. Total hip BMD 2. Total spine BMD	12	Change score (mean % change ± SE) Men 1. Total hip BMD A. Tai Chi: −0.48 ± 0.37 B. Resistance: −1.20 ± 0.38 2. Total spine BMD A. Tai Chi: 1.35 ± 0.40 B. Resistance: 1.27 ± 0.42 Women 1. Total hip BMD A. Tai Chi: 0.07 ± 0.64 B. Resistance: 0.09 ± 0.62 2. Total spine BMD A. Tai Chi: 0.10 ± 0.50 B. Resistance: 1.98 ± 0.48

BMC: bone mineral content (g); BMD: bone mineral density (g/cm²); BMI: body mass index (kg/m²); BW: bone width; NR: not reported; RCT: randomised controlled trial. When data was available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score.

*Indicate studies also included in the exercise vs control comparison (Table 1), but only the results for exercise comparisons are presented here.

[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 often include one or more types of exercise. We categorised exercise based on a modification of 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. We also considered whether the exercise explicitly included bone loading eg hopping or heel drops. None of the studies detected a statistically significant between-group difference.

TABLE 3. Description of included studies investigating the association between different doses of physical activity on osteoporosis prevention

Reference PEDro score	Study design Allocated/ Analysed	Participants (n, age mean (SD), % women, setting, health status)	Intervention Primary exercise type according to ProFANE[a]	Relevant comparison	Outcomes	Follow up (mo)	Results
Kemmler 2010 6/10	RCT 246/227	**Setting**: Community; Germany **Health status**: Healthy **A. Multi-component exercise training** **n**= 123 (randomised); 115 (analysed) **Age**: 68.9 (3.9) **B. Low intensity multicomponent programme** **n**= 123 (randomised); 112 (analysed) **Age**: 69.2 (4.1) **Female**: 100%	**A.** Two 60-minute supervised group sessions: warm-up/ aerobic dance (20 min), balance training (5 min); functional gymnastics, isometric strength training with 1-3 sets of isometric floor exercises for trunk flexors and extensors hip flexors and extensors and leg abductors and adductors; upper body exercises. Two home training session that includes strength and flexibility training. **Frequency**: 4 sessions/week **Intensity**: Aerobic dance: 70%-85% of maximum heart rate; Upper body exercise: 10-15 reps x 2-3sets; Home training session: 1-2 sets of 6-8 isometric exercise and 10-15 reps x 2 sets of belt exercises **Session duration:** 60 mins/group class & 20 mins/home training session **Delivered by**: Certified trainer **Duration of the intervention (wks)**: 72 **Primary exercise type**: Multiple (balance and function plus resistance) **B**. Low intensity multicomponent programme including walking, muscular relaxation, endurance and strength training **Frequency:** 1 session/week **Intensity**: Walking at 50-60 % maximum heart rate Endurance and strength training: low to moderate intensity **Session duration:** 60 mins/ session **Delivered by**: Certified trainer **Duration of the intervention (wks)**: 72 [every 10 weeks of training was followed by 10 weeks of rest] **Primary exercise type**: Multiple (balance and function plus endurance)	A vs B	1. Lumbar spine BMD 2. Femoral neck BMD	18	Mean difference (95% CI) 1. Lumbar spine BMD: 0.014 (0.006 to 0.021) 2. Femoral neck BMD: 0.015 (0.008 to 0.021)[¥]
Ashe 2013	RCT 155/ 147	**Setting**: Community; Canada **Health status**: Healthy **A. Balance and tone (BT)** Not relevant for this comparison	**B. RT1:** Low-frequency, group-based supervised resistance training for upper and lower body with the use of resistance equipment. **Frequency**: 1 time/week **Intensity**: 2 sets of 8 RM **Session duration:** NR **Primary exercise type**: Resistance	B vs C	1. Tibial volumetric cortical density (CovBMD) 2. Total area (ToA) midtibia	12	Final score (mean ± SD) 1. Tibial CovBMD B. -1.81 ± -0.17 C. -4.67 ± -0.45 2. Total area (ToA) midtibia

		B. Once a week resistance training (RT1) **n**= 54 (randomised); 47 (analysed) **Age**: 69.4 (3.0) **C. Twice a week resistance training (RT2)** **n**= 52 (randomised); 46 (analysed) **Age**: 69.2 (3.0) **Female**: 100%	**C. RT2**: High-frequency, group-based supervised resistance training for upper and lower body with the use of resistance equipment. **Frequency**: 2 times/week **Intensity**: 2 sets of 8 RM **Primary exercise type**: Resistance **Duration of the interventions (wks)**: 52 weeks **Delivered by**: Certified fitness instructors		3. Tibial bone strength		B. 0.86 ± 0.21 C. 0.93 ± 0.22 3. Tibial bone strength B. 124.83 ± 0.64 C. 9.94 ± 0.05
**Pruitt 1995* 4/10	RCT 40/26	**Setting**: Community; America **Healthy status**: Healthy **Female**: 100% **A. High intensity resistance training** **n**= 15 (randomised); 8 (analysed) **Age**: 67.0 (0.5) **B. Low intensity resistance training** **n**= 13 (randomised); 7 (analysed) **Age**: 67.6 (1.4) **C. Control:** not relevant for this comparison	**A and B**. Supervised exercise session comprising bench press, lateral pull down, military press, biceps curl, knee extension, knee flexion, hip abduction and adduction, leg press, back extension. **A. Intensity:** High 14 reps x 1 set at 40% 1RM for warm up; 7 reps x 2 sets at 80% 1RM **B. Intensity:** Low 14 reps x 3 sets at 40% 1RM For both A and B: **Frequency**: 3 times/week **Session duration**: 50 -55mins/ lifting time **Delivered by**: NR **Duration of the intervention (wks)**: 52	A vs B	1. Total hip BMD 2. Femoral neck BMD 3. Ward's triangle BMD 4. Lumbar spine (L2-L4) BMD	12	Change score (mean ± SD) 1. Total hip BMD A. High intensity: 0.005 ± 0.014 B. Low intensity: 0.008 ± 0.012 2. Femoral neck BMD A. High intensity: -0.002 ± 0.154 B. Low intensity: 0.025 ± 0.008 3. Ward's triangle BMD A. High intensity: 0.018 ± 0.032 B. Low intensity: 0.022 ± 0.045 4. Lumbar spine (L2-L4) BMD A. High intensity: 0.007 ± 0.018 B. Low intensity: 0.005 ± 0.027
**Taaffe 1999* 5/10	RCT 53/46	**Setting**: Community; United States **Health status**: Healthy **A. High-intensity resistance training (1 day per week)** **n**= 14 (randomised); 11(analysed) **Age**: 68.5 (3.6) **Female**: 36% **B. High-intensity resistance training (2 days per week)** **n**= 14 (randomised); 12 (analysed) **Age**: 69.4 (3.0) **Female**: 29%	Training includes the whole body (bench press, military press, latissimus pull-down, biceps curl, and leg press) All trainings were started with a warm up that included stretching and one set each of bench press and leg press (40% of 1-RM, 10 repetitions) and concluded with a cool-down period of stretching. Intensity: started at 60% of the 1RM and gradually increase in intensity **A. Frequency**: 1 time/week **B. Frequency**: 2 times/week **C. Frequency**: 3 times/week **Intensity**: 8 reps x 3 sets at 80% of 1 RM **Session duration**: NR	A vs B A vs C B vs C	1. Lumbar spine (L2-L4) BMD 2. Total hip BMD 3. Midradius BMD 4. Total body BMC	6	Final score (mean ± SD) 1. Lumbar spine (L2-L4) BMD A. Resistance 1x/week: 1.025 ± 0.006 B. Resistance 2x/week: 1,033 ± 0.006 C. Resistance 3x/week: 1.032 ± 0.007 2. Total hip BMD A. Resistance 1x/week: 0.865 ± 0.010 B. Resistance 2x/week: 0.866 ± 0.006 C. Resistance 3x/week: 0.864 ± 0.010 3. Midradius BMD A. Resistance 1x/week: 0.605 ± 0.003 B. Resistance 2x/week: 0.604 ± 0.003 C. Resistance 3x/week: 0.608 ± 0.003 4. Total body BMC A. Resistance 1x/week: 2552 ± 15

		C. High-intensity resistance training (3 days per week) **n**= 11(randomised & analysed) **Age**: 71.0 (4.1) **Female**: 36% **D. Control**: not relevant for this comparison	**Delivered by**: NR **Duration of the intervention (wks)**: 24				B. Resistance 2x/week: 2530 ± 14 C. Resistance 3x/week: 2525 ± 14

BMC: bone mineral content (g); BMD: bone mineral density (g/cm²); BMI: body mass index (kg/m²); BW: bone width; NR: not reported; RCT: randomised controlled trial. When data was available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score.
*Indicate studies also included in the exercise vs control comparison (Table 1) or in the one or more forms of physical activity comparison (Table 2), but only the results for different doses of exercise are presented here.
[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 often include one or more types of exercise. We categorised exercise based on a modification of 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. We also considered whether the exercise explicitly included bone loading eg hopping or heel drops. Shading indicates studies which detected a statistically significant between-group difference. ¥indicates statistically significant between-group difference at $p < 0.05$.

TABLE 4. Description of included studies investigating the association between physical activity and osteoporosis employing an observational design

Reference	Study design Included / Analysed	Participants (n, age mean (SD), % women, setting, health status)	Exposure	Outcomes	Results
Greendale 1995	Retrospective study 1,703	**Setting**: Community; United States **Health status**: Healthy **n**= 1,703 **Mean age**: 73 **Female**: 60%	Lifetime leisure physical activity, calculated based on leisure time physical activity (collected retrospectively via questionnaire) for the past year, age 30 years and age 50 years Exercise level: classified by the highest level of exercise performed for at least 15 minutes per session at least three times per week. Participants were divided into levels of physical activity according to the tertiles A. Low B. Medium C. High **Classification:** leisure physical activity	1. Total hip BMD 2. Intertrochanter BMD 3. Femoral neck BMD 4. Greater trochanter BMD 5. Lumbar spine (L1-4) BMD 6. Distal radius BMD 7. Midshaft radius BMD	Adjusted mean (p-value for comparison A vs C) 1. Total hip BMD (p=0.002)[¥] A. Low: 0.8241 B. Medium: 0.8367 C. High: 0.8507 2. Intertrochanter BMD (p=0.007)[¥] A. Low: 0.9631 B. Medium: 0.9769 C. High: 0.9908 3. Femoral neck BMD (p=0.003)[¥] A. Low: 0.6597 B. Medium: 0 6716 C. High: 0.6819 4. Greater trochanter BMD (p = 0.0001)[¥] A. Low: 0.5969 B. Medium: 0.6093 C. High: 0.6248 5. Lumbar spine (L1-4) BMD A. Low: 0.9324 B. Medium: 0.9612 C. High: 0.9479 6. Distal radius BMD: NR 7. Midshaft radius BMD: NR
Huddleston 1980	Observational study 35/ 35	**Setting**: Community; United States **Health status**: Healthy tennis athletes **n**=35 **Age**: range 70-79 **Female**: 0%	Lifetime tennis exposure in athletes with tennis experience ranging from 25 to 72 years Results were presented for: A. Playing arm B. Non-playing arm C. Comparison with data for a "normal male population" **Classification:** tennis	1. Radius midshaft BMC	1. Radius BMC 4% to 33% greater for the playing arms as compared with the nonplaying arms The mean difference between the playing arm and nonplaying arm: 13% Reference data suggest difference between dominant and nondominant BMC values of 6% to 9%

Rikkonen 2010	Cohort (15 years follow up) 8560	**Setting**: Community; Finland **Health status:** Healthy **n** =8560 (analysed) **A. Physical activity quartile I** **Age**: 52.1 (2.9) **B. Physical activity quartile II** **Age**: 52.0 (2.9) **C. Physical activity quartile III** **Age**: 52.2 (2.9) **D. Physical activity quartile IV** **Age**: 52.3 (2.8) **Female**: 100%	Leisure-time physical activity (self-reported) collected at 5 years intervals **A.** 15-year average PA, hours/week: 0.35 (0.35) **B**. 15-year average PA, hours/week: 1.7 (0.39) **C**. 15-year average PA, hours/week: 3.2 (0.54) **D**. 15-year average PA, hours/week: 7.0 (2.9) **Classification**: leisure-time physical activity	1. Femoral neck BMD 2. Trochanter BMD 3. Ward's triangle BMD 4. Lumbar spine (L2-4) BMD	Beta ± SE (quartile IV vs inactive) 1. Femoral neck BMD 1.752 ± 0.493 2. Trochanter BMD 1.783 ± 0.581 3. Ward's triangle BMD 2.412 ± 0.723 4. Lumbar spine (L2-4) BMD 0.040 ± 0.649 All results were significant (except for lumbar spine) and suggest a positive effect of physical activity on BMD.

BMC: bone mineral content (g); BMD: bone mineral density (g/cm2). Shading indicates studies which detected a statistically significant between-group difference. ¥indicates statistically significant between-group difference at $p < 0.05$.

TABLE 5. Overall overview of results of included studies comparing physical activity with a control intervention on the main outcome of the studies

Reference PEDro score	Study design Randomised/ Analysed	Intervention	Type of exercise according to ProFaNE classification[a]							Control	Main outcome*	Follow up (mo)	Results for main outcome	Effect
			Balance and functional	Strength or resistance	Flexibility training	3D exercise	General physical activity	Endurance exercise	Other exercise					
Allison 2013 5/10	RCT 50/35	A. High impact unilateral exercise	P	-	-	-	-	-	-	B. No exercise	Total hip BMD	12	Final score (mean ± SD) A. Exercise: 1.030 ± 0.017 B. Control: 1.027 ± 0.018	Pos / NS
Bunout 2001 4/10	RCT 149/98	A. Resistance training B. Supplementation + Resistance training C. Supplementation	P P -	- - -	- - -	- - -	- - -	- - -	- - -	D. No training	Whole body BMD	18	Decreased significantly in all groups (p = 0.006), but the decline was less marked in the strength training combined with nutritional supplements compared with supplements	Pos / Sig
De Jong 2000 5/10	RCT 217/143	A. Multi-component exercise B. Multicomponent exercise + nutrition C. Nutrition	P P -	- - -	- - -	- - -	- - -	- - -	- - -	D. Control (social programme)	Whole body BMD	4.5	Change score (mean ± SD) A. Exercise: 0.000±0.022 B. Combination: 0.003±0.023 C. Nutrition: 0.006±0.014 D. Control: −0.003±0.018	Pos / NS (A vs D) Neg / NS (B vs C)

Duckham 2015 6/10	RCT 319/283	A. OEP. Strengthening and balance exercise B. FaME (Falls and exercise management)	P P	- -	- -	- -	- -	- -	- -	C. Usual care	Lumbar spine BMD	6	Mean difference (95% CI) A. OEP: 0.003 (−0.012 to 0.019) B. Community based: 0.005 (−0.010 to 0.020)	Pos / NS (A vs C) Pos / NS (B vs C)
Lau 1992 4/10	RCT 60/50	A. Exercise Stepped up and down a B. Calcium C. Exercise + calcium	P - P	- - -	- - -	- - -	- - -	- - -	- - -	D. Control (no exercise and placebo tablet daily)	Lumbar spine (L2-L4) BMD	10	Change score (mean %; 95% CI) A. Exercise: -1.9 (-6.7 to 2.8) B. Calcium: -0.08 (-5.2 to 5.1) C. Calcium and exercise: -1.1 (-3.7 to 1.4) D. Control: -2.5 (-6.5 to 1.4)	Pos / NS (A vs D) Neg / NS (B vs C)
Lord 1996 4/10	RCT 179/138	A. Exercise	P	-	-	-	-	-	-	B. Control (No organised activity)	Lumbar spine (L2-L4) BMD	12	Change score (% change ± SD) A. Exercise: 1.07 ± 2.59 B. Control: 0.36 ± 3.91	Pos / NS
Marques 2011 5/10	RCT 60/60	A. Exercise	P	-	-	-	-	-	-	B. Control	Lumbar spine (L1-L4) BMD	8	Final score (mean ± SD) A. Exercise: 0.868 ± 0.094 B. Control: 0.863 ± 0.065	Pos / NS
McMurdo 1997 4/10	RCT 118/92	A. Weight bearing exercise and calcium	P	-	-	-	-	-	-	B. Calcium	Lumbar spine BMD	24	Change score (mean % change ± 95% CI) A. Exercise and calcium: -0.91 (-6.8 to 5.0) B. Calcium: -2.65 (-5.7 to 0.4)	Pos / NS
Sakai 2010 4/10	RCT 94/84	A. Unipedal standing exercise	P	-	-	-	-	-	-	B. Usual activity	Total hip BMD	6	% change between groups Total hip: p=0.889 Results reported in a graph	Pos / NS
Helge 2014 5/10	RCT 27/23	A. Football Supervised training B. Resistance	P -	- P	- -	- -	- -	- -	- -	C. Inactive control	Femoral neck BMD	12	Final score (mean ± SD) Right femoral neck BMD A. Football: 0.921 ± 0.034 B. Resistance: 1.000 ± 0.042 C. Control: 1.008 ± 0.063	Neg / NS (A vs C) Neg / NS (B vs C)
Karinkanta 2007 7/10	RCT 149/144	A. Balance B. Resistance C. Balance + Resistance	P - P	- P P	- - -	- - -	- - -	- - -	- - -	D. Control	Femoral neck BMC	12	Final score (mean ± SD) Femoral neck BMC A. Balance: 2.73 ± 0.40 B. Resistance: 2.71 ± 0.33 C. Combined: 2.65 ± 0.29	Pos / NS (A vs D) Pos / NS (B vs D)

													D. Control: 2.67 ± 0.44	Neg / NS (C vs D)
Binder 2004 7/10	RCT 90/78	A. Physical Therapy and exercise training B. Control	P	P						D. Control (home exercise)	1. Whole Body BMD	6	Final score (mean ± SD) A. Exercise: 1.03 ± 0.13 B. Control: 1.00 ± 0.11	Pos / NS
Englund 2005 5/10	RCT 48/40	A. Exercise group (COMB)	P	P	-	-	-	P	-	B. Not offered COMB	Lumbar spine BMD	12	Mean difference (95% CI) (on % changes) 2.1 (-0.4 to 3.4)	Pos / NS
Jessup 2003 5/10	RCT 18/16	A. Resistance and balance exercises	P	P	-	-	-	-	-	B. Control	Lumbar spine BMD	8	Change score (ANCOVA, p-value) A. Exercise: 0.11 B. Control: -0.003 F (1, 15) = 2.70, P = 0.121	Pos / Sig
Park 2008 5/10	RCT 50/50	A. Multi-component exercise	P	-	-	-	-	P	-	B. Control	Lumbar spine (L2 to L4) BMD	12	Final score (mean ± SD) A. Exercise: 1.059 ± 0.082 B. Control: 0.891 ± 0.155	Pos / NS
von Stengel 2011 7/10	RCT 151/141	A. Dancing aerobics	P	P	P	-	-	P	-	B. Wellness programme	Lumbar spine (L1-L4) BMD	18	Mean difference (95% CI) 0.015 (0.001 to 0.029)	Pos / Sig
Villareal 2004 4/10	RCT 119/112	A. Multicomponent exercise	P	P	-	-	-	P	-	B. Low intensity exercise	Lumbar spine (L2-L4) BMD	9	Final score, g/cm² (mean ± SD) A. Exercise: 1.08 ± 0.28 B. Control: 0.97 ± 0.23	Pos / NS
Woo 2007 6/10	RCT 180/176	A. Tai Chi B. Resistance exercise	- -	- P	- -	P -	- -	- -	- -	C. No exercise prescribed	Total spine BMD	12	Change score (mean % change ± SE) Men A. Tai Chi: 1.35 ± 0.40 B. Resistance: 1.27 ± 0.42 C. Control: 0.54 ± 0.42 Women A. Tai Chi: 0.10 ± 0.50 B. Resistance: 1.98 ± 0.48 C. Control: 0.98 ± 0.47	Pos / NS (A vs C men) Neg / NS (A vs C women) Pos / NS (B vs C men) Pos / NS

														(B vs C women)
Pruitt 1995 4/10	RCT 40/26	A. High intensity resistance exercises B. Low intensity resistance exercises	- -	P P	- -	- -	- -	- -	- -	C. No exercises	Total hip BMD	12	Change score (mean ± SD) A. High intensity: 0.005 ± 0.014 B. Low intensity: 0.008 ± 0.012 C. Control: 0.007 ± 0.010	Neg / NS (A vs C) Pos / NS (B vs C)
Rhodes 2000 5/10	RCT 44/38	A. Exercise	-	P	-	-	-	-	-	B. Control (no exercise)	Femoral neck BMD	12	Final score (mean ± SD) A. Exercise: 0.83 ± 0.12 B. Control: 0.73 ± 0.10	Pos / NS
Taaffe 1999 5/10	RCT 53/46	Resistance exercise: A. Once a week B. Twice a week C. Three times a week	-	P	-	-	-	-	-	D. Control	Lumbar spine (L2-L4) BMD	6	Final score (mean ± SD) A. Resistance 1x/week: 1.025 ± 0.006 B. Resistance 2x/week: 1.033 ± 0.006 C. Resistance 3x/week: 1.032 ± 0.007 D. Control: 1.041 ± 0.006	Neg / NS (A vs D) Neg / NS (B vs D) Neg / NS (C vs D)
Paillard 2004 5/10	RCT 21/21	A. Walking	-	-	-	-	-	P	-	B. Control	Hip BMD	3	Final score (mean ± SD) Hip BMD A. Walking: 0.84 ± 0.11 B. Control: 0.95 ± 0.12	Neg / NS
Yoo 2010 4/10	RCT 28/21	A. Exercise	-	-	-	-	-	P	-	B. Control	Spine BMD	3	Final score (mean ± SD) A. Exercise: 1.056 ± 0.188 B. Control: 1.010 ± 0.167	Pos / NS
No intervention effect reported														
Blumenthal 1991 6/10	RCT 101/85	A. Aerobic Training	-	-	-	-	-	P	-	C. Waiting list control	Distal radius BMD	14	No between-group differences. Quantitative estimates not reported for between-group comparisons.	NR / NS
McCartney 1995 3/10	RCT 68/NR	A. Resistance exercises	-	P	-	-	-	-	-	B. Control	Whole body BMD	10.5	No significant changes in BMD and BMC as a result of the training programme.	NR / NS

													Quantitative estimates not reported.	
Non-randomised trials														
Kohrt 1997§ 3/10	Quasi-randomised trial 39/30	A. Ground reaction force B. Joint reaction force	- -	- P	P P	- -	- -	P P	- -	C. No exercise	Lumbar spine (L2–L4) BMD	12	Between-group analysis relative to control A. Ground reaction: $p < 0.05$ B. Joint reaction: $p < 0.01$ (chance scores provided in a graph)	Pos / Sig (A vs C) Pos / Sig (B vs C)
Kwon 2008§ 3/10	Quasi-randomised trial 40/NR	A. Exercise	P	P	-	-	-	P	-	B. Control	Lumbar spine (L2-L4) BMD	6	Final score (mean ± SD) A. Exercise: 0.85 ± 0.15 B. Control: 0.85 ± 0.10	Neu / NS
Rikli 1990§ 1/10	Quasi-randomised trial 37/31	A. General exercise B. General and resistance exercise	- -	- P	- -	- -	- -	P P	- -	C. No exercise	Distal radius BMC/BW	10	Change score (%) Distal radius BMC/BW A. General exercise: 0.921 B. General exercise and weight: 1.734 C. Control: -2.577	Pos / Sig (A vs C) Pos / Sig (B vs C)
Smith 1981§ 2/10	Quasi-randomised trial 80/51	A. Exercise + placebo B. Calcium and vitamin D C. Exercise + calcium and vitamin D	- - -	- - -	- - -	- - -	- - -	P - P	- - -	D. Control (placebo tablets)	Radius BMC	36	Change score (%) Radius BMC A. Exercise: 2.29% D. Control: - 3.29%	Pos / Sig
Villareal 2003§ 4/10	Quasi-randomised trial 28/28	A. Multicomponent exercise	P	P	-	-	-	P	-	B. Low intensity exercise	Lumbar spine BMD	9	Change score ± SD (g/cm^2) A. Exercise: 0.034 ± 0.022 B. Control: 0.015 ± 0.022	Pos / Sig

BMD: body mineral density (g/cm2); BMC: bone mineral content (g); RCT: randomised controlled trial; Pos: positive effect of physical activity on the outcome; Neg: negative effect of physical activity on the outcome; Neu: neutral effect; Sig: statistically significant; NS: non-statistically significant.
*Main outcome was selected according to the study's selection of main outcome. For studies where primary outcome was not clearly defined, we selected the outcome that would be considered more relevant according to the type of intervention (e.g., whole body for exercises involving the whole body). We selected lumbar spine in preference to hip when both were presented, and the

exercise was primarily undertaken in a standing position. In case exercises were mostly performed in non-standing positions (e.g., seated, supine) and were targeted at the lower limb, hip measures were preferred. For studies that reported multiple hip measures, preference was given to total hip measures, if available. Preference was given to bone mineral density when compared to other measures, such as bone mineral content. When data was available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score.

[§] Indicate studies not included in the GRADE approach because of study design.

[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 often include one or more types of exercise. We categorised exercise based on a modification of 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. We also considered whether the exercise explicitly included bone loading eg hopping or heel drops. Shading indicates studies which detected a statistically significant between-group difference in the main outcome of the studies.

TABLE 6. Overview of included studies comparing physical activity with a control intervention on femoral neck bone mineral density

Reference PEDro score	Study design Randomised/ Analysed	Intervention	Type of exercise according to ProFaNE classification[a]							Control	Follow up	Results for femoral neck BMD*	Effect
			Balance and functional training	**Strength or resistance training**	**Flexibility training**	**3D exercise**	**General physical activity**	**Endurance exercise**	**Other exercise**				
Randomised controlled trials													
Allison 2013 5/10	RCT 50/35	A. High impact unilateral exercise	P	-	-	-	-	-	-	B. No exercise	12	Final score (mean ± SD) A. Exercise: 0.954 ± 0.017 B. Control: 0.945 ± 0.018	Pos / Sig
Duckham 2015 6/10	RCT 319/283	A. OEP. Strengthening and balance exercise B. FaME (Falls and exercise management)	P P	- -	- -	- -	- -	- -	- -	C. Usual care Participants not offered the FaME or OEP programmes	6	Mean difference (95% CI) A. OEP: −0.003 (−0.011 to 0.005) B. Community based: −0.002 (−0.010 to 0.005)	Neg / NS (A vs C) Neg / NS (B vs C)
Englund 2005 5/10	RCT 48/40	A. Exercise group (COMB)	P	P	-	-	-	P	-	B. Not offered COMB	12	Mean difference (95% CI) (on % changes) 0 (-3.8 to 2.6)	Neu / NS

Helge 2014 5/10	RCT 27/23	A. Football Supervised training B. Resistance	P -	- P	- -	- -	- -	- -	- -	C. Inactive control	12	Final score (mean ± SD) Right femoral neck BMD A. Football: 0.921 ± 0.034 B. Resistance: 1.000 ± 0.042 C. Control: 1.008 ± 0.063 Left femoral neck BMD A. Football: 0.939 ± 0.034 B. Resistance: 1.006 ± 0.036 C. Control: 1.018 ± 0.043	Neg / NS (A vs C) Neg / NS (B vs C)
Jessup 2003 5/10	RCT 18/16	A. Resistance and balance exercises	P	P	-	-	-	P	-	B. Control	8	Change score (ANCOVA, p-value) A. Exercise: 1.7 B. Control: -0.04 F (1, 15) = 7.38, P = 0.016	Pos / Sig
Lau 1992 4/10	RCT 60/50	A. Exercise Stepped up and down a block B. Calcium C. Exercise + calcium	P - P	- - -	- - -	- - -	- - -	- - -	- - -	D. Control (no exercise and placebo tablet daily)	10	Change score (%; mean, 95% CI) A. Exercise: -6.6 (-12 to 0.8) B. Calcium: -3.5 (-9 to 1.8) C. Calcium and exercise: 5.0 (-0.77 to 10) D. Control: -1.1 (-7.4 to 5.3)	Neg / NS (A vs D) Pos / NS (B vs C)
Lord 1996 4/10	RCT 179/138	A. Exercise	P	-	-	-	-	-	-	B. Control: No organised activity	12	Change score (% change ± SD) A. Exercise: 1.52 ± 5.19 B. Control: 3.12 ± 6.52	Neg / NS
Marques 2011 5/10	RCT 60/60	A. Exercise	P	-	-	-	-	-	-	B. Control	8	Final score (mean ± SD) A. Exercise: 0.717 ± 0.085 B. Control: 0.671 ± 0.051	Pos / Sig

Park 2008 5/10	RCT 50/50	A. Exercise	P	-	-	-	-	P	-	B. Control	12	Final score (mean ± SD) A. Exercise: 0.857 ± 0.078 B. Control: 0.748 ± 0.063	Pos / Sig
Pruitt 1995 4/10	RCT 40/26	A. High intensity resistance exercises B. Low intensity resistance exercises	- -	P P	- -	- -	- -	- -	- -	C. No exercises	12	Change score (mean ± SD) A. High intensity: -0.002 ± 0.154 B. Low intensity: 0.025 ± 0.008 C. Control: 0.005 ± 0.019	Neg / NS Pos / NS
Rhodes 2000 5/10	RCT 44/38	A. Exercise	-	P	-	-	-	-	-	B. Control	12	Final score (mean ± SD) A. Exercise: 0.83 ± 0.12 B. Control: 0.73 ± 0.10	Pos / NS
Sakai 2010 4/10	RCT 94/84	A. Unipedal standing exercise	P	-	-	-	-	-	-	B. Usual activity	6	% change between exercise group and control group p=0.993 (Results reported in a graph)	Neg / NS
Villareal 2004 4/10	RCT 119/112	A. Multicomponent training	P	P	-	-	-	P	-	B. Low level exercise	9	Final score (mean ± SD) A. Exercise: 0.70 ± 0.17 B. Control: 0.63 ± 0.11	Pos / NS
Yoo 2010 4/10	RCT 28/21	A. Exercise	-	-	-	-	-	P	-	B. Control	3	Final score (mean ± SD) A. Exercise: 0.770 ± 0.132 B. Control: 0.729 ± 0.124	Pos / NS
Non-randomised trials													
Kohrt 1997[§] 3/10	Quasi-randomised trial 39/30	A. Ground reaction force B. Joint reaction forces	P -	- P	P P	- -	- -	P P	- -	C. No exercise	12	Between-group analysis relative to control A. Ground reaction: p < 0.01 B. Joint reaction: no difference (results provided in a graph)	Pos / Sig

Kwon 2008§ 3/10	Quasi-randomised trial 40/NR	A. Exercise	P	P	-	-	-	P	-	B. Control	6	Final score (mean ± SD) A. Exercise: 0.68 ± 0.12 B. Control: 0.70 ± 0.07	Neg / NS
Villareal 2003§ 4/10	Quasi-randomised trial 28/28	A. Flexibility and resistance exercise	P	P	-	-	-	P	-	B. Low level of physical activity	9	No quantitative estimates reported. There were no significant group-by-time interaction effects. (Results reported in a graph)	Pos / NS

BMD: body mineral density (g/cm^2); NR: not reported; RCT: randomised controlled trial; Pos: positive effect of physical activity on the outcome; Neg: negative effect of physical activity on the outcome; Neu: neutral effect; Sig: statistically significant; NS: non-statistically significant. *When data were available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score. § Indicates studies not included in the GRADE approach because of study design. Shading indicates studies which detected a statistically significant between-group difference in femoral neck bone mineral density.

TABLE 7. Overview of results of included studies comparing physical activity with a control intervention on lumbar spine bone mineral density

Reference PEDro score	Study design Randomised/ Analysed	Intervention	Type of exercise according to ProFaNE classification[a]							Control	Follow up	Results for lumbar spine BMD*	Effect
			Balance and functional training	Strength or resistance training	Flexibility training	3D exercise	General physical activity	Endurance exercise	Other exercise				
Duckham 2015 6/10	RCT 319/283	A. OEP Progressive leg strengthening and balance exercise. B. FaME (Falls and exercise management) programme	P P	- -	- -	- -	- -	- -	- -	C. Usual care	6	Mean difference (95% CI) A. OEP: 0.003 (−0.012 to 0.019) B. Community based: 0.005 (−0.010 to 0.020)	Pos / NS (A vs C) Pos / NS (B vs C)
Englund 2005 5/10	RCT 48/40	A. Exercise (COMB)	P	P	-	-	-	P	-	B. Control	12	Mean difference (95% CI) (on % changes) 2.1 (-0.4 to 3.4)	Pos / NS
Jessup 2003 5/10	RCT 18/16	A. Resistance training	P	P	-	-	-	P	-	B. Control	8	Change score (ANCOVA, p-value) A. Exercise: 0.11 B. Control: -0.003 F(1, 15) = 2.70, P = 0.121 Final score (mean ± SD) A. Exercise: 0.88 ± 0.08 B. Control: 1.14 ± 0.32	Pos / NS

Lau 1992 4/10	RCT 60/50	A. Exercise + placebo B. Calcium C. Calcium + exercise	P - P	- - -	- - -	- - -	- - -	- - -	- - -	D. Control (no exercise)	10	Change score (%; mean, 95% CI) A. Exercise: -1.9 (-6.7 to 2.8) B. Calcium: -0,08 (-5.2 to 5.1) C. Calcium + exercise: -1.1 (-3.7 to 1.4) D. Control: -2.5 (-6.5 to 1.4)	Pos / NS (A vs D) Neg / NS (B vs C)
Lord 1996 4/10	RCT 179/138	A. Group exercise	P	-	-	-	-	-	-	B. Control (no organised activity)	12	Final score (mean ± SD) / % change ± SD A. Exercise: 1.036 ± 0.209 / 1.07 ± 2.59 B. Control: 1.008 ± 0.189 / 0.36 ± 3.91	Pos / NS
Marques 2011 5/10	RCT 60/60	A. Multicomponent exercise	P	-	-	-	-	-	-	B. Control	8	Final score (mean ± SD) A. Exercise: 0.868 ± 0.094 B. Control: 0.863 ± 0.065	Pos / NS
McMurdo 1997 4/10	RCT 118/92	A. Weight bearing exercise and calcium	P	-	-	-	-	-	-	B. Calcium	24	Change score (mean % change ± 95% CI) A. Exercise and calcium: -0.91 (-6.8 to 5.0) B. Calcium: -2.65 (-5.7 to 0.4)	Pos / NS
Park 2008 5/10	RCT 50/50	A. Multicomponent exercise	P	-	-	-	-	P	-	B. Control	12	Final score (mean ± SD) A. Exercise: 1.059 ± 0.082 B. Control: 0.891 ± 0.155	Pos / NS
Pruitt 1995 4/10	RCT 40/26	A. Low intensity exercise B. High intensity exercise	- -	P P	- -	- -	- -	- -	- -	C. No exercises	12	Change score (mean ± SD) A. High intensity: 0.007 ± 0.018 B. Low intensity: 0.005 ± 0.027 C. Control: 0.000 ± 0.020	Pos / NS (A vs C) Pos / NS (B vs C)

Rhodes 2000 5/10	RCT 44/38	A. Exercise	-	P	-	-	-	-	-	B. Control (no exercise)	12	Final score (mean ± SD) A. Exercise: 1.13 ± 0.18 B. Control: 1.01 ± 0.17	Pos / NS
von Stengel 2011 7/10	RCT 151/ 141	A. Dancing aerobics	P	P	P	-	-	P	-	B. Wellness programme	18	Mean difference (95% CI): 0.015 (0.001 to 0.029)	Pos / Sig
Taaffe 1999 5/10	RCT 53/46	Resistance exercise: A. Once a week B. Twice a week C. Three times a week	-	P	-	-	-	-	-	D. Control	6	Final score, g/cm^2 (mean ± SD) A. Resistance 1x/week: 1.025 ± 0.006 B. Resistance 2x/week: 1.033 ± 0.006 C. Resistance 3x/week: 1.032 ± 0.007 D. Control: 1.041 ± 0.006	Neg / NS (A vs D) Neg / NS (B vs D) Neg / NS (C vs D)
Villareal 2004 4/10	RCT 119 /112	A. Multicomponent exercise	P	P	-	-	-	P	-	B. Low intensity exercise	9	Final score, g/cm^2 (mean ± SD) A. Exercise: 1.08 ± 0.28 B. Control: 0.97 ± 0.23	Pos / NS
No intervention effect reported													
McCartney 1995 3/10	RCT 68/NR	A. Resistance exercises	-	P	-	-	-	-	-	B. Control	10.5	No significant changes as a result of the training programme. Quantitative estimates not reported.	NR / NS
Non-randomised trials													
Kohrt 1997[§] 3/10	Quasi-randomised trial 39/30	A. Ground reaction force exercise B. Joint reaction force exercise	P -	- P	P P	- -	- -	P P	- -	C. No exercise	12	Between-group analysis relative to control A. Ground reaction: $p < 0.05$ B. Joint reaction: $p < 0.01$ Quantitative estimates were not reported (chance scores provided in a graph)	Pos / Sig Pos / Sig

Kwon 2008§ 3/10	Quasi-randomised trial 40/NR	A. Multicomponent exercise	P	P	-	-	-	P	-	B. Control	6	Final score (mean ± SD) A. Exercise: 0.85 ± 0.15 B. Control: 0.85 ± 0.10	Neu / NS
Villareal 2003§ 4/10	Quasi-randomised trial 28/28	A. Multicomponent exercise	P	P	-	-	-	P	-	B. Low intensity exercise	9	Change score ± SD (g/cm²) A. Exercise: 0.034 ± 0.022 B. Control: 0.015 ± 0.022	Pos / NS

BMD: body mineral density (g/cm^2); NR: not reported; RCT: randomised controlled trial; Pos: positive effect of physical activity on the outcome; Neg: negative effect of physical activity on the outcome; Neu: neutral effect; Sig: statistically significant; NS: non-statistically significant. *When data were available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score. § Indicates studies not included in the GRADE approach because of study design. Shading indicates studies which detected a statistically significant between-group difference in lumbar spine bone mineral densit

TABLE 8. Overview of results of included studies comparing balance and functional exercises with a control intervention on the main outcome of included studies

Reference PEDro score	Study design Randomised/ Analysed	Intervention	Control	Main outcome*	Follow up (mo)	Results for main outcome	Effect
Allison 2013 5/10	RCT 50/35	A. High impact unilateral exercise	B. No exercise	Total hip BMD	12	Final score (mean ± SD) A. Exercise: 1.030 ± 0.017 B. Control: 1.027 ± 0.018	Pos / NS
Bunout 2001 4/10	RCT 149/98	A. Resistance training B. Supplementation + Resistance training C. Supplementation	D. No training	Whole body BMD	18	Decreased significantly in all groups (p = 0.006), but the decline was less marked in the strength training combined with nutritional supplements compared with supplements (statistically significant).	Pos / Sig
De Jong 2000 5/10	RCT 217/143	A. Multi-component exercise B. Multicomponent exercise + nutrition C. Nutrition	D. Control (social programme)	Whole body BMD	4.5	Change score (mean ± SD) A. Exercise: 0.000±0.022 B. Combination: 0.003±0.023 C. Nutrition: 0.006±0.014 D. Control: −0.003±0.018	Pos / NS (A vs D) Neg / NS (B vs C)
Duckham 2015 6/10	RCT 319/283	A. OEP. Strengthening and balance exercise B. FaME (Falls and exercise management)	C. Usual care	Lumbar spine BMD	6	Mean difference I (95% CI) A. OEP: 0.003 (−0.012 to 0.019) B. Community based: 0.005 (−0.010 to 0.020)	Pos / NS (A vs C) Pos / NS (B vs C)
Helge 2014 5/10	RCT 27/23	A. Football Supervised training	C. Inactive control	Femoral neck BMD	12	Final score (mean ± SD) Right femoral neck BMD A. Football: 0.921 ± 0.034 B. Resistance: 1.000 ± 0.042 C. Control: 1.008 ± 0.063	Neg / NS (A vs C)
Karinkanta 2007 7/10	RCT 149/144	A. Balance	D. Control	Femoral neck BMC	12	Final score (mean ± SD) Femoral neck BMC A. Balance: 2.73 ± 0.40 B. Resistance: 2.71 ± 0.33 C. Combined: 2.65 ± 0.29 D. Control: 2.67 ± 0.44	Pos / NS (A vs D)
Lau 1992 4/10	RCT 60/50	A. Exercise Stepped up and down a B. Calcium C. Exercise + calcium	D. Control (no exercise and placebo tablet daily)	Lumbar spine (L2-L4) BMD	10	Change score (%; mean, 95% CI) A. Exercise: -1.9 (-6.7 to 2.8) B. Calcium: -0.08 (-5.2 to 5.1)	Pos / NS (A vs D) Neg / NS (B vs C)

						C. Calcium and exercise: -1.1 (-3.7 to 1.4) D. Control: -2.5 (-6.5 to 1.4)	
Lord 1996 4/10	RCT 179/138	A. Exercise	B. Control (No organised activity)	Lumbar spine (L2-L4) BMD	12	Change score (% ± SD) A. Exercise: 1.07 ± 2.59 B. Control: 0.36 ± 3.91	Pos / NS
Marques 2011 5/10	RCT 60/60	A. Exercise	B. Control	Lumbar spine (L1-L4) BMD	8	Final score (mean ± SD) A. Exercise: 0.868 ± 0.094 B. Control: 0.863 ± 0.065	Pos / NS
McMurdo 1997 4/10	RCT 118/92	A. Weight bearing exercise and calcium	B. Calcium	Lumbar spine BMD	24	Change score (mean % change ± 95% CI) A. Exercise and calcium: -0.91 (-6.8 to 5.0) B. Calcium: -2.65 (-5.7 to 0.4)	Pos / NS
Sakai 2010 4/10	RCT 94/84	A. Unipedal standing exercise	B. Usual activity	Total hip BMD	6	% change between groups Total hip: p=0.889 Results reported in a graph	Pos / NS

BMD: body mineral density (g/cm2); BMC: bone mineral content (g); RCT: randomised controlled trial; Pos: positive effect of physical activity on the outcome; Neg: negative effect of physical activity on the outcome; Neu: neutral effect; Sig: statistically significant; NS: non-statistically significant.
*Main outcome was selected according to the study's selection of main outcome. For studies where primary outcome was not clearly defined, we selected the outcome that would be considered more relevant according to the type of intervention (e.g., whole body for exercises involving the whole body). We selected lumbar spine in preference to hip when both were presented, and the exercise was primarily undertaken in a standing position. In case exercises were mostly performed in non-standing positions (e.g., seated, supine) and were targeted at the lower limb, hip measures were preferred. For studies that reported multiple hip measures, preference was given to total hip measures, if available. Preference was given to bone mineral density when compared to other measures, such as bone mineral content. When data were available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score. Shading indicates studies which detected a statistically significant between-group difference in the main outcome of the study.

TABLE 9. Overview of results of included studies comparing multiple exercises with a control intervention on the main outcome of included studies

Reference PEDro score	Study design Randomised/ Analysed	Intervention	Control	Main outcome*	Follow up (mo)	Results for main outcome	Effect
Binder 2004 7/10	RCT 90/79	A. Physical Therapy and exercise training B. Control	D. Home exercise	1. Whole body BMD	6	Final score (mean ± SD) A. Exercise: 1.03 ± 0.13 B. Control: 1.00 ± 0.11	Pos / NS
Englund 2005 5/10	RCT 48/40	A. Exercise group (COMB)	B. Not offered COMB	Lumbar spine BMD	12	Mean difference (95% CI) (on % changes) 2.1 (-0.4 to 3.4)	Pos / NS
Jessup 2003 5/10	RCT 18/16	A. Resistance and balance exercises	B. Control	Lumbar spine BMD	8	Change score (ANCOVA, p-value) A. Exercise: 0.11 B. Control: -0.003 F (1, 15) = 2.70, P = 0.121	Pos / Sig
Karinkanta 2007 7/10	RCT 149/144 (48 for the relevant comparison)	C. Balance + Resistance	D. Control	Femoral neck BMC	12	Final score (mean ± SD) Femoral neck BMC A. Balance: 2.73 ± 0.40 B. Resistance: 2.71 ± 0.33 C. Combined: 2.65 ± 0.29 D. Control: 2.67 ± 0.44	Neg / NS
Park 2008 5/10	RCT 50/50	A. Multi-component exercise	B. Control	Lumbar spine (L2 to L4) BMD	12	Final score (mean ± SD) A. Exercise: 1.059 ± 0.082 B. Control: 0.891 ± 0.155	Pos / NS
von Stengel 2011 7/10	RCT 151/141 (95 for the relevant comparison)	A. Dancing aerobics	B. Wellness programme	Lumbar spine (L1-L4) BMD	18	Mean difference (95% CI) 0.015 (0.001 to 0.029)	Pos / Sig
Villareal 2004 4/10	RCT 119/112	A. Multicomponent exercise	B. Low intensity exercise	Lumbar spine (L2-L4) BMD	9	Final score, g/cm² (mean ± SD) A. Exercise: 1.08 ± 0.28 B. Control: 0.97 ± 0.23	Pos / NS

BMD: body mineral density (g/cm2); BMC: bone mineral content (g); RCT: randomised controlled trial; Pos: positive effect of physical activity on the outcome; Neg: negative effect of physical activity on the outcome; Neu: neutral effect; Sig: statistically significant; NS: non-statistically significant.
*Main outcome was selected according to the study's selection of main outcome. For studies where primary outcome was not clearly defined, we selected the outcome that would be considered more relevant according to the type of intervention (eg, whole body for exercises involving the whole body). We selected lumbar spine in preference to hip when both were presented, and the exercise was primarily undertaken in a standing position. In case exercises were mostly performed in non-standing positions (eg, seated, supine) and were targeted at the lower limb, hip measures were preferred. For studies that reported multiple hip measures, preference was given to total hip measures, if available. Preference was given to bone mineral density when compared to other measures, such as bone mineral content. When data were available for more than one time-point, we extracted the post-intervention data. Mean estimates were extracted in the following hierarchical order: mean difference, change score and final score. Shading indicates studies which detected a statistically significant between-group difference in the main outcome of the study.

APPENDIX 1. Eligibility criteria

Category	Inclusion criteria	Exclusion criteria
Publication language	• Studies published with full text in English	
Publication date	• Reviews published 2008 to present	
Publication status	• Studies published in peer-reviewed journals	• Grey literature, including unpublished data, abstracts, conference proceedings
Study design	• Systematic review • Meta-analyses	• Narrative reviews • Commentaries • Editorials • Systematic review protocols
Characteristics of studies included in the reviews		
Study design of studies included in the reviews	• Randomised controlled trials • Non-randomised controlled trials • Prospective cohort studies • Retrospective cohort studies • Systematic reviews • Meta-analyses	• Cross-sectional studies • Before-and-after studies
Study subjects	• Human subjects • Adults over 64 years of age • Trials that included younger participants were included if the mean age minus one standard deviation was more than 64 years • No restriction will be applied to participants' health status or setting	• Participants with osteoporosis at baseline.
Exposure / Intervention	• All types and intensities of physical activity • Studies where participants received multiple interventions may be included if the only difference between the groups was the physical activity intervention	• Studies that only used physical activity as a confounding variable • Studies of multimodal interventions where physical activity is not the main component, or that do not present data on physical activity alone

Comparison	No physical activity or lesser volume, duration, frequency, or intensity of physical activity.	
Outcome	**Include studies in which the outcome is** • Osteoporosis, including (but not limited to): o bone mineral density from any location (e.g., neck of femur, spine) o bone mineral content o Calcium bone index o Cortical bone density o Bone quality index	• Fracture

APPENDIX 2. Search strategy

Database: PubMed; Date of Search: 06/11/2019; Results: 140

Description	Search terms*
Limit: language and exclude animal only	(English[lang]) NOT ("Animals"[Mesh] NOT ("Animals"[Mesh] AND "Humans"[Mesh]))
Limit: age groups	NOT (("infant"[Mesh] OR "child"[mesh] OR "adolescent"[mh]) NOT (("infant"[Mesh] OR "child"[mesh] OR "adolescent"[mh]) AND "adult"[Mesh]))
Limit: date	AND ("2008/01/01"[PDAT] : "3000/12/31"[PDAT])
Publication type	AND (systematic[sb] OR meta-analysis[pt] OR “systematic review”[tiab] OR “systematic literature review”[tiab] OR metaanalysis[tiab] OR "meta analysis"[tiab] OR metanalyses[tiab] OR "meta analyses"[tiab] OR "pooled analysis"[tiab] OR “pooled analyses”[tiab] OR "pooled data"[tiab])
Limit: publication type	NOT (“comment”[Publication Type] OR “editorial”[Publication Type])
Physical activity	AND (("Exercise"[mh] OR "Exercise"[tiab] OR "Physical activity"[tiab] OR "Sedentary behavior"[mh] OR "Lifestyle activities"[tiab] OR "Lifestyle activity"[tiab] OR "Recreational activities"[tiab] OR "Recreational activity"[tiab] OR "Tai ji"[mh] OR "Yoga"[mh] OR "Activities of daily living"[tiab] OR "Activity of daily living"[tiab] OR "Free living activities"[tiab] OR "Free living activity"[tiab] OR "Balance training"[tiab] OR "Qigong"[mh] OR "Functional training"[tiab]) OR (("Aerobic activities"[tiab] OR "Aerobic activity"[tiab] OR "Cardiovascular activities"[tiab] OR "Cardiovascular activity"[tiab] OR "Endurance activities"[tiab] OR "Endurance activity"[tiab] OR "Physical activities"[tiab] OR "Physical conditioning"[tiab] OR "Resistance training"[tiab] OR "strength training"[tiab] OR "Sedentary"[tiab] OR "Tai chi"[tiab] OR "Tai ji"[tiab] OR "Yoga"[tiab] OR "Walk"[tiab] OR "Walking"[tiab] OR "Chi kung"[tiab] OR "Qigong"[tiab] OR "stretching"[tiab]) NOT medline[sb]))
Osteoporosis	AND ("Osteoporosis"[mh] OR “Osteoporosis”[tiab] OR “Osteoporoses”[tiab] OR “Post-Traumatic Osteoporosis” [tiab] OR “Senile Osteoporosis” [tiab] OR “Age-Related Bone Loss” [tiab] OR “Age-Related Bone Losses” [tiab] OR “Age-Related Osteoporosis” [tiab] OR “Age Related Osteoporosis” [tiab] OR “Age-Related Osteoporoses” [tiab])

*Search strategy created by Guideline Development Group

APPENDIX 3. Categories of physical activity programmes (ProFaNE): definitions and application

Physical activity 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 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 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	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

	intervention to the individual's abilities; and progression of the exercise programme as ability improves	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	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

	physical or mental health improvement is indicated	
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		

APPENDIX 4. Criteria used to apply the GRADE framework

The GRADE system classifies the evidence in one of four levels:

High certainty: We are very confident that the true effect lies close to that of the estimate of the effect. Further research is very unlikely to change our confidence in the estimate of 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. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low certainty: Our confidence in the effect estimate is limited. The true effect may be substantially different from the estimate of the effect. Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

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. Any estimate of effect is very uncertain.

Evidence based on **randomised controlled** trials begins as high quality evidence, but our confidence in the evidence may be decreased for:	
Study limitations	We considered the methodological quality of the included studies. We downgraded the evidence if > 50% of included trials had a PEDro score* <6/10.
Imprecision	We considered the sample size of included studies. We downgraded the evidence if total number of participants was less than 400 across all studies.
Inconsistency of results	We considered the heterogeneity of included studies in terms of direction of effect. We downgraded the evidence if < 75% of effects were in the same direction.
Indirectness of evidence	Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.
Publication bias	In the absence of a funnel plot to assess publication bias we looked at the number of small studies (n<50) published that did not find a significant effect. We downgraded the evidence if there was no small study that did not find a significant effect.

*PEDro scale was used to assess the methodological quality of included studies.

APPENDIX 5. Reasons for exclusion at full-text screening for existing systematic reviews and meta-analysis

Citation	Study type	Population (age <65 years)	Population (osteoporosis at study entry)	Physical activity	Outcome
*Abrahin O, Rodrigues RP, Marcal AC, Alves EA, Figueiredo RC, Sousa EC. Swimming and cycling do not cause positive effects on bone mineral density: a systematic review. *Rev Bras Reumatol.* 2016; pii: S0482-5004(16)00026-7	x	x			
*Babatunde OO, Bourton AL, Hind K, Paskins Z, Forsyth JJ. Exercise Interventions for Preventing and Treating Low Bone Mass in the Forearm: A Systematic Review and Meta-analysis. *Arch Phys Med Rehabil.* 2019/08/30		x			
Bittar ST, Pfeiffer PS, Santos HH, Cirilo-Sousa MS. Effects of blood flow restriction exercises on bone metabolism: a systematic review. *Clin Physiol Funct Imaging.* 2018;38:pp930-935		x	x		x
*Bolam KA, van Uffelen JG, Taaffee DR. The effect of physical exercise on bone density in middle-aged and older men: a systematic review. *Osteoporosis Int.* 2013;24(11):2749-62		x			
*Chow TH, Lee BY, Ang ABF, Cheung VYK, Ho MMC, Takemura S. The effect of Chinese material arts Tai Chi Chuan on prevention of osteoporosis: A systematic review. *J Orthop Translat.* 2018;12:74-84		x	x		
De Kam D, Smulders E, Weerdesteyn V, Smits-Engelsman BC. Exercise interventions to reduce fall-related fractures and their risk factors in individuals with low bone density: a systematic review of randomized controlled trials. *Osteoporos Int.* 2009;20(12):2111-25		x	x		
Dionello CF, Sa-Caputo D, Pereira HV, Sousa-Gonclaves CR, Maiwarm AI, Morel DS, Moreira-Marconi E, Paineiras-Domingos LL, Bemben D, Bernado-Filho M. Effect of whole body vibration exercises on bone mineral density of women with postmenopausal		x	x	x	

osteoporosis without medications: novel findings and literature review. *J Musculoskelet Neuronal Interact.* 2016;16(3):193-203					
*Gomez-Cabello A, Ara L, Gonzalez-Aguero A, Casajus JA, Vincente-Rodriguez G. Effects of training on bone mass in older adults: a systematic review. *Sports Med.* 2012;42(4):301-25		x			
*Howe TE, Shea B, Dawson LJ, Downie F, Murray A, Ross C, Harbour RT, Caldwell LM, Creed G. Exercise for preventing and treating osteoporosis in postmenopausal women. *Cochrane Databse Syst Rev.* 2011;7:Cd000333		x			
Huston P, McFarlane B. Health benefits of tai chi: What is the evidence? *Can Fam Physician.* 2016;62(11):881-890	x	x	x		
Jepson DB, Thomsen K, Hansen S, Jorgensen NR, Masud T, Ryg J. Effect of whole-body vibration exercise in preventing falls and fractures: a systematic review and meta-analysis. *BMJ Open.* 2017;7(12):e018342		x		x	
*Kelley GA, Kelley KS, Kohrt WM. Effects of ground and joint reaction force exercise on lumbar spine and femoral neck bone mineral density in postmenopausal women: a meta-analysis of randomized controlled trials. *BMC Musculoskeletal Disord.* 2012;13:177		x			
*Kemmler W, Shojaa M, Kohl M, von Stengel S. Exercise effects on bone mineral density in older men: a systematic review with special emphasis on study interventions. *Osteoporos Int.* 2018;29(7):1493-1504		x			
Lau RW, Liao LR, Yu F, Teo T, Chung RC, Pang MY. The effects of whole body vibration therapy on bone mineral density and leg muscle strength in older adults: a systematic review and meta-analysis. *Clin Rehabil.* 2011;25(11):975-88		x		x	
*Lee MS, Pittler MH, Shin BC, Ernst E. Tai chi for osteoporosis: a systematic review. *Osteoporos Int.* 2008;19(2):139-46*		x			
*Ma D, Wu L, He Z. Effects of walking on the preservation of bone mineral density in perimenopausal and post		x			

menopausal women: a systematic review and meta-analysis. *Menopause.* 2013;20(11):1216-26					
*Marques EA, Mota J, Carvalho J. Exercise effects on bone mineral density in older adults: a meta-analysis of randomized controlled trials. *Age* 2012; 34(6):1493-515.		x	x	x	
Manferdelli G, La Torre A, Codella R. Outdoor physical activity bears multiple benefits to health and society. *J Sports Med Phys Fitness.* 2019;59(5):868-879		x	x		x
Marin-Cascales E, Alcaraz PE, Ramos-Campo DJ, Martinez-Rodriguez A, Chung LH, Rubio-Arias JA. Whole-body vibration training and bone health in postmenopausal women: A systematic review and meta-analysis. *Medicine (Baltimore)* 2018;97(34):e11918		x		x	
*Marin-Cascales E, Alcaraz PE, Ramos-Campo DJ, Rubio-Arias JA. Effects of multicomponent training on lean and bone mass in postmenopausal and older women: a systematic review. *Menopause.* 2018;25(3):346-356		x	x		
*Martyn-St M, Carroll S. Meta-analysis of walking for preservation of bone mineral density in postmenopausal women. *Bone.* 2008;43(3):521-31		x			
*Martyn-St M, Carroll S. A meta-analysis of impact exercise on postmenopausal bone loss: the case for mixed loading exercise programmes. *Br J Sports Med.* 2009;43(12):898-908		x			
Merriman H, Jackson K. The effects of whole-body vibration training in aging aults: a systematic review. *J Geriatr Phys Ther.* 2009;32(3):134-45				x	
*Moayyeri A. The association between physical activity and osteoporotic fractures: a review of the evidence and implications for future research. *Ann Epidemiol.* 2008;18(11):827-35		x			
*Nikander R, Sievanen H, Heinonen A, Daly RM, Uusi-Rasi K, Kannus P. Targeted exercise against osteoporosis: A systematic review and meta-analysis for optimising bone strength throughout life. *BMC Med.* 2010;8:47		x			
*Oh EG, Lee JE, Yoo JY. A systematic review of the effectiveness of lifestyle interventions for improving bone health		x	x		

in women at high risk of osteoporosis. *JBI Libr Syst Rev.* 2012;10(30):1738-1784*					
Oliveira LC, Oliveira RG, Pires-Oliveira DA. Effects of whole body vibration on bone mineral density in postmenopausal women: a systematic review and meta-analysis. *Osteoporos Int.* 2016;27(10):2913-33		x		x	
*Polidoulis I, Beyene J, Cheung AM. The effect of exercise on pQCT parameters of bone structure and strength in postmenopausal women- - a systematic review and meta-analysis of randomized controlled trials. *Osteoporos Int.* 2012;23(1):39-51		x			
*Simas V, Hing W, Pope R, Climstein M. Effects of water-based exercise on bone health of middle-aged and older adults: a systematic review and meta-analysis. *Open Access J Sports Med.* 2017;8:39-60		x	x		
*Sun Z, Chen H, Berger MR, Zhang L, Guo H, Huang Y. Effects of tai chi exercise on bone health in perimenopausal and postmenopausal women: a systematic review and meta-analysis. *Osteoporos Int.* 2016;27(10):2901-11		x			
Wei X, Xu A, Yin Y, Zhang R. The potential effect of Wuqinxi exercise for primary osteoporosis: A systematic review and meta-analysis. *Maturitas.* 2015;82(4):346-54		x	x		
*Xu J, Lombardi G, Jiao W, Banfi G. Effects of Exercise on Bone Status in Female Subjects, from Young Girls to Postmenopausal Women: An Overview of Systematic Reviews and Meta-Analyses. *Sports Med.* 2016;46:1165-82		x			
*Zhang Y, Chai Y, Pan X, Shen H, Wei X, Xie Y. Tai chi for treating osteopenia and primary osteoporosis: a meta-analysis and trial sequential analysis. *Clin Interv Aging.* 2019;14:91-104		x	x		
*Zhao R, Zhang M, Zhang Q. The Effectiveness of Combined Exercise Interventions for Preventing Postmenopausal Bone Loss: A Systematic Review and Meta-analysis. *J Orthop Sports Phys Ther.* 2017;47(4):241-251*		x			

*Zhao R, Zhao M, Xu Z. The effects of differing resistance training modes on the preservation of bone mineral density in postmenopausal women: a meta-analysis. *Osteoporos Int.* 2015;26(5):1605-18		x			
*Zou L, Wang C, Chen K, Shu Y, Chen X, Luo L, Zhao X. The Effect of Taichi Practice on Attenuating Bone Mineral Density Loss: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Int J Environ Res Public Health.* 2017;14(9)		x			

*indicates reviews that were excluded, but included studies that are relevant to the present review.

APPENDIX 6. Methodological quality and reporting of included studies

Study	PEDro Scale Items[a]											PEDro Score (0 to 10)
	1[b]	2	3	4	5	6	7	8	9	10	11	
Allison et al. (2013)	Y	Y	N	Y	N	N	Y	N	N	Y	Y	5
Ashe et al. (2013)	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	6
Binder et al. (2004)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Blumenthal et al. (1991)	N	Y	N	N	N	N	Y	Y	Y	Y	Y	6
Bunout et al. (2001)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
de Jong et al. (2000)	N	Y	Y	Y	N	N	N	N	N	Y	Y	5
Duckham et al. (2015)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Englund et al. (2005)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Helge et al. (2014)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Jessup et al. (2003)	Y	Y	N	N	N	N	Y	Y	N	Y	Y	5
Karinkanta et al. (2007)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Kemmler et al. (2010)	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	6
*Kohrt et al. (1997)	N	N	N	Y	N	N	N	N	N	Y	Y	3
*Kwon et al. (2008)	Y	N	N	Y	N	N	N	N	N	Y	Y	3
Lau et al. (1992)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
Lord et al. (1996)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
Marques et al. (2011)	Y	Y	Y	Y	N	N	N	N	N	Y	Y	5
McCartney et al. (1995)	N	Y	N	Y	N	N	N	N	N	Y	N	3
McMurdo et al. (1997)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
Paillard et al. (2004)	N	Y	N	Y	N	N	N	Y	N	Y	Y	5
Park et al. (2008)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Pruitt et al. (1995)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
Rhodes et al. (2000)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
*Rikli et al. (1990)	N	N	N	N	N	N	N	N	N	Y	N	1

Sakai et al. (2010)	N	Y	N	Y	N	N	N	N	N	Y	Y	4
Shen et al. (2007)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
*Smith et al. (1981)	Y	N	N	N	N	N	N	N	N	Y	Y	2
Taaffe et al. (1999)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
*Villareal et al. (2003)	Y	N	N	N	N	N	N	Y	Y	Y	Y	4
*Villareal et al. (2004)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
von Stengel et al. (2011)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Woo et al. (2007)	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Yoo et al. (2010)	Y	Y	N	Y	N	N	N	N	N	Y	Y	4

Y = yes, N = no.
[a]1 = Eligibility criteria and source of participants, 2 = random allocation, 3 = concealed allocation, 4 = baseline comparability, 5 = blinded participants, 6 = blinded therapists, 7 = blinded assessors, 8 = adequate follow-up, 9 = intention-to-treat analysis, 10 = between-group comparisons, 11 = point estimates and variability.
[b]Item 1 does not contribute to the total score.
* Indicate studies where reviewers performed the rating as PEDro scores were not available on PEDro database.
Observational studies were not included in this table: Greendale et al. (1995); Huddleston et al. (1980); Rikkonen et al. (2010).

APPENDIX 7. Level of evidence according to the GRADE approach: Exercise vs control on the main outcome of the included studies

The GRADE approach was applied to 23 randomised controlled trials comparing physical activity with control. The quasi-randomised trials (n=5) and the studies that did not report intervention effect (n=2) were not considered. We also considered the resutls from the exploratory meta-analysis to judge the level of evidence (pooled standardised effect size 0.21, 95% CI 0.06 to 0.36; n=18 trials).

Overall result: Physical activity interventions probably improve bone health and prevent osteoporosis in older adults.	
Level of evidence: 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. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.	
Study limitations	We downgraded the evidence by one level as 18/23 studies (78%) had a PEDro score <6/10. Additionally, 15/18 (83%) of studies in the meta-analysis had a PEDro score <6/10.
Imprecision	The 23 included studies had a total of 1,915 participants analysed and the meta-analysis had 1,331 participatns analysed.Therefore, we did not downgrade the evidence.
Inconsistency of results	We did not downgraded the evidence by one level due to heterogeneity of included studies. Although only 69% of comparisons were in the same direction (24/35 comparisons showed a positive effect and 11/35 showed a negative effect for physical activity), most of the comparisons in the meta-analysis were in the same direction (80%, 20/25).
Indirectness of evidence	Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.
Publication bias	We did not downgrade the evidence for publication bias since several small studies did not find a significant effect.

APPENDIX 8. Level of evidence according to the GRADE approach: Exercise vs control on femoral neck bone mineral density (BMD)

The GRADE approach was applied to 14 randomised controlled trials comparing physical activity with control on bone mineral density (BMD) of the femoral neck. The quasi-randomised trials (n=3) were not considered. Since some studies included more than one intervention group, there were 18 relevant comparisons between physical activity and control groups. We also considered the results from the exploratory meta-analysis to judge the level of evidence (pooled standardised effect size 0.34, 95% CI 0.05 to 0.62; n=12 trials).

Overall result: Physical activity interventions may improve bone mineral density of the femoral neck in older adults.	
Level of evidence: Low certainty Our confidence in the effect estimate is limited. The true effect may be substantially different from the estimate of the effect. Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.	
Study limitations	We downgraded the evidence by one level as 13/14 studies (93%) had a PEDro score <6/10. Additionally 11/12 studies (92%) included in the meta-analysis had a PEDro score <6/10.
Imprecision	The 14 included studies had a total of 976 participants analysed. There were 877 participants included in the meta-analysis. Therefore, we did not downgrade the evidence.
Inconsistency of results	We downgraded the evidence by one level due to heterogeneity of included studies (9/18 comparisons showed a positive effect for physical activity, 1/18 showed a neutral effect, 8/18 showed negative effect for physical activity). Inconsistency was also found in the studies included in the meta-analysis where 5/15 comparisons showed a negative effect, 1/15 showed a neutral effect and 9/15 a positive effect.
Indirectness of evidence	Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.
Publication bias	We did not downgrade the evidence for publication bias since several small studies did not find a significant effect.

APPENDIX 9. Level of evidence according to the GRADE approach: Exercise vs control on lumbar spine bone mineral density (BMD)

The GRADE approach was applied to 13 randomised controlled trials comparing physical activity with control on lumbar spine bone mineral density (BMD). The quasi-randomised trials (n=3) and one study that did not report intervention effect were not considered. Since some studies included more than one intervention group, there were 18 relevant comparisons between physical activity and control groups. We also considered the resutls from the exploratory meta-analysis to judge the level of evidence (pooled standardised effect size 0.27, 95% CI 0.06 to 0.47; n=11 trials).

<table>
<tr><td colspan="2">Overall result: Physical activity interventions probably improve bone mineral density of the lumbar spine in older adults.</td></tr>
<tr><td colspan="2">Level of evidence: 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. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.</td></tr>
<tr><td>Study limitations</td><td>We downgraded the evidence by one level as 11/13 studies (76%) had a PEDro score <6/10. Additioanlly 8/11 studies (73%) included in the meta-analysis had a PEDro score <6/10.</td></tr>
<tr><td>Imprecision</td><td>The 13 included studies had a total of 1,092 participants analysed. There were 903 participants inlcuded in the exploratory meta-analysis. Therefore, we did not downgrade the evidence.</td></tr>
<tr><td>Inconsistency of results</td><td>We did not downgrade the evidence due to heterogeneity of included studies as most comparisons (14/18) showed a positive effect for exercise. Similarly, in the meta-analysis most comparisons were in the same direction (80%, 12/15)</td></tr>
<tr><td>Indirectness of evidence</td><td>Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.</td></tr>
<tr><td>Publication bias</td><td>We did not downgrade the evidence for publication bias since several small studies did not find a significant effect.</td></tr>
</table>

APPENDIX 10. Level of evidence according to the GRADE approach: balance and functional exercises vs control on the main outcome of included studies

The GRADE approach was applied to 11 randomised controlled trials comparing balance and functional exercises with control on the main outcome of included studies. Since some studies included more than one intervention group, there were 14 relevant comparisons between physical activity and control groups. We also considered the results from the exploratory meta-analysis to judge the level of evidence (pooled standardised effect size 0.13, 95% CI -0.03 to 0.28; n=7 trials).

Overall result: Balance and functional exercises may improve bone health and prevent osteoporosis in older adults.	
Level of evidence: Low certainty We are uncertain about the effect estimate. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.	
Study limitations	We downgraded the evidence by one level as 9/11 studies (82%) had a PEDro score <6/10. Additionally 5/7 studies (71%) included in the meta-analysis had a PEDro score <6.
Imprecision	The 11 included studies had a total of 1,150 participants analysed. There were 636 participants included in the exploratory meta-analysis. The confidence intervals were relatively wide so we downgraded the evidence.
Inconsistency of results	We did not downgrade the evidence due to heterogeneity of included studies as most comparisons (11/14) showed a positive effect for exercise. Additionally, all studies included in the exploratory meta-analysis were in the same direction.
Indirectness of evidence	Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.
Publication bias	We did not downgrade the evidence for publication bias since several small studies did not find a significant effect.

APPENDIX 11. Level of evidence according to the GRADE approach: multiple exercises vs control on the main outcome of the included studies

The GRADE approach was applied to 7 randomised controlled trials comparing multiple exercise types with control on the main outcome of the included studies. The quasi-randomised trials (n=4) were not considered. We also considered the results from the exploratory meta-analysis to judge the level of evidence (pooled standardised effect size 0.47, 95% CI 0.17 to 0.77; n=7 trials).

Overall result: Interventions involving a combination of multiple exercise types probably improve bone health and prevent osteoporosis in older people.	
Level of evidence: 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. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.	
Study limitations	We downgraded the evidence by one level as 4/7 studies (57%) had a PEDro score <6/10. Similarly, in the exploratory meta-analysis 4/7 studies (57%) had a PEDro score <6/10.
Imprecision	The 7 included studies had a total of 440 participants analysed (all included in the exploratory meta-analysis). Therefore, we did not downgrade the evidence.
Inconsistency of results	We did not downgrade the evidence due to heterogeneity of included studies as most studies (6/7) showed a positive effect for exercise. Similarly, in the exploratory meta-analysis 6/7 studies showed a positive effect.
Indirectness of evidence	Since we only included similar studies in terms of population, intervention, comparator and outcome, we did not downgrade the evidence based on this criterion.
Publication bias	We did not downgrade the evidence for publication bias since two small studies did not find a significant effect.

APPENDIX 12. Abstracts of included studies

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Allison SJ, Folland JP et al. High impact exercise increase femoral neck bone mineral density in older men: a randomised unilateral intervention. Bone. 2012;53(2):321-328.</td></tr>
<tr><td>Purpose: to investigate the influence of a 12 month high impact unilateral exercise intervention on femoral neck BMD in older men.</td><td rowspan="6">Abstract:
Introduction: There is little evidence as to whether exercise can increase BMD in older men with no investigation of high impact exercise. Lifestyle changes and individual variability may confound exercise trials but can be minimised using a within-subject unilateral design (exercise leg [EL] vs. control leg [CL]) that has high statistical power.
Purpose: This study investigated the influence of a 12 month high impact unilateral exercise intervention on femoral neck BMD in older men.
Methods: Fifty, healthy, community-dwelling older men commenced a 12 month high impact unilateral exercise intervention which increased to 50 multidirectional hops, 7 days a week on one randomly allocated leg. BMD of both femurs was measured using dual energy X-ray absorptiometry (DXA) before and after 12 months of exercise, by an observer blind to the leg allocation. Repeated measures ANOVA with post hoc tests was used to detect significant effects of time, leg and interaction.
Results: Thirty-five men (mean±SD, age 69.9±4.0 years) exercised for 12 months and intervention adherence was 90.5±9.1% (304±31 sessions completed out of 336 prescribed sessions). Fourteen men did not complete the 12 month exercise intervention due to: health problems or injuries unrelated to the intervention (n=9), time commitments (n=2), or discomfort during exercise (n=3), whilst BMD data were missing for one man. Femoral neck BMD, BMC and cross-sectional area all increased in the EL (+0.7, +0.9 and +1.2 % respectively) compared to the CL (−0.9, −0.4 and −1.2%); interaction effect Pb0.05. Although the interaction term was not significant (P>0.05), there were significant main effects of time for section modulus (P=0.044) and minimum neck width (P=0.006). Section modulus increased significantly in the EL (P=0.016) but not in the CL (P=0.465); mean change+2.3% and+0.7% respectively, whereas minimum neck width increased significantly in the CL (P=0.004) but not in the EL (P=0.166); mean changes being +0.7% and +0.3% respectively.
Conclusion: A 12 month high impact unilateral exercise intervention was feasible and effective for improving femoral neck BMD, BMC and geometry in older men. Carefully targeted high impact exercises may be suitable for incorporation into exercise interventions aimed at preventing fractures in healthy community-dwelling older men.</td></tr>
<tr><td>Follow-up duration: 12 months</td></tr>
<tr><td>Total # participants included: 50</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: BMD and BMC of whole body and both proximal femurs</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Ashe, M. C., et al. "Does frequency of resistance training affect tibial cortical bone density in older women? A randomized controlled trial. Osteoporosis international 2013; 24(2): 623-632.</td></tr>
<tr><td>Purpose:
to determine the effect of three different RT frequencies (0, 1, and 2 times per week) on tibial CovBMD in healthy, community-dwelling postmenopausal women aged 65–75 years of age. Our secondary objective was to investigate the effect ofRT frequency on ToA and tibial bone strength in older women.</td><td rowspan="6">Abstract:
Summary This randomized controlled trial evaluated the effect of resistance training frequency (0, 1, and 2 times/week) on cortical volumetric bone mineral density (vBMD) at the tibia in older women. There was no mean difference in change in tibial cortical vBMD in older women who engaged in resistance training (RT) one or two times/week compared with the control group over 12 months after adjusting for baseline values.
Introduction National guidelines recommend RT two to three times/week to optimize bone health. Our objective was to determine the effect of a 12-month intervention of three different RT frequencies on tibial volumetric cortical density (CovBMD) in healthy older women.
Methods We randomized participants to the following groups: (1) 2×/week balance and tone group (i.e., no resistance beyond body weight, BT), (2) 1×/week RT (RT1), and (3) 2×/week RT (RT2). Treatment allocation was concealed, and measurement team and the bone data analyst were blinded to group allocation. We used peripheral quantitative computed tomography to acquire one 2.3-mm scan at the 50% tibia, and the primary outcome was CovBMD. Data were collected at baseline, 6 and 12 months, and we used linear mixed modelling to assess the effect at 12 months.
Results We assessed 147 participants; 100 women provided data at all three points. Baseline unadjusted mean (SD) tibial CovBMD (in milligrams per cubic centimeter) at the 50% site was 1,077.4 (43.0) (BT), 1,087.8 (42.0) (RT1), and 1,058.7 (60.4) (RT2). At 12 months, there were no statistically significant differences (−0.45 to −0.17 %) between BT and RT groups for mean difference in change in tibial CovBMD for exercise interventions (BT, RT1, RT2) after adjusting for baseline tibial CovBMD.
Conclusion We note no mean difference in change in tibial CovBMD in older women who engaged in RT one or two times/week compared with the control group over 12 months. It is unknown if RT of 3× or 4×/week would be enough to promote a statistically significant difference in change ofbone density.</td></tr>
<tr><td>Follow-up duration: 12 months</td></tr>
<tr><td>Total # participants included: 147</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 6/10</td></tr>
<tr><td>Outcomes addressed:
1. Tibial volumetric cortical density (CovBMD)
2. Tibial area
3. Tbial bone strength</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Binder EF, Brown M et al. Effects of extended outpatient rehabilitation after hip fracture: a randomized controlled trial. JAMA. 2004:292(7);837-846</td></tr>
<tr><td>Purpose: to determine whether extended outpatient rehabilitation that includes progressive resistance training improves physical function and reduces disability compared with low-intensity home exercise among physically frail elderly patients with hip fracture.</td><td rowspan="6">Abstract:
Context Hip fractures are common in the elderly, and despite standard rehabilitation, many patients fail to regain their prefracture ambulatory or functional status.
Objective To determine whether extended outpatient rehabilitation that includes progressive resistance training improves physical function and reduces disability compared with low-intensity home exercise among physically frail elderly patients with hip fracture.
Design, Setting, and Patients Randomized controlled trial conducted between August 1998 and May 2003 among 90 community-dwelling women and men aged 65 years or older who had had surgical repair of a proximal femur fracture no more than 16 weeks prior and had completed standard physical therapy.
Intervention Participants were randomly assigned to 6 months of either supervised physical therapy and exercise training (n=46) or home exercise (control condition; n=44).
Main Outcome Measures Primary outcome measures were total scores on a modified Physical Performance Test (PPT), the Functional Status Questionnaire physical function subscale (FSQ), and activities of daily living scales. Secondary outcome measures were standardized measures of skeletal muscle strength, gait, balance, quality of life, and body composition. Participants were evaluated at baseline, 3 months, and 6 months.
Results Changes over time in the PPT and FSQ scores favored the physical therapy group (P= .003 and P=.01, respectively). Mean change (SD) in PPT score for physical therapy was +6.5 (5.5) points (95% confidence interval [CI], 4.6-8.3), and for the control condition was +2.5 (3.7) points (95% CI, 1.4-3.6 points). Mean change (SD) in FSQ score for physical therapy was +5.2 (5.4) points (95% CI, 3.5-6.9) and for the control condition was +2.9 (3.8) points (95% CI, 1.7-4.0). Physical therapy also had significantly greater improvements than the control condition in measures of muscle strength, walking speed, balance, and perceived health but not bone mineral density or fat-free mass.
Conclusion In community-dwelling frail elderly patients with hip fracture, 6 months of extended outpatient rehabilitation that includes progressive resistance training can improve physical function and quality of life and reduce disability compared with low intensity home exercise.</td></tr>
<tr><td>Follow-up duration: 6 months</td></tr>
<tr><td>Total # participants included: 90</td></tr>
<tr><td>Participants bone health at baseline: Physically frail elderly with hip fracture no more than 16 weeks prior</td></tr>
<tr><td>PEDro score: 7/10</td></tr>
<tr><td>Outcomes addressed: BMD of the whole body and hip</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Blumenthal JA, Emery CF et al. Effects of Exercise Training on Bone Density in Older Men and Women. Journal of the American Geriatrics Society. 1991:39(11);1065-1070</td></tr>
<tr><td>Purpose: to determine the effects of up to 14 months of aerobic exercise on measures of bone density in older adults.</td><td rowspan="6">Abstract:
Objectives: To determine the effects of up to 14 months of aerobic exercise on measures of bone density in older adults.
Design: Randomized controlled trial with subjects assigned to either an aerobic exercise condition, non-aerobic yoga, or a wait list non-exercise control group for 4 months. Aerobic fitness and bone density were evaluated in all subjects at baseline (Time 1) and after 4 months (Time 2). A semicrossover design was utilized with all subjects completing 4 months of aerobic exercise, followed by another evaluation (Time 3). All subjects were then given the option of 6 additional months of aerobic exercise, after which they had a fourth evaluation (Time 4).
Setting: An outpatient exercise rehabilitation facility at a large, major medical center.
Subjects: One-hundred-one healthy men (n = 50) and women (n = 51) over age 60 (Mean age = 67.0), recruited from the community. Intervention: The exercise program included stretching, cycle ergometry, and walking three times per week for 60 minutes throughout the course of the study.
Outcome Measures: Aerobic fitness (V02max) as assessed by cycle ergometry, and bone density (bone mineral content) measured by single photon absorptiometry.
Results: Subjects achieved a 10%-15% increase in VOzmax after 4 months of exercise training, and 1%-6% further improvement with additional training. Aerobic fitness was associated with significant increases in bone density in men, but not women, who maintained aerobic exercise for 14 months.</td></tr>
<tr><td>Follow-up duration: 14 months</td></tr>
<tr><td>Total # participants included: 101</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 6/10</td></tr>
<tr><td>Outcomes addressed: BMD of distal radius of the non-dominant arm</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Bunout D, Barrera G, et al. The impact of nutritional supplementation and resistance training on the health functioning of free-living Chilean elders: results of 18 months of follow up. J Nutr. 2001:131(9);244IS-6S.</td></tr>
<tr><td>Purpose: to assess the impact of an 18-mo nutritional supplementation and resistance training program on health functioning of elders.</td><td rowspan="6">Abstract:
Body composition changes and loss of functionality in the elderly are related to substandard diets and progressive sedentariness. The aim of this study was to assess the impact of an 18-mo nutritional supplementation and resistance training program on health functioning of elders. Healthy elders aged ≥70 y were studied. Half of the subjects received a nutritional supplement. Half of the supplemented and nonsupplemented subjects were randomly assigned to a resistance exercise training program. Every 6 mo, a full assessment was performed. A total of 149 subjects were considered eligible for the study and 98 (31 supplemented and trained, 26 supplemented, 16 trained and 25 without supplementation or training) completed 18 mo of follow-up. Compliance with the supplement was 48%, and trained subjects attended 56% of programmed sessions. Activities of daily living remained constant in the supplemented subjects and decreased in the other groups. Body weight and fat-free mass did not change. Fat mass increased from 22.2 ± 7.6 to 24.1 ± 7.7 kg in all groups. Bone mineral density decreased less in both supplemented groups than in the nonsupplemented groups (ANOVA, $P < 0.01$). Serum cholesterol remained constant in both supplemented groups and in the trained groups, but it increased in the control group (ANOVA, $P < 0.05$). Upper and lower limb strength, walking capacity and maximal inspiratory pressure increased in trained subjects. In conclusion, patients who were receiving nutritional supplementation and resistance training maintained functionality, bone mineral density and serum cholesterol levels and improved their muscle strength.</td></tr>
<tr><td>Follow-up duration: 18 months</td></tr>
<tr><td>Total # participants included: 149</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 4/10</td></tr>
<tr><td>Outcomes addressed: BMD and BMC of whole body</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: de Jong N, Chin A et al. Dietary supplements and physical exercise affecting bone and body composition in frail elderly persons. Am J Public Health. 2000:90(6);947-954</td></tr>
<tr><td>Purpose: to determine the effect of enriched foods and all-around physical exercise on bone and body composition in frail elderly persons.</td><td rowspan="6">Abstract:
Objectives. This study determined the effect of enriched foods and all-around physical exercise on bone and body composition in frail elderly persons.
Methods. A 17-week randomized, controlled intervention trial, following a 2 ×2 factorial design—(1) enriched foods, (2) exercise, (3) both, or (4) neither—was performed in 143 frail elderly persons (aged 78.6±5.6 years). Foods were enriched with multiple micronutrients; exercises focused on skill training, including strength, endurance, coordination, and flexibility. Main outcome parameters were bone and body composition.
Results. Exercise preserved lean mass (mean difference between exercisers and nonexercisers: 0.5 kg±1.2 kg; P<.02). Groups receiving enriched food had slightly increased bone mineral density (+0.4%), bone mass (+0.6%), and bone calcium (+0.6%) compared with groups receiving nonenriched foods, in whom small decreases of 0.1%, 0.2%, and 0.4%, respectively, were found. These groups differed in bone mineral density (0.006±0.020 g/cm2; P= .08), total bone mass (19±g; P=.04), and bone calcium (8±21 g; P=.03).
Conclusions. Foods containing a physiologic dose of micronutrients slightly increased bone density, mass, and calcium, whereas moderately intense exercise preserved lean body mass in frail elderly persons.</td></tr>
<tr><td>Follow-up duration: 17-week</td></tr>
<tr><td>Total # participants included: 161</td></tr>
<tr><td>Participants bone health at baseline: Frail elderly BMI ≤ 25 kg/m2</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: Body composition/ BMD of whole body</td></tr>
</table>

Study design: Randomised controlled trial **Citation:** Duckam RL, Masud T, et al. Randomised controlled trial of the effectiveness of community group and home-based falls prevention exercise programmes on bone health in older people: the ProAct65+ bone study. *Age Ageing.* 2015:44(4);573-9.	
Purpose: to evaluate the skeletal effects of home (Otago Exercise Programme, OEP) and group (Falls Exercise Management, FaME) falls prevention exercise programmes relative to usual care in older people. **Follow-up duration:** 24 weeks **Total # participants included:** 319 **Participants bone health at baseline:** Healthy **PEDro score:** 6/10 **Outcomes addressed:** BMD of femoral neck, whole body, lumbar spine, proximal femur and distal forearm	**Abstract:** **Background:** exercise can reduce osteoporotic fracture risk by strengthening bone or reducing fall risk. Falls prevention exercise programmes can reduce fall incidence, and also include strengthening exercises suggested to load bone, but there is little information as to whether these programmes influence bone mineral density (BMD) and strength. **Objective:** to evaluate the skeletal effects of home (Otago Exercise Programme, OEP) and group (Falls Exercise Management, FaME) falls prevention exercise programmes relative to usual care in older people. **Methods:** men and women aged over 65 years were recruited through primary care. They were randomised by practice to OEP, FaME or usual care. BMD, bone mineral content (BMC) and structural properties were measured in Nottingham site participants before and after the 24-week intervention. **Results:** participants were 319 men and women, aged mean (SD) 72(5) years. Ninety-two percentage of participants completed the trial. The OEP group completed 58(43) min/week of home exercise, while the FaME group completed 39(16) and 30(24) min/week of group and home exercise, respectively. Femoral neck BMD changes did not differ between treatment arms: mean (95% CI) effect sizes in OEP and FaME relative to usual care arm were −0.003(−0.011,0.005) and −0.002(−0.010,0.005) g cm−2, respectively; P= 0.44 and 0.53. There were no significant changes in BMD or BMC at other skeletal sites, or in structural parameters.

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Englund U, Littbrand H, et al. A 1-year combined weight-bearing training program is beneficial for bone mineral density and neuromuscular function in older women. Osteoporosis Int. 2005:16(9);1117-23.</td></tr>
<tr><td>Purpose: to determine if a combined weight-bearing training program twice a week would be beneficial to bone mineral density and neuromuscular function.</td><td rowspan="6">Abstract:
Forty-eight community living women 66–87 years old volunteered to participate in a 12-month prospective, randomized, controlled, trial. The aim was to determine if a combined weight-bearing training program twice a week would be beneficial to bone mineral density and neuromuscular function. The participants were pairwise age-matched and randomly assigned to either an exercise group (n=24) or a control group (n=24). Twenty-one subjects in the intervention group and 19 in the control group completed the study. The exercise program lasted for 50 min and consisted of a combination of strengthening, aerobic, balance and coordination exercises. The mean percentage of scheduled sessions attended for the exercise group was 67%. At the completion of the study, the intervention group showed significant increments in bone mineral density of the Ward's triangle (8.4%, P<0.01) as well as improvement in maximum walking speed (11.4%, P<0.001) and isometric grip strength (9.9%, P<0.05), as compared to the control group. The conclusion was that a combined weight-bearing training program might reduce fracture risk factors by improving bone density as well as muscle strength and walking ability. This program could be suitable for older community living women in general, and might, therefore, have important implications for fracture prevention.</td></tr>
<tr><td>Follow-up duration: 12 months</td></tr>
<tr><td>Total # participants included: 48</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed:
1. BMD of lumbar spine, femoral neck, trochanter, Ward's triangle, arms, total body (g/cm2)
2. BMC total body (g)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Restropective study
Citation: Greedale GA, Barrett-connor E et al. Lifetime leisure exercise and osteoporosis – The Rancho-Bernardo study. American Journal of Epidemiology. 1995:141(90); 951-9.</td></tr>
<tr><td>Purpose: the effect of self-reported current and prior leisure time physical activity on axial and appendicular bone mineral density (BMD) and osteoporotic fracture in a population-based sample of older adults.</td><td rowspan="6">Abstract:
Between 1988 and 1991, the relation between leisure time physical activity, bone mineral density (BMD), and osteoporotic fracture was evaluated in a cohort of community-dwelling California adults (1,014 women and 689 men) with a mean age of 73 years. By means of a modified Paffenbarger questionnaire, participants were asked to report exercise from the past year and to recall their level of exercise during three other periods: the teenage years, age 30 years, and age 50 years. The survey asked the number of times strenuous (e.g., jogging), moderate (e.g., fast walking), or mild (e.g., golfing) exercise was undertaken in an average week. A summary score was constructed to represent lifetime exercise. Analyses of the exercise-fracture and exercise BMD associations were performed using logistic and linear regression analyses, respectively. Linear regression models were controlled for age, body mass index, sex, diagnosis of arthritis, dietary calcium intake, and use of cigarettes, alcohol, thiazides, and estrogen (women only). No association between current or former exercise and BMD at the radius, wrist, or spine was found. A positive association between current exercise and BMD was found at the total hip (p = 0 001) and at each hip component—greater trochanter (p = 0.02), intertrochanter (p = 0.001), and femoral neck (p = 0.02). Mean hip bone densities of strenuous (p = 0.004) and moderate (p = 0.004) current exercisers were higher than those of mild or less than mild exercisers. Lifetime exercise was also positively associated with BMD of the total hip (p = 0.008) and hip components, and demonstrated a borderline-significant association (p = 0.06) with spine BMD. At the hip, each pairwise comparison between the highest and lowest tertiles of lifetime exercise showed a significant difference (p ^ 0.007). Exercise was unassociated with minimal trauma fracture occurring at any site between 1972 and 1991. These data suggest a protective effect of current and lifelong exercise on hip BMD, but not on osteoporotic fracture, in older men and women.</td></tr>
<tr><td>Follow-up duration: NA</td></tr>
<tr><td>Total # participants included: 1,703</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: NA</td></tr>
<tr><td>Outcomes addressed: BMD of subject's non dominant arm at distal radius and midshaft radius, lumbar spine (L1-4) and hip (femoral neck, intertrochanter, greater trochanter and total hip)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Helge EW, Anderson TR et al. Recreational football improves bone mineral density and bone turnover marker profile in elderly men. Scand J Med Sci Sports. 2014:24(1);98-104.</td></tr>
<tr><td>Purpose: the effect of recreational football and resistance training on bone mineral density (BMD) and bone turnover markers (BTMs) in elderly men</td><td rowspan="6">Abstract:
This study examined the effect of recreational football and resistance training on bone mineral density (BMD) and bone turnover markers (BTMs) in elderly men. Twenty-six healthy sedentary men (age 68.2 ± 3.2 years) were randomized into three groups: football (F; n = 9) and resistance training (R; n = 9), completing 45–60 min training two to three times weekly, and inactive controls (C; n = 8). Before, after 4 months, and after 12 months, BMD in proximal femur (PF) and whole body (WB) were determined together with plasma osteocalcin (OC), procollagen type-1 amino-terminal propeptide (P1NP), and carboxy-terminal type-1 collagen crosslinks (CTX-1). In F, BMD in PF increased up to 1.8% ($P < 0.05$) from 0 to 4 months and up to 5.4% ($P < 0.001$) from 0 to 12 months; WB-BMD remained unchanged. After 4 and 12 months of football, OC was 45% and 46% higher ($P < 0.001$), and P1NP was 41% and 40% higher ($P < 0.001$) than at baseline, respectively. After 12 months, CTX-1 showed a main effect of 43% ($P < 0.05$). In R and C, BMD and BTM remained unchanged. In conclusion, 4 months of recreational football for elderly men had an osteogenic effect, which was further developed after 12 months, whereas resistance training had no effect. The anabolic response may be due to increased bone turnover, especially improved bone formation.</td></tr>
<tr><td>Follow-up duration: 12 months</td></tr>
<tr><td>Total # participants included: 26</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: BMD of whole body and proximal femur</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Observational study
Citation: Huddleston, A. L., et al. Bone mass in lifetime tennis athletes.1980; JAMA 244(10): 1107-1109.</td></tr>
<tr><td>Purpose: to present the results of a study in which the relationship between bone mineral mass and exercise was investigated for a population of lifetime athletes</td><td rowspan="6">Abstract:
The effects of physical exercise on the status of bone mineralization for a population of lifetime athletes were investigated. The bone mineral content of the radii of experienced male tennis players was measured. The bone mass of the radius of the playing arm (mean, 1.37 g/cm) was greater than that of the nonplaying arm (mean, 1.23 g/cm) in all but one person. The results were compared with data for a nonathletic (normal) population. The quantity of bone mineral present in the playing arms of the athletic population was greater than that of the dominant arms of nonathletes, which suggests that playing tennis during a lifetime may produce a localized increase in bone mineralization that is greater than that found in non-athletes.</td></tr>
<tr><td>Follow-up duration: NA</td></tr>
<tr><td>Total # participants included:</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: NA</td></tr>
<tr><td>Outcomes addressed: BMC and bone width of midshaft of radius</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Jessup JV, Horne C et al. Effects of exercise on bone density, balance and self-efficacy in older women. Biol Res Nurs. 2003:4(3);171-180.</td></tr>
<tr><td>Purpose: the effects of weighted vest walking and strength-training exercises on bone mineral density (BMD), balance, strength, and self-efficacy were tested in older women.</td><td rowspan="6">Abstract:
The effects of weighted vest walking and strength-training exercises on bone mineral density (BMD), balance, strength, and self-efficacy were tested in older women. Eighteen women, age 69.2 ± 3.5 years, were randomly assigned to an exercise group (EG) (n= 9), or a sedentary control group (CG) (n= 9). The EG participated in 32 weeks (three 1-h sessions/week) of supervised strength training and walking, stair climbing, and balance exercises while wearing weighted vests. The CG did not exercise. All women took Ca2+ and vitamin D during the study period. Measures included 1) BMD of the hip and lumbar spine measured by dual-energy X-ray absorptiometry, 2) strength, 3) balance, and 4) scores on a self-efficacy instrument. The EG had significant improvements in bone density of the femoral neck and balance and a significant weight loss (P < 0.05). There were no changes in self-efficacy in either group.</td></tr>
<tr><td>Follow-up duration: 32 weeks</td></tr>
<tr><td>Total # participants included: 18</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: BMD of femoral neck and lumbar spine</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Karinkanta S, Heinonen A et al. A multi-component exercise regimen to prevent functional decline and bone fragility in home-dwelling elderly women: randomized, controlled trial. Osteoporosis Int. 2007:18(4);453-62.</td></tr>
<tr><td>Purpose: the effects of two different training programs and their combination on physical functioning and bone in home-dwelling elderly women.</td><td rowspan="6">Abstract:
Summary This study showed that combination of strength, balance, agility and jumping training prevented functional decline and bone fragility in home-dwelling elderly women. The finding supports the idea that it is possible to maintain good physical functioning by multi-component exercise program and thus postpone the age-related functional problems.
Introduction This 1-year randomized, controlled exercise intervention trial assessed the effects of two different training programs and their combination on physical functioning and bone in home-dwelling elderly women.
Methods One hundred and forty-nine healthy women aged 70–78 years were randomly assigned into: group 1—resistance training (RES), group 2—balance-jumping training (BAL), group 3—combination of resistance and balance-jumping training (COMB), and group 4—controls (CON). Self-rated physical functioning, leg extensor force, dynamic balance, and bone mass and structure were measured.
Results Self-rated physical functioning improved in the COMB group, but was reduced in the CON group; the mean inter-group difference was 10% (95% CI: 0–22%). Mean increase in the leg extensor force was higher in the RES (14%; 4–25%) and COMB (13%; 3–25%) compared with the CON groups. Dynamic balance improved in the BAL (6%; 1–11%) and in the COMB (8%; 3–12%) groups. There were no inter-group differences in BMC at the proximal femur. In those COMB women who trained at least twice a week, the tibial shaft structure weakened 2% (0–4%) less than those in the CON group.
Conclusions Strength, balance, agility, and jumping training (especially in combination) prevented functional decline in home-dwelling elderly women. In addition, positive effects seen in the structure of the loaded tibia indicated that exercise may also play a role in preventing bone fragility.</td></tr>
<tr><td>Follow-up duration: 1 year</td></tr>
<tr><td>Total # participants included: 149</td></tr>
<tr><td>Participants bone health at baseline: healthy and excluded participants with osteoporosis</td></tr>
<tr><td>PEDro score: 7/10</td></tr>
<tr><td>Outcomes addressed: Bone mineral content of Femoral neck</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Kemmler W, von Stengel S et al. 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.</td></tr>
<tr><td>Purpose: to determine whether a single exercise program affects fracture risk (bone mineral density [BMD] and falls), coronary heart disease (CHD) risk factors, and health care costs in community dwelling elderly women.

Follow-up duration: 18-month

Total # participants included: 227

Participants bone health at baseline: Healthy

PEDro score: 6/10

Outcomes addressed: Lumbar spine and femoral neck BMD</td><td>Abstract:
Background: Physical exercise affects many risk factors and diseases and therefore can play a vital role in general disease prevention and treatment of elderly individuals and may reduce costs. We sought to determine whether a single exercise program affects fracture risk (bone mineral density [BMD] and falls), coronary heart disease (CHD) risk factors, and health care costs in community dwelling elderly women.
Methods: We conducted a randomized, single-blinded, controlled trial from May 1, 2005, through July 31, 2008, recruiting women 65 years or older who were living independently in the area of Erlangen-Nuremberg, Germany. In all, 246 women were randomly assigned to an 18-month exercise program (exercise group) or a wellness program (control group). The exercise group (n=123) performed a multipurpose exercise program with special emphasis on exercise intensity; the controls (n=123) focused on well-being with a low-intensity, low-frequency program. The main outcome measures were BMD, the number of falls, the Framingham-based 10-yearCHD risk, and direct health care costs.
Results: For the 227 women who completed the 18month study, significant exercise effects were observed for BMD of the lumbar spine (mean [95% confidence interval (CI)] percentage of change in BMD [baseline to follow-up] for the exercise group: 1.77% [1.26% to 2.28%] vs controls: 0.33% [−0.24% to 0.91%]; P<.001), femoral neck (exercise group: 1.01% [0.37% to 1.65%] vs controls: −1.05% [−1.70% to −0.40%]; P<.001), and fall rate per person during 18 months (exercise group: 1.00 [0.76 to 1.24] vs controls: 1.66 [1.33 to 1.99]; P=.002). The 10 year CHD risk was significantly affected in both subgroups (absolute change for the exercise group: −1.96% [95% CI, −2.69% to −1.23%] vs controls: −1.15% [−1.69% to −0.62%]; P=.22), with no significant difference between the groups. The direct health care costs per participant during the 18-month intervention showed nonsignificant differences between the groups (exercise group: €2255 [95% CI, €1791-€2718] vs controls: €2780 [€2187€3372]; P=.20).
Conclusion: Compared with a general wellness program, our 18-month exercise program significantly improved BMD and fall risk, but not predicted CHD risk, in elderly women. This benefit occurred at no increase in direct costs.</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Quasi-randomised trial
Citation: Kohrt W, Ehsani AA et al. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. J Bone Miner Res. 1997:12(8);1253-1261.</td></tr>
<tr><td>Purpose: This study compared the effects of two exercise training programs, 11 months in duration, on bone mineral density (BMD) in older, sedentary women.</td><td rowspan="6">Abstract:
This study compared the effects of two exercise training programs, 11 months in duration, on bone mineral density (BMD) in older, sedentary women. Thirty-nine women, aged 60–74 years, were assigned to the following groups: (a) a group that performed exercises that introduced stress to the skeleton through ground-reaction forces (GRF) (i.e., walking, jogging, stairs); (b) a group that performed exercises that introduced stress to the skeleton through joint-reaction forces (JRF) (i.e., weight lifting, rowing); or (c) a no-exercise control group. BMD of the whole body, lumbar spine, proximal femur, and distal forearm was assessed five times at ~3-month intervals. The GRF and JRF exercise programs resulted in significant and similar increases in BMD of the whole body (2.0 ± 0.8% and 1.6 ± 0.4%, respectively), lumbar spine (1.8 ± 0.7% and 1.5 ± 0.5%, respectively), and Ward's triangle region of the proximal femur (6.1 ± 1.5% and 5.1 ± 2.1%, respectively). There was a significant increase in BMD of the femoral neck only in response to the GRF exercise program (GRF, 3.5 ± 0.8%; JRF, -0.2 ± 0.7%). There were no significant changes in BMD in control subjects. Among all exercisers, there was a significant inverse (r = -0.52, p < 0.01) relationship between increases in whole body BMD and reductions in fat mass, suggesting a dose response effect of exercise on bone mass. Although femoral neck BMD was responsive only to the GRF exercise program, some adaptations (i.e., increase in lean body mass and strength) that were specific to the JRF exercise program may be important in preventing osteoporotic fractures by reducing the risk for falls. It remains to be determined whether all of these benefits can be gained through a training program that combines the different types of exercises employed in this study.</td></tr>
<tr><td>Follow-up duration: 11 months</td></tr>
<tr><td>Total # participants included: 39</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 3/10</td></tr>
<tr><td>Outcomes addressed:
1. BMD of Lumbar spine L2–L4 and femoral neck and whole body</td></tr>
</table>

Study design: Quasi-randomised trial **Citation:** Kwon, Y, Park S et al. The effects of multi-component exercise training on VO_2max, muscle mass, whole bone mineral density and fall risk in community-dwelling elderly women. 2008 Japanese Journal of Physical Fitness and Sports Medicine 57: 339-348.	
Purpose: to investigate the changes in maximum oxygen consumption, muscle mass, whole bone mineral density, and risk factors for falls after 24 weeks of multi-component exercise training	**Abstract:** The purpose of this study was to investigate the changes in maximum oxygen consumption, muscle mass, whole bone mineral density, and risk factors for falls after 24 weeks of multi-component exercise training. Subjects were consisted of forty elderly women from the same community who had an MMSE score higher than 24. The combined exercise program included stretching for 20 minutes, low impact aerobic exercises for 30 minutes, and 30 minutes of resistance training. The program was conducted 3 times a week for 24 weeks. We found that the VO_2 max, muscle mass and BMD of greater trochanter were significantly increased. Balance function and body sway were also significantly improved. Therefore, it appears that increased physical activity through multi-component exercise training plays a positive role in improving body composition and reducing risk factors for falls due to aging.
Follow-up duration: 6 months	
Total # participants included: 40	
Participants bone health at baseline: Healthy	
PEDro score: 3/10	
Outcomes addressed: BMD of lumbar spine (L2-4), femoral neck, ward's triangle, greater trochanter and the whole body	

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Lau EM, Woo J et al. The effects of calcium supplementation and exercise on bone density in elderly Chinese women. Osteoporosis Int. 1992:2(4);168-73.</td></tr>
<tr><td>Purpose: to determine whether calcium supplementation and load-bearing exercise can increase or maintain bone mass in the elderly.</td><td rowspan="6">Abstract:
A randomized controlled trial was carried out to determine whether calcium supplementation and load-bearing exercise can increase or maintain bone mass in the elderly. Fifty Chinese women, aged 62-92 years, living in a hostel for the elderly in Hong Kong were randomized to enter one of four treatment groups: (I) calcium supplementation of 800 mg (as calcium lactate gluconate) daily; (II) load-bearing exercise four times a week plus a daily placebo tablet; (III) calcium supplementation daily and load-bearing exercise four times a week; (IV) a placebo tablet daily. The interventions went on for 10 months. The bone mineral density (BMD) was measured at three sites in the hip (femoral neck, Ward's triangle and intertrochanteric area) and the L2-4 level of the spine. The percentage change in BMD in 10 months was used as the main outcome measurement. The parathyroid hormone level and indices of bone metabolism were also measured before and after 10 months of intervention. The BMD at Ward's triangle and the intertrochanteric area increased significantly in subjects on calcium supplement (p<0.05), but there was no significant change at the spine and femoral neck. Exercise had no effect on bone loss at any site. However, the results of two-way analysis of variance showed a significant joint effect of calcium supplements and exercise at the femoral neck (p<0.05), but not at the other sites. The parathyroid hormone levels fell significantly in subjects on calcium supplements (p<0.01). Calcium supplement in the form of calcium lactate gluconate was adequately absorbed in elderly Chinese women with a calcium intake of less than 300 mg per day. It was effective in reducing bone loss at the hip, and there may be interaction effects with exercise in maintaining bone density.</td></tr>
<tr><td>Follow-up duration: 10 months</td></tr>
<tr><td>Total # participants included: 50</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 4/10</td></tr>
<tr><td>Outcomes addressed:
% change in BMD hip (neck of femur, Wards triangle) and lumbar spine</td></tr>
</table>

Study design: Randomised controlled trial **Citation:** Lord SR, Ward JA et al. The effects of a community exercise program on fracture risk factors in older women. *Osteoporosis Int.* 1996:6(5);361-7.	
Purpose: to determine whether a program of twice-weekly structured exercise has beneficial effects on three factors associated with osteoporotic fractures: quadriceps strength, postural sway and bone density.	**Abstract:** One hundred and seventy-nine women aged 60-85 years (mean age 71.6 years, SD 5.3 years) were randomly recruited from the community to participate in a 12-month randomized controlled trial to determine whether a program of twice-weekly structured exercise has beneficial effects on three factors associated with osteoporotic fractures: quadriceps strength, postural sway and bone density. At initial testing, there were no significant differences in the strength, sway and bone density measures (assessed at the hip and lumbar spine) between the exerciser and control groups. The exercise classes included strengthening, coordination and balance exercises, and approximately 35 min of each class comprised weight-bearing exercise. The mean number of classes attended for the 68 exercisers who completed the program was 59.8 of the 82 classes (72.9%). At the completion of the trial, the intervention group showed significant improvements in quadriceps strength and sway but not bone mineral density when compared with the control group. Indices of fracture risk, indicated by (i) the sum of standard score results and (ii) the sum of quartile grades of the femoral neck bone density, sway and strength measures, decreased significantly in the exercisers at the end of the trial compared with the controls. In conclusion, the program of general aerobic exercise may have reduced overall fracture risk, even though it did not significantly increase bone density. Further long-term studies are required that include acceptable weight-loaded exercises to determine optimal programs for reducing fracture risk factors by improving bone density as well as strength and balance.
Follow-up duration: 12 month	
Total # participants included: 179	
Participants bone health at baseline: Healthy	
PEDro score: 4/10	
Outcomes addressed: BMD of Lumbar spine, femoral neck, trochanter	

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Marques EA, Mota J et al. Multicomponent training program with weight-bearing exercises elicits favorable bone density, muscle strength and balance adaptations in older women. Calcif Tissue Int. 2011:88(2);117-29.</td></tr>
<tr><td>Purpose: to examine the effects of 8-month multicomponent training with weight-bearing exercises on different risk factors of falling, including muscle strength, balance, agility, and bone mineral density (BMD) in older women.</td><td rowspan="6">Abstract:
Physical exercise is advised as a preventive and therapeutic strategy against aging-induced bone weakness. In this study we examined the effects of 8-month multicomponent training with weight-bearing exercises on different risk factors of falling, including muscle strength, balance, agility, and bone mineral density (BMD) in older women. Participants were randomly assigned to either an exercise-training group (ET, n = 30) or a control group (CON, n = 30). Twenty-seven subjects in the ET group and 22 in the CON group completed the study. Training was performed twice a week and was designed to load bones with intermittent and multidirectional compressive forces and to improve physical function. Outcome measures included lumbar spine and proximal femoral BMD (by dual X-ray absorptiometry), muscle strength, balance, handgrip strength, walking performance, fat mass, and anthropometric data. Potential confounding variables included dietary intake, accelerometer-based physical activity, and molecularly defined lactase nonpersistence. After 8 months, the ET group decreased percent fat mass and improved handgrip strength, postural sway, strength on knee flexion at 180°/s, and BMD at the femoral neck (+2.8%). Both groups decreased waist circumference and improved dynamic balance, chair stand performance, strength on knee extension for the right leg at 180°/s, and knee flexion for both legs at 60°/s. No associations were found between lactase nonpersistence and BMD changes. Data suggest that 8 months of moderate-impact weight-bearing and multicomponent exercises reduces the potential risk factors for falls and related fractures in older women.</td></tr>
<tr><td>Follow-up duration: 8 month</td></tr>
<tr><td>Total # participants included: 60</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: BMD of whole body, lumbar spine (L1-L4) and femoral neck</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: McCartney N, Hicks AL et al. Long-term resistance training in the elderly: effects on dynamic strength, exercise capacity, muscle and bone. J Gerontol A Biol Sci Med Sci. 1995:50(2);B97-104.</td></tr>
<tr><td>Purpose: to examine the effects of progressive weight-lifting training on muscle strength, peak power output, endurance, knee extensor cross-sectional areas, and bone mineral density and content in men and women aged 60-80</td><td rowspan="6">Abstract:
We examined the effects of 42 weeks of progressive weight-lifting training on dynamic muscle strength, peak power output in cycle ergometry, symptom limited endurance during progressive treadmill walking and stair climbing, knee extensor cross-sectional areas, and bone mineral density and content in healthy males and females aged 60-80 years, currently enrolled in a 2-year resistance training program. Subjects were randomized into either exercise (EX) or control (CON) groups (60-70 years: 38 males and 36 females; 70-80 years: 25 males and 43 females). EX trained several muscle groups twice per week for 42 weeks at intensities ranging from 50-80% of the load that they could lift once only (1 RM); CON did usual daily activities. After the 10 months there was no change in 1 RM strength in CON, but significant gains (mean increases up to 65%) in EX (no independent age or gender effects); 30% and 47% of the increase in 1 RM had occurred by 6 and 12 weeks, respectively. In EX, the 7.1% increase in peak cycling power output was significantly greater than in CON (+1.1%). The 17.8% improvement in symptom limited treadmill walking endurance was also greater than in CON (+3.4%), but the difference between groups during stair climbing was not significant (EX + 57%, CON + 33%). The cross-sectional areas of the knee extensors increased significantly by 5.5% in EX but were unchanged in CON. There were no changes in bone mineral density or content in either group. We conclude that long-term resistance training in older people is feasible and results in increases in dynamic muscle strength, muscle size, and functional capacity.</td></tr>
<tr><td>Follow-up duration: 24 weeks</td></tr>
<tr><td>Total # participants included: 142</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 3/10</td></tr>
<tr><td>Outcomes addressed: BMD and BMC of whole body and lumbar spine (L2-4)</td></tr>
</table>

Study design: Randomised controlled trial **Citation:** McMurdo, MET, Mole PA et al. Controlled trial of weight bearing exercise in older women in relation to bone density and falls. *British Medical Journal* 1997: 314(7080): 569.	
Purpose: to assess the effects of weight bearing exercise on bone in elderly women	This publication has no abstract
Follow-up duration: 2 years	
Total # participants included: 92	
Participants bone health at baseline: Healthy	
PEDro score: 4/10	
Outcomes addressed: BMC of the non-dominant distal forearm BMD of lumbar vertebral bone	

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Paillard T, Lafont C et al. Effects of brisk walking on static and dynamic balance, locomotion, body composition and aerobic capacity in ageing healthy active men. Int J Sports Med. 2004:25(7);529-46.</td></tr>
<tr><td>Purpose: to analyse the short-term physiological and neurophysiological effects of a brisk walking programme in ageing, healthy, active men.</td><td rowspan="6">Abstract:
This work analyses the short-term physiological and neurophysiological effects of a brisk walking programme in ageing, healthy, active men. Twenty-one men 63 to 72 years of age were recruited and separated into 2 groups. One group performed a walking programme (WP) (n = 11) and another served as control (C) group (n = 10). The walking programme lasted for twelve weeks and included five sessions per week. Several parameters were assessed before and after the programme for the WP group. The same tests were performed (separated by twelve weeks) in group C. During each assessment, the subjects were put through static and dynamic balance tests, spatio-temporal gait analysis, body composition measurements and determination of aerobic capacity and bone mineral density. The statistic analysis showed a significant improvement in dynamic balance performance, especially in lateral sway when the subjects kept their eyes open, an increase of VO2 max and loss of fat mass in the WP group. However, no alterations appeared in spatiotemporal gait characteristics, static balance performance, lean mass or bone mineral density (total body and hip). According to these results, this walking programme may have positive effects on preventing ageing subjects from falling.</td></tr>
<tr><td>Follow-up duration: 12 weeks</td></tr>
<tr><td>Total # participants included: 21</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: BMD of total body and hip</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Park H, Kim KJ et al. 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.</td></tr>
<tr><td>Purpose: to investigate whether a 48-week multicomponent exercise program could improve the risk factors for fall and hip fracture.</td><td rowspan="6">Abstract:
The purpose of this study was to investigate whether a 48-week multicomponent exercise program could improve the risk factors for fall and hip fracture. Fifty elderly women 65–70 years of age participated. These participants were divided into an exercise group (25 subjects) that attended an exercise program and a control group (25 subjects) that did not. The exercise program included stretching for 9 min, strength training for 10 min followed by 23 min of weight-bearing exercise at an intensity above 65%–75% of the maximal heart rate, and 18 min of balance and posture correction training. The program was conducted three times per week for 48 weeks. The 10-m maximal walk time, maximal step length, and eyes-open-one-legged-stand time in the exercise group improved significantly (P < 0.05). Concerning deoxypyridinoline, the exercise group achieved a significant improvement (P < 0.05) after the 48 weeks. Bone mineral density (BMD) of the femoral neck and trochanter in the exercise group was significantly increased after the exercise program; also body sway was significantly improved (P < 0.05). In conclusion, a multicomponent exercise program with weight-bearing exercise at a moderate intensity and gait training may be effective in offsetting a decline in BMD and improving aggravation of bone resorption in this population. In addition, this program has a positive effect on postural stability and gait ability.</td></tr>
<tr><td>Follow-up duration: 28 weeks</td></tr>
<tr><td>Total # participants included: 50</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: BMD of femoral neck, lumbar spine (L2 to L4), trochanter and ward’s triangle</td></tr>
</table>

Study design: Randomised controlled trial **Citation:** Pruitt LA, Taaffe DR et al. Effects of a one-year high-intensity versus low-intensity resistance training program on bone mineral density in older women. *J Bone Miner Res.* 1995:10(11);1788-1795.	
Purpose: to determine the effects of a 12-month resistance training program, of two different intensities, on bone mineral density (BMD) in healthy, older women.	**Abstract:** The purpose of this study was to determine the effects of a 12-month resistance training program, of two different intensities, on bone mineral density (BMD) in healthy, older women. Twenty-six Caucasian women (aged 65-79 years) completed the study. Subjects were randomly assigned to one of three groups: high-intensity (HI; n = 8), low-intensity (LI; n = 7), and control (CON; n = 11). The active groups performed 10 exercises, 3 days/week under supervision. Exercise intensity was maintained at 80% of one-repetition maximum (1-RM) for the HI group, and at 40% 1-RM for the LI group. The volume of work was maintained constant between the two groups by assigning the LI group twice as many repetitions for each exercise. Maximal muscular strength and BMD of the lumbar spine and total hip were measured at baseline and at 12 months. Strength was evaluated using the 1-RM method, and BMD was determined by dual-energy X-ray absorptiometry. Exercise session attendance was similar for the two groups (81.0% HI, 76.8% LI). Muscular strength improved in the exercisers compared with the CON group ($p \leq 0.05$). Percentage change in lumbar spine BMD was 0.7 ± 1.9%, 0.5 ± 2.4%, and -0.1 ± 23% for the HI, LI, and CON groups, respectively. Percentage change in total hip BMD was 0.8 ± 23% (HI), 1.0 ± 1.7% (LI), and 0.9 ± 1.3% (CON). Group differences in BMD change were not significant ($p > 0.05$). These findings suggest that high-intensity and low-intensity resistance training regimens effectively increase muscular strength, but not lumbar spine or total hip BMD, in healthy, older women.
Follow-up duration: 12 month	
Total # participants included: 26	
Participants bone health at baseline: Healthy	
PEDro score: 4/10	
Outcomes addressed: BMD lumbar spine, hip (total hip, femoral neck, Wards triangle)	

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Rhodes EC, Martin AD et al. Effects of one year of resistance training on the relation between muscular strength and bone density in elderly women. Br J Sports Med. 2000:34(1);18-22.</td></tr>
<tr><td>Purpose: to investigate the effects of one year of progressive resistance exercise (PRE) on dynamic muscular strength and the relations to bone mineral density (BMD) in elderly women.</td><td rowspan="6">Abstract:
Objectives—There is a paucity of long term studies on exercise training in elderly women. The purpose of this study was to investigate the effects of one year of progressive resistance exercise (PRE) on dynamic muscular strength and the relations to bone mineral density (BMD) in elderly women.
Methods—Forty four healthy sedentary women (mean age 68.8 years) volunteered for this study and were randomly assigned to either an exercise group or a control group. The exercise group were involved in three one hour sessions a week for 52 weeks of supervised PRE to strengthen the large muscle groups of the body, while the control group were instructed to continue their normal lifestyle. The exercise circuit included three sets of eight repetitions at 75% of one repetition maximum focused on the large muscle groups. BMD was measured by dual energy x ray absoptiometry (Lunar DPX) at the lumbar spine and at three sites in the proximal femur. Other selected parameters of physical fitness were also measured.
Results—Statistical analyses (analysis of covariance) showed significant strength gains (p<0.01) in bilateral bench press (>29%), bilateral leg press (>19%), and unilateral biceps curl (>20%). No significant difference between groups was evident in bodyweight, grip strength, flexibility, waist to hip ratio, or the sum of eight skinfolds. Significant relations (p<0.05) were recorded between dynamic leg strength and the BMD of the femoral neck, Ward's triangle, and the lumbar spine.
Conclusions—Significant strength changes, after one year of PRE, were evident in elderly women, and the muscle increases may parallel changes in BMD; however, correlation coefficients were moderate.</td></tr>
<tr><td>Follow-up duration: 12 months</td></tr>
<tr><td>Total # participants included: 44</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed: Femoral neck BMD, Ward's triangle BMD, Trochanter BMD, Lumbar spine (L2-L4) BMD, Femoral neck BMC, Ward's triangle BMC, Trochanter BMC, Lumbar spine (L2-L4) BMC</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Cohort
Citation: Rikkonen, T, Sa;pvaara K et al. Physical activity slows femoral bone loss but promotes wrist fractures in postmenopausal women: a 15-year follow-up of the OSTPRE study. J Bone Miner Res 2010: 25(11): 2332-2340.</td></tr>
<tr><td>Purpose: to determine whether there is an association between long-term regular PA and the risk of fractures among postmenopausal women. Second, we aimed to find out whether specific fracture types are associated with PA and to clarify the relationship among PA, long-term BMI change, and bone loss.</td><td rowspan="6">Abstract:
Results on fracture risk among physically active persons are contradictory. The aim of this study was to investigate the long-term association between the self-reported physical activity (PA), the risk of fractures, and bone loss among peri- and postmenopausal women. The association between PA and fracture risk was examined during 15 years of follow-up in the population-based Osteoporosis Risk Factor and Prevention (OSTPRE) Study among 8560 women with a mean age of 52.2 years (range 47 to 56 years) at baseline. The amount and type of PA, as well as the types and mechanisms of fractures, were registered with self-administered questionnaires at 5-year intervals (i.e., 1989, 1994, 1999, and 2004). A total of 2641 follow-up fractures were verified in 2073 women (24.2%). The study cohort was divided into quartiles by average hours of reported PA during the whole follow-up. Areal bone mineral density (aBMD) at the proximal femur (n¼2050) and lumbar spine (L2–L4; n¼1417) was followed at 5-year intervals from a random stratified subsample with dual X-ray absorptiometry (DXA). Risk of fracture was estimated by using the Cox proportional hazards model with a mean follow-up time of 15.2 years. Weekly average time spent on leisure-time PA was 0.4, 1.7, 3.3, and 7.0 hours from the least to the most active quartiles, respectively. The risk of wrist fracture was higher in the active quartiles (II to IV) than in the most inactive quartile (I), with hazard ratios (HRs) of 1.3 [95% confidence interval (CI) 1.05–1.57, p¼.014] for the second (II), 1.2 (95% CI 1.01–1.51, p¼.045) for the third (III), and 1.4 (95% CI 1.14–1.69, p¼.001) for the fourth (IV) quartile, respectively. Overall, most of the fractures were reported as a result of a fall (69.0%), with a 2.1 times higher rate of wrist fractures during the winter (November to April) than during summer season. There were no significant associations of PA with any other fracture types. Bone loss at the femoral neck, trochanter, and Ward's triangle was significantly associated with long-term PA (ANCOVA p<.05), whereas no associations of bone loss and PA in lumbar spine were seen. PA is associated with a moderate rise in wrist fracture risk, which might be explained in part by a higher number of outdoor activities. Regular PA of at least 1½ hours per week does not seem to increase the risk of other fractures and might significantly decrease proximal femur bone loss among peri- and postmenopausal women. ß 2010 American Society for Bone and Mineral Research.</td></tr>
<tr><td>Follow-up duration: 15 years</td></tr>
<tr><td>Total # participants included: 8560</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: NA</td></tr>
<tr><td>Outcomes addressed: BMD of proximal femur, lumbar spine (L2-4)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Quasi-randomised trial
Citation: Rikli RE, McManis BG. Effects of exercise on bone mineral content in postmenopausal women. Res Q Exerc Sport. 1990:61(3);243-9.</td></tr>
<tr><td>Purpose: to test the effects of a 10-month exercise program on bone mineral content (BMC) and bone mineral content/bone width (BMC/BW) of postmenopausal women.</td><td rowspan="6">Abstract:
The purpose of this study was to test the effects of a 10-month exercise program on bone mineral content (BMC) and bone mineral content/bone width (BMC/BW) of postmenopausal women. Thirty-one women (ages 57-83) completed either a general aerobics exercise program (n =10), a general aerobics plus upper body weight training exercise program (n =10), or served as nonexercising control subjects (n =11). Average compliance rates for the exercise subjects ranged from 72 to 80%. All subjects were pre- and post-tested for BMC and BMC/BW in the radius of the nondominant forearm. ANDVA results indicated that there were significant differences between the exercise and control subjects in the amount of change in BMC and in BMC/BW (p < .05) during the course of the study. The exercise subjects experienced mean increases of 1.38% and 133% in BMC and BMC/BW, respectively, whereas the control group had decreases of 2.50% and 2.58%. No significant differences were found for subjects in the two types of exercise programs, suggesting that the effects of exercise relative to maintenance of bone density may be general as well as localized.</td></tr>
<tr><td>Follow-up duration: 10 month</td></tr>
<tr><td>Total # participants included: 31</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 1/10</td></tr>
<tr><td>Outcomes addressed: Bone mineral content (BMC) at ½ distal radius</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Sakai A, Oshige T et al. Unipedal standing exercise and hip bone mineral density in postmenopausal women: a randomized controlled trial. J Bone Miner Metab. 2010:28(1);42-8.</td></tr>
<tr><td>Purpose: to test the effect of unipedal standing exercise on bone mineral density (BMD) of the hip in postmenopausal women.</td><td rowspan="6">Abstract:
The aim of this study was to test the effect of unipedal standing exercise on bone mineral density (BMD) of the hip in postmenopausal women. Japanese postmenopausal women (n = 94) were assigned at random to an exercise or control group (no exercise). The 6-month exercise program consisted of standing on a single foot for 1 min per leg 3 times per day. BMD of the hip was measured by dual-energy X-ray absorptiometry. There was no significant difference in age and baseline hip BMD between the exercise group (n = 49) and control group (n = 45). Exercise did not improve hip BMD compared with the control group. Stepwise regression analysis identified old age as a significant determinant (p = 0.034) of increased hip total BMD at 6 months after exercise. In 31 participants aged C70 years, the exercise group (n = 20) showed significant increase in the values of hip BMD at the areas of total (p = 0.008), intertrochanteric (p = 0.023), and Ward’s triangle (p = 0.032). The same parameters were decreased in the control group (n = 11). The percent changes in hip BMD of the exercise group were not significantly different from those of the control group either in the participants with low baseline hip total BMD (<80% of the young adult mean) or high baseline hip total BMD (≥80% of the young adult mean). In conclusion, unipedal standing exercise for 6 months did not improve hip BMD in Japanese postmenopausal women. Effect of exercise on hip total BMD was age dependent. In participants aged ≥70 years, the exercise significantly increased hip total BMD.</td></tr>
<tr><td>Follow-up duration: 6 month</td></tr>
<tr><td>Total # participants included: 94</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 4/10</td></tr>
<tr><td>Outcomes addressed: BMD DEXA neck, trochanter, intertrochanter, Ward's triangle</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Shen CL, Williams JS et al. Comparison of the effects of Tai Chi and resistance training on bone metabolism in the elderly: a feasibility study. Am J Clin Med. 2007:35(3);369-81.</td></tr>
<tr><td>Purpose: to compare the effects of Tai Chi (TC) and resistance training (RT) on bone metabolism in the elderly.</td><td rowspan="6">Abstract:
This feasibility study compared the effects of Tai Chi (TC) and resistance training (RT) on bone metabolism in the elderly. Twenty eight sedentary, elder adults, were randomized into either TC (n = 14, 78.8 +/−1.3 years) or RT (n = 14, 79.4 +/−2.2 years) to participate in 40 min of exercise per session, 3 sessions/week for 24 weeks. The outcome measures assessed were the concentrations of serum bone-specific alkaline phosphatase (BAP), pyridinoline (PYD), parathyroid hormone (PTH) and calcium, and urinary calcium. The TC group had a higher compliance rate than the RT group. After 6 weeks, (i) both TC and RT resulted in higher level of serum BAP relative to the baseline and the TC group exhibited a greater increase in serum BAP than the RT group; (ii) there was an increase of serum PYD in the RT group only, not in the TC group; and (iii) the BAP/PYD ratio was higher than baseline only in the TC group, and the increase of the ratio in the TC group was greater than that in the RT group. After 12 weeks, the increase in serum PTH in the TC group was higher than the RT group. After 24 weeks, there was a reduction of the urinary calcium level in the TC group relative to the baseline. In conclusion, these findings support that TC is beneficial for increasing bone formation in elderly, and long-term application is needed to substantiate the effect of TC as an alternative exercise in promotion of bone health.</td></tr>
<tr><td>Follow-up duration: 24 weeks</td></tr>
<tr><td>Total # participants included: 28</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 6/10</td></tr>
<tr><td>1) Bone specific alkaline phosphatase (BAP), concentration change (%)
2) Pyridinoline (PYD), concentration change (%)
3) Parathyroid hormone (PTH), concentration change (%)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Stengel S, Kemmler W et al. Effects of whole body vibration on bone mineral density and falls: results of the randomized controlled ELVIS study with postmenopausal women. Osteoporosis International. 2011:22(1);317-325.</td></tr>
<tr><td>Purpose: to determine whether the effect of exercise on bone mineral density (BMD) and falls can be enhanced by whole body vibration (WBV). In summary, the multipurpose exercise training was effective to increase lumbar BMD but added WBV did not enhance this effect.</td><td rowspan="6">Abstract:
Summary We determined whether the effect of exercise on bone mineral density (BMD) and falls can be enhanced by whole body vibration (WBV). In summary, the multipurpose exercise training was effective to increase lumbar BMD but added WBV did not enhance this effect. However, falls were lowest in the exercise program combined with WBV.
Introduction WBV is a new approach to reduce the risk of osteoporotic fractures. In the “Erlangen Longitudinal Vibration Study” (ELVIS), we investigated whether WBV enhances the effect of multifunctional exercise on BMD and falls.
Methods One hundred fifty-one postmenopausal women (68.5±3.1 years) were randomly assigned to a: (1) conventional training group (TG); (2) conventional training group including vibration (TGV); and (3) wellness control group (CG). TG conducted an exercise program consisting of 20 min dancing aerobics, 5 min balance training, 20 min functional gymnastics, and 15 min dynamic leg-strength training on vibration plates (without vibration) twice a week. TGV performed an identical exercise regimen with vibration (25–35 Hz) during the leg-strengthening sequence. CG performed a low-intensity wellness program. BMD was measured at the hip and lumbar spine at baseline and follow-up using the DXA method. Falls were recorded daily via the calendar method.
Results After 18 months, an increase in BMD at the lumbar spine was observed in both training groups (TGV: +1.5% vs. TG: +2.1%). The difference between the TG and the CG (1.7%) was significant. At the hip no changes were determined in either group. The fall frequency was significantly lower in TGV (0.7 falls/person) compared with CG (1.5), whereas the difference between TG (0.96) and CG was not significant.
Conclusions A multifunctional training program had a positive impact on lumbar BMD. The application of vibration did not enhance these effects. However, only the training including WBV affected the number of falls significantly.</td></tr>
<tr><td>Follow-up duration: 18 months</td></tr>
<tr><td>Total # participants included: 151</td></tr>
<tr><td>Participants bone health at baseline:
Healthy</td></tr>
<tr><td>PEDro score: 7/10</td></tr>
<tr><td>Outcomes addressed:
BMD of proximal femur and lumbar spine (L1 to L4)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Quasi-randomised trial
Citation: Smith, EL, Reddan W, et al. Physical activity and calcium modalities for bone mineral increase in aged women. Med Sci Sports Exerc 1981:13(1): 60-64.</td></tr>
<tr><td>Purpose: to test whether physical activity, and/or calcium and vitamin D taken as an oral dietary supplement, would effectively slow bone loss, maintain and/ or increase bone mineral content in aged females over a 36-month period</td><td rowspan="6">Abstract:
This study tested the hypothesis that physical activity and/or supplemental calcium (0.75 g/day) and vitamin D (400 IU) would effectively slow bone loss, and/or increase bone mineral content (BMC) in aged females (V = 81) over three years. In vivo BMC and width of the radius was determined by photon absorptiometry at two sites. Four groups were formed: a control, a drug, a physical activity, and a physical activity plus drug. A single tailed t-test was used to compare the slope of the linear regression of 10 data points collected on each subject. The BMC of the control group declined 3.29%, while the physical activity group and drug group demonstrated a 2.29% (p<.05) increase and a 1.58% (p<.07) increase respectively, during the study.</td></tr>
<tr><td>Follow-up duration: 3 years</td></tr>
<tr><td>Total # participants included: 51</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: NA</td></tr>
<tr><td>Outcomes addressed:
BMC and bone width(BW) of the radius at 1/3 the distance from the olecranon to the head of the ulnar</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Taaffe DR, Durect C et al. Once-weekly resistance exercise improves muscle strength and neuromuscular performance in older adults. J Am Geriatr Soc. 1999:47(10);1208-14.</td></tr>
<tr><td>Purpose: to determine the effect of frequency of resistive training on gain in muscle strength and neuromuscular performance in healthy older adults.</td><td rowspan="6">Abstract:
OBJECTIVE: To determine the effect of frequency of resistive training on gain in muscle strength and neuromuscular performance in healthy older adults. DESIGN A randomized controlled trial with subjects assigned either to high-intensity resistance training 1 (EXl), 2 (EX2), or 3 (EX3) days per week for 24 weeks or to a control group (CO).
SETTING: An exercise facility at an academic medical center.
SUBJECTS: Forty-six community-dwelling healthy men (n = 29) and women (n = 17) aged 65 to 79 years.
INTERVENTION: Progressive resistance training consisting of three sets of eight exercises targeting major muscle groups of the upper and lower body, at 80% of one-repetition maximum (1-RM) for eight repetitions, either 1,2, or 3 days per week.
MEASURES: Dynamic muscle strength (1-RM) using isotonic equipment every 4 weeks, bone mineral density and body composition by dual energy X-ray absorptiometry (DXA), and neuromuscular performance by timed chair rise and 6-meter backward tandem walk.
RESULTS: For each of the eight exercises, muscle strength increased in the exercise groups relative to CO (P < .Ol), with no difference among EX1, EX2 and EX3 groups at any measurement interval. Percent change averaged 3.9 ± 2.4 (CO), 37.0 ± 15.2 (EXl), 41.9 ± 18.2 (EX2), and 39.7 ± 9.8 (EX3). The time to rise successfully from the chair 5 times decreased significantly (P < .01) at 24 weeks, whereas improvement in the 6-meter backward tandem walk approached significance (P = .10) in the three exercise groups compared with CO. Changes in chair rise ability were correlated to percent changes in quadriceps strength (T = -0.40, P < .01) and lean mass (T = -0.40, P < .01).
CONCLUSIONS: A program of once or twice weekly resistance exercise achieves muscle strength gains similar to 3 days per week training in older adults and is associated with improved neuromuscular performance. Such improvement could potentially reduce the risk of falls and fracture in older adults.</td></tr>
<tr><td>Follow-up duration: 24 weeks</td></tr>
<tr><td>Total # participants included: 46</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 5/10</td></tr>
<tr><td>Outcomes addressed:
BMD of the lumbar spine (L2 to L4), total hip, midradius, and total body bone mineral content (TBBMC, g)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Quasi-randomised trial
Citation: Villareal DT, Binder EF et al. Effects of Exercise Training Added to Ongoing Hormone Replacement Therapy on Bone Mineral Density in Frail Elderly Women. Journal of the American Geriatrics Society. 2003:51(7);985-990.</td></tr>
<tr><td>Purpose: to determine whether exercise training added to ongoing hormone replacement therapy (HRT) increases bone mineral density (BMD) in physically frail elderly women.</td><td rowspan="6">Abstract:
OBJECTIVES: To determine whether exercise training added to ongoing hormone replacement therapy (HRT) increases bone mineral density (BMD) in physically frail elderly women.
DESIGN: Prospective controlled trial.
SETTING: University-based research center.
PARTICIPANTS: Twenty-eight women on HRT, aged 75 and older with physical frailty.
INTERVENTIONS: Participants were assigned to 9 months of supervised (EXER) or home (HOME) exercise. The EXER program started with physical therapy and gradually incorporated resistance and endurance training. The HOME program consisted of flexibility exercises.
MEASUREMENTS: Changes in BMD and body composition.
RESULTS: There were larger increases in lumbar spine BMD in response to EXER than with HOME (3.5% vs 1.5%, P = .048), with a trend for larger increases in total body BMD (1.5% vs 0.2%, P = .058). There were no significant between-group differences in hip BMD. The EXER group had decreases in weight (- 2.2 ± 0.3 kg, P = .010) and fat mass (- 2.7 ± 0.4 kg, P = .018) and increases in muscle strength (9–30%, P < .05).
CONCLUSION: In physically frail elderly women on HRT, relatively vigorous exercise training significantly increased lumbar spine BMD. The improved BMD and strength in response to exercise could reduce fracture risk in frail women already on HRT</td></tr>
<tr><td>Follow-up duration: 9 months</td></tr>
<tr><td>Total # participants included: 28</td></tr>
<tr><td>Participants bone health at baseline: Mild to moderate physical frailty who remained with hormone replacement therapy</td></tr>
<tr><td>PEDro score: 4/10</td></tr>
<tr><td>Outcomes addressed: BMD of whole body, lumbar spine and hip</td></tr>
</table>

Study design: Quasi-randomsied trial **Citation:** Villareal, DT, Steger-May K et al. Effect of exercise training on bone mineral density in frail older women and men: a randomized controlled trial. *Age and Ageing*. 2004:33(3); 309-12.	
Purpose: to evaluate the effects of a multi component exercise programme, compared with low intensity home exercise, on BMD in older frail individuals.	This publication has no abstract
Follow-up duration: 9 months	
Total # participants included: 119	
Participants bone health at baseline: Mild-to-moderate physical frailty	
PEDro score: NA	
Outcomes addressed: BMD of whole body, lumbar spine and proximal femur	

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Woo J, Hong A et al. 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.</td></tr>
<tr><td>Purpose: to examine the effects of Tai Chi (TC) and resistance exercise (RTE) on bone mineral density (BMD), muscle strength, balance and flexibility in community living elderly people.</td><td rowspan="6">Abstract:
Background: the beneficial role of exercise in improving bone mineral density, muscle strength and balance, has been documented predominantly in younger populations. These findings may not apply to elderly populations with limited ability to perform exercises of high intensity.
Objective: to examine the effects of Tai Chi (TC) and resistance exercise (RTE) on bone mineral density (BMD), muscle strength, balance and flexibility in community living elderly people.
Design: randomised controlled trial, using blocked randomization with stratification by sex.
Setting: a community in the New Territories Region of Hong Kong, China.
Subjects: one hundred eighty subjects (90 men, 90 women) aged 65–74, were recruited through advertisements in community centres.
Methods: subjects were assigned to participate in TC, RTE three times a week, or no intervention (C) for 12 months. Measurements were carried out at baseline, 6 and 12 months. Analyses of covariance (ANCOVA) adjusted for age, and baseline values of variables that were significantly different between groups: i.e. smoking and flexibility for men; quadriceps strength for women.
Results: compliance was high (TC 81%, RTE 76%). In women, both TC and RTE groups had less BMD loss at total hip compared with controls. No effect was observed in men. No difference in either balance, flexibility or the number of falls was observed between either intervention or controls after 12 months.
Conclusion: the beneficial effects of TC or RTE on musculoskeletal health are modest and may not translate into better clinical outcomes.</td></tr>
<tr><td>Follow-up duration: 12 months</td></tr>
<tr><td>Total # participants included: 180</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 6/10</td></tr>
<tr><td>Outcomes addressed:
Bone mineral density (total hip +spine)</td></tr>
</table>

<table>
<tr><td colspan="2">Study design: Randomised controlled trial
Citation: Yoo EJ, Jun TW et al. The effects of a walking exercise program on fall-related fitness, bone metabolism, and fall-related psychological factors in elderly women. Res Sports Med. 2010:18(4);236-50.</td></tr>
<tr><td>Purpose: to determine the effects of a 3-month walking exercise program with ankle weights on fall-related fitness, bone metabolism, and fall-related psychological factors.</td><td rowspan="6">Abstract:
The purpose of this study was to determine the effects of a 3-month walking exercise program with ankle weights on fall-related fitness, bone metabolism, and fall-related psychological factors. Fall-related fitness was determined from strength, balance, agility, aerobic endurance, muscle mass, and fat mass measures. Bone metabolism was measured using bone density, hormones, and biochemical markers. Fall-related psychological factors included fear of falling and falls efficacy. A 2 × 2 factorial with repeated measures design was used. All subjects were community-dwelling elderly women who volunteered to participate, and randomly were assigned to either an exercise group (n = 11) or a control group (n = 10). Results revealed significant changes in upper body strength, leg strength, aerobic endurance, and body composition. Additionally, hormones and biochemical markers changed significantly over time. Trunk fat and fear of falling changed differently among the two groups. In conclusion, this study suggests that a 3-month walking exercise program with ankle weights may have positive effects on fall-related fitness, bone metabolism, and fall-related psychological factors.</td></tr>
<tr><td>Follow-up duration: 3 month</td></tr>
<tr><td>Total # participants included: 21</td></tr>
<tr><td>Participants bone health at baseline: Healthy</td></tr>
<tr><td>PEDro score: 4/10</td></tr>
<tr><td>Outcomes addressed: BMD of spine, whole body and total hip</td></tr>
</table>

REFERENCES

1. World Health Organization. Global Strategy on Diet, Physical Activity and Health 2010.
2. 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.
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