# Effectiveness of exercise interventions on physical function in community-dwelling frail older people: an umbrella review of systematic reviews

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## ABSTRACT

**Objectives:** This umbrella review aimed to determine the effectiveness of exercise interventions, alone or in combination with other interventions, in improving physical function in community-dwelling older people identified as pre-frail or frail.

**Introduction:** Exercise is said to have a positive impact on muscle mass and strength which improves physical function and hence is beneficial for the treatment of frailty. Several systematic reviews discuss the effects of exercise interventions on physical function parameters, such as strength, mobility, gait, balance and physical performance, and indicate that multi-component exercise, including resistance, aerobic, balance and flexibility training, appears to be the best way in which to improve physical function parameters in frail older people. However, there is still uncertainty as to which exercise characteristics (type, frequency, intensity, duration and combinations) are the most effective and sustainable over the long-term.

**Inclusion criteria:** Participants were adults, 60 years or over, living in the community and identified as pre-frail or frail. Quantitative systematic reviews, with or without meta-analysis that examined the effectiveness of exercise interventions of any form, duration, frequency and intensity, alone or in combination with other interventions designed to alter physical function parameters in frail older people, were considered. The quantitative outcome measures were physical function, including muscular strength, gait, balance, mobility and physical performance.

**Methods:** An iterative search strategy for ten bibliometric databases and gray literature was developed. Critical appraisal of seven systematic reviews was conducted independently by two reviewers using a standard Joanna Briggs Institute tool. Data was extracted independently by two reviewers using a standard Joanna Briggs Institute data extraction tool and summarized using a narrative synthesis approach.

**Results:** Seven systematic reviews were included in this umbrella review, with a total of 58 relevant randomized controlled trials and 6927 participants. Five systematic reviews examined the effects of exercise only, while two systematic reviews reported on exercise in combination with a nutritional approach, including protein supplementations, as well as fruit and dairy products. The average exercise frequency was 2–3 times per week (mean $3.0 \pm 1.5$ times per week; range 1–7 weekly) for 10–90 minutes per session (mean of $52.0 \pm 16.5$ mins) and a total duration of 5–72 weeks with the majority lasting a minimum of 2.5 months (mean $22.7 \pm 17.7$ weeks). Multi-component exercise interventions can currently be recommended for pre-frail and frail older adults to improve muscular strength, gait speed, balance and physical performance, including resistance, aerobic, balance and flexibility tasks. Resistance training alone also appeared to be beneficial, in particular for improving muscular strength, gait speed and physical performance. Other types of exercise were not sufficiently studied and their effectiveness is yet to be established.

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**Conclusions:** Interventions for pre-frail and frail older adults should include multi-component exercises, including in particular resistance training, as well as aerobic, balance and flexibility tasks. Future research should adopt a consistent definition of frailty and investigate the effects of other types of exercise alone or in combination with nutritional interventions so that more specific recommendations can be made.

**Keywords** Community-dwelling; exercise interventions; frailty; older people; umbrella review

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## Introduction

The world's population is aging. The proportion of Australians aged 65 years and over, for example, increased from 11.8% to 14.7% between 1994 and 2014.[1] Maintaining health and independence, avoiding functional decline and improving health-related quality of life are significant challenges for older adults.[2]

Because aging is accompanied by physiological changes, such as reduced hormone production, oxidative stress, poor cellular oxygenation and reduced mobility,[3] the proportion of older people in danger of becoming frail will increase as the population ages.[4] While many people can experience the natural physiological alteration of aging cells with no uncommon issues, for a large number of the elderly, growing older means growing frailer. Many researchers and geriatricians now consider frailty to be a clinical syndrome, defined by the presence of specified symptoms and signs. The World Health Organization has noted that frailty has become an indicator of unsuccessful aging.[5]

The most commonly used frailty phenotype criteria by Fried *et al.*[6] categorizes people into robust, pre-frail and frail by using a physiological approach to frailty. Fried *et al.* propose that the following five indicators are related to each other within a framework of frailty: unintentional weight loss, exhaustion, slow walking speed, low grip strength and low physical activity. A person with three or more of these criteria is categorized as frail; a person with one or two criteria is considered to be pre-frail; and those with none of the indicators are considered to be robust.

In the last two decades there has been a sharp rise in frailty research due to the increasing need for effective interventions to manage the condition.[7] Evidence suggests that exercise interventions can be used to restore or maintain functional independence in older adults[8] and subsequently help prevent institutionalization and increasing health care costs. Exercise interventions may also potentially prevent, delay or reverse frailty.[9,10]

A preliminary search revealed that several systematic reviews have been conducted to examine the effects of exercise interventions, both alone[10-14] and in combination with nutritional supplements,[15,16] on important functional parameters in frail older people, such as strength, mobility, gait speed, balance and physical performance. Low muscular strength and slow gait speed, for example, are strong indicators for frailty.[6] Mobility includes a person's ability to physically move and is usually measured by tests including muscular strength and gait, while physical performance is based on the combination of mobility, gait speed and balance tasks representing a person's ability to physically function as a multidimensional concept.[17]

The exercise interventions described in the various reviews indicate that multi-component exercises, including resistance, aerobic and balance training, can alleviate functional decline and improve strength in frail older people.[11,12] However, the randomized controlled trials included in two of the systematic reviews demonstrated both positive and negative outcomes of the exercise interventions.[13,14] Interventions including both exercise and nutrition supplements also showed contentious results. Lee *et al.*[18] showed that exercise combined with diet improves strength and gait speed more significantly than exercise alone, whereas Cruz-Jentoft *et al.*[15] demonstrated that resistance exercise in combination with protein supplementation did not improve muscle strength and physical performance. Uncertainty exists for which exercise characteristics (type, frequency, duration, and intensity) are the most effective, either alone or in combination with other interventions. Nevertheless, the American College of Sports Medicine's (ACSM)[19] has published updated guidelines for physical activity in older adults that recommend the prioritization of resistance exercise over aerobic training for this

population. The conflicting results of some of the systematic reviews indicate the need for an umbrella review to better understand and evaluate the effectiveness of exercise interventions and their characteristics.

Therefore, an umbrella review was conducted to examine the effectiveness of exercise intervention, alone or in combination with other interventions, for improving physical function in community-dwelling older people identified as frail or at-risk of frailty. This review was conducted according to an *a priori* published protocol.[20]

## Review objective

The objectives of this umbrella review were to: i) determine the effectiveness of exercise interventions, alone or in combination with other interventions, for improving physical function in community-dwelling older people who are identified as frail or at-risk of frailty, and (ii) identify if any particular intervention type or characteristic is more effective than others.

## Inclusion criteria

### *Participants*

This umbrella review included systematic reviews involving individuals:

- Aged 60 years and above: more specifically, it was proposed that at least 50% of the people included in the review were 60 years or over, OR that the mean age of the people in the study was at least 60 years. If one of these criteria was fulfilled but the other was not, the review was included.
- Living in the community: more specifically, it was proposed that at least 50% of people included in the review were living in the community in their own homes.
- Identified as frail or at-risk of frailty using an operationalized definition of frailty or standardized criteria to measure frailty: more specifically, it was proposed that at least 50% of the people included in the review were identified as frail or at-risk of frailty.

The following indices for measuring frailty identified by Bouillon *et al.*[21] were accepted in this umbrella review: Gronigen Frailty Indicator (GFI),[22] Frailty Index (FI),[23] Canadian Study of Health and Aging (CSHA), Clinical Frailty Scale,[24] Vulnerable Elder Survey-13 (VES-13),[25] Tilburg Frailty Indicator (TFI),[26] Physical Frailty Score,[27] Phenotype of Frailty,[6] Edmonton Frail Scale (EFS)[28] and the Study of Osteoporotic Fractures Index (SOF Index).[29]

Any other frailty indicators used by author/s of systematic reviews which were based on the indices above were also considered for inclusion.

Reviews that did not provide sufficient detail about the sample populations of included studies were excluded. Reviews that did not use an operationalized definition of frailty or standardized criteria to measure frailty according to Bouillon *et al.* were excluded.[21] Reviews that focused on healthy older people or older people in hospital, sub-acute settings or nursing homes were excluded. Nursing homes were defined as ''a facility with a domestic-styled environment that provides 24-hour functional support and care for persons who require assistance with activities of daily living (ADL) and who often have complex health needs and increased vulnerability''.[30(p.183)]

### *Interventions*

Systematic reviews that evaluated exercise interventions of any form, duration, frequency and intensity, alone or in combination with other interventions designed to alter physical function in frail older people, were included in this umbrella review. The types of exercise interventions included but were not limited to:

- Resistance or strength training
- Aerobic or endurance training
- Balance training
- Flexibility or stretching training
- Multi-component training.

Systematic reviews that included interventions that were not combined with exercise were excluded. To determine the effectiveness of exercise interventions, included reviews had to use either a control group (i.e. no intervention, placebo intervention, usual care) or a comparator group (i.e. another type of exercise, exercise in combination with other interventions).

### *Outcomes*

The primary outcomes were quantitative measures of physical function in frail older people including:

- Muscular strength defined as the maximal amount of force a muscle can produce measured

by, for example, grip strength or lower limb strength.
- Gait speed defined as the time it takes to walk a specific distance measured by, for example, six-minute walking test (6MWT).
- Balance defined as the ability to maintain a controlled body position during task performance measured by, for example, Berg Balance Scale or tandem stand.
- Mobility defined as the person's ability to move physically measured by, for example, the Timed Up and Go Test or chair rise and stand.
- Physical performance defined as a multidimensional concept based on the combination of mobility, gait speed and balance skills measured by, for example, the Physical Performance Test.

The umbrella review excluded systematic reviews of physical function outcomes that were measured using non-standard or invalidated measures.

### *Types of studies*

This umbrella review considered any quantitative systematic reviews with or without meta-analysis that examined the effectiveness of exercise interventions, alone or in combination with other interventions, in relation to improving physical function in frail older people. Included systematic reviews provided:

- A clearly articulated and comprehensive search strategy including at least two or more bibliographic databases.
- Evidence of critical appraisal/assessment of risk of bias.

If it was not clear whether the inclusion criteria had been met, authors were contacted for confirmation before including or excluding the review. Furthermore, literature reviews, withdrawn or retracted publications, systematic reviews not published in English, and earlier versions of updated systematic reviews were also excluded.

## Methods

### *Search strategy*

The search strategy aimed to find both published and unpublished reviews. The following electronic databases/sources were broadly searched for published systematic reviews and meta-analyses: PubMed, Embase, CINAHL, Scopus, The Cochrane Database of Systematic Reviews, *JBI Database of Systematic Reviews and Implementation Reports*, Web of Science, Campbell Collaboration Library of Systematic Reviews and Google Scholar. Gray literature was searched using Google and ProQuest Dissertations and Theses. Only reviews published in the English language were considered for inclusion in this umbrella review. Reviews published from 1990 (as this pre-dates some of the earliest work in this field) until September 2016 were considered for inclusion.

The final search strategies, which were developed using an iterative process to minimize false positives and optimize results, are included in Appendix I.

### *Assessment of methodological quality*

Reviews selected for retrieval were assessed using the eligibility criteria listed in Appendix II. Reviews that met all the eligibility criteria were appraised by two independent reviewers for methodological validity using a standardized critical appraisal instrument from the Joanna Briggs Institute System for the Unified Management, Assessment and Review Instrument (JBI SUMARI) and the JBI Reviewers' Manual.[31]

The quality of each review was ranked based on the following criteria: 0–33% of criteria met (low quality), 34–66% of criteria met (medium quality) and 67% or more of criteria met (high quality).[31] No review was excluded on the basis of a critical appraisal score, and all reviews that were appraised and met the eligibility criteria were included in data extraction. Any differences of opinion between the reviewers were resolved through discussion or by consulting a third reviewer (TS).

### *Data extraction and synthesis*

The data were extracted using a standardized JBI instrument designed for umbrella reviews.[31] The following information was extracted from each review included in the umbrella review: i) type of study design; ii) country where the review was conducted; iii) number of studies in the review; iv) sample size; v) type of exercise intervention and its characteristics, and its combination with other interventions; vi) effect on physical function parameters; and vii) main results.

Data related to interventions were extracted from selected systematic reviews and tabulated, accompanied by a narrative synthesis to address the review question. All possible statistical measures were

retrieved, such as effect size, 95% confidence intervals and heterogeneity.

Interventions were judged on the strength of the evidence for their effectiveness. Beneficial and effective interventions were given a tick (✓). Interventions that did not show any benefit were marked with a cross (X). An earlier protocol[20] suggesting the use of traffic light colours was not used because it was not possible to differentiate between a lack of effect (orange) and a detrimental effect (red) for any intervention compared to a control. The effectiveness of the intervention was based on the total number of participants affected positively across the relevant trials (i.e. seven trials [n = 391] showed an increase [↑]; four trials [n = 602] showed no effects [−]; overall decision X).

An overall assessment of the quality of the evidence for each comparison using GRADE (Grading of Recommendations, Assessment, Development and Evaluation)[31] was not possible. The original GRADE scores derived for the included systematic reviews were rendered inaccurate because the umbrella review extracted a subset of relevant RCTs from the included systematic reviews for all interventions.

## Results

### *Review inclusion/exclusion*

The literature search identified 1437 titles, of which 1390 records were from bibliometric databases (Fig. 1). The search in gray literature identified 47 records. After removing duplicates (n = 263), the

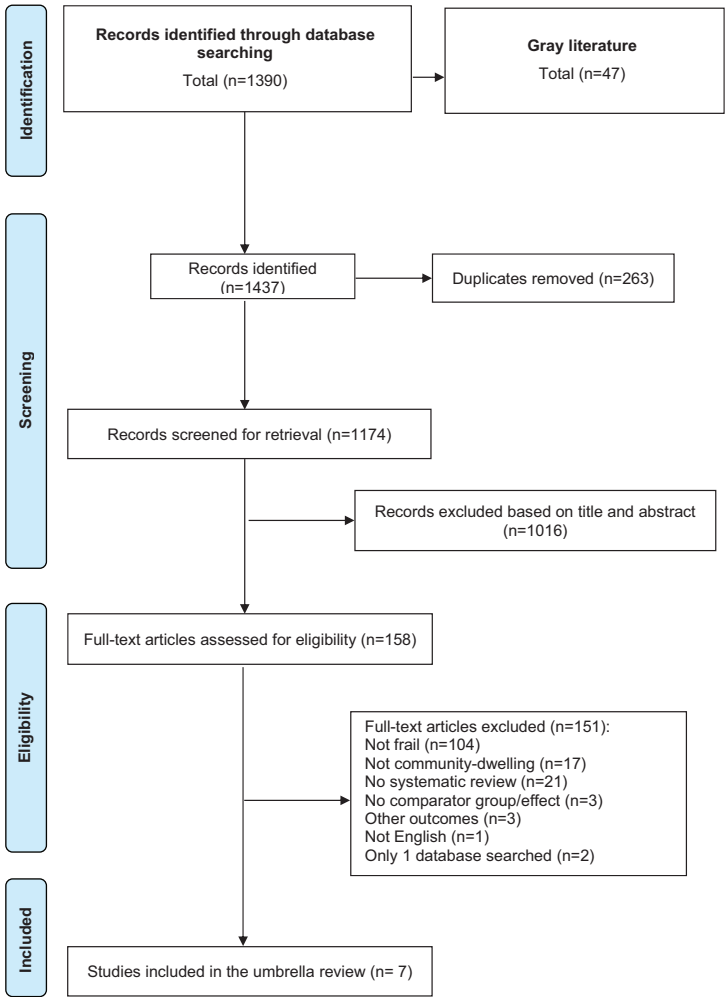


**Figure 1: PRISMA flowchart chart of study selection and inclusion process[32]**

titles and abstracts of 1174 records were screened independently by two reviewers and 1016 records were excluded as irrelevant to the umbrella review. Full text reviews assessing the eligibility of the remaining 158 records were conducted by two reviewers independently and 151 records failed to meet at least one of the five eligibility criteria (type of study, participants, interventions, outcomes and language). The remaining seven records progressed to the critical appraisal stage using the checklist for the verification of review eligibility (Appendix II). All seven systematic reviews had been identified from the original search of bibliometric databases. The last search was conducted in September 2016.

### Characteristics of included reviews

The seven systematic reviews included a total of 157 randomized controlled trials (RCTs), but only 59 (37.6%) RCTs were considered to be relevant for this review based on the inclusion criteria (Appendix II). The relevant RCTs included one duplicate[11,13] which was considered only once throughout this umbrella review, resulting in 58 relevant RCTs. Information from this subset of RCTs relevant to the umbrella review question was extracted from the selected reviews (Appendix III). The number of participants involved in the relevant trials (n = 58) was 6927 (from a total sample size of 14,642). The grand mean of the mean age from selected reviews was 80.9 years.

Five systematic reviews reported on the gender of participants from included RCTs[10,12-15] and the majority of the participants were female (68.5%). In regards to the classification of pre-frail and frail participants, five systematic reviews[11-13,15,16] included RCTs only if they followed an operationalized definition of frailty or used standardized criteria to measure frailty. Two systematic reviews,[10,14] including 21 relevant RCTs, however, did not include RCTs based on operationalized definitions or standardized criteria. Instead, participants were simply identified as frail in either text, title or abstract. The 21 RCTs were therefore checked individually to ensure they met the inclusion criteria of this umbrella review.

Of the seven eligible systematic reviews, three were from the Netherlands, two from Spain and one each from the UK and Canada. The reviews were conducted or published between 2008 and 2015. In regards to the individual RCTs (n = 58), it was observed that most RCTs (n = 52; 89.7%) were conducted in or after 2000 and only six RCTs (10.3%) dated back to 1998.

Heterogeneity was calculated in only one systematic review, which included a meta-analysis in addition to a narrative synthesis.[11] The other six systematic reviews conducted a narrative synthesis only.[10,12-16]

### Methodological quality

The critical appraisal results for each of the seven systematic reviews are summarized in Table 1. Six out of seven systematic reviews were of high quality and only one was of medium quality as per the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses.[31] The minimum number of criteria met was six and the maximum was nine, out of 11. Criteria 2–5, relating to inclusion criteria, search strategy, and study appraisal, were met by all

**Table 1: Assessment of methodological quality**

| Citation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | % | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chin *et al.*[14] | Y | Y | Y | Y | Y | Y | Y | N | N | N | Y | 72 | High |
| Clegg *et al.*[13] | Y | Y | Y | Y | Y | N | Y | Y | U | Y | Y | 82 | High |
| Cruz-Jentoft *et al.*[15] | N | Y | Y | Y | Y | U | U | N | N | Y | Y | 55 | Medium |
| Daniels *et al.*[16] | Y | Y | Y | Y | Y | Y | Y | Y | U | U | Y | 82 | High |
| De Labra *et al.*[12] | Y | Y | Y | Y | Y | Y | U | Y | N | U | Y | 73 | High |
| De Vries *et al.*[11] | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | N | 82 | High |
| Theou *et al.*[10] | N | Y | Y | Y | Y | Y | Y | Y | U | Y | Y | 82 | High |

N, criteria not met; U, unclear; Y, criteria met.
0–33% low quality; 34–66% medium quality; ≥67% high quality.

included systematic reviews. Only one systematic review, however, stated that the likelihood of publication bias had been assessed (criteria 9). No reviews were excluded on the basis of methodological quality criteria.

## Findings

### *Intervention characteristics*

#### Type

Five systematic reviews examined the effects of exercise intervention only,[10-14] while two systematic reviews included trials examining exercise in combination with nutritional intervention.[15,16]

In regards to the exercise interventions, 33 trials included multi-component exercises involving resistance, balance, flexibility and aerobic exercises. Fifteen trials examined the effects of resistance exercise only.[10-14] One trial examined resistance exercise with an additional component of motion exercise[13] and one trial assessed balance only.[11] Another trial examined the effect of a horse riding simulator,[10] while another used sit-to-stand exercises with the help of an electronic device called GrandStand™.[11,13] Three trials performed personalized exercise without providing further information on the type of exercise.[11]

Three trials in two systematic reviews[15,16] evaluated the effects of exercise in combination with a nutritional approach. One trial examined the effects of resistance exercise combined with protein supplementation of 30 g per day.[15] Another trial examined multi-component exercise, including resistance, aerobic and balance exercises combined with nutrition (without details of the nutritional supplement),[15] and another trial looked at exercise combined with fruit and dairy products.[16]

#### Frequency

Six systematic reviews reported on the frequency of exercise interventions with a range of 1–7 exercise sessions per week.[10-14,16] The majority of the systematic reviews (n = 3) reported a frequency of 2–3 times per week.[10,13,14] Other systematic reviews reported frequencies of 2–5 sessions per week,[16] 3–7 sessions per week,[12] and 1–7 sessions per week. One systematic review did not provide any information on frequency.[15] The mean exercise frequency was $3.0 \pm 1.5$ times per week. The length of the exercise sessions was stated in five systematic reviews, and ranged between 10 to 90 minutes each session, with a mean of $52.0 \pm 16.5$ mins.[10-12,14,16] Two systematic reviews did not provide any information on the length of the exercise sessions.[13,15]

#### Duration

All seven systematic reviews reported on the duration of the exercise interventions. The total duration of the interventions ranged from 5 to 72 weeks with a mean of $22.7 \pm 17.7$ weeks. The majority of systematic reviews (n = 4) reported a minimum duration of 2.5 months.[10,12,14,16] One systematic review reported a minimum duration of 12 weeks,[15] while two other systematic reviews reported shorter durations of 5 to 6 weeks.[11,13] The maximum duration of exercise interventions ranged between 9, 12 and 18 months.

#### Intensity

The intensity of the exercise interventions was reported in two systematic reviews[12,14] and ranged from 2–3 times of 8–12 repetitions at 85–100% 1RM (repetition maximum), as well as 30–80% 1RM and 60–80% 1RM for resistance exercises. The intensity of aerobic exercises ranged from 15 minutes at 65–70% of VO2max (equivalent to 80% of maximum heart rate in older adults of 65 years) and 3–5 minutes at 85–90% VO2max (equivalent to 90–95% maximum heart rate in older adults of 65 years) to 6–8 points on a 10-point perceived exertion scale. Personalized intensity, and low, medium and high intensity were discussed without further definition. Three systematic reviews did not include any information on intensity[13,15,16] and two systematic reviews stated either low to high intensity or low versus high intensity without any further information.[11,14]

### *Effects on physical function*

#### Muscle strength

Muscular strength was measured using knee extension and flexion for lower limb strength, and grip strength and shoulder strength for upper limb strength. Strength exercises included progressive resistance training alone or with Thera bands, as well as a variation of concentric, isometric and eccentric knee-extension exercises.

Four systematic reviews[12,13,15,16] involving 15 relevant trials and 1395 participants evaluated the impact of exercise interventions on muscular strength.

  

Eleven trials (75.6%; n = 1055 participants) showed a positive impact on muscular strength using multi-component exercises (n = 5 trials),[12,16] resistance exercises (n = 5 trials)[12,13,15,16] and multi-component exercises in combination with nutrition (no details stated) (n = 1 trial).[15] Four trials (24.4%; n = 340 participants) failed to show improvements in muscular strength using multi-component exercises (n = 2 trials),[12,13] strength and motion exercises (n = 1 trial),[13] as well as resistance exercises in combination with protein supplementation of 30 g per day (n = 1 trial).[15] With regards to the overall effect, multi-component exercises, including resistance training, as well as resistance exercises on their own, seemed to be most effective in improving muscular strength (Table 2). The exercises were performed 2–5 times per week for 20–90 minutes each session for a duration of 2.5–9 months. The intensity of the resistance training ranged from 40–70% 1RM using 6–12 repetitions and 1–3 sets.[12] Trials that did not show any improvements of muscular strength did not provide any information on intensity. An overview of the extracted data is presented in Table 3.

### Gait speed

Gait speed was measured using 2.4, 3, 4, 5, 6, 10 and 400 meter tests; normal, rapid and maximal gait speed; as well as the 6MWT.

Five systematic reviews[10-12,14,16] involving 34 trials (n = 4017 participants) included gait speed as an outcome measure. However, only 13 trials (40.5%; n = 1626) out of three systematic reviews reported on the effects on gait speed as an individual outcome. The remaining two systematic reviews included gait speed as part of their mobility and physical performance assessments and did not report on gait speed specifically.

Ten trials (31.1%; n = 1250 participants) showed a positive impact on gait speed using multi-component exercises (n = 7 trials)[12,14,16] and resistance exercises (n = 3 trials);[12,14] while three trials (9.4%; n = 376 participants) failed to show improvements in gait speed using multi-component exercises (n = 3 trials).[11,12,14]

With regards to the overall effect, multi-component and resistance exercises on their own seemed to be most effective in improving gait speed. The exercises were performed 2–5 times per week for 20–90 minutes per session over 2.5–18 months. The intensity for the resistance exercises ranged from 1–3 sets of 6–8 repetitions at 70% 1RM[12] to less specific information stating low, moderate and high intensity without further details.[14]

### Mobility

Mobility was measured by chair rise and stand, as well as the Timed Up and Go Test (TUG) alone or in combination with gait speed. Six systematic reviews[10-14,16] including 36 trials (n = 4791 participants) reported on mobility as an outcome.

Nineteen trials (52.8%; n = 2545 participants) showed a positive effect on mobility using multi-component exercises (n = 9 trials),[10-13,16] resistance exercises (n = 6 trials),[10-12] personalized training (n = 3 trials)[11] and resistance exercises combined with range of motion exercises (n = 1 trial).[13] However, 17 trials (47.2%; n = 2246 participants) failed to show any improvement using multi-component exercises (n = 10 trials),[11,13,14] resistance exercises (n = 4 trials),[11,14,16] GrandStand™ based exercises (n = 1 trial),[11,13] the horse riding simulator (n = 1 trial)[10] or balance exercises (n = 1 trial).[11]

With regards to the overall effect, the results were inconclusive and suggested that only personalized exercises seemed to consistently be effective in improving mobility. However, a sufficient number of trials showed positive effects on mobility using multi-component exercises (n = 9 trials; 1205 participants) and resistance exercises (n = 6 trials; 391 participants) to suggest that these interventions might also be of benefit. The exercises were performed 1–7 times per week for 26–90 minutes per session and over a period of 5 weeks to 18 months. The intensity for resistance exercises was 60–80% 1RM using 6–10 repetitions and 1–3 sets,[10,12] as well as personalized intensity without further details.[11]

### Balance

Five systematic reviews[10,12-14,16] including 24 trials (n = 2552 participants) reported on balance as an outcome. However, only 13 trials (54.2%, n = 1630 participants) reported on the effects of exercise on balance as an individual outcome measure. How balance was assessed was not stated.

Nine trials (46.0%; n = 1174 participants) showed a positive effect on balance using multi-component exercises (n = 8)[10,12,13,16] and resistance exercise (n = 1).[16] Four trials (17.9%; n = 456 participants)

failed to show improvements in balance using multi-component (n = 1 trial),[13] resistance (n = 1 trial),[14] resistance combined with a range of motion (n = 1 trial)[13] or GrandStand™ based exercise (n = 1 trial).[11,13]

With regards to the overall effect, multi-component exercises seemed to be most effective in improving balance. The exercises were performed from 3 times per day to 3 times per week for 20–75 minutes each session for a duration of 2.5 weeks to 18 months. The intensity ranged from 3 times of 8–12 repetitions at 85–100% 1RM for resistance exercise, and 15 mins at 65–70% VO2max and 3–5 mins at 85–90% VO2max for aerobic exercise.[10]

### Physical performance

Physical performance was measured using the Physical Performance Test (PPT), the Tinetti Performance-Oriented Mobility Assessment (POMA) and the MacArthur Battery.

All seven included systematic reviews including 27 trials (n = 3765 participants) reported on physical performance as an outcome measure.

Twenty-two trials (81.5%, n = 3067 participants) showed positive effects on physical performance using multi-component (n = 16 trials),[10-12,14,16] resistance (n = 4 trials),[10,11,16] personalized (n = 1 trial)[11] and balance exercises (n = 1 trial).[11] Five trials (18.3%; n = 698 participants) reported in three systematic reviews[11,13,15] failed to show improvements in physical performance following multi-component (n = 1 trial),[13] resistance (n = 1 trial),[11] GrandStand™ based (n = 1 trial) [11,13] and personalized exercises (n = 1 trial),[11] as well as exercise combined with protein supplementation (n = 1 trial).[15]

With regards to the overall effect, multi-component exercises, resistance exercises on their own, as well as balance exercises, appeared to be the most effective in improving physical performance. The exercises were performed between 1 and 5 times per week for 20–90 minutes each session and over a period of 2.5–18 months. The intensity ranged from 2–3 times of 8–12 repetitions at 85–100% 1RM for resistance exercise; 15 minutes at 65–70% VO2max and 3–5 minutes 85–90% VO2max, as well as 6–8 points on a 10-point perceived exertion scale for aerobic exercise. Exercises conducted at a personalized intensity, as well as low, medium and high intensity did not provide any further details.[10,11]

**Table 2: Effects on physical function parameters**

| Outcome<br>Intervention | Muscle strength | Gait speed | Mobility | Balance | Physical performance |
|---|---|---|---|---|---|
| MCT* | 5 trials (n = 548) ↑<br>2 trials (n = 192) -<br>✓ | 7 trials (n = 887) ↑<br>3 trials (n = 376) -<br>✓ | 9 trials (n = 1205) ↑<br>10 trials (n = 1482) –<br>X | 8 trials (n = 1102) ↑<br>1 trial (n = 61) –<br>✓ | 16 trials (n = 2370) ↑<br>1 trial (n = 61) -<br>✓ |
| Resistance training | 5 trials (n = 311) ↑<br>1 trial (n = 86) -<br>✓ | 3 trials (n = 363) ↑<br>✓ | 7 trials (n = 391) ↑<br>4 trials (n = 602) –<br>X | 1 trial (n = 72) ↑<br>2 trials (n = 329) -<br>X | 4 trials (n = 436) ↑<br>1 trial (n = 21) -<br>✓ |
| Balance training | | | 1 trial (n = 73) -<br>X | | 1 trial (n = 73) ↑<br>✓ |
| GrandStand™ | | | 1 trial (n = 68) -<br>X | | 1 trial (n = 68) –<br>X |
| Personalized training | | | 3 trials (n = 847) ↑<br>✓ | | 1 trial (n = 188) ↑<br>1 trial (n = 486) -<br>X |
| Horse riding simulator | | | 1 trial (n = 21) –<br>X | | |
| RT + protein | 1 trial n = 62 –<br>X | | | | 1 trial (n = 62) –<br>X |
| MCT + nutr | 1 trial n = 96↑<br>✓ | | | | |

*MCT, multi-component training including resistance, aerobic, balance and flexibility exercises; RT, resistance training; Nutr, nutrition.
✓, overall increase; X, overall no effect; ↑, effect, -, no effect.
The overall decision whether an intervention is effective or not was based on the total number of participants across the trials.

**Table 3: Data extraction of included systematic reviews**

| Systematic review | Studies | Participants | Intervention | Characteristics | Outcomes | Findings/effects |
|---|---|---|---|---|---|---|
| Chin *et al.*[14] | 8 out of 20 trials | 956 out of 2515<br>Mean age 80.5<br>Community & frail | 6 × MCT<br>2 × RT | 2.5–9 months<br>2–3 × weekly<br>45–90mins per session<br>Intensity low-high | Gait<br>Mobility<br>Balance<br>PP | MCT: ↑ gait, PP, 1x NE<br>RT: ↑ gait |
| Clegg *et al.*[13] | 5 out of 6 trials | 799 out of 987<br>Mean age 82.8<br>Community & frail | 2 × MCT<br>1 × RT<br>1 × RT & motion<br>1 × GrandStand™ | 1.5–18 months<br>3–7 × weekly<br>Intensity not stated | Strength<br>Gait<br>Mobility<br>Balance | MCT: ↑ balance, mobility, 1x NE<br>RT: ↑ strength<br>RT & motion: ↑ mobility<br>GrandStand™: NE |
| Cruz-Jentoft *et al.*[15] | 3 out of 19 trials | 249 out of 1453<br>Mean age 81.0<br>Community & frail | 1 × RT<br>1 × RT & protein<br>1 × MCT & NUTR | 3–9 months<br>Frequency not stated<br>Intensity not stated | Strength<br>PP | RT: ↑ strength<br>RT & protein: NE<br>MCT & NUTR: ↑ strength |
| Daniels *et al.*[16] | 7 out of 10 trials | 837 out of 1191<br>Mean age 80.0<br>Community & frail | 4 × MCT<br>2 × RT<br>1 × EX & NUTR | 2.5–18 months<br>2–3 × weekly<br>45–75mins per session<br>Intensity not stated | Strength<br>Gait<br>Mobility<br>Balance<br>PP & FC | MCT: ↑ strength, balance, gait, mobility, PP<br>RT: ↑ strength, balance, PP<br>EX & NUTR: ↑ FC |
| De Labra *et al.*[12] | 5 out of 9 trials | 562 out of 1067<br>Mean age 80.6<br>Community & frail | 4 × MCT<br>1 × RT | 2.5–12 months<br>2–5 × weekly<br>20–90mins per session<br>30–80% 1RM | Strength<br>Mobility<br>Balance | MCT: ↑ strength, balance, gait, mobility, PP<br>RT: ↑ strength, gait, mobility |
| De Vries *et al.*[11] | 18 out of 18 trials | 2580 out of 2580<br>Age range 60-85<br>Community & frail | 9 × MCT<br>4 × RT<br>1 × Balance<br>1 × GrandStand™<br>3 × Personalized | 1.25–18 months<br>1–7 × weekly<br>10–90mins per session<br>Intensity low vs high | Gait<br>Mobility<br>PP | MCT: ↑ gait, mobility, PP<br>RT: ↑ mobility, PP<br>Balance: ↑ PP<br>GrandStand™: NE<br>Personalized: ↑ mobility, PP |
| Theou *et al.*[10] | 13 out of 75 trials | 1010 out of 4915<br>Mean age 80.3<br>Community & frail | 8 × MCT<br>4 × RT<br>1 × Horse simulator | 2.5–18 months<br>2–3 × weekly<br>10–60mins per session<br>6–8 on 10-point scale<br>60–80% & 85–100% 1RM | Gait<br>Mobility<br>Balance<br>PP | MCT: ↑ gait, balance, mobility, PP<br>RT: ↑ mobility, PP<br>Horse simulator: NE |

↑, increase; EX, exercise; FC, functional capacity; MCT, multi-component training; NE, no effects; NUTR, nutrition; PP, physical performance; RT, resistance training.

### Compliance, dropout rates and safety

Five[10-12,14,16] of the seven systematic reviews reported on compliance and dropout rates. Dropouts were defined as the number of randomized participants having no post intervention measurements. One systematic review, including eight relevant trials, reported dropout rates from 4% to 32%.[14] Two other systematic reviews, including 23 relevant trials, only assessed whether the dropout rate was below or above 15%. Seventeen trials had less than a 15% dropout rate, while six had higher dropout rates without providing further information.[11,12] As part of their methodological quality assessment, Daniels *et al.*[16] determined whether the compliance in the trials was acceptable. Out of seven relevant trials, four demonstrated meaningful compliance. Two trials did not provide any data about compliance and another was not compliant. In the systematic review of Theou *et al.*,[10] eight out of 13 relevant trials included information regarding exercise compliance; however, specific information was not available. Additionally, five of these trials reported on adverse events, stating that no adverse events had occurred in the intervention group, or, if they had, they were similar to the control group, demonstrating that exercise is a safe intervention for frail older people.[10]

## Discussion

Key findings suggest that studies should follow a consistent definition of frailty to clearly identify the target population group and investigate the effects of

different exercise types, alone or in combination with nutritional interventions on physical function parameters in frail older adults. Studies should also provide sufficient information and report on frequency, intensity and duration of exercise so that more specific recommendations for frail older people can be made.

This umbrella review summarized the evidence from seven systematic reviews including 58 relevant trials and involving 6,927 participants. The majority of the included trials examined mobility (n = 36 trials), followed by physical performance (n = 27 trials), gait speed (n = 13 trials), muscle strength (n = 15 trials) and balance (n = 12 trials).

Multi-component exercise interventions can currently be recommended for pre-frail and frail older adults to improve muscular strength, gait speed, balance and physical performance, including resistance, aerobic, balance and flexibility tasks. Resistance training was also suggested to be beneficial in particular for improving muscular strength, gait speed and physical performance and should be considered as part of a multi-component exercise intervention. Other types of exercise were not sufficiently studied and their effectiveness is yet to be established. Exercise combined with nutritional interventions was also comparatively little studied and results were mixed.

Most of the systematic reviews stated an average frequency of 2–3 times per week for 10–90 minutes per exercise session. The total duration of the interventions ranged from 5 to 72 weeks, with the majority of the reviews reporting a minimum duration of 2.5 months (mean 22.7 ± 17.7 weeks). The intensity of the exercise interventions ranged from 30–80% 1RM to 2–3 times of 8–12 repetitions at 85–100% 1RM for resistance exercise; 15 minutes at 65–70% VO2max and 3–5 minutes at 85–90% VO2max, as well as 6–8 points on a 10-point perceived exertion scale for aerobic exercise.

### *Type and effects of exercise interventions*

The current exercise recommendations for healthy older adults aged 65 years and older include a combination of aerobic (150 minutes of moderate intensity or 75 minutes of vigorous intensity per week) and resistance training (at least twice per week).[33] The results of this umbrella review extend these recommendations and suggest that multi-component exercises, including a combination of resistance, aerobic, flexibility and balance exercises, are effective in improving physical function parameters, such as strength, gait speed, balance and physical performance, in older adults who are frail or at-risk of frailty. The extended recommendations agree with recent published literature that suggests that pre-frail and frail older adults should aim to meet the current recommendations for healthy older adults but should participate in a multi-component exercise program that includes resistance, aerobic, balance and flexibility exercises.[34]

Bray *et al.*[34] also suggest a focus on resistance exercises, including lower extremity muscle groups for pre-frail older adults and longer aerobic exercise sessions for frail older adults. The results of this umbrella review support the observation that an important element of multi-component exercise interventions is resistance training. For three out of four physical function parameters (strength, gait speed, physical performance), resistance training made a positive difference. This concurs with Cadore *et al.*[35] who conducted a systematic review on the effects of exercise interventions in frail older adults and reported that resistance training (either alone or as part of a multi-component exercise program) revealed greater strength gains in physical frail older adults than multi-component exercise interventions without resistance training. However, the participants' setting was not stated, and therefore no definite comparisons to the results of this umbrella review can be made.

The effects of exercise interventions on mobility were inconclusive as both multi-component and resistance exercises resulted in mixed results. Other types of exercise were not sufficiently studied and their effectiveness is yet to be established. Only personalized exercises tailored for the individual frail older adult seemed to increase mobility consistently A possible reason for the inconclusive results across the trials included in this umbrella review could also be variations in the use of the TUG which is an assessment tool for mobility. It has been reported that TUG scores can be affected by several circumstances, like the use of an assistive device or the height of the chair.[36] Another reason why the TUG could have been a major reason for the inconclusive results is that mobility was also assessed by gait speed which increased in the majority of the trials using multi-component interventions and resistance training. It is suggested that future trials should

use an additional test to the TUG and examine the effectiveness of other potential exercise types further.

Numerous studies have demonstrated substantial benefits of protein supplementation in combination with resistance exercise in healthy older adults.[37] However, few studies have been conducted in frail older adults and those that have been undertaken have yielded conflicting results on the benefits of protein in combination with exercise on physical function parameters.[38-40] This umbrella review also found mixed results in studies that combined exercise with nutritional interventions. Inconclusive findings might be due to a low number of studies and heterogeneous study designs, with some study samples being too small or others providing insufficient doses of nutrition or administering the nutritional supplements on different timings. One systematic review confirmed that the timing of nutritional intervention before or after exercise should be explored in further clinical trials, as basic studies suggest there may be time-sensitive factors that influence the outcome of nutrition intervention in association with exercise.[15] More studies are needed before recommendations for frail older adults can be made related to nutrition and exercise in combination.

### Frequency

This umbrella review supports current literature that suggests an optimal frequency of 2–3 times per week (mean $3.0 \pm 1.5$ times per week; range 1–7 weekly) for multi-component exercise interventions involving pre-frail and frail older adults.[34,35] Bray *et al.*[34] suggest that less than two times per week would likely not improve physical function parameters and more than three exercise sessions per week could cause some pre-frail and frail older adults to become over trained and lose interest. Nevertheless, whenever possible, pre-frail and frail older adults should be encouraged to increase their exercise frequency to at least three exercise sessions per week.[41]

### Duration

The duration of the exercise sessions noted in this umbrella review ranged from 10–90 minutes (mean of $52.0 \pm 16.5$ mins). One of the systematic reviews suggested that the optimal duration for exercise sessions was 45–60 minutes for pre-frail older adults and 30–45 minutes for frail older adults.[10] This observation agrees with recently published literature that suggests a total duration of multi-component exercise sessions of up to 60 minutes for pre-frail older adults (20 mins resistance, 10 mins aerobic, 20 mins balance, 10 mins flexibility) and up to 45 minutes for frail older adults (10 mins resistance, 20 mins aerobic, 8 mins balance, 7 mins flexibility).[34] The appropriate duration depends on frailty status, age and consistency of exercise participation.[34] Exercise sessions may start at lower durations but should progress to the recommended levels.[35]

### Intensity

The intensity of exercise was reported in only two systematic reviews and was of higher intensity than the recommendations in the literature. When using heart rate as an indicator for intensity, according to current guidelines, aerobic exercises should be performed at 70–75% of older people's maximal heart rate.[42] The intensity in this umbrella review was reported to be between 80–95% of the maximum heart rate.

Another quantifiable measure of intensity is the Borg scale, a scale that allows a rating of perceived exertion (RPE). A RPE between 12 and 14 (somewhat hard) is reported to be the optimal intensity range for frail and pre-frail adults[35] which is equivalent to 3–4 on the 10-point Borg scale.[34] Recent literature does recommend that pre-frail and frail older adults should eventually progress to a reasonably moderate-vigorous intensity,[8] working toward the upper end of the RPE scale.[34] The intensity found in this umbrella review was reported to be higher, 6–8 points on a 10-point perceived exertion scale. It should be noted that many older adults are using medications that might influence their heart rates. When using heart rate as a measurement for exercise intensity, therefore, measurements should be adjusted.

Resistance exercises should be performed using an estimated percentage of the 1RM starting with three sets of 8–12 repetitions at an intensity of 20–30% 1RM and progressing to 80% of 1RM[35] or beyond (if appropriate)[34] as high-intensity resistance training appears to be more effective than low-intensity training.[43] Another progression strategy could be higher repetitions (12–15) at a lower intensity (55% of 1RM) to build up muscular endurance, and progress to fewer repetitions (4–6) at a greater intensity (>80% of 1RM) to maximize muscular

  

strength.[34] The recommended level of exercise is in agreement with the results of this umbrella review, which states an intensity of eight to 12 repetitions at 85–100% 1RM, as well as resistance exercises performed at 30–80% and 60–80% 1RM.

### *Strengths and limitations*

The strengths of this umbrella review include the comprehensiveness of the search strategy, the currency of the studies and the large number of RCTs and participants representing the effects of exercise interventions on physical function parameters in community-dwelling frail older adults.

A limitation of this umbrella review was the heterogeneity of RCTs in the included systematic reviews due to different types of exercise interventions and outcome parameters. However, predefined inclusion and exclusion criteria aimed to minimize this heterogeneity. Further, there was not enough evidence from which we could draw any conclusions in relation to the effectiveness of other types of exercise, resulting in only limited recommendations focusing on multi-component and resistance interventions only.

Another limitation was the lack of consensus in the definition of frailty and the use of various criteria to define frailty. A consistent definition of frailty would help to ensure a more uniform target population, allowing for a more rational examination of the effects of exercise interventions on the status of an individual's frailty.

The intensity of exercise interventions was reported in only two systematic reviews, which makes conclusions in regards to this exercise characteristic difficult. Systematic reviews should provide sufficient information and report on frequency, intensity, duration and type of exercise so that more specific recommendations for frail older people can be made.

## Conclusion

To the best of our knowledge, this is the first umbrella review examining the effects of exercise interventions on physical function parameters in community-dwelling frail older adults. The review sought to determine the most effective exercise interventions for improving physical well-being in this group. The results compiled from the systematic reviews indicate that pre-frail and frail older adults should participate in a multi-component exercise program, including in particular resistance training, as well as aerobic, balance and flexibility exercises. However, other types of exercise interventions have not been sufficiently studied and their effectiveness is yet to be established. Nevertheless, to optimize the exercise interventions and improve physical function, an optimal combination of intensity, duration and frequency is crucial, as well as gradual increases in these characteristics. Multi-component interventions should be performed up to three times per week for 45–60 minutes per exercise session at a moderate to high intensity aiming to progress to "somewhat hard" on the Borg scale for aerobic exercises and $\geq$80% of 1RM for resistance exercises for a duration of at least 2.5 months.

### *Recommendations for practice*

Evidence suggests that multi-component exercise interventions, including in particular, resistance training, as well as aerobic, balance and flexibility exercises, are an effective strategy to improve physical function (i.e. strength, gait speed, balance, physical performance) in pre-frail and frail older adults. However, other types of exercise interventions may also be effective but have not been sufficiently studied yet to draw any conclusions. Nevertheless, an optimal combination of frequency, duration and intensity is crucial to ensuring a positive response in physical function. Frail older people should not only gradually increase the frequency of their exercise from once or twice per week up to at least three times per week, but also increase the intensity and duration of their exercise. Multi-component intervention programs should be promoted more actively amongst older adults to increase their participation in exercise and to tackle frailty in the community.

### *Recommendations for research*

Future research should adopt a consistent definition of frailty to clearly identify the target population and investigate the effects of other exercise types, alone or in combination with nutritional interventions on physical function in frail older adults. Also, systematic reviews should provide sufficient information and report on frequency, intensity, duration and type of exercise so that more specific recommendations for frail older people can be made. Furthermore, compliance and dropout rates need to be reported

consistently across studies so that exercise interventions for frail older people can be optimized.

Investigations into the management of the proposed increase in intensity, frequency and duration over time are required, as is research into how to monitor the quality of exercise interventions. Results of these investigations would assist in the optimization of exercise interventions for frail older adults.

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## Appendix I: Search strategies

**PubMed (pubmed.gov):** Searched on 02/09/2016

| Search | Query |
|---|---|
| #1 | Aged [MH] OR Elder* [all] OR Older [all] |
| #2 | Frail* [all] OR Functionally Impair* [all] |
| #3 | systematic[sb] OR review[pt] OR meta-analyses[pt] |
| #4 | Exercise [MH] OR Exercis* [all] OR Physical Activity |
| #5 | #1 AND #2 AND #3 AND #4 |
| Limited to 1990 and English language | |

**Embase (Elsevier)**

| Search | Query |
|---|---|
| #1 | Aged/syn OR Elder* OR Older |
| #2 | Frail* OR 'Functionally impaired' OR 'functional impairment' OR 'functional impairments' |
| #3 | 'systematic review'/SYN OR 'meta analysis'/SYN |
| #4 | Exercise/SYN OR 'Physical Activity' |
| #5 | #1 AND #2 AND #3 AND #4 |
| Limited to 1990 and English language | |

**CINAHL (EBSCO)**

| Search | Query |
|---|---|
| #1 | (MH ''Frail Elderly'') OR (MH ''Aged'') OR TI Aged OR AB Aged OR TI Elder* OR AB Elder*OR TI Older OR AB Older |
| #2 | TI Frail* OR AB Frail* OR TI Functional* OR AB Functional* |
| #3 | (MH ''Systematic Review'') OR (MH ''Meta Analysis'') ORTI ''systematic review*'' OR TI ''meta analysis'' OR TI metaanalysis OR AB ''systematic review*'' OR AB ''meta analysis'' OR AB metaanalysis |
| #4 | TI Exercis* OR TI ''Physical Activity'' OR AB ''Physical Activity'' |
| #5 | #1 AND #2 AND #3 AND #4 |
| Limited to 1990 and English language | |

  

**Scopus (Elsevier)**

| Search | Query |
|---|---|
| #1 | Aged OR Elder* OR Older |
| #2 | Frail* OR Functionally Impair* |
| #3 | "systematic review*" OR "meta analysis" OR metaanalysis |
| #4 | Exercis* OR "Physical activity" |
| #5 | #1 AND #2 AND #3 AND #4 |
| Limited to 1990 and English language | |

**Cochrane Database of Systematic Reviews, *JBI Database of Systematic Reviews and Implementation Reports*, Web of Science, Campbell Collaboration Library of Systematic Reviews**

| Search | Query |
|---|---|
| #1 | Aged OR Elder* OR Older |
| #2 | Frail* OR Functionally Impair* |
| #3 | systematic review OR meta analysis OR metaanalysis |
| #4 | Exercis* OR Physical activity |
| #5 | #1 AND #2 AND #3 AND #4 |
| Limited to 1990 and English language | |

**Google Scholar and Grey Literature**

| Search | Query |
|---|---|
| #1 | Older<br>Exercise<br>Physical Activity<br>Review<br>(with all of the words) |
| #2 | aged OR<br>elder OR<br>frail OR<br>functional impairment OR<br>systematic review OR<br>meta analysis OR metanalysis OR<br>Exercise<br>Physical Activity<br>(with at least one of these words) |
| #3 | #1 AND #2 |
| Limited to 1990 and English language | |

**ProQuest Dissertations and Theses**

| Search | Query |
|---|---|
| #1 | Aged OR Elder OR Older |
| #2 | Frail OR Functionally Impair* |
| #3 | systematic review OR meta analysis |
| #4 | Exercise OR Physical activity |
| #5 | #1 AND #2 AND #3 AND #4 |
| Limited to 1990 and English language | |

  

## Appendix II: Verification of review eligibility

| | |
|---|---|
| AUTHOR AND YEAR | |
| JOURNAL | |
| TITLE | |
| NAME/CODE OF REVIEWER | |
| Design: The article is/contains a systematic review with or without meta-analysis | Yes |
| Review type:<br>For effectiveness reviews, a comparator group is utilized | Yes |
| Participants:<br>Participants of interested are older people aged 60 years and over,<br>identified as pre-frail, frail or at-risk of frailty in title, abstract or text<br>and living in the community | Yes<br>Yes<br>Yes |
| Interventions:<br>Interventions of interest are exercise interventions, alone or combined with other interventions | Yes |
| Outcomes:<br>Outcomes of interest are: muscular strength, gait ability including gait speed and gait performance, balance and mobility | Yes |
| IF YOU HAVE NOT ANSWERED YES TO ALL OF THE ABOVE QUESTIONS, YOU SHOULD EXCLUDE THE STUDY. IF YOU ANSWERED YES TO ALL, PLEASE CONTINUE. | |

## Appendix III: Details of included reviews

| | 1. Chin *et al.*[14] | 2. Clegg *et al.*[13] |
|---|---|---|
| Databases searched | PubMed, Embase, CENTRAL | MEDLINE, AMED, CINAHL, The Cochrane Library, Embase, PsychINFO, PEDro |
| Range of included studies | 2000–2005 | 1995–2007 |
| Total number of studies/total relevant | 20 trials/8 trials | 6 trials/5 trials |
| Total number of participants/ total relevant | 2515/956<br>Female 62.2% | 987/799<br>Female 75.5% |
| Heterogeneity[$] | Not calculated | Not calculated |
| Setting | Community-dwelling | Community-dwelling |
| Age | Mean age 80.5 years | Mean age 82.8 years |
| Intervention | 6 × Multi-component (MCT)<br>2 × Resistance (RT) | 2 × Multi-component (MCT)<br>1 × Resistance (RT)<br>1 × Strength & motion<br>1 × GrandStand™ |
| Characteristics | Frequency 2–3 × weekly of 45–90 mins<br>Duration 2.5–9 months<br>Intensity 1 × low intensity<br>2 × moderate intensity<br>1 × high intensity<br>4 × Intensity not stated | Frequency 3–7 × weekly<br>Duration 6 weeks–18 months<br>Intensity not stated |
| Intervention setting | 2 × Home-based<br>3 × Centre-based<br>1 × Centre & home-based<br>2 × Not stated | Home-based |
| Control | 3 × Home-based exercise<br>4 × Exercise - no setting stated<br>1 × Usual care | Not stated |
| Outcomes | Gait<br>Mobility (TUG & Chair rise/stand)<br>Balance (BBS & other tests)<br>Physical Performance (PP) | Strength<br>Gait<br>Mobility<br>Balance |
| Effect size | MCT: ↑ gait, PP, 1 × no effect<br>RT: ↑ gait | MCT: ↑ balance, mobility, 1 × NE<br>RT: ↑ strength<br>RT & Motion: ↑ mobility<br>GrandStand™: no effect |
| Type of studies | RCTs | RCTs |
| Analyses | Narrative synthesis | Narrative synthesis |

| (*Continued*) | | |
|---|---|---|
| | **1. Chin *et al.*[14]** | **2. Clegg *et al.*[13]** |
| Confidence intervals | Not calculated | Not calculated |
| P value | Not calculated | Not calculated |
| Follow-up | 10 weeks–9 months | Not stated |
| | **3. Cruz-Jentoft *et al.*[15]** | **4. Daniels *et al.*[16]** |
| Databases searched | PubMed, Dialogue | PubMed, CENTRAL, CINAHL |
| Range of included studies | 2005–2012 | 1998–2005 |
| Total number of studies/total relevant | 19 trials/3 trials | 10 trials/7 trials |
| Total number of participants/ total relevant | 1453/249<br>Female 62.7% | 1191/837<br>Female: No information provided |
| Heterogeneity[$] | Not calculated | Not calculated |
| Setting | Community-dwelling | Community-dwelling |
| Age | Mean age 81 years<br>1 trial > 75 years | Mean age 80.0 years |
| Intervention | 1 × Resistance (RT)<br>1 × Resistance + protein<br>1 × Multi-component + nutrition | 4 × Multi-component (MCT)<br>2 × Resistance (RT)<br>1 × Exercise + nutrition (fruit + diary product) |
| Characteristics | Frequency not stated<br>Duration 3–9 months<br>Intensity 3 × not stated | Frequency 2–3 × weekly of 45–75 mins<br>Duration 2.5–18 months<br>Intensity not stated |
| Intervention setting | Not stated | 1 × Home-based<br>4 × Home & centre-based supervised<br>2 × Centre-based |
| Control | 1 × Home based low intensity<br>1 × No intervention<br>1 × Not stated | 4 × No intervention<br>3 × Usual care |
| Outcomes | Strength<br>Physical Performance (PP) | Strength<br>Gait<br>Mobility<br>Balance<br>Physical Performance (PP)<br>Functional/aerobic capacity (FC) |
| Effect size | RT: ↑ strength<br>RT & Protein: no effect<br>MCT & NUTR: ↑ strength | MCT: ↑ strength, balance, gait, mobility, PP<br>RT: ↑ strength, balance, PP<br>EX & NUTR: ↑ FC |
| Type of studies | RCTs | RCTs |

| (*Continued*) | | |
|---|---|---|
| | **3. Cruz-Jentoft *et al.*[15]** | **4. Daniels *et al.*[16]** |
| Analyses | Narrative synthesis | Narrative synthesis |
| Confidence intervals | Not calculated | Not calculated |
| P value | >0.05 in 2 trials | Not calculated |
| Follow-up | Not stated | 2.5–18 months |
| | **5. De Labra *et al.*[12]** | **6. De Vries *et al.*[11]** |
| Databases searched | PubMed, Web of Science, The Cochrane Library | PubMed, CINAHL, Embase, PEDro, The Cochrane Library |
| Range of included studies | 2005–2015 | 1998–2010 |
| Total number of studies/total relevant | 9 trials/5 trials | 18 trials/18 trials |
| Total number of participants/ total relevant | 1067/562<br>Female 75.3% | 2580/2580<br>Female: No information provided |
| Heterogeneity[$] | Not calculated | Mobility exercise vs non $I^2$ 9%<br>Mobility intensity/duration $I^2$ 0%<br>PP exercise vs non $I^2$ 27%<br>PP intensity: $I^2$ 67% dura: $I^2$ 83% |
| Setting | Community-dwelling | Community-dwelling |
| Age | Mean age 80.6 years | Age range: 60–85 years |
| Intervention | 4 × Multi-component (MCT)<br>1 × Resistance (RT) | 9 × Multi-component (MCT)<br>4 × Resistance (RT)<br>1 × Balance<br>3 × Personalized/not stated<br>1 × GrandStand™ |
| Characteristics | Frequency 2–5 × weekly of 20–90mins<br>Duration 2.5–12 months<br>Intensity 30–80% 1RM | Frequency 1–7 × weekly of 10–90mins<br>Duration 5 weeks–18 months<br>Intensity: low vs high without definition |
| Intervention setting | 1 × Home-based<br>4 × Not stated | 2 × Centre-based<br>5 × Home-based<br>2 × Home & centre-based supervised<br>4 × Centre vs home<br>5 × Not stated |
| Control | Not stated | 10 × No intervention<br>4 × Home-based; 4 × Not stated |
| Outcomes | Strength<br>Mobility<br>Balance & Physical Performance (PP) | Gait<br>Mobility<br>Physical Performance (PP) |

| (*Continued*) | | |
|---|---|---|
| | **5. De Labra *et al.*[12]** | **6. De Vries *et al.*[11]** |
| Effect size | MCT: ↑ strength, balance, gait, mobility, PP<br>RT: ↑ strength, gait, mobility<br>Small to very small effect size | Mobility EX vs no EX: SMD: 0.18<br>Intensity SMD: −0.05<br>Duration SMD −0.09 short duration<br>SMD 0.00 long duration<br>PP EX vs no EX: SMD: 2.93<br>Intensity SMD: 0.22<br>Duration SMD 0.13/0.38 short<br>SMD 0.26 long |
| Type of studies | RCTs | RCTs |
| Analyses | Narrative Synthesis | Meta-analysis + Narrative synthesis |
| Confidence intervals | Not calculated | Mobility EX vs no EX: CI: 0.05–0.30<br>Intensity CI: −0.25–0.15<br>Duration: CI: −0.35–0.18 short<br>CI: −0.32–0.32 long<br>PP EX vs no EX: CI:2.50–3.36<br>Intensity: CI: −0.17–0.62<br>Duration: CI: −0.34–0.61 short<br>CI: −0.48–1.25 short<br>CI: −0.35–0.87 long |
| P value | Not calculated | Not calculated |
| Follow-up | 2.5–12 months | 5 weeks -18 months |
| | **7. Theou *et al.*[10]** | |
| Databases searched | MEDLINE, Embase, PsychINFO, CINAHL, Scopus, AgeLine, ERIC, SPORTDiscus | |
| Range of included studies | 1998–2008 | |
| Total number of studies/total relevant | 75 trials/13 trials | |
| Total number of participants/ total relevant | 4915/1010<br>Female 70.0% | |
| Heterogeneity[$] | Not calculated | |
| Setting | Community-dwelling | |
| Age | Mean age 80.3 years | |
| Intervention | 8 × Multi-component (MCT)<br>4 × Resistance (RT)<br>1 × Horse riding simulator | |

| (*Continued*) | |
|---|---|
| | **7. Theou *et al.*[10]** |
| Characteristics | Frequency 2–3 × weekly 10–60mins<br>Duration 10 weeks–36 weeks<br>Intensity 1 trail: 6–8 on 10-point scale<br>2 trials: 3 × 8–12 repetitions at 85–100% 1RM<br>1 trial: 60–80% 1RM |
| Intervention setting | 2 × Home-based<br>3 × Centre-based supervised<br>8 × Not stated |
| Control | Not stated |
| Outcomes | Gait<br>Mobility<br>Balance<br>Physical Performance (PP) |
| Effect size | Not stated for community-dwelling separately<br>MCT: ↑ gait, balance, mobility,<br>PP<br>RT: ↑ mobility, PP<br>Horse Simulator: no effect |
| Type of studies | RCTs |
| Analyses | Narrative synthesis |
| Confidence intervals | Not calculated |
| P value | Not calculated |
| Follow-up | Not stated |