The Journal of Frailty & Aging 15 (2026) 100187

Contents lists available at ScienceDirect

The Journal of Frailty & Aging

journal homepage: www.elsevier.com/locate/tjfa

Review

Exercise to prevent falls in older adults with physical frailty: A systematic review and meta-analysis

Poonam Mehta [a], Eduardo Caldas Costa [b], Leony Morgana Galliano [b], Lara Vlietstra [c], Bruno T Saragiotto [a,g], Eduardo Lusa Cadore [d], Mikel Izquierdo [e], Debra L. Waters [c,f,*]

[a] Discipline of Physiotherapy, Graduate School of Health, Faculty of Health, University of Technology Sydney, Sydney, NSW, Australia
[b] Federal University of Rio Grande do Norte, Natal, Rio Grande do Norte, Brazil
[c] University of Otago, Dunedin, New Zealand
[d] Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil
[e] Navarrabiomed, Hospital Universitario de Navarra (HUN), Universidad Pública de Navarra (UPNA), Instituto de Investigación Sanitaria de Navarra (IdiSNA), Pamplona, España
[f] University of New Mexico, Albuquerque, NM, USA
[g] Masters and Doctoral Programs in Physical Activity, Universidade Cidade de São Paulo, Sao Paulo, Brazil

A R T I C L E I N F O

Keywords:
Aging
Fried frailty phenotype
Exercise
Falls
Systematic review

A B S T R A C T

Introduction: Physical frailty is associated with increased risk of falls. Although exercise mitigates age-related declines, evidence regarding its effects on falls in older adults with frailty is limited. This systematic review examined the effects of exercise on fall-related outcomes in older adults with frailty.

Methods: We searched MEDLINE, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, Scopus, and CINAHL for randomised controlled trials published from 2001 (when the Fried frailty phenotype was introduced) to January 2024. Eligible studies included older adults with frailty and reported at least one of the following outcomes: i) physical function (gait speed, strength, balance), ii) fear of falling, or iii) falls incidence. Meta-analyses were conducted using random-effects models, with results presented as weighted/standardized mean differences with 95% confidence intervals.

Results: Fourteen studies (n = 2719; mean age range 73–86 years) were included, most of which used the Fried frailty phenotype (n = 12) and were conducted in Europe (n = 6). Most interventions included multicomponent (n = 10) and resistance (n = 4) training. Exercise improved gait speed (MD 0.09 m/s, 0.02/0.15; I^2=94%; n = 5), TUG (MD -3.73 s, -5.92/-1.55; I^2=95%; n = 6), and 5-times sit-to-stand (MD -2.66 s, -4.19/-1.14; I^2=77%; n = 4) over short-term period (≤12 weeks), with low-to-very low certainty evidence. A trend toward improved balance was also noted (SMD 2.80, -0.17/5.76; p = 0.06; I^2=99%; n = 5), with very low certainty evidence. Limited data was observed for fear of falling (n = 1) and falls incidence (n = 2).

Conclusions: Exercise training enhances physical function in older adults with physical frailty. However, its impact on fear of falling and fall incidence remains uncertain.

Prospero registry: CRD42024502865

1. Introduction

Physical frailty, defined by the physical frailty phenotype proposed by Fried et al. in 2001, is a significant concern in ageing populations. According to this model, physical frailty is characterised by the presence of at least three of the following five criteria: low grip strength in lowest 20th percentile adjusted for BMI and gender, slow walking speed - ≥6 s to walk 15 feet stratified by gender and height, self-reported exhaustion, unintentional weight loss of ≥4.5 kg over the past year, and low physical activity - based on kilocalories expended per week using leisure-activity questionnaire [1]. Based on this framework, the prevalence of physical frailty among individuals aged ≥ 65 years is estimated to be 10–14% globally, with an incidence rate of approximately 40 cases per 1000 person-years [2,3]. International clinical practice guidelines characterize physical frailty as a pre-disability state, with disability defined as the need for assistance in Basic Activities of Daily Living [4].

* Corresponding author at: School of Physiotherapy, University of Otago, Dunedin, Otago, 9054, New Zealand.
E-mail address: Debra.waters@otago.ac.nz (D.L. Waters).

https://doi.org/10.1016/j.tjfa.2026.100187
Received 3 February 2026; Received in revised form 30 June 2026; Accepted 9 July 2026
Available online 18 August 2026
2260-1341/© 2026 Published by Elsevier Masson SAS on behalf of SERDI Publisher. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Physical frailty is a dynamic, transitional condition rather than a static state [5]. Individuals may progress toward worsening physical frailty or recover with appropriate interventions. Importantly, physical frailty is associated with a heightened risk of a range of adverse health outcomes, including falls, hospitalisations, disability, and loss of independence [3]. As the population continues to age, the prevalence of physical frailty is expected to rise, placing a greater burden on healthcare systems. The economic impact is also substantial, with individual frailty components ranging from $275 to $10,559 per person annually [6]. This rising burden has led to increased research interest in understanding how frailty and its individual components influence broader health determinants in older adults. There is also a strong focus on developing and evaluating therapeutic strategies to reverse physical frailty and mitigate its associated health risks.

One of the main concerns about physical frailty is its strong association with risk of falls. A recent meta-analysis involving over one million individuals aged $\geq$ 65 years found that physical frailty, assessed using the Fried frailty phenotype, was significantly associated with a 32% higher risk of falls compared with non-frail individuals (RR = 1.32, 95% CI: 1.17–1.48) [7]. Falls are not only common among older adults with physical frailty but also result in serious outcomes, including fractures, hospitalisations, loss of independence, and increased mortality [8]. Therefore, preventing falls among older adults with physical frailty is a key priority in clinical and public health settings aimed at reducing the burden of frailty-related consequences.

According to the World Falls Prevention Guidelines, there is a GRADE 1A recommendation for exercise interventions to prevent falls [8]. Additionally, these guidelines provide a stratification algorithm for fall risk management, identifying older adults with both a history of falling in the past year and physical frailty as a high-risk group. Immediate and targeted interventions are strongly recommended for these individuals. Although it is well established that exercise training reduces both the risk and rate of falls among older adults, including those living in the community [9–11] and long-term care facilities [12], the evidence remains limited and inconclusive for individuals with physical frailty. Indeed, recent systematic reviews with meta-analyses have highlighted significant gaps in the literature regarding the effects of exercise training on fall-related outcomes, specifically in older adults with physical frailty, underscoring the need for further high-quality, targeted research in this population [11,12].

Using a systematic review and meta-analysis, we aimed to investigate the effects of exercise training across a broader range of fall-related outcomes in older adults with physical frailty, including intermediate outcomes (e.g., physical function and fear of falling) and critical outcomes (e.g., falls incidence). Our secondary aim was to identify the minimal and optimal dose and type of exercise to improve fall-related outcomes in older adults with physical frailty. By addressing this gap in the literature, this evidence synthesis may aid clinicians by providing valuable insights into treating physical frailty, delaying its progression, and preventing falls in this high-risk population. The evidence from this review could help inform clinical guidelines and best practices.

2. Methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13]. The protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO; reference number: CRD42024502865).

2.1. Search strategy

A systematic literature search was performed in MEDLINE (via Ovid), Embase (via Ovid), Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, Scopus, and CINAHL (via EBSCO). In consultation with a university librarian, database-specific search terms, including but not limited to keywords and MeSH headings, were used under four broad areas: "older adults with physical frailty and all synonyms", "design, that is, randomised controlled trials and all synonyms", "falls and all synonyms", and "exercise interventions and all synonyms" to search the databases (Appendix 1). We also performed backwards and forward citation tracking of the included studies, relevant systematic reviews, and clinical guidelines. The searches and selection were restricted to English. Given that the physical frailty phenotype was defined in 2001 [1], we limited the search to the period from 2001 to January 2024.

2.2. Eligibility criteria

2.2.1. Participants

This study included older adults aged $\geq$65 years with physical frailty, as defined by Fried's frailty phenotype. Accordingly, physical frailty was defined as the presence of at least 3 of the following five criteria: low grip strength, slow walking speed, self-reported exhaustion, unintentional weight loss of $\geq$4.5 kg in the past year, and low physical activity [1,4]. Studies incorporating physical components similar to those in Fried's model (e.g., the Study of Osteoporotic Fractures) and meeting frailty criteria were also included. Studies that included mixed samples of older adults who were physically robust, pre-frail, or frail were excluded unless specific sub-analyses were provided for only those with physical frailty. Studies that included instruments for assessing frailty using multidimensional model, such as the Deficit Accumulation Index [14], or Tilburg Frailty Indicator [15] were not considered to avoid variability that could arise from using broader or mixed definitions.

2.2.2. Interventions

Interventions included prescribed exercise training programs delivered in non-hospital settings (such as community dwellings, residential care facilities, nursing homes, or retirement villages), whether individual or group-based, and supervised (in-person), semi-supervised (a mix of in-person and home-based), or unsupervised (home-based). The included studies aimed to improve physical function related to fall risk, fear of falling, and/or the incidence of falls in older adults with physical frailty. Studies with exercise training programs combined with other interventions (e.g. diet) were considered only if the control group without exercise (comparator) also received the same additional intervention. Studies that provided only physical activity counselling without a structured exercise training regimen, or that combined exercise with other interventions (e.g., diet) without matching the additional intervention across control groups, were excluded.

2.2.3. Comparator

The comparator groups maintained their habitual lifestyle (no treatment or waitlist) or received usual care (e.g., advice). In addition, these groups could include low-intensity upper limb or stretching exercises without progression in frequency, intensity, duration, type, or balance challenges. Finally, studies involving other interventions (e.g., diet) were considered only if they did not include an exercise training program.

2.2.4. Outcomes

Three categories of fall-related outcomes were considered: 1) lower limb physical function and performance through clinical tests (e.g. gait speed, timed up and go, sit-to-stand, balance test, short physical performance battery [SPPB]); 2) fear of falling measured with validated questionnaires (e.g. Falls Efficacy Scale –International [FES-I]); and 3) incidence of falls, reported through different metrics such as the number of falls, fall rate, and/or number of individuals who experienced falls throughout and/or after the exercise training intervention period. A fall was defined according to the WHO as "*an event which results in a person coming to rest inadvertently on the ground, floor, or other lower level*" [16]. Falls data were included only when recorded prospectively, either during the exercise intervention or at post-intervention follow-up, using fall calendars, phone calls, or hospital records.

2.2.5. Study design

Eligible studies included randomised controlled trials (RCTs), including parallel, cluster, and crossover designs, with only the first phase of crossover trials considered for the analysis.

2.3. Study selection and data extraction

Screening of the title/abstract and full text for eligible studies was independently performed against the selection criteria by two raters (PM/ECC/EC/LG) using Covidence. Disagreements were discussed, and if consensus could not be reached, they were resolved by a 3rd author. The authors independently extracted data using a custom-made Excel (Version 16.70) data extraction form. Disagreements in data extraction were resolved through discussion with the 3rd author. The extracted data included the primary author, publication year, patient population, geographical location, number of randomised patients, age, sex, confirmation of frailty by the Fried phenotype or equivalent, characteristics of the exercise training intervention, and fall-related outcomes. Post-intervention scores or change scores were used for analysis and change scores were preferred if studies presented both.

2.4. Quality of assessment

To assess the quality and reporting of exercise training trials, the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) scale was used by two independent reviewers (PM/ECC/LG). The TESTEX scale consists of 15 points (5 points for study quality and 10 points for reporting), each assigned either a '1′ or '0' by the reviewers. Thus, the quality of the studies was classified according to their total TESTEX score as "high" ($\geq$ 12 points), "good" (7–11), or "low" ($\leq$ 6). This tool assesses explicitly the study quality and reporting of RCTs, with clinical intervention trials in mind, where participant or researcher blinding is extremely difficult to implement [17].

2.5. Assessment of risk of bias

The risk of bias in the included trials was assessed using the Revised Cochrane Risk of Bias Tool for Randomised Trials [18]. Two reviewers independently resolved any disagreements by consensus or a third review author. The overall risk of bias was determined as 'low risk' when all domains were judged as low risk; studies were defined as having 'some concerns' if at least one domain raised concerns without any being high risk; and an overall 'high risk of bias' was assigned when at least one domain was rated high risk or when multiple domains raised concerns that substantially lowered confidence in the results [18].

2.6. Data analysis

We contacted the corresponding authors to request any missing study characteristics and data points when required. Where possible, we preferred to use intention-to-treatment analyses to include all people who were randomised. We calculated mean differences (MD) with 95% confidence intervals (CI) when studies used continuous outcome variables on the same scale. When different scales per outcome were used, we used standardised mean differences (SMD) or effect sizes with 95% CIs to account for variability across studies and provide a standard metric for comparison. We interpreted effect sizes from SMDs using Cohen's d, with ⟨0.2, 0.2–0.5, 0.5–0.8, and > 0.8 indicating no, small, medium, and significant effects, respectively [19]. For dichotomous data, risk ratios (RR) with corresponding 95% CIs were calculated. Meta-analyses were conducted using a random-effects model in Review Manager (RevMan) version (7.11.0), The Cochrane Collaboration, London, UK, 2023; Available at revman.cochrane.org. Statistical heterogeneity was assessed using the I^2 statistic, where values below 30% were considered low, 30–60% moderate, 50–90% substantial, and 75–100% considerable high [20]. If more than 10 trials were included in the analysis, we assessed reporting bias by visually inspecting the funnel plots for asymmetry. If asymmetry was detected, possible reasons were explored.

2.7. Certainty of evidence

We assessed the certainty of evidence for each outcome using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) as recommended by the Cochrane Handbook [21]. The certainty of evidence was based on the performance of the studies for five domains: 1) study limitations (downgraded by one level if 25% or more of the participants in the comparison are from studies with low methodological quality); 2) inconsistency (downgraded by one level if, by visual inspection, the presence of wide variation of effect estimates is verified or the I^2 test is greater than 50%; downgraded by 2 levels if I^2 was higher than 75%); 3) indirectness (downgraded by one level if more than 50% of participants vary from the population of interest (e.g. mixed populations or multiple disorders)); 4) imprecision (a) downgraded by one level if, in continuous outcomes, the total sample size was less than 400 participants; (b) when the 95% CI around the pooled or best estimate of effect included no effect and the CI crossed an effect size of SMD = 0.5, we downgraded the evidence by one level; downgrade the evidence by two levels when there is imprecision due to both (a) and (b); and 5) publication bias (downgraded by one level if publication bias was identified by visual inspection of funnel plots if more than 10 studies are included in the comparison).

2.8. Deviations from the protocol

Initially, we proposed to include only trials in which frailty was defined according to Fried's Frailty Phenotype. However, during the selection process, we also included studies that used other validated definitions of frailty, incorporating objective physical components similar to those in Fried's model [22,23].

To evaluate the study quality and reporting of the included trials, the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) was used, which is specifically designed to facilitate a comprehensive review of exercise training trials.

We planned to conduct subgroup analyses based on (i) participants' characteristics (e.g. age and gender) and (ii) characteristics of the exercise training interventions (e.g. frequency, intensity, duration, and type). However, due to the limited number of studies meeting the inclusion criteria, we were only able to present subgroup analyses based on the duration of follow-up (short term: ≤12 weeks; long term: >12 weeks).

We intended to perform a network meta-analysis but were unable to do so. Fourteen trials were included, and performing a network meta-analysis was not the best practice, as the nodes were too small and the studies were too diverse to create a meaningful network. Thus, it was not possible to address our secondary aim of identifying the minimal and optimal dose and type of exercise to improve fall-related outcomes in older adults with physical frailty. Therefore, we performed a systematic review with a meta-analysis.

3. Results

Database searches identified 3574 articles, of which 3490 remained after deduplication. Following title and abstract screening, 86 articles were selected for full-text review, of which 72 were excluded based on the eligibility criteria. Fig. 1 presents the hierarchical reasons and exclusion counts at the full-text stage. Fourteen trials met the inclusion criteria and were included in the evidence synthesis [22–35]; however, two trials [22,23] lacked appropriate data for the meta-analysis.

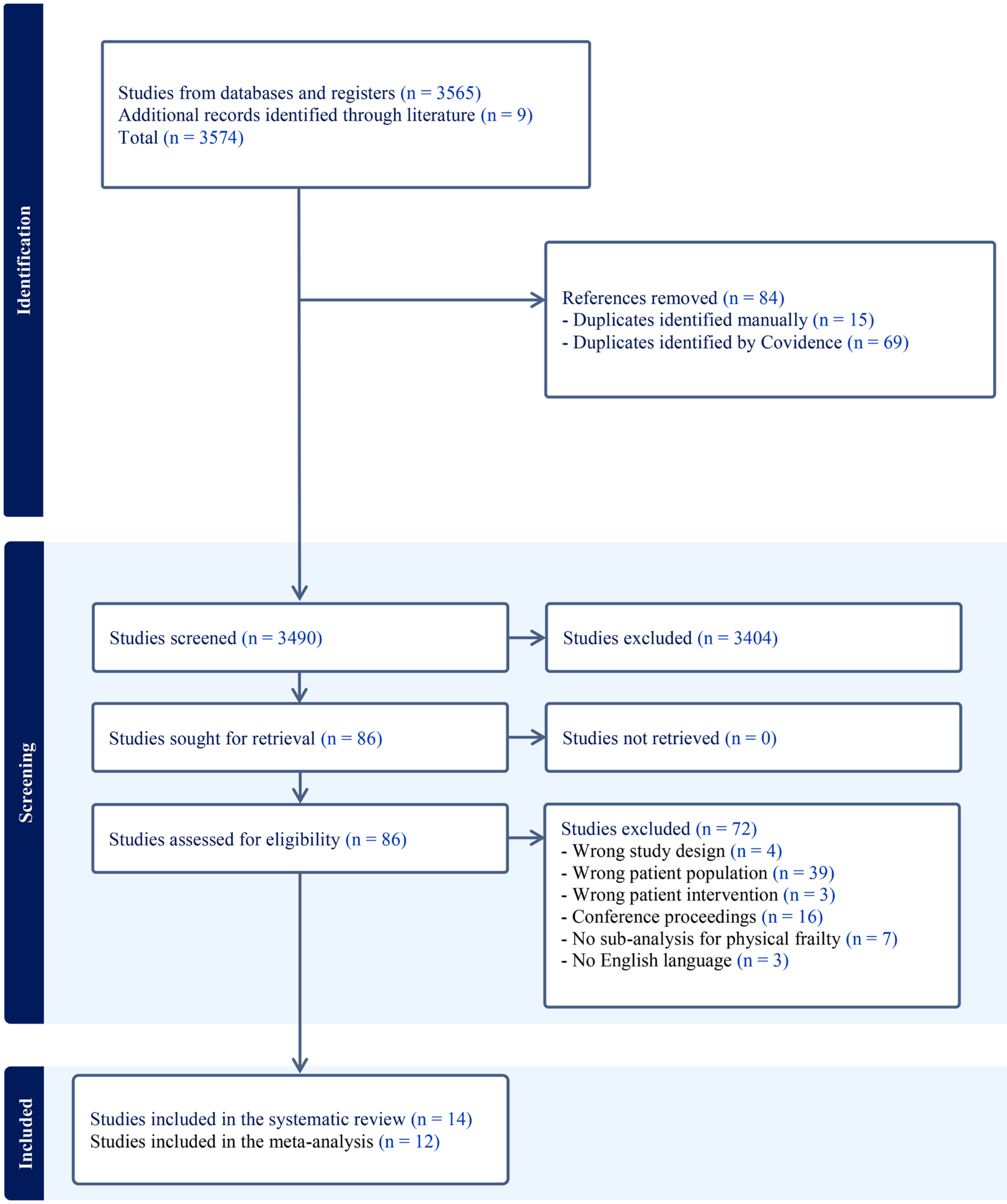

Fig. 1. Flow chart study selection.

Attempts to contact the study authors were unsuccessful, and as a result, these two trials were excluded from the meta-analysis.

3.1. Characteristics of included studies

The participant and study characteristics are presented in Tables 1 and 2. The 14 studies included in the qualitative synthesis involved 2756 older participants (n = 2719 from 12 studies included in meta-analysis) aged ≥65 years with physical frailty (mean age ranged from 73.3 to 93.4 years); the proportion of females ranged from 49% to 100%, one study including all female participants only [25]. All of the included RCTs had fewer than 280 participants (ranging from 30 to 278), with the exception of one study, which had 1635 participants [23]. The studies were conducted in Europe (n = 6), Asia (n = 4), Brazil (n = 2), (n = 1) for Turkey, and the USA, with participants who were community-dwelling (n = 3) or living in nursing homes (n = 11). The tools used to assess frailty included standardised tools such as Fried's frailty phenotype (n = 12), but also other validated definitions of frailty that incorporate objective physical components, similar to those in Fried's model, the Study of Osteoporotic Fractures [22,23]. Most interventions (n = 10) consisted of multicomponent exercises (including endurance, strength, balance, and coordination), followed by resistance (n = 3) and mind-body exercises (n = 1), and were performed in a group (n = 7) or individually (n = 4) under in-person supervision (Table 2).

3.2. Quality of assessment

The quality of the included studies was overall good; the 15-point

Table 1
Characteristics of included trials.

Reference	Participants (sample size, sex, age)	Setting (country)	Frailty criterion	Outcome measures
Aas et al., 2020	n = 41, 49% females Exercise plus protein: 86.6 ± 6.9 y Control plus protein: 84.5 ± 7.2 y	Nursing homes or day care facilities (Norway)	Fried	*Physical function* - 5 x sit-to-stand - Gait speed (10 m)
Cadore et al., 2014	n = 32, 70% females Exercise: 93.4 ± 3.2 y Control: 90.1 ± 1.1 y	Nursing home (Spain)	Fried	*Physical function* - Gait speed (5 m) - Timed up and go - Balance FICSIT-4 tests - 30 s sit-to-stand *Incidence of falls* - Number of falls
Mollinedo Cardalda et al., 2019	n = 77, 70% females Exercise (group 1): 85.5 ± 8.1 y Exercise (group 2): 83.8 ± 8.3 y Control: 85.2 ± 7.4 y	Institutionalized (Spain)	Fried	*Physical function* - 5 x sit-to-stand
Chou et al., 2022	n = 81, 51% females Exercise: 80.9 ± 7.9 y Control: 78.4 ± 8.2 y	Long-term care facilities (China)	Study of Osteoporotic Fractures	*Physical function* - 30 s sit-to-stand
Faber et al., 2006	n = 278, 79% females Exercise (group 1): 85.4 ± 5.9 y Exercise (group 2): 84.4 ± 6.4 y Control: 84.9 ± 5.9 y	Long-term care facilities (Netherlands)	Fried	*Physical function* - Physical performance scale (walking speed, timed sit-to-stand, timed up and go, FICSIT-4 balance) *Incidence of falls* - Incidence of falls
Ferreira et al., 2018	n = 45, not reported Exercise: 73.3 ± 6.4 y Control: 77.8 ± 8.0 y	Institutionalized (Brazil)	Fried	*Physical function* - 5 x sit-to-stand - Timed up and go
García-Gollarte et al., 2023	n = 111, 69% females Exercise: 86.0 ± 5.9 y Exercise plus nutrition: 84.9 ± 6.0 y Control: 87.3 ± 5.3 y	Institutionalized (Spain)	Fried	*Physical function* - 5 x sit-to-stand - Timed up and go - Berg Balance Scale - Gait speed (10 m) - SPPB
Gomes et al., 2018	n = 30, 93% females Exercise: 83 ± 5.9 y Control: 85 ± 6.2 y	Institutionalized (Brazil)	Fried	*Physical function* - Mini-BESTest *Fear of falling* - Fear of falling
Kim et al., 2015	n = 131, 100% females MFGM: 81.0 ± 2.8 y Exercise plus MFGM: 81.0 ± 2.6 y Placebo: 80.3 ± 3.3 y Exercise plus placebo: 81.1 ± 2.8 y	Community based (Japan)	Fried	*Physical function* - Gait speed (5 m) - Timed up and go
Sadjapong et al., 2020	n = 64, 61% females Exercise: 76.8 ± 1.1 y Control: 78.9 ± 1.3 y	Community-dwelling adults (Thailand)	Fried	*Physical function* - Time up and go - Berg Balance Scale
Sahin et al., 2018	n = 66, not reported Exercise (group 1): 84.5 ± 4.8 y Exercise (group 2): 84.2 ± 6.8 y Control: 85.4 ± 4.7 y	Institutionalized (Turkey)	Fried	*Physical function* - SPPB
Tarazona-Santabalbina et al., 2016	n = 100, 54% females Exercise: 79.7 ± 3.6 y Control: 80.3 ± 3.7 y	Nursing home (Spain)	Fried	*Physical function* - SPPB - Tinetti Balance Index *Incidence of falls* - Number of falls
Trombetti et al., 2018	n = 1635, 67% females Exercise: 78.7 ± 5.2 y Control: 79.1 ± 5.2 y	Community dwelling (USA)	Study of Osteoporotic Fractures	*Physical function* - 5 x sit-to-stand
Yoon et al., 2018	n = 65, 70% females Exercise: 73.8 ± 4.4 y Control: 74.0 ± 4.3 y	Home based (Korea)	Fried	*Physical function* - Gait speed (4 m) - Timed up and go - SPPB

Notes: MFFP = multifactorial falls prevention; MFGM= milk fat globule membrane supplementation; SPPB = Short Physical Performance Battery.

TESTEX scores of the included studies ranged from 8 to 14 (mean ± SD: 10.6 ± 1.5). Ten (71%) studies showed good methodological quality, and 4 (29%) were deemed to be of high quality. The main reporting limitations identified were insufficient description of exercise volume and energy expenditure (13/14 studies), absence of activity monitoring in the control groups (11/14), and lack of intention-to-treat analysis (9/14) (Appendix 2).

3.3. Assessment of risk of bias

Using the Cochrane Collaboration risk of bias tool-1 [20], we found that 13/14 studies had a high risk of bias, and one study had a low risk of bias. The high risk of bias was mainly due to performance bias (blinding of participants and personnel) and detection bias (blinding of outcome assessment) (Table 3).

3.4. Effect of exercise on lower-limb physical function

All 14 studies reported the effects of exercise training on markers of lower limb function related to falls risk, as measured by clinical tests (e.g., gait speed, timed up and go, sit-to-stand, and SPPB). Faber et al., 2006 [26] (physical performance scale, without individual item scores),

Table 2
Detailed exercise training interventions of included trials.

Reference	Exercise intervention	Exercises prescribed	Frequency	Exercise session	Intensity	Progression	Supervision
Aas et al., 2020	10 weeks Strength training	Leg press and knee extension	2 x week	2–4 sets 12–6 reps 2 min rest 3 min warm-up	12–6 RMs	Week 1: 2–3 sets of 12 reps with submaximal loads Week 2–10: individually adjusted from 3 sets of 12 RMs to 4 sets of 6 RMs	In-person (individual) by experienced training instructors
Cadore et al., 2014	12 weeks Multicomponent training (strength, balance, and gait training)	*Strength training:* bilateral leg extension, bilateral leg flexion, seated bench press *Balance and gait training:* semi-tandem foot standing, line walking, stepping practice, walking with small obstacles, proprioceptive exercises on unstable surfaces (foam pads sequence), and altering the base of support and weight transfer from one leg to the other	2 x week	*Strength training:* 20 min 2–3 sets 8–10 reps 2 min rest *Balance and gait training:* 10 min 5 min warm-up 5 min cool-down	40–60% of 1RM at high velocity of motion	*Strength training:* loads were progressively increased to optimize muscle power *Balance and gait training:* progressive difficulty tasks	In-person (individual) by experienced training instructors
Mollinedo Cardalda et al., 2019	12 weeks Theraband: strength-based training for lower limbs with elastic bands Multi-callisthenics: traditional physical exercise program focused on mobility and coordination for lower limbs	*Theraband:* plantar and dorsal flexors, flexors and knee extensors, flexors, extensors, abductors and hip rotators *Multi-callisthenics:* the exercises were performed mostly in the seated position	2 x week	*Theraband:* 2–4 exercises 2–3 sets 10–15 reps 30–50 s rest 10 min warm-up 45 min 5 min cool-down *Multi-callisthenics:* ? exercises ? sets ? reps ? rest 1 session of calisthenics exercises and 1 session of playful callisthenic games per week 60 min	*Theraband:* not reported *Multi-callisthenics:* not reported	*Theraband:* Week 1–3: 2 exercises, 2 sets of 10 reps with 40 s rest between sets, 60 s rest between exercises Week 4–6: 3 exercises, 3 sets of 15 reps, with the same rest. Week 7–8: 2 exercises, 3 sets of 15 reps, with the same rest. Weeks 10–12: 4 exercises, 3 sets of 15 reps, but 30 s of rest between sets, 50 s rest between exercises *Multi-callisthenics:* not reported	*Theraband:* in-person (groups with 8–9 individuals) by health and fitness professionals specializing in physical activity for older adults *Multi-callisthenics:* in-person (groups with 7–9 individuals) by health and fitness professionals specializing in physical activity for older adults
Chou et al., 2022	24 weeks Vitality Acupunch exercise	Phoenix Fist (palm side of the fist), Tiger Fist (thumb side of the fist), Dragon Fist (little finger side of the fist), Trunk Fist (dorsal side of the fist), and Palm Beat (cupped palm)	3 x week	Three phases with 5 min rest: 8 min Activating qi and blood (5 movements) 19 min Acupunch exercise (14 movements) 8 min Relaxing the body and mind (5 movements) 40 min	Not reported	The initial 4 weeks were motion teaching period. At each session, 2–3 new motions were taught and the previously learnt motions were repracticed	In-person (not reported) by a trained instructor with 2–3 assistants
Faber et al., 2006	20 weeks Functional walking: balance, mobility, and transfer training In Balance: Tai Chi-based exercise program	*Functional walking:* standing up from a chair, standing with the feet parallel shoulder width apart, moving objects between two tables, heel stands and walk, walking along s straight line forward,	1–2 x week	*Functional walking:* 10 exercises ? sets ? reps ? rest 90 min (30 min social activities) *In Balance:* not reported	*Functional walking:* not reported *In Balance:* not reported	*Functional walking:* 1 x week (week 1–4) 2 x week (week 5–20) Emphasis was put on a correct and safe performance rather than on speed and maximum performance.	In-person (group) by experienced instructors in providing exercise activities for older adults and their assistants

(continued on next page)

Table 2 (*continued*)

Reference	Exercise intervention	Exercises prescribed	Frequency	Exercise session	Intensity	Progression	Supervision
		backward, and sideward, stepping, getting up and down a staircase, heel-toe standing and walking, one-leg stand *In Balance:* elements of Tai Chi (relaxion exercises, stretch and relax exercises, pelvis exercise, foot and angle exercise, sitting on a chair, leg strengthening, balance exercises, balance dance, functional exercises). Tai Chi forms were introduced with the emphasis on slow and continuous motions, trunk rotation, and weight shifting		90 min (30 min social activities)		Each exercise was described in 3 or 4 variations to provide various levels of complexity, thus creating the possibility for individual tailoring *In Balance:* the exercises were tailored to the individual abilities of the participants, in that participants were allowed to perform some exercises in a sitting instead of standing position because of fatigue or poor balance control	
Ferreira et al., 2018	12 weeks Multicomponent (mobility, flexibility, strength, and aerobic exercise training)	Not reported	3 x week	15–20 min Mobility training 10 min Flexibility training 10–20 min Aerobic training 15–30 min Strength training ? exercises ? sets ? reps ? rest 40 min	Moderate, RPE between 5–7 at adapted OMNI Scale	The intensity and complexity of exercises were defined based on the initial assessment and adjusted weekly considering the RPE reported by each participant	In-person (groups with 5 individuals) by 2 physical educators and 3 monitors in a personalized and individualized way
García-Gollarte et al., 2023	24 weeks Otago Exercise Program (OEP; balance, strength, and aerobic training) OEP plus oral nutritional supplementation	*Strength training:* knee extensor, knee flexor, hip abductor, ankle plantar flexors (up on toes), ankle dorsiflexors (back on heels) *Balance training:* knee bends, backward walking, walking and turning around, sideways walking, tandem stance, tandem walk, heel walking, toe walking, sit to stand *Aerobic training:* walking	3 x week	45–60 min sets, reps, and rest followed the OEP implementation approach	*Strength training:* exercises at a "somewhat hard" (5–6/10) intensity according to the OMNI Scale with elastic bands in older adults, and the Modified-RPE Scale. *Aerobic training:* the same approach of strength training	Six weeks spent on each of the 4 levels comprising the program. The progression of the exercises, intensity (reps and resistance), and difficulty (support and performance) of the program was structured according to the guidelines for the practical implementation of the OEP. *Strength training:* started with the yellow band at level 1, which provided 1 to 2 kg of resistance, and increased the by 1 to 1.5 kg at levels 2, 3, and 4	In-person (group) by a physical therapist. The chairs were set out in a semicircle in front of the physical therapist to favor participant eye contact
Gomes et al., 2018	7 weeks Nintendo Wii Fit Plus (NWFP) interactive video games	10 NWFP games Table Tilt, Rhythm Parade, Obstacle Course, Single Leg Extension, Tilty City, Basic Step, Penguin, Heading Soccer, Basic Run, Torso Twist	2 x week	2 × 5 games of 2–3 min with 3 min rest between games 50 min	Not reported	The first attempt was with the assistance of a physical therapist to correct the movements and posture using manual guidance and verbal feedback, while the subsequent attempt was performed	In-person (individual) by a physical therapist

(*continued on next page*)

Table 2 (*continued*)

Reference	Exercise intervention	Exercises prescribed	Frequency	Exercise session	Intensity	Progression	Supervision
						independently but under super-vision of the physical therapist	
Kim et al., 2015	12 weeks Multicomponent (strength, balance, and gait exercise training) and MFGM supplementation Multicomponent (strength, balance, and gait exercise training) and placebo	*Strength training:* seated position: toe raises, heel raises, knee lifts, knee extensions standing upright: hip flexions, lateral leg raises elastic bands: leg extensions, hip flexions, double-arm pull downs, biceps curls *Balance training:* standing on one leg and multidirectional weight shifts. Maintenance of stability during walking, and increasing stride length, toe elevation of the forward limb, heel elevation of the rear limb, frequency of stepping, and arm swinging	3 x week	30 min Strength training 20 min Balance and gait training 5 min warm-up 2 min cool-down 60 min	Moderate, with RPE 12–14 on the 6–20 Borg RPE Scale	*Strength training:* progressive sequence from the seated to standing positions, and progressive resistance was applied with the Therabands, and increasing reps of each time of exercise. Resistance or progression was increased on a group basis when the participants were able to properly execute each exercise without significant fatigue or loss of proper execution	In-person (group) by an instructor and two assistant trainers
Sadjapong et al., 2020	24 weeks Multicomponent (aerobic, resistance, and balance training)	Based on songs and postures *Chair aerobic training:* seated marching, leg marching, arm swing, tap and clap, side bend, and arm raised *Strength training with Theraband:* arm curl, backward arm press, hip flexor, hip extensor, hip adductor, hip abductor, knee flexor, knee extensor, ankle plantar flexor, and ankle dorsiflexor *Balance training:* sit to stand, knee bends, backwards walking, walking and turning around, sideways walking, heel toe standing, heel toe walking, one leg stand	3 x week	10–20 min Chair aerobic training 25–30 min Strength training 10 exercises 1–2 sets, 6–8 reps 10 min Balance training 8 stations (static and dynamic balance exercises based on OEP) 5–10 min warm-up 60 min	Moderate, with RPE between 12–13 on the 6–20 Borg RPE Scale) The intensity was set by the color of the Theraband, (red, green, blue, and black (1–8 kg)	Week 1–4: 1–2 sets, 6–8 reps, 65% of 1RM. Week 5–12: 85–100% of initial 1RM, 3 sets, 8–12 reps	In-person (group) by a qualified trainer at the health service center in the community for 12 weeks and unsupervised home-based exercises for 12 weeks. A qualified trainer in exercise trained the volunteers 3 x week for 4 weeks and then became the exercise leader to facilitate the intervention study. Both the exercise leader and physical therapists were present taking care of all participants throughout the study period. All participants performed the exercises together under observation and care from the leader and physical therapists (groups with 8 individuals)
Sahin et al., 2018	8 weeks Low-intensity training: strength training plus balance training High-intensity training: strength training plus balance training	*Strength training with free weights:* hip flexion, extension and abduction, knee flexion, extension and dorsiflexion and plantar flexion, shoulder flexion and abduction, elbow flexion and extension	3 x week	20 min Strength training 1 set 6–10 reps 6–8 s per rep Balance training not reported 10 min warm-up 10 min cool-down 40 min	*Low-intensity training:* strength training at 40% of the 1RM *High-intensity training:* strength training at 70% of the 1RM	Not reported	In-person (not reported) by a physical therapist

(*continued on next page*)

Table 2 (*continued*)

Reference	Exercise intervention	Exercises prescribed	Frequency	Exercise session	Intensity	Progression	Supervision
		Balance training: not reported			The adjustable ankle cuff system was used for lower-limb strength exercises and dumbbells for upper-limb strength exercises		
Tarazona-Santabalbina et al., 2016	24 weeks Multicomponent (aerobic, strength, coordination, balance, and flexibility training)	*Aerobic training:* walking around a circuit and climbing stairs *Strength training:* elastic bands and included isometric, concentric, and eccentric exercises with arms, hands, and legs *Proprioception training (balance and coordination):* postural sway and dynamic balance, coordination, and flexibility of the lumbo-pelvic area *Flexibility training:* stretching exercises including arms, legs, and neck	5 x week (proprioception and balance training) 3 x week (aerobic training) 2 x week (strength training) 5 x week (flexibility training)	10–15 min Proprioception and balance training 40 min Aerobic training 40 min Strength training 1–3 sets 8–30 reps ? rest 5 min Flexibility training 65–70 min Aerobic and strength training were performed on alternating days	*Aerobic training:* 40–65% of HRmax *Strength training:* 25–75% of 1RM	*Aerobic training:* initially at 40% of HRmax increasing progressively to 65% of HRmax *Strength training:* Week 1:	In-person (group) by trainers at a ratio of 1:15
Trombetti et al., 2018	24 months Multicomponent (aerobic, strength, balance, and flexibility training	*Aerobic training:* walking *Strength training:* knee extension, knee flexion, squats, side leg raises, and toe raises *Balance training:* exercises that challenge balance by first decreasing arm support, then decreasing base of support, and finally increasing the complexity of the movements are included *Flexibility training:* brief lower extremity stretching routine	Month 1: 3 x week (2 x week center-based training and 1 x week home-based training) Month 2: 4 x week (2 x week center-based training and 2 x week home-based training) Month 3–24: 5–6 x week (2 x week center-based training and 3–4 x week home-based training)	40 min Aerobic training 10 min Strength training 2 sets 10 reps ? rest 10 min Balance training ? min Flexibility training	*Aerobic training:* moderate, with RPE 13 on the 6–20 Borg RPE Scale *Strength training:* vigorous, with RPE 15–16 on the 6–20 Borg RPE Scale *Balance training:* not reported *Flexibility training:* not reported	Lighter intensity and gradually increase intensity over time Month 1–12: Month 13–24:	In-person (not reported) by instructors
Yoon et al., 2018	16 weeks High-speed strength training	Seated row, one leg press, applied pec deck flus, seated leg raise, lateral raise, semi squats, wide squats, bridging using elastic bands	3 x week	40 min 2–3 sets 12–15 reps contraction phase as quickly as possible, a 1-s pause, and an eccentric contraction exceeding 2 s ? rest 10 min warm-up 10 min cool-down 60 min	Exercise intensities were set by the color of the elastic bands. Blue elastic bands (tension: low, 20 Nm) were used and the participants were instructed to perform exercise training at a RPE between 12–13 on the Borg 6–20 Scale	Not reported	In-person (individual) by an exercise instructor

Notes: reps = repetitions; RM = repetition maximum; RPE = rating of perceived exertion; HRmax = maximum heart rate.

Sahin et al., 2018 [23] (SPPB), and Trombetti et al., 2018 [22] (5 x sit-to-stand) did not provide data in the required form. Therefore, these data were not included in the physical function meta-analysis.

3.4.1. Gait speed

Five trials (seven comparisons) [25,27,29,31,35] provided data for the pooled analysis. Exercise interventions significantly increased gait speed compared to usual care in the short term (≤12 weeks; MD = 0.09 m/s, 95%CI 0.02 to 0.15 m/s; I^2 = 94%; n = 333) (Fig. 2). The certainty of evidence was very low (downgraded three levels due to high risk of bias, inconsistency, and imprecision) (Supplementary table). One study (two comparisons) [25] provided data for the long term (>12 weeks), and exercise interventions did not affect gait speed (MD = 0.08 m/s, 95%CI −0.01 to 0.17 m/s; I^2 = 30%; n = 130) (Fig. 2). The certainty of evidence was very low (downgraded three levels due to a single study, high risk of bias, and imprecision) (Supplementary table).

3.4.2. Timed up and go test

Six studies (eight comparisons) [25,29–31,33,35] provided sufficient data for the pooled analysis at short-term (≤12 weeks), and showed a significant difference in favour of exercise interventions (MD = −3.73 s, 95%CI −5.92 to −1.55 s; I^2 = 95%; n = 409) (Fig. 3). The certainty of evidence was low (downgraded two levels due to high risk of bias and inconsistency) (Supplementary table). Two trials (three comparisons) [25,33] provided data for long-term (>12 weeks) exercise interventions, and the results showed that exercise interventions did not affect the TUG test (MD = −2.17 s, 95% CI −4.88 to 0.54 s; I^2 = 91%; n = 194) (Fig. 3). The certainty of evidence was very low (downgraded three levels due to high risk of bias, inconsistency and imprecision) (Supplementary table).

3.4.3. Sit-to-stand tests

3.4.3.1. 30 s sit-to-stand. Two trials [24,29] provided sufficient data for pooled analysis and showed no difference in the 30 s sit-to-stand test in the short term (≤12 weeks; MD = 1.65, 95% CI −2.76 to 6.06 rep; I^2 = 78%; n = 105) and long term (>12 weeks; MD = 0.03, 95% CI −1.06 to 1.12; I^2 = NA; n = 81) (Fig. 4). The certainty of evidence was very low (downgraded three levels due to high risk of bias, inconsistency and imprecision) (Supplementary table).

3.4.3.2. 5 x sit-to-stand. Four trials (six comparisons) [27,28,30,31] provided sufficient data for pooled analysis at short-term (≤12 weeks), and showed a significant difference in favour of exercise interventions (MD = −2.66 s, 95%CI −4.19 to −1.14 s; I^2 = 77%; n = 250) (Fig. 5). The certainty of evidence was very low (downgraded three levels due to high risk of bias, inconsistency, and imprecision) (Supplementary table).

One study [22] lacked sufficient data to be included in the meta-analysis. However, findings from the study suggested that the prevalence of inability to rise from a chair was 2.8% to 5.8% lower in the physical activity group compared to the health education group across assessment visits.

3.4.4. Balance

Five studies (six comparisons) [29,31–34] reported effects of exercise training on balance using measures such as, FICSIT-4 tests, Berg Balance scale, Tinetti Balance Index, and Mini-BESTest. They provided sufficient data for the pooled analysis of balance in the short term (≤12 weeks) and showed no difference in favour of exercise interventions (SMD = 2.80, 95% CI −0.17 to 5.76; I^2 = 99%; n = 311) (Fig. 6). The certainty of evidence was very low (downgraded three levels due to high risk of bias, inconsistency, and imprecision) (Supplementary table). One trial [33] provided data for the long-term (>3 months), and exercise interventions significantly improved balance (significant effect) (SMD = 1.13, 95% CI, 0.60 to 1.66; I^2 = NA; n = 64) (Fig. 6). The certainty of evidence was very low (downgraded by three levels, being a single study, high risk of bias, and imprecision) (Supplementary table)

3.4.5. SPPB

Three studies (four comparisons) [31,34,35] provided sufficient data for the pooled analysis of SPBB in the short term (≤12 weeks). Exercise interventions did not affect SPPB scores in the short term (≤12 weeks; MD = 0.52, 95% CI −0.59 to 1.63; I^2 = 99%; n = 236) (Fig. 7). The certainty of evidence was very low (downgraded three levels due to high risk of bias, inconsistency and imprecision) (Supplementary table).

One study [23] lacked sufficient data to be included in the meta-analysis. However, the findings from this study suggested that the final SPPB score was significantly better in the high-intensity group compared to the low-intensity group (p = 0.036).

3.4.6. Fear of falling

Only one study [32] reported the effects of exercise on fear of falling, and exercise interventions did not have any impact on fear of falling, with no significant benefits (MD = 5.60, 95% CI −3.60 to 14.80; I^2 = NA; n = 30) (Fig. 8). The certainty of evidence was very low (downgraded three levels being a single study, high risk of bias, and imprecision) (Supplementary table).

Table 3
Risk of bias assessment (Cochrane Risk of Bias 1 tool).

Reference	Selection bias		Performance bias	Detection bias	Attrition bias	Reporting bias	Other bias
	Random sequence generation	*Allocation concealment*	*Blinding of participants and personnel*	*Blinding of outcome assessment*	*Incomplete outcome data*	*Selective reporting*	
Aas et al., 2020	High risk	High risk	High risk	Low risk	High risk	Low risk	High risk
Cadore et al., 2014	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk
Mollinedo Cardalda et al., 2019	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Low risk
Chou et al., 2022	Low risk	Unclear	High risk	Low risk	Low risk	Low risk	Unclear
Faber et al., 2006	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Ferreira et al., 2018	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk
García-Gollarte et al., 2023	Low risk	Low risk	High risk	Low risk	High risk	Low risk	Low risk
Gomes et al., 2018	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk
Kim et al., 2015	Low risk	Low risk	High risk	Low risk	Low risk	Unclear	Low risk
Sadjapong et al., 2020	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Low risk
Sahin et al., 2018	Low risk	High risk	High risk	High risk	Low risk	Low risk	Unclear
Tarazona-Santabalbina et al., 2016	Low risk	Unclear	High risk	Low risk	Low risk	Low risk	Low risk
Trombetti et al., 2018	Low risk	High risk	High risk	Low risk	Low risk	Low risk	Low risk
Yoon et al., 2018	Low risk	Unclear	High risk	High risk	High risk	Unclear	Low risk

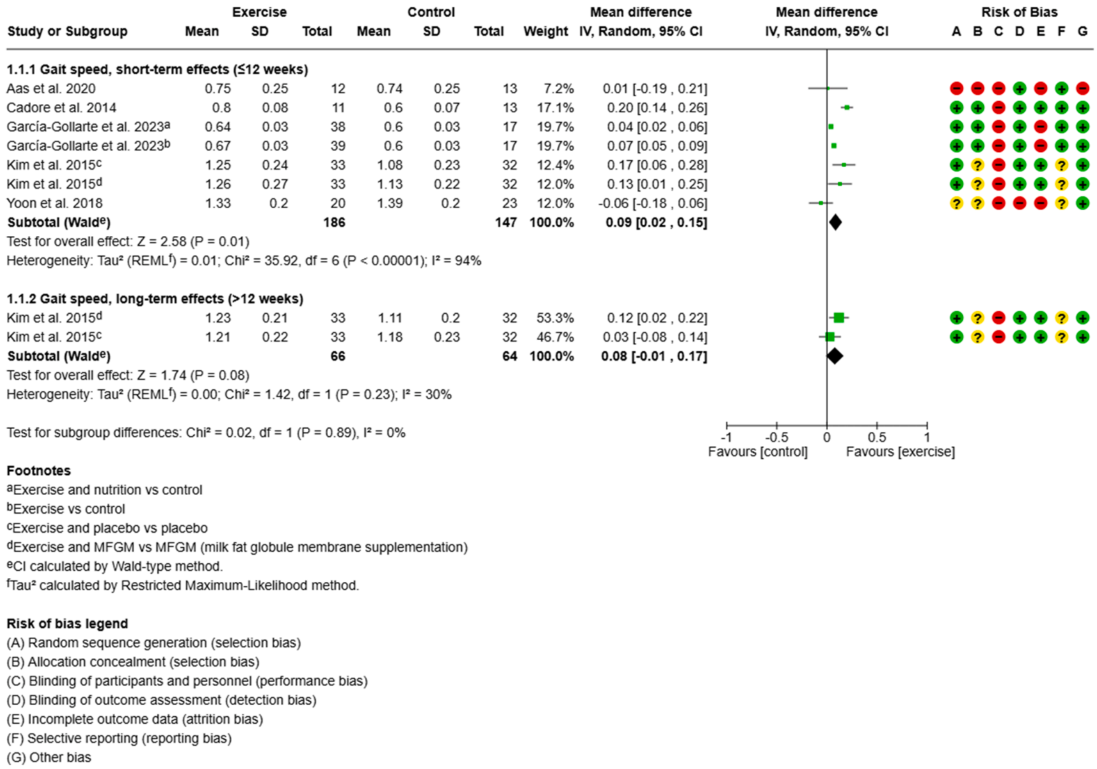

Fig. 2. Effects of exercise interventions on gait speed in older adults with physical frailty.

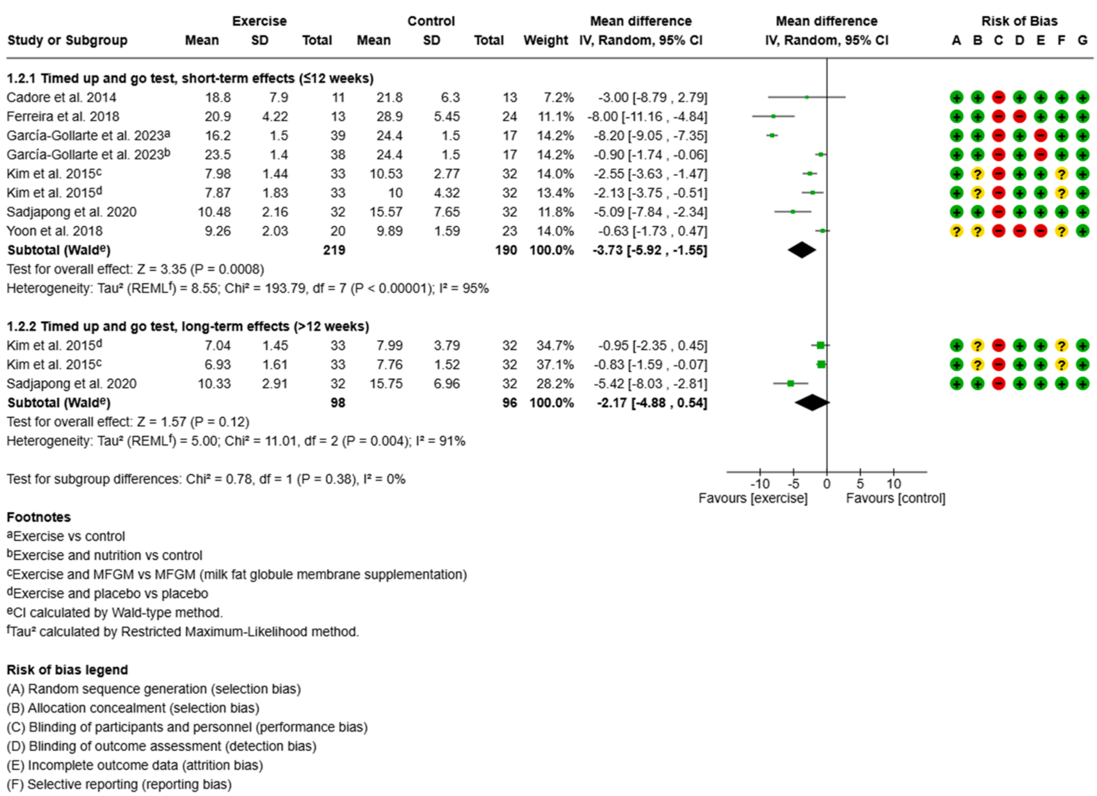

Fig. 3. Effects of exercise interventions on timed up and go performance in older adults with physical frailty.

3.4.7. Incidence of falls

Two studies (three comparisons) [26,34] provided data for pooled analysis for short-term ($\leq$ 12 weeks) fall incidence, and showed no difference in favour of exercise interventions (MD = −0.16, 95% CI −0.54 to 0.23; I^2 = 0%; n = 314) (Fig. 9). The certainty of evidence was low (downgraded by two level due to a high risk of bias, and imprecision) (Supplementary table).

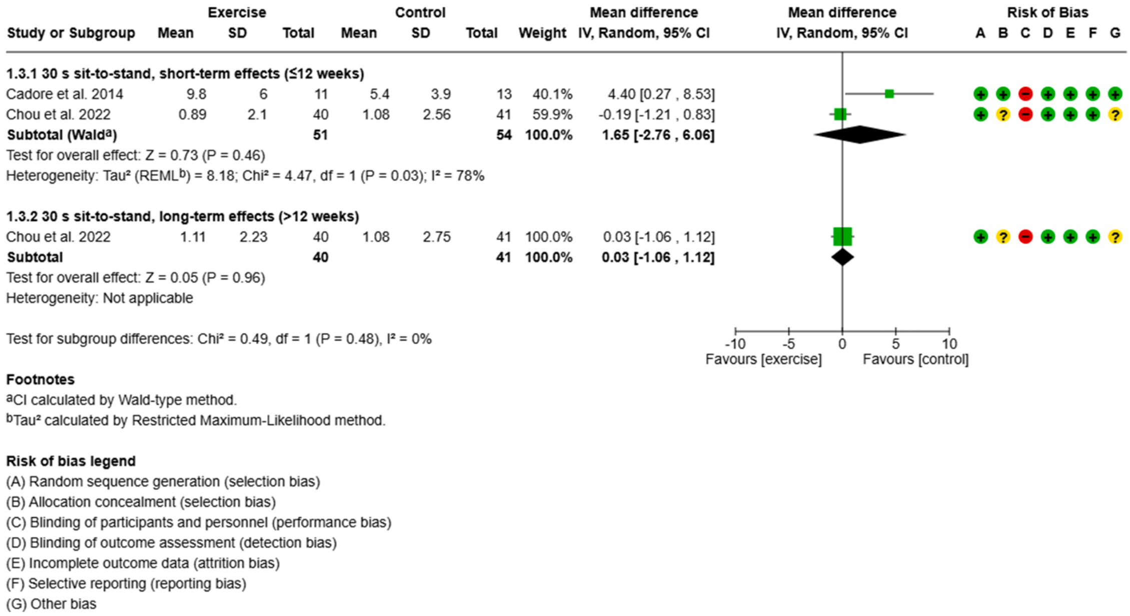

Fig. 4. Effects of exercise interventions on 30 s sit-to-stand performance in older adults with physical frailty.

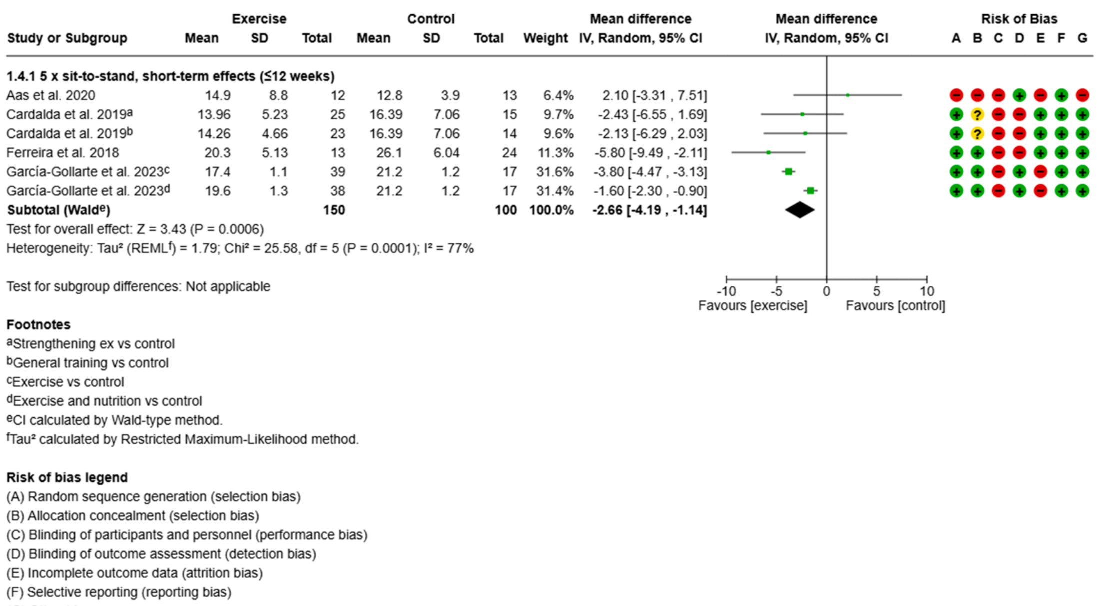

Fig. 5. Effects of exercise interventions on 5 × sit-to-stand performance in older adults with physical frailty.

4. Discussion

This systematic review examined the effects of exercise training on a broad range of fall-related outcomes in older adults with physical frailty, including intermediate outcomes (e.g., physical function and fear of falling) and critical outcomes (e.g., falls incidence). Overall, exercise interventions were associated with short-term improvements in key measures of physical function, particularly gait speed, TUG, and the 5-times sit-to-stand test, with a trend toward improved balance. However, there was no consistent evidence of benefit for fear of falling or falls incidence, and long-term effects were largely inconsistent or non-significant across all outcomes.

From a clinical perspective, the observed improvements in functional lower-limb performance are highly relevant. Gait speed, TUG, sit-to-stand, and balance tests are widely used in clinical and institutional settings and are sensitive markers of mobility, functional reserve, and risk of future disability [36]. These observed benefits are aligned with previous research highlighting the role of exercise interventions, particularly multicomponent and resistance training in improving mobility-related outcomes in older adults with frailty [37,38]. Improvements in these measures may translate into better independence in daily activities, safer transfers, and improved capacity to cope with mobility challenges. We observed mean improvements of 0.09 m/s in gait speed, 3.7 s in the TUG, and 2.7 s in the 5-times sit-to-stand test. These changes exceed commonly reported minimal clinically important difference (MCID) thresholds for older adults and are therefore likely to be clinically meaningful, even though MCID values are not specifically established for older adults with physical frailty [39–43]. In addition, increased gait speed has been consistently associated with greater functional independence and a lower risk of adverse outcomes,

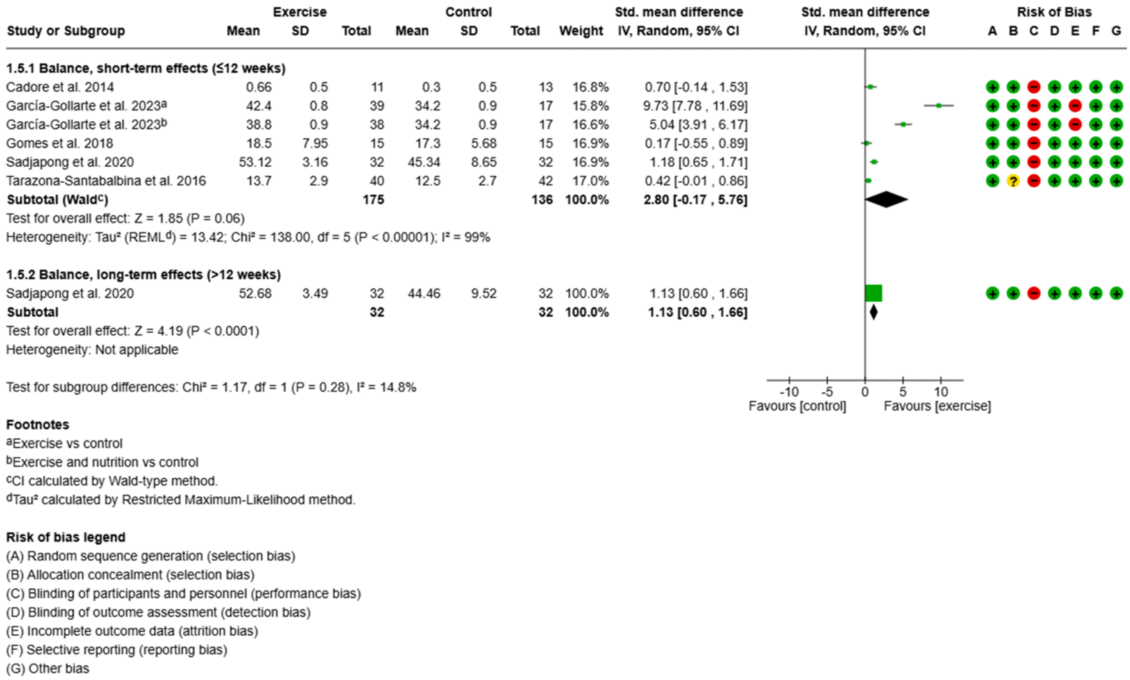

Fig. 6. Effects of exercise interventions on balance performance in older adults with physical frailty.

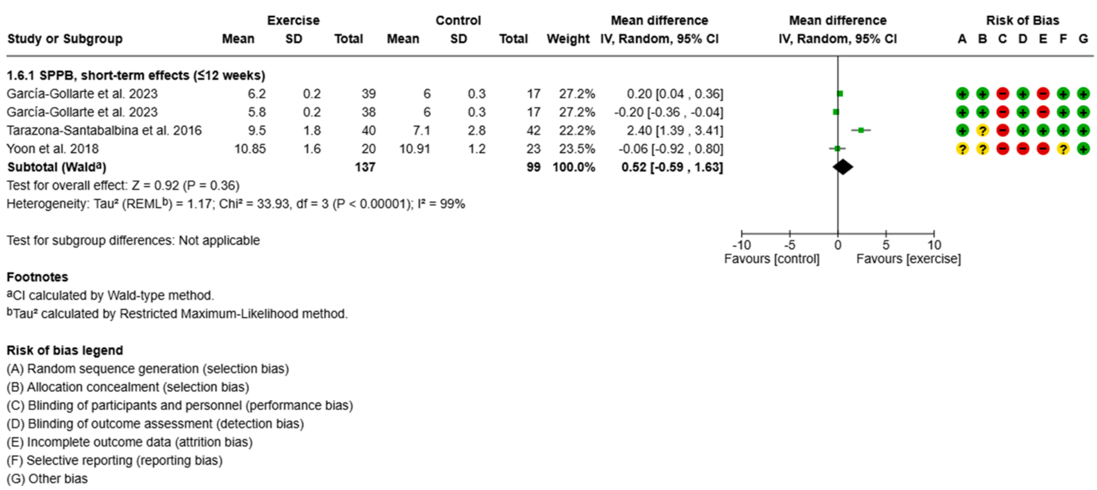

Fig. 7. Effects of exercise interventions on short physical performance battery (SPPB) in older adults with physical frailty.

including falls, in older adults with and without frailty [44]. Even modest gains in gait speed are considered clinically meaningful, as they have been linked to improved independence and mobility in daily life [45]. Taken together, these findings support the role of exercise interventions in improving intermediate fall-related outcomes, particularly lower-limb functional performance.

Fear of falling is another important intermediate outcome in the falls pathway, as it has been associated with activity restriction, loss of independence, and functional decline in older adults [46]. In addition, fear of falling is a strong predictor of future falls in older populations [47]. In the present review, evidence on the effects of exercise interventions on fear of falling was very limited, with only one small trial addressing this outcome and showing no significant benefit. This result indicates that the effects of exercise interventions on fear of falling in older adults with physical frailty remain uncertain, highlighting the need for future studies specifically designed to address this fall-related outcome.

Similar findings were observed for falls incidence, which is the critical outcome for assessing the effectiveness of exercise interventions in preventing falls. In the present review, only two studies evaluated this outcome, and the results were non-significant. Importantly, none of the studies included in this review reported adverse events during the intervention period. Thus, evidence regarding the safety of exercise interventions in individuals with physical frailty remains limited [48]. Given the small number of trials and the relatively short follow-up durations, no definitive conclusions can be drawn regarding the effects of exercise training on falls incidence in older adults with physical frailty. It should be noted that previous systematic reviews have consistently demonstrated that exercise interventions, particularly multicomponent programmes combining functional and balance exercises with resistance training, reduce falls rates, injurious falls, and the number of older adults experiencing falls [9–12]. However, these reviews included broader older adult populations, and none specifically focused on individuals with established physical frailty. Therefore, pragmatic RCTs specifically targeting older adults with physical frailty are needed to determine whether exercise interventions are safe and can effectively

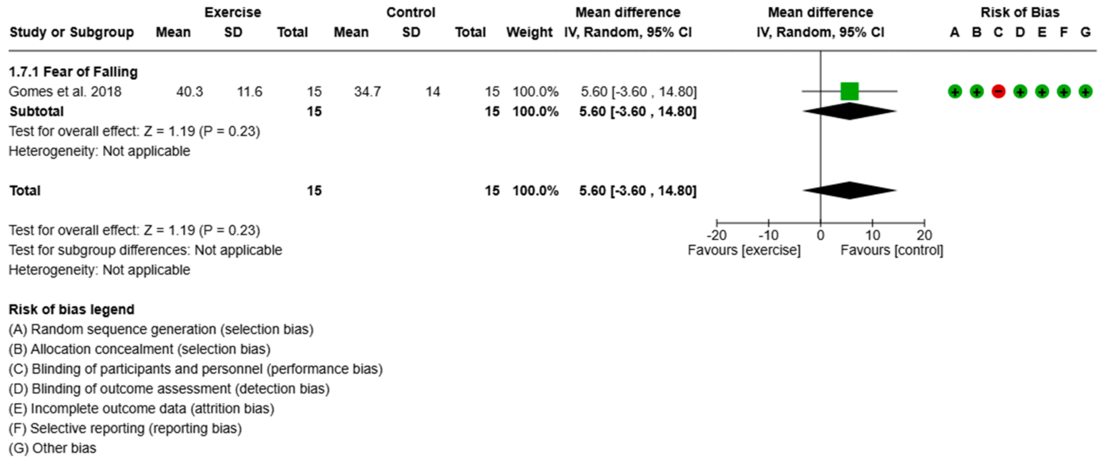

Fig. 8. Effects of exercise interventions on fear of falling in older adults with physical frailty.

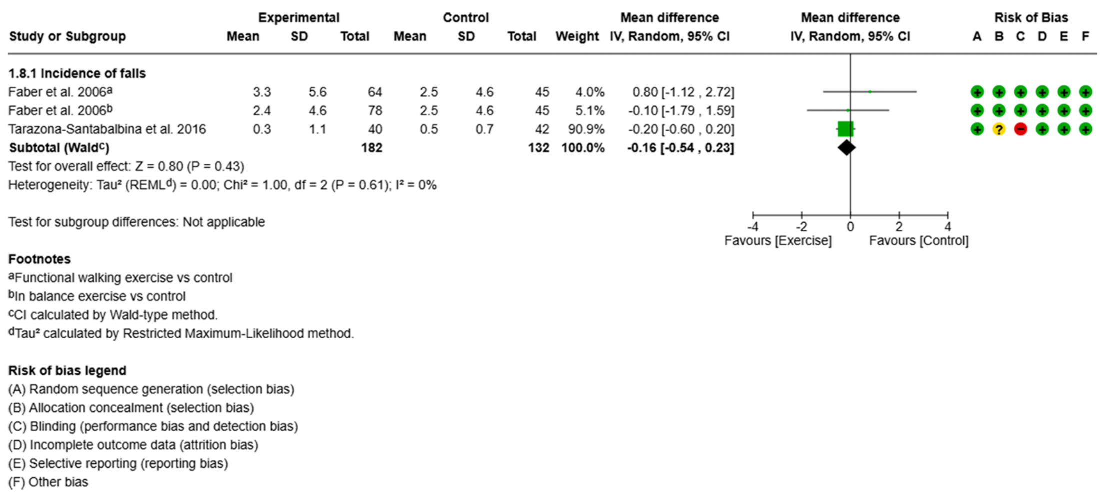

Fig. 9. Effects of exercise interventions on the incidence of falls in older adults with physical frailty.

reduce falls incidence in this high-risk population.

The exercise protocols included in this review were predominantly multicomponent, combining strength, balance, and gait training, and were mostly delivered under in-person supervision in institutional or community settings, supporting their feasibility in older adults with physical frailty [49,50]. However, the substantial heterogeneity observed across outcomes is likely multifactorial. Included studies varied considerably in exercise modality, intervention duration, frequency, supervision, setting, baseline frailty severity, and outcome measurement. Although most interventions were multicomponent, the relative emphasis on strength, balance, gait, and functional training differed substantially across studies. Furthermore, several trials provided limited information regarding exercise intensity, progression, adherence, and monitoring of control-group activity, making it difficult to determine whether differences in exercise dosage contributed to the variability in outcomes. Differences in participant characteristics, particularly baseline physical function and frailty severity, may have also influenced responsiveness to exercise interventions. Consequently, the pooled estimates should be interpreted as evidence supporting the general benefits of structured exercise for improving physical function in older adults with physical frailty. These issues limit reproducibility, clinical translation, and the identification of optimal exercise characteristics for improving fall-related outcomes in this population. Despite this, supervised multicomponent exercise programmes combining strength, balance, gait, and functional training appeared to provide the most consistent benefits on intermediate fall-related outcomes, particularly functional lower-limb performance, in older adults with physical frailty. Future research should prioritise RCTs that include falls incidence as a primary outcome, incorporate longer follow-up periods, safety data, and use standardised and clearly reported exercise protocols.

Of note, our findings are consistent with previous meta-analyses showing that multicomponent exercise programmes improve physical function in older adults, including both community-dwelling and residential care settings [51]. Similarly, most interventions included in our review were multicomponent and resulted in significant improvements in mobility-related outcomes, including gait speed, TUG, and sit-to-stand performance. Regarding fear of falling, the effects of multicomponent exercise programmes appear to be more variable across studies and exercise modalities. Although some benefits have been reported, improvements tend to be more consistent in interventions with a greater emphasis on balance training and mind-body exercise [52–54]. In contrast, exercise has consistently been shown to reduce both falls incidence, including multicomponent exercise interventions [55]. However, while these benefits are well established in broader older adult populations, the limited number of studies evaluating fear of falling and falls outcomes in physically frail older adults precluded firm conclusions regarding these effects in the present review.

4.1. Strengths and limitations

A key strength of this review is the use of a rigorous methodology aligned with established guidelines for systematic reviews. All stages including study selection, data extraction, and risk-of-bias assessment were conducted in duplicate and independently to minimise errors and reviewer bias. However, we do acknowledge that this study has several limitations, majority of which were impossible to control by the authors of the current review. First, the overall quality of the included studies was low, with 13/14 RCTs judged to be at high risk of bias, mainly due to inadequate blinding and incomplete reporting. This significantly reduces the confidence in the evidence. However, this uncertainty highlights the need for further high-quality studies. Second, the wide variability in exercise type, frequency, weekly volume, supervision, and progression introduced substantial methodological and statistical heterogeneity, which limited the ability to draw firm conclusions about the most effective exercise strategies. Third, the certainty of evidence for most outcomes was rated as low to very low, driven by small sample sizes, inconsistency, and imprecision of the studies. Another potential limitation of this study is that only English-language trials were included in the analysis. This restriction may have led to language bias and the exclusion of potentially relevant studies published in other languages from our review. Finally, subgroup analyses to explore heterogeneity (e.g., by exercise type, intensity, weekly volume, or setting) were not feasible because of the small number of studies per outcome.

5. Conclusion

This systematic review indicates that multicomponent exercise interventions provide short-term benefits in intermediate fall-related outcomes, particularly functional lower-limb performance (gait speed, TUG, and 5-times sit-to-stand), in older adults with physical frailty. In contrast, evidence regarding fear of falling, another intermediate outcome, as well as falls incidence, the critical outcome for falls prevention, remains limited and inconclusive. Together, these findings highlight important gaps in the current literature and underscore the need for well-designed, adequately powered RCTs with standardised exercise protocols and rigorous reporting. Structured and supervised multicomponent exercise training should remain a core component of physical frailty management to preserve mobility and functional independence; however, the available evidence does not support exercise interventions alone as an effective strategy to reduce key fall-related outcomes in older adults with physical frailty.

Declaration of generative AI and AI-assisted technologies in the writing process

AI was not used in the preparation of this manuscript.

Ethical statement

This systematic review and meta-analysis used data from previously published studies and did not involve direct recruitment of human participants or animals by the authors. Therefore, additional ethical approval and informed consent were not required for the present review. All included studies involving human participants were expected to have obtained ethical approval and informed consent according to their local institutional requirements. The review protocol was registered in PROSPERO (CRD42024502865).

Declaration of funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Poonam Mehta: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eduardo Caldas Costa:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Leony Morgana Galliano:** Writing – review & editing, Validation, Investigation, Data curation, Conceptualization. **Lara Vlietstra:** Writing – review & editing, Validation, Methodology, Data curation, Conceptualization. **Bruno T Saragiotto:** Writing – review & editing, Formal analysis, Conceptualization. **Eduardo Lusa Cadore:** Writing – review & editing, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Mikel Izquierdo:** Writing – review & editing, Validation, Methodology, Data curation, Conceptualization. **Debra L. Waters:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank the UTS librarian for assisting finalising the search.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjfa.2026.100187.

Data availability

All data used in this systematic review and meta-analysis were extracted from published articles. The extracted datasets and analytic files are available from the corresponding author upon reasonable request.

References

[1] Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56(3):M146–57. https://doi.org/10.1093/gerona/56.3.m146.
[2] Johns Hopkins University. Frailty Science: Promoting Resilience and Healthy Aging. Published 2021. Accessed May 26, 2025. https://frailtyscience.org/research-topics/epidemiology/.
[3] Thompson MQ, Theou O, Karnon J, Adams RJ, Visvanathan R. Frailty prevalence in Australia: findings from four pooled Australian cohort studies. Australas J Ageing 2018;37(2):155–8. https://doi.org/10.1111/ajag.12483.
[4] Dent E, Morley JE, Cruz-Jentoft AJ, et al. Physical frailty: ICFSR international clinical practice guidelines for identification and management. J Nutr Health Aging 2019;23(9):771–87. https://doi.org/10.1007/s12603-019-1273-z.
[5] Lang PO, Michel JP, Zekry D. Frailty syndrome: a transitional state in a dynamic process. Gerontology 2009;55(5):539–49. https://doi.org/10.1159/000211949.
[6] Chi J, Chen F, Zhang J, et al. Impacts of frailty on health care costs among community-dwelling older adults: a meta-analysis of cohort studies. Arch Gerontol Geriatr 2021;94:104344. https://doi.org/10.1016/j.archger.2021.104344.
[7] Yang ZC, Lin H, Jiang GH, et al. Frailty is a risk factor for falls in the older adults: a systematic review and meta-analysis. J Nutr Health Aging 2023;27(6):487–95. https://doi.org/10.1007/s12603-023-1935-8.
[8] Montero-Odasso M, van der Velde N, Martin FC, et al. World guidelines for falls prevention and management for older adults: a global initiative. Age Ageing 2022;51(9):afac205. https://doi.org/10.1093/ageing/afac205.
[9] Pillay J, Gaudet LA, Saba S, et al. Falls prevention interventions for community-dwelling older adults: systematic review and meta-analysis of benefits, harms, and patient values and preferences. Syst Rev 2024;13(1):289. https://doi.org/10.1186/s13643-024-02681-3. Published 2024 Nov 26.
[10] Wang BY, Sherrington C, Fairhall N, et al. Exercise for fall prevention in community-dwelling people aged 60+: more effective in trials with higher fall rates in control groups. J Clin Epidemiol 2023;159:116–27. https://doi.org/10.1016/j.jclinepi.2023.05.003.
[11] Guirguis-Blake JM, Perdue LA, Coppola EL, Bean SI. Interventions to prevent falls in older adults: updated evidence report and systematic review for the US preventive services task force. JAMA, J Am Med Assoc 2024;332(1):58. https://doi.org/10.1001/jama.2024.4166.

[12] Dyer SM, Kwok WS, Suen J, et al. Interventions for preventing falls in older people in care facilities. Cochrane Database Syst Rev 2025;2025(8):CD016064. https://doi.org/10.1002/14651858.CD016064. Published 2025 Aug 20.
[13] Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71. Published 2021 Mar 29.
[14] Rockwood K, Howlett SE. Age-related deficit accumulation and the diseases of ageing. Mech Ageing Dev 2019;180:107–16. https://doi.org/10.1016/j.mad.2019.04.005.
[15] Gobbens RJ, van Assen MA, Luijkx KG, Wijnen-Sponselee MT, Schols JM. The tilburg frailty indicator: psychometric properties. J Am Med Dir Assoc 2010;11(5):344–55. https://doi.org/10.1016/j.jamda.2009.11.003.
[16] World Health Organization. Falls, Published April 26, 2021. Accessed May 26, 2025. https://www.who.int/news-room/fact-sheets/detail/falls.
[17] Smart NA, Waldron M, Ismail H, et al. Validation of a new tool for the assessment of study quality and reporting in exercise training studies: TESTEX. Int J Evid Based Healthc 2015;13(1):9–18. https://doi.org/10.1097/XEB.0000000000000020.
[18] Higgins JPT, Altman DG, Gøtzsche PC, et al. The cochrane collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011;343:d5928. https://doi.org/10.1136/bmj.d5928.
[19] Cohen J. Statistical power analysis for the behavioral sciences, 2. Hillsdale (NJ): Eribaum; 1988.
[20] Higgins J.P.T., Thomas J., Chandler J., et al., editors. *Cochrane Handbook for Systematic Reviews of Interventions*. Version 6.5, updated August 2024. Cochrane; 2024. Available from: https://www.cochrane.org/handbook.
[21] Santesso N, Glenton C, Dahm P, et al. GRADE guidelines 26: informative statements to communicate the findings of systematic reviews of interventions. J Clin Epidemiol 2020;119:126–35. https://doi.org/10.1016/j.jclinepi.2019.10.014.
[22] Trombetti A, Hars M, Hsu FC, et al. Effect of physical activity on frailty: secondary analysis of a randomized controlled trial. Ann Intern Med 2018;168(5):309–16. https://doi.org/10.7326/M16-2011.
[23] Sahin UK, Kirdi N, Bozoglu E, et al. Effect of low-intensity versus high-intensity resistance training on the functioning of the institutionalized frail elderly. Int J Rehabil Res 2018;41(3):211–7. https://doi.org/10.1097/MRR.0000000000000285.
[24] Chou CP, Chen KM, Tung HT, Belcastro F, Hsu HF. Physical fitness and frailty status of frail older adults in long-term care facilities after acupunch exercises: a cluster-randomized controlled trial. Exp Gerontol 2022;163:111799. https://doi.org/10.1016/j.exger.2022.111799.
[25] Kim H, Suzuki T, Kim M, Kojima N, Ota N, Shimotoyodome A, Hase T, Hosoi E, Yoshida H. Effects of exercise and milk fat globule membrane (MFGM) supplementation on body composition, physical function, and hematological parameters in community-dwelling frail Japanese women: a randomized double blind, placebo-controlled, follow-up trial. PLoS One 2015;10(2):e0116256. https://doi.org/10.1371/journal.pone.0116256.
[26] Faber MJ, Bosscher RJ, Chin A Paw MJ, van Wieringen PC. Effects of exercise programs on falls and mobility in frail and pre-frail older adults: a multicenter randomized controlled trial. Arch Phys Med Rehabil 2006;87(7):885–96. https://doi.org/10.1016/j.apmr.2006.04.005.
[27] Aas SN, Breit M, Karsrud S, Aase OJ, Rognlien SH, Cumming KT, Reggiani C, Seynnes O, Rossi AP, Toniolo L, Raastad T. Musculoskeletal adaptations to strength training in frail elderly: a matter of quantity or quality? J Cachexia Sarcopenia Muscle 2020;11(3):663–77. https://doi.org/10.1002/jcsm.12543.
[28] Mollinedo Cardalda I, López A, Cancela Carral JM. The effects of different types of physical exercise on physical and cognitive function in frail institutionalized older adults with mild to moderate cognitive impairment. A randomized controlled trial. Arch Gerontol Geriatr 2019;83:223–30. https://doi.org/10.1016/j.archger.2019.05.003.
[29] Cadore EL, Casas-Herrero A, Zambom-Ferraresi F, Idoate F, Millor N, Gómez M, Rodriguez-Mañas L, Izquierdo M. Multicomponent exercises including muscle power training enhance muscle mass, power output, and functional outcomes in institutionalized frail nonagenarians. Age (Dordr) 2014;36(2):773–85. https://doi.org/10.1007/s11357-013-9586-z.
[30] Ferreira CB, Teixeira PDS, Alves Dos Santos G, Dantas Maya AT, Americano do Brasil P, Souza VC, Córdova C, Ferreira AP, Lima RM, Nóbrega OT. Effects of a 12-week exercise training program on physical function in institutionalized frail elderly. J Aging Res 2018;2018:7218102. https://doi.org/10.1155/2018/7218102.
[31] García-Gollarte F, Mora-Concepción A, Pinazo-Hernandis S, Segura-Ortí E, Amer-Cuenca JJ, Arguisuelas-Martínez MD, Lisón JF, Benavent-Caballer V. Effectiveness of a supervised group-based Otago exercise program on functional performance in frail institutionalized older adults: a multicenter randomized controlled trial. J Geriatr Phys Ther 2023;46(1):15–25. https://doi.org/10.1519/JPT.0000000000000326.
[32] Gomes GCV, Simões MDS, Lin SM, Bacha JMR, Viveiro LAP, Varise EM, Carvas Junior N, Lange B, Jacob Filho W, Pompeu JE. Feasibility, safety, acceptability, and functional outcomes of playing Nintendo Wii Fit PlusTM for frail older adults: a randomized feasibility clinical trial. Maturitas 2018;118:20–8. https://doi.org/10.1016/j.maturitas.2018.10.002.
[33] Sadjapong U, Yodkeeree S, Sungkarat S, Siviroj P. Multicomponent exercise program reduces frailty and inflammatory biomarkers and improves physical performance in community-dwelling older adults: a randomized controlled trial. Int J Environ Res Public Health 2020;17(11):3760. https://doi.org/10.3390/ijerph17113760.
[34] Tarazona-Santabalbina FJ, Gómez-Cabrera MC, Pérez-Ros P, Martínez-Arnau FM, Cabo H, Tsaparas K, Salvador-Pascual A, Rodriguez-Mañas L, Viña J. A multicomponent exercise intervention that reverses frailty and improves cognition, emotion, and social networking in the community-dwelling frail elderly: a randomized clinical trial. J Am Med Dir Assoc 2016;17(5):426–33. https://doi.org/10.1016/j.jamda.2016.01.019.
[35] Yoon DH, Lee JY, Song W. Effects of resistance exercise training on cognitive function and physical performance in cognitive frailty: a randomized controlled trial. The journal of nutrition. Health Aging 2018;22(8):944–51. https://doi.org/10.1007/s12603-018-1090-9.
[36] Beaudart C, Rolland Y, Cruz-Jentoft AJ, et al. Assessment of muscle function and physical performance in daily clinical practice: a position paper endorsed by the European society for clinical and economic aspects of osteoporosis, osteoarthritis and musculoskeletal diseases (ESCEO). Calcif Tissue Int 2019;105(1):1–14. https://doi.org/10.1007/s00223-019-00545-w.
[37] Haider S, Grabovac I, Dorner TE. Effects of physical activity interventions in frail and prefrail community-dwelling people on frailty status, muscle strength, physical performance and muscle mass-a narrative review. Wien Klin Wochenschr 2019;131(11–12):244–54. https://doi.org/10.1007/s00508-019-1484-7.
[38] Vlietstra L, Fordyce AM, Costa EC, et al. Exercise interventions to improve physical frailty and physical frailty components in older adults with hypertension: a systematic review. Ageing Res Rev 2025;107:102714. https://doi.org/10.1016/j.arr.2025.102714.
[39] Bohannon RW, Glenney SS. Minimal clinically important difference for change in comfortable gait speed of adults with pathology: a systematic review. J Eval Clin Pract 2014;20(4):295–300. https://doi.org/10.1111/jep.12158.
[40] Kon SS, Canavan JL, Nolan CM, et al. The 4-metre gait speed in COPD: responsiveness and minimal clinically important difference. Eur Respir J 2014;43(5):1298–305. https://doi.org/10.1183/09031936.00088113.
[41] Beauchamp MK, Hao Q, Kuspinar A, et al. Reliability and minimal detectable change values for performance-based measures of physical functioning in the Canadian longitudinal study on aging. J Gerontol A Biol Sci Med Sci 2021;76(11):2030–8. https://doi.org/10.1093/gerona/glab175.
[42] Gautschi OP, Stienen MN, Corniola MV, et al. Assessment of the minimum clinically important difference in the timed up and go test after surgery for lumbar degenerative disc disease. Neurosurgery 2017;80(3):380–5. https://doi.org/10.1227/NEU.0000000000001320.
[43] Goldberg A, Chavis M, Watkins J, Wilson T. The five-times-sit-to-stand test: validity, reliability and detectable change in older females. Aging Clin Exp Res 2012;24(4):339–44. https://doi.org/10.1007/BF03325265.
[44] Figgins E, Pieruccini-Faria F, Speechley M, Montero-Odasso M. Potentially modifiable risk factors for slow gait in community-dwelling older adults: a systematic review. Ageing Res Rev 2021;66:101253. https://doi.org/10.1016/j.arr.2020.101253.
[45] Van Abbema R, De Greef M, Crajé C, Krijnen W, Hobbelen H, Van D, Schans C. What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. BMC Geriatr 2015;15:72. https://doi.org/10.1186/s12877-015-0061-9. Published 2015 Jul 1.
[46] MacKay S, Ebert P, Harbidge C, Hogan DB. Fear of falling in older adults: a scoping review of recent literature. Can Geriatr J 2021;24(4):379–94. https://doi.org/10.5770/cgj.24.521. Published 2021 Dec 1.
[47] Ellmers TJ, Ventre JP, Freiberger E, et al. Does concern about falling predict future falls in older adults? A systematic review and meta-analysis. Age Ageing 2025;54(4):afaf089. https://doi.org/10.1093/ageing/afaf089.
[48] García-Hermoso A, Ramirez-Vélez R, Sáez de Asteasu ML, et al. Safety and effectiveness of long-term exercise interventions in older adults: a systematic review and meta-analysis of randomized controlled trials. Sports Med 2020;50(6):1095–106. https://doi.org/10.1007/s40279-020-01259-y.
[49] Izquierdo M, de S, Barreto P, Arai H, et al. Global consensus on optimal exercise recommendations for enhancing healthy longevity in older adults (ICFSR). J Nutr Health Aging 2025;29(1):100401. https://doi.org/10.1016/j.jnha.2024.100401.
[50] Fragala MS, Cadore EL, Dorgo S, et al. Resistance training for older adults: position statement from the national strength and conditioning association. J Strength Cond Res 2019;33(8):2019–52. https://doi.org/10.1519/JSC.0000000000003230.
[51] Valenzuela PL, Saco-Ledo G, Morales JS, et al. Effects of physical exercise on physical function in older adults in residential care: a systematic review and network meta-analysis of randomised controlled trials. Lancet Healthy Longev 2023;4(6):e247–56. https://doi.org/10.1016/S2666-7568(23)00057-0.
[52] Zhou L, Huang J, Wang C, et al. Effect of exercise interventions on fear of falling in older adults: a systematic review and network meta-analysis of randomised controlled trials. Age Ageing 2026;55(5):afag152. https://doi.org/10.1093/ageing/afag152.
[53] Feng C, Adebero T, DePaul VG, Vafaei A, Norman KE, Auais MA. Systematic review and meta-analysis of exercise interventions and use of exercise principles to reduce fear of falling in community-dwelling older adults. Phys Ther 2022;102(1):pzab236. https://doi.org/10.1093/ptj/pzab236.
[54] Kruisbrink M, Delbaere K, Kempen GIJM, et al. Intervention characteristics associated with a reduction in fear of falling among community-dwelling older people: a systematic review and meta-analysis of randomized controlled trials. Gerontologist 2021;61(6):e269–82. https://doi.org/10.1093/geront/gnaa021.
[55] Sherrington C, Fairhall NJ, Wallbank GK, et al. Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev 2019;2019(1):CD012424. https://doi.org/10.1002/14651858.CD012424.pub2. Published 2019 Jan 31.