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Effective fall prevention exercise in residential aged care: an intervention component analysis from an updated systematic review

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ABSTRACT

Objective The effect of fall prevention exercise programmes in residential aged care (RAC) is uncertain. This paper reports on an intervention component analysis (ICA) of randomised controlled trials (RCTs), from an update of a Cochrane review, to develop a theory of features of successful fall prevention exercise in RAC.

Methods Trial characteristics were extracted from RCTs testing exercise interventions in RAC identified from an update of a Cochrane review to December 2022 (n=32). Eligible trials included RCTs or cluster RCTs in RAC, focusing on participants aged 65 or older, assessing fall outcomes with stand-alone exercise interventions. ICA was conducted on trials with >30 participants per treatment arm compared with control (n=17). Two authors coded trialists' perceptions on intervention features that may have contributed to the observed effect on falls. Inductive thematic analysis was used to identify the key differences between the trials which might account for positive and negative outcomes.

Results 32 RCTs involving 3960 residents including people with cognitive (57%) and mobility (41%) impairments were included. ICA on the 17 eligible RCTs informed the development of a theory that (1) effective fall prevention exercise delivers *the right exercise* by specifically targeting balance and strength, tailored to the individual and delivered simply at a moderate intensity and (2) successful implementation needs to be *sufficiently resourced* to deliver structured and supervised exercise at an adequate dose.

Conclusions This analysis suggests that delivering the right exercise, sufficiently resourced, is important for preventing falls in RAC. This clinical guidance requires confirmation in larger trials.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Exercise reduces the risk of falls for older people in the community with tailored balance and functional exercise having the strongest fall prevention effect.
⇒ The evidence concerning the effects of fall prevention exercise in residential aged care (RAC) is less clear, limiting guidance for clinicians working in RAC.

WHAT THIS STUDY ADDS

⇒ This intervention component analysis (ICA) used a mixed method approach to develop a theory of potential features of effective fall prevention exercise in RAC that can be explored and validated in future analyses. This theory indicates that (1) exercise interventions for fall prevention in RAC should include balance and strength exercise delivered at a moderate intensity and tailored to the individual and (2) exercise programmes in RAC are more likely to be successful if structured, supervised and resourced to deliver an adequate dose.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Findings from this ICA will assist implementation of fall prevention programmes in RAC; guide a qualitative comparative analysis and subgroup meta-analysis in RAC and inform the design of interventions to be tested in future large clinical trials in RAC.

INTRODUCTION

Falls are prevalent in residential aged care (RAC), affecting half of residents annually, diminishing independence, increasing care burden and imposing economic costs.[1 2] Implementing effective interventions holds the potential to benefit older individuals and alleviate healthcare burden.[3]

The 2019 Cochrane Review in community-dwelling older adults reported exercise prevents falls, particularly with balance and functional exercises, reducing rates by 24% (rate ratio (RaR) 0.76, 95% CI 0.70 to 0.81; 7920 participants, 39 studies; I^2=29%, high-certainty evidence).[4] Programmes combining balance, functional and resistance exercises reduced the rate of falls by 34% (RaR 0.66, 95% CI 0.50 to 0.88; 1374 participants, 11 studies; I^2=65%, moderate-certainty evidence). Conversely, the 2018 Cochrane Review for residents in aged care reported uncertain effects of exercise on falls (RaR=0.93, 95% CI 0.72 to 1.20; 2002 participants, 10 studies; I^2=76%, very low-quality evidence).[5] Subgroup analyses couldn't explain high outcome heterogeneity, challenging clinicians in selecting effective exercise programmes.[6]

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In this study, we conducted an intervention component analysis (ICA), a method utilising inductive qualitative analysis to collate trialists' reflections on the factors influencing the success or failure of an intervention. Our objective is to answer three research questions. (1) What are the characteristics of trials included in the updated Cochrane Review?[5] (2) Using ICA, what are the intervention and implementation features that are present in successful fall prevention exercise programmes in RAC? and (3) What explanatory theory does the information in the first two questions suggest for supporting knowledge translation of fall prevention programmes and informing future research in RAC?[7]

METHODS

This systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[8] This ICA was developed according to the methodology detailed in an existing published theory.[7]

Selection of studies

Criteria followed Cameron *et al*'s 2018 Cochrane Review on preventing falls in older care facility residents.[5] New trials from 2017 to December 2022 were sourced from CENTRAL, MEDLINE, Embase and CINAHL databases, adhering to the Cochrane Review's search methods.[5] Only randomised controlled trials (RCTs) and cluster RCTs with participants aged 65+ in RAC, reporting fall rates or risk and comparing exercise interventions to usual care or control were considered. Trials with ≥30 participants per arm were included to mitigate small sample bias,[9] encompassing outcomes that reduced, had no effect neutral, or increased falls (figure 1).

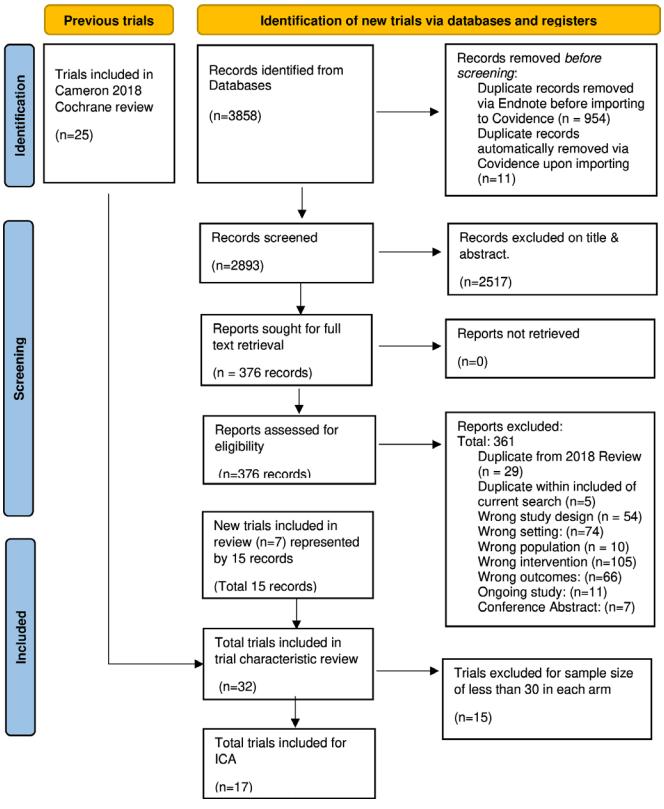

Figure 1 PRISMA flowchart of trial selection. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Data extraction

Trial features

Two aged care physiotherapists (RD and WK) extracted trial and participant characteristics (trial design, sample size, age, gender, cognitive and mobility status), exercise features (type, duration, dose, delivery, supervision, tailoring, intensity) and fall outcomes from new trial's final endpoint or the Cochrane Review.[5] Adherence was classified as good if the participant exercise session attendance rate exceeded 50%, and/or if 75% or more of the participants attended 50% or more of the exercise sessions.[10] Exercise classifications adhered to the Prevention of Falls Network Europe (ProFANE) exercise taxonomy[11] and include standardised intensity ratings like the Borg Rating of Perceived Exertion Scale[12] and trialist's self-classification. Low-intensity exercise refers to gentle physical activity where the heart rate and breathing are low; moderate-intensity exercise elevates heart rate and breathing moderately; while high-intensity exercise elevates heart rate and breathing to near maximal effort, making it difficult to sustain a conversation.[12] The ProFANE group's exercise descriptors cover structured programmes including strength exercises (resistance training with weights and/or body weight), gait, balance and functional exercises mirroring daily movements (eg, stepping, sit-to-stand), flexibility, general physical activity and 3D exercises like Tai Chi. Disagreements were resolved through discussion and involvement of a third author as required (SD and JS).

Fall outcomes were expressed as rate or risk ratio with 95% CI. They were coded positive (<0.75), neutral (0.75 to 1.25) or negative (>1.25) based on Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) group guidance for consideration of 'appreciable benefit or harm'.[13] Data analysed in Excel.

Trial quality

Two trained independent physiotherapists (RD, WK) assessed study quality using the Physiotherapy Evidence Database (PEDro) scale, which evaluates 11 criteria: inclusion criteria, random allocation, concealed allocation, baseline similarity, blinding of subjects, therapists and assessors, completeness of follow-up, intention-to-treat analysis, between-group statistical comparisons and outcome measures.[14] Disagreements were resolved through discussion. External validity, the first item, does not contribute to the score, yielding scores from 0 to 10. Ratings: 0–4 (poor), 4–5 (fair) and 6–8 (good). Scores of 9–10 (excellent) are n't feasible in exercise trials due to blinding constraints.

Intervention component analysis

We conducted ICA over four stages:

1. Authors (RD and WK) described the trial features, quality and classified fall outcomes in Excel.[13]
2. Authors (RD and JS) coded trialists' reflections on effective and ineffective features in eligible publications' discussion and conclusion sections, including any additional trial-related documents (eg, protocols, process evaluations) identified through systematic search, pearling and hand searching. A selection of publications was coded independently in duplicate; the remainder were extracted by RD and checked by JS, with disagreements resolved through discussion. Codes were stored in NVivo V.12.[15]

3. RD conducted an inductive thematic analysis in NVivo on included trials, grouping codes to develop themes and subthemes on successful intervention features and implementation.[16] JS and SD reviewed groupings to ensure thematic agreement. Both JS and SD experienced qualitative and falls researchers, respectively, offered critical perspectives to the thematic analysis as non-exercise professionals.
4. RD reviewed the themes against the trial outcomes and the intervention features to develop a theory regarding the types of intervention features and implementation strategies most likely to be effective in preventing falls in RAC. All authors were involved with developing the final theory.

Equity, diversity and inclusion statement

The author group consists of junior, mid-career and senior researchers from different countries and disciplines, most of whom are women. Our study population included both male and female older adults from different socioeconomic and geographical backgrounds.

RESULTS

Trial and participant characteristics from an updated systematic review

Thirty-two trials were included across 16 countries involving 3960 participants with 35 exercise intervention arms. Many trials have small sample sizes, with a median number of 71 participants and a range from 16[17] to 682 participants.[18] Participant ages ranged from 68[19] to 92 years,[20 21] with a median of 82 years; 74% were women. Eighteen (57%) trials included people with cognitive impairment and 13 (41%) trials included those with mobility disabilities. Trial length varied from 4 weeks[22] to 104 weeks,[23] with a median of 12 weeks (IQR 12–26). Total intervention hours ranged from 1.5 hours[24] to 112 hours,[25] with a median trial dose of 22 hours (IQR 14–36) or 1.8 hours per week, comprising a median of three sessions per week (IQR 2–3) with a median session duration of 33 min (IQR 25–48). Sixteen (52%) trials met good exercise adherence criteria. Ten (32%) trials reported adverse events, including two falls during exercise.[26 27] Most trials compared an exercise intervention with usual care, defined as seated low-intensity range of movement exercise programmes, self-directed or social programmes (online supplemental material A).

Intervention components

The most common exercise intervention was gait, balance and functional training combined with strength training in 18 (51%) intervention arms. The most common single intervention was gait, balance and functional training in five (14%) arms. In 20 (63%) trials, exercise interventions were tailored to the individual. Fifteen (47%) trials delivered exercise at moderate intensity, 14 (44%) at low intensity and three (9%) at high intensity. Thirteen (41%) trials were led by physiotherapists, three (9%) by other health professionals and trained non-exercise professionals led 14 (44%) trials; five trials (16%) did not report who led the intervention. There was a mix of supervised and unsupervised individual and group exercise, with supervised groups being the most common in 19 trials (59%) with a median of five participants per group (IQR 5–8) (online supplemental material B)

Quality assessment

The PEDro study quality summary is displayed in online supplemental material C. The median PEDro quality score for the trials included in the ICA was ‘good’ (6/10).

Intervention component analysis

The ICA included 17 trials involving 3293 participants with a median age of 82 years (ranging from 75 to 86 years); 73% were female participants. Ten trials (59%) included people with cognitive impairment and seven trials (41%) included people with mobility disability (table 1). The participant characteristics of the ICA trials reflected the 32 trials included in the updated Cochrane review. ICA identified two major themes related to exercise features and implementation, each with three subthemes (table 2). ICA Codebook outlines the coding framework, which is displayed in online supplemental material D. The correspondence between the themes and the trial’s effectiveness synthesis are summarised in table 3. The ICA also identified some study design features that could be associated with intervention effects.

The right exercise

The most common theme supported by the trialist’s commentary focused on providing the *right exercise* to reduce falls. The results of our thematic analysis suggest that the right exercise is a combination of exercise that targets balance and strength, tailored to the individual’s physical and cognitive comorbidities and delivers moderate-intensity exercise (table 2). Ten trials targeted progressive standing balance and strength exercise,[27–36] 12 studies delivered tailored exercise prescription[18 27–35 37 38] and 6 studies delivered moderate-intensity exercise subtheme[27–32] (table 2). Six of eight effective trials[27–32] supported the right exercise theme, while zero out of nine neutral or negative trials did not (table 3).

Supporting exercise engagement

The second theme centred on *supporting exercise engagement*. However, there was less trialist commentary on this theme (table 2) and only two of eight effective trials included all the subthemes.[27 31] Only the first subtheme had sufficient evidence to progress to the ICA theory (table 3). Four of eight effective trials provided sufficient resourcing as defined as trials that delivered structured and supervised exercise at a dose greater than 30 hours[27 28 30 32] compared with two of nine neutral or negative trials.[34 38] Group exercise that offers socialisation opportunities were offered in five of eight effective trials[27 28 30–32] but was also offered in four of nine neutral or ineffective trials.[33 34 36 38] Fall prevention education was a feature in three of eight effective trials[27 29 31] and one of nine neutral or negative trials.[23] The effectiveness synthesis demonstrated that there was insufficient evidence to involve the group exercise and fall education subthemes in the final ICA theory displayed in figure 2.

Trial methodological design features

Two features emerged as themes relating to trial design and their impact on effective fall prevention trials. Seven authors commented that some trials are too small to detect significant changes in falls.[23 28 30 33 34 36 38] Five authors commented that trial designs that involved an active control diluted the fall effect.[30–33 36]

DISCUSSION

ICA is a valuable tool for researchers, clinicians and policymakers, enabling the identification of promising intervention components and their implementation strategies. Through ICA methodology, trialist perspectives are plotted against trial outcomes, culminating in the development a theory of effectiveness that can be explored and validated though subsequent analyses. This ICA theory indicates that effective fall prevention

Table 1 Summary characteristics of 17 ICA trials at inclusion

First author, year	N	Age	Cognitive impairment	Mobility	Trial length (weeks)	Dose (hours)	Exercise ProFANE category	Tailored	Exercise intensity	Delivery mode	Exercise leader
Trials that reduced falls*											
Arrieta, 2019	112	84.9	Mild	1	26	52	BGF/strength	Yes	Mod	Group	EP
Dhargrave, 2020	162	74.6	Mild	1	12	42	BGF/strength	Yes	Mod	Individual	PT
Fu, 2015	60	82.3	NR	2	6	18	Balance	Yes	Low	NR	PT
Hewitt, 2018	221	86.0	Mild to moderate	4	52	76	BGF/strength	Yes	Mod	Group	PT
Irez, 2011	60	75.4	NR	NR	12	36	BGF/strength	Yes	Mod	Group	TNP
Jahanpeyma 2020	71	75.2	Nil	1	12	27	BGF/strength	Yes	Mod	Group	TNP
Kovacs, 2013	86	77.8	Mild to moderate	1	52	104	BGF/strength	Yes	Mod	Group	PT
Yokoi, 2015	105	79.3	Nil	1	26	22	General physical activity	No	Low	Individual	TNP
Trial interventions that had no effect on falls*											
Buckinx, 2014	62	83.2	Mild to moderate	3	26	1.5	BGF/strength	No	Low	Individual	PT
Faber, 2006	168	84.4	Mild to moderate	1	20	36	1.BGF/ strength 2.Tai Chi	Yes	1.Mod 2.Low	Group	TNP
Kerse, 2008	682	84.3	Mild	1	26	91	BGF	Yes	Low	Individual	TNP
Nowalk, 2001	110	84.0	NR	1	104	NR	1.End/strength 2.Tai Chi	No	1.Low 2.Low	1.NR 2.Group	1.EP 2.TNP
Rosendahl, 2008	191	84.7	Mild to moderate	4	12	22	BGF/strength	Yes	High	Group	PT
Sakamoto, 2006	533	81.6	Mild to moderate	3	26	18	BGF	No	Low	Individual	PT
Toots, 2019	186	85.1	Mild to moderate	3	16	30	BGF/strength	Yes	High	Group	PT
Trial interventions that increased falls*											
Mulrow, 1994	194	80.6	Mild to moderate	2	16	24	BGF/strength	Yes	Low	Individual	PT
Sitja Rabert, 2015	159	82.0	Nil	4	6	9	BGF/strength and WBV	No	Low	Group	NR

1 = walk without staff assistance, 2 = walk with staff assistance, 3 = stand without staff assistance, 4 = stand with staff assistance.
*We sought to identify whether the trials that reported positive fall outcomes (fall risk or rate ratio<0.75) were qualitatively different to those with neutral (fall risk or rate ratio 0.75 to 1.25) or negative outcomes (fall risk or rate ratio>1.25).
BGF, ProFANE category referring to Balance, Gait or Functional exercises; End, endurance exercise; EP, exercise physiologist; ICA, intervention component analysis; Mod, moderate; NR, not reported; PT, physiotherapist; TNP, trained non-exercise professional; WBV, whole body vibration.

programmes within RAC centre on the delivery of the *right exercise* when *sufficiently resourced*. However, larger trials are required to expand the evidence base for effective fall prevention exercise programmes in RAC.

In this ICA, we propose that *right exercise* is tailored, moderate intensity, balance and strength exercise. In general, this is in accordance with the evidence for effective exercise programmes in the community.[4] However, Sherrington and colleagues' subgroup analysis revealed that balance and functional exercises with or without resistance exercises had the greatest fall prevention effects in the community.[45] Cameron and colleagues' subgroup analysis for combination exercises in RAC, including balance and strength exercise[30 32 33 35 38] or physical activity plus strength,[17] did not find a significant reduction in falls (RaR 0.94, 95% CI 0.6 to 1.47); however, there were only six trials in this subgroup analysis.[5] Our ICA was based on an update of Cameron *et al*'s Cochrane review, which reported that balance and strength exercises were the most prescribed interventions in effective trials (88%) compared with those with neutral or negative fall outcomes (33%). Becker and colleagues' multifactorial trial in RAC also supports this finding. They reported that progressive standing balance and strength exercises reduced the rate of falls by 45%.[39]

Our review of trial characteristics revealed that 20 out of the 32 trials were tailored to the individual. In the ICA, 88% of positive trials tailored the exercise programmes compared with 56% of trials with neutral or negative fall outcomes. Several trialists stated that exercise needs to be tailored throughout the programme to cater for participants' changing physical and cognitive capabilities to learn the programme and to maintain exercise adherence, which is a key factor in reducing falls.[33 35 38 40] Contrary to this finding, a recent review of tailored exercise delivered in the community found no significant reduction in fall outcomes.[41]

Six effective trials delivered exercise at a moderate intensity[27–32] compared with two effective trials that delivered exercise at a low intensity.[37 40] Among the trials with neutral or negative fall outcomes, both low or high intensity models were tested. Kerse *et al* revealed that low-intensity exercise delivered in small doses throughout the day by care workers as part of the resident's usual activities was ineffective.[18] Faber *et al* reported that high-intensity individual training was neither effective nor sustainable for long-term exercise due to the resident's high level of comorbidities.[38] Nowalk, Yokoi and Sakamoto and colleagues all commented that successful exercise interventions should be delivered in a way that is simple and easy to learn to maximise exercise compliance in RAC and increase exercise intensity over time.[23 40 42]

Trialists provided limited comments on ideal implementation strategies. However, the ICA suggested the importance of adequate resources to support exercise structure, supervision and dosage. Analysis of trial characteristics revealed a median weekly dose of 1.8 hours across 32 trials from this updated Cochrane search, significantly lower than the 3 hours/week recommended by Sherrington *et al*'s meta-regression for effective community-based fall prevention.[43] Kerse *et al* emphasised

Table 2 Development of intervention and implementation themes in the ICA

Subtheme	Trials (n)	Examples of informal evidence	Correspondence between themes and trial outcome*
Theme 1: the right exercise			
Balance and strength (21 codes)	11	'Multicomponent exercise program focusing primarily on strength and balance training found to be the most effective strategy in the management of falls in the elderly'. Dhargave *et al*,[29] p57	6/8 trials with positive findings tested the effect of exercise interventions that combined progressive standing balance and strength. 4/9 trials with neutral or negative findings also involved balance and strength exercise.
Tailored to the individual (34 codes)	12	'This pattern (fluctuating adherence) of commitment to exercise interventions, suggests that exercise programs may need to be specially tailored for individual seniors' changing needs, interests, physical, and cognitive capabilities'. Nowalk *et al*,[23] p864	7/8 positive trials tailored their exercise programme to the individual and progressed it accordingly. 5/9 trials with neutral or negative findings tailored the programme.
Moderate intensity (21 codes)	8	'6 months of individualised and progressive multicomponent exercise at moderate intensity composed of strength, balance and walking recommendations in long term nursing home residents was effective to prevent falls'. Arrieta *et al*,[28] p1149	6/8 trials with positive findings tested exercise interventions at a moderate intensity. The other two trials tested low intensity exercise. 0/9 trials with neutral or negative findings tested moderate intensity exercise.
Theme 2: exercise engagement support			
Sufficiently resourced (17 codes)	8	'The study identified an overall reduction in the risk of falls in individuals who underwent structured exercise program, whereas we identified that those who were not provided with any of the supervised training had an increase in risk of falls after the study period'. Dhargave *et al*,[29] p57 'A dose of 30 or more hours of this type of exercise over a 25 week time frame may therefore produce outcomes similar to those with the higher doses previously recommended'. Hewitt *et al*,[27] p7	4/8 positive trials sufficiently resourced via funding the trials to deliver structured and supervised balance and strength exercise interventions>30 hours compared with 2/9 trials with neutral to negative findings.
Group exercise to allow for socialisation (6 codes)†	3	'Elderly people can reduce their risk of falling by participating in moderate intensity group-exercise programs. Another reason for preferring moderate intensity exercise is that a key element in sustaining exercise participation of older people is the opportunity to socialize. Faber *et al*,[38] p893	5/8 trials delivered their exercise interventions in a group that supported participant socialisation. 4/9 trials with neutral or negative findings also delivered group exercise.
Staff and resident education (6 codes)†	4	'Educating staff and residents on the potential benefits of progressive resistance training (PRT) and balance training may have resulted in higher participation rates'. Hewitt *et al*,[27] p7	3/8 trials with positive findings employed educational strategies to increase adherence – one trial highlighted staff education, one resident education and one both. 1/9 trials with neutral or negative findings provided staff and resident educational strategies.

*Trial was included in the thematic table if they included 100% of the intervention component.
†Subtheme was unable to differentiate clearly between successful and neutral/negative trials and therefore did not proceed to the final ICA theory.
ICA, intervention component analysis.

the need for funding to support more intensive interventions and supervision,[18] while Kovacs *et al* stressed the importance of sufficient physiotherapy resources for effective fall prevention exercise.[32] More research is required to better understand the implementation of an ideal fall prevention exercise programme in RAC. However, there is likely a higher need for supervision in this setting, given the high level of frailty and comorbidities in this population.

This ICA suggests future RCTs on fall prevention exercises in RAC should increase their sample size, enhance study quality by reducing bias in the design and improve reporting. A total PEDro score of 8 is optimal for multifaceted interventions like exercise trials, contrasting with the median trial score of 6.[44] In the 32 trials identified in the Cochrane review update, 15 enrolled fewer than 60 participants, requiring a larger sample size to detect differences in fall rates.[9] Additionally, many trials did not meet the standards of the Consolidated Standards of Reporting Trials (CONSORT) statement.[45] The reporting of almost two-thirds of trials did not describe allocation concealment, with some not clearly describing their control group. This poor reporting made coding exercise features difficult and reduces the generalisability of this ICA.

Hewitt *et al*'s Sunbeam trial achieved an optimal PEDro score of 8,[27] demonstrating effective fall prevention through a physiotherapy-led tailored, progressive standing balance and strength exercises. With a 55% fall rate reduction and improved mobility outcomes, the trial implemented exercise engagement supports detailed in our thematic analysis (table 3). It provided a mean exercise dose of 36 hours, employing user-friendly electronic equipment, fostering high programme adherence via staff and resident education and supervised group exercise for socialisation. Similarly, the Otago Exercise Program, known for its balance and strength focus, demonstrated effectiveness in community settings and merits investigation in RAC.[46]

Research implications

The ICA theory will inform a qualitative comparative analysis (QCA), which examines the ICA theory's consistency and identifies conditions contributing to effective falls prevention programmes.[7] While both ICA and QCA facilitate identifying processes and potential mechanisms that link intervention features and outcomes, we acknowledge that causation cannot be definitively established using probabilistic or counterfactual accounts using these approaches. A recent study employing ICA and QCA methodologies on multifactorial fall prevention interventions highlighted the importance of incorporating exercise and engaging aged care staff and managers in implementing tailored strategies in RAC.[47] These findings emphasise the need for future research to explore multifactorial interventions in RAC settings, explore specific programme needs for recurrent fallers who may have different needs compared with single

Table 3 Presence of themes and subthemes in ICA trials (effectiveness synthesis)

First author, year	Balance and strength	Tailored to individual	Moderate intensity	Right exercise	Sufficiently resour-ced	Group exercise allowing socialisation	Staff and resident education	Exercise engagement support*	Falls outcome (95% CI)
Trial interventions that reduced falls†									
Arrieta, 2019	Yes	Yes	Yes	Yes	Yes	Yes	No	Partial	0.45‡ (0.29 to 0.69)
Dhargrave, 2020	Yes	Yes	Yes	Yes	Partial	No	Yes	Partial	0.72‡ (0.44 to 1.17)
Fu, 2015	No	Yes	NR	Partial	Partial	NR	No	No	0.35‡ (0.19 to 0.63)
Hewitt, 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0.45‡ (0.17 to 0.74)
Irez, 2011	Yes	Yes	Yes	Yes	Yes	Yes	No	Partial	0.28‡ (0.15 to 0.54)
Jahanpeyma, 2020	Yes	Yes	Yes	Yes	Partial	Yes	Yes	Yes	0.39‡ (0.23 to 0.66)
Kovacs, 2013	Yes	Yes	Yes	Yes	Yes	Yes	No	Partial	0.67§ (0.37 to 1.23)
Yokoi, 2015	No	No	No	No	Partial	No	No	No	0.30§ (0.07 to 1.28)
Trial interventions that had no effect on falls†									
Buckinx, 2014	No	No	No	No	No	No	No	No	0.96‡ (0.58 to 1.60)
Faber, 2006	Partial	Yes	Partial	Partial	Yes	Yes	No	Partial	1.13‡ (0.95 to 1.35)
Kerse, 2008	No	Yes	No	Partial	Partial	No	No	No	1.11‡ (0.84 to 1.45)
Nowalk, 2001	Partial	Partial	No	Partial	Partial	Partial	Yes	Partial	NR; No sig. difference
Rosendahl, 2008	Yes	Yes	No	Partial	Partial	Yes	No	Partial	0.82‡ (0.44 to1.53)
Sakamoto, 2006	No	No	No	No	Partial	No	No	No	0.82‡ (0.65 to 1.04)
Toots, 2019	Yes	Yes	No	Partial	Yes	Yes	No	Partial	0.9‡ (0.5 to 1.61)
Trial interventions that increased falls†									
Mulrow, 1994	Yes	Yes	No	Partial	Partial	No	No	No	1.32‡ (0.95 to 1.85)
Sitja Rabert, 2015	Yes	No	No	Partial	Partial	Yes	No	Partial	1.28§ (0.71 to 2.31)

*We used the definition based on two quotes for sufficient resourcing for trials that allocated funding to deliver structured and supervised exercise at a dose of 30+ hours, excludes trials that incorporated exercise into usual care.
†We sought to identify whether the trials that reported positive fall outcomes (fall risk or rate ratio<0.75) were qualitatively different to those with neutral (fall risk or rate ratio 0.75 to 1.25) or negative outcomes (fall risk or rate ratio>1.25).
‡Fall rate ratio.
§Fall risk ratio.
ICA, intervention component analysis.

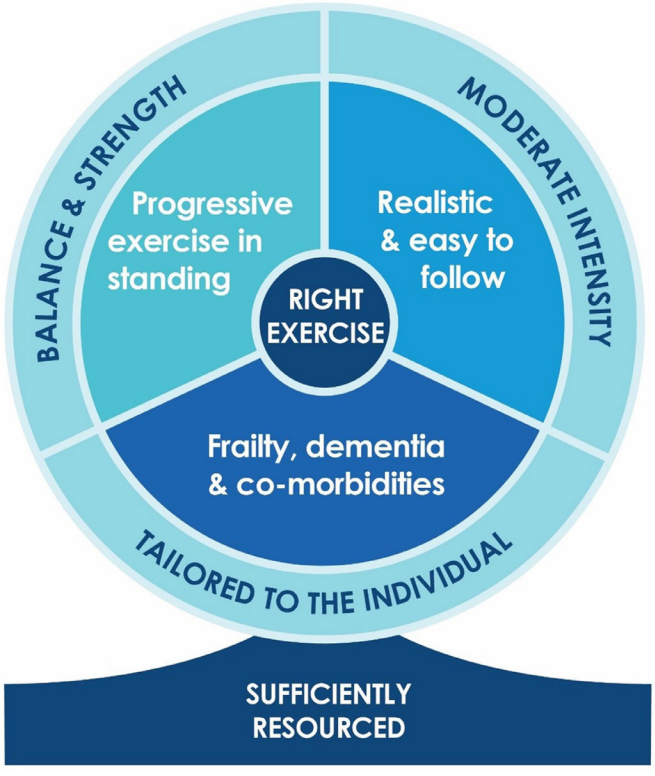

Figure 2 ICA theory of effective fall prevention exercise in residential aged care. ICA, intervention component analysis.

fallers and in other settings to enhance the generalisability of our ICA and bolster the quality of evidence.

To enhance reporting, future trials should adhere to recognised trial reporting guidelines such as the CONSORT statement,[45] Standard Protocol Items: Recommendations for Interventional Trials statement,[48] Template for Intervention Description and Replication checklist[49] and Consensus on Exercise Reporting guidelines[50] to enhance reporting.

Strengths and Limitations

This updated systematic review, incorporating ICA, ensures rigorous methodology. Nonetheless, limitations include the exclusion of conference abstracts, trial records and studies on exercise within multifactorial interventions. Some trials excluded older adults with high cognitive and mobility impairments, potentially limiting result generalisability. Additionally, exercise descriptions were often broad, lacking specificity like sensorimotor training. Incomplete reporting may have compromised ICA quality, hindering a more comprehensive explanatory theory.

CONCLUSION

Examining trial characteristics in the updated Cochrane Review on fall prevention exercise in RAC reveals intervention heterogeneity. This ICA enriches trial descriptors, aiding theory development and practical applications. Trialists suggest sufficiently resourced, tailored balance and strength exercises delivered at moderate intensity may prevent falls. Future larger trials should scrutinise this ICA theory, delivery mode, dose, different implementation and engagement strategies, and adhere to reporting guidelines.

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Contributors All authors conceptualised and designed the study and were involved in applying the ICA methodology in this study. Analysis of data was undertaken by RD, WSK, JS and SD. RD drafted the manuscript. RD is the guarantor and has access to the data, accepts full responsibility for the conduct of the study and controlled the decision to publish. All authors critically revised the manuscript for intellectual content, approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Supplementary material A: Characteristics of the included trials

Clinically and statistically significant reduction in falls (point estimate is less than 0.75 and the confidence interval does not cross 1)															
Author, year, Trial Design	**Cont[1]**	**RACF**	**N, Rand**	**Trial Location**	**Age, mean**	**Gender % women**	**Mean number co-morb.**	**Cognitive Impair. at baseline**	**Mobility criteria at enrollment**	**Adhe-rence[2]**	**Severe Adverse events[3]**	**Summary of exercise intervention (frequency, session length, planned trial dose)**	**Falls rate ratio**	**Falls risk ratio**	**Other effect data**
Arrieta, 2019, RCT, 2 arms	Y	HC	112	Spain	84.9	71	2	Mild	Walk without staff assistance	Yes	Nil	26/52 tailored, progressive strength, gait, balance and functional group program, EP led, moderate intensity. (2/wk, 60min/session, 52hrs)	26/52 0.45 (0.29, 0.69)	26/52 0.86 (0.52, 1.41)	NR
Brett, 2021, RCT, 3 arms	Y	HC	60	Australia	85	65	9	Mild, moderate or severe	All level of mobility	Yes	Nil	12/52 tailored, progressive group strength, balance, endurance and flexibility program., PT led, moderate intensity. Intervention A: (1/wk, 45 min/session, 9 hrs.) Intervention B: (3/wk, 15min/session, 9hrs)	12/52 0.23 (0.14, 0.37	12/52 0.48 (0.27, 0.87)	NR
Fu, 2015, RCT, 2 arms	N	HC	60	China	82.3	65	NR	NR	Walk with staff assistance	Yes	NR	6/52 progressive Wii Fit balance program, PT led, intensity NR. (3/wk, 60min/session, 18 hrs)	52/52 0.35 [0.19, 0.63]	NR	NR
Hewitt, 2018, Cluster RCT, 2 arms	Y	HC	221	Australia	86	65	3	Mild to moderate	Stand with staff assistance	Yes in 6/12 active section No in main-tenance	Nil	25/52 tailored and progressive strength using HUR Health and Fitness equipment, functional and balance group program, PT led, moderate intensity. (2/wk, 60min/session,50 hrs); followed by 6/12 maintenance program	52/52 0.45 [0.17, 0.74]	52/52 0.66 (0.47, 0.93)	Fall-related fracture risk ratio: 0.76 (0.21 to 2.74
Irez, 2011, RCT, 2 arms	Y	IC	60	Turkey	75.4	100	NR	NR	NR	Yes	NR	12/52 tailored, progressive group Pilates program (strength and balance components), TNP led, moderate intensity. (3/wk, 60min/session, 36 hrs)	12/52 0.28 [0.15, 0.54]	NR	NR

Jahanpeyma, 2020 RCT, 2 arms	Y	HC	71	Turkey	75.2	75	NR	Nil	Walk without staff assistance	NR	NR	12/52 tailored, progressive Otago Exercise Program, TNP led, moderate intensity (3/wk,45min/session, 27 hrs) + walking prescription (3/wk, 30 min/session, 18 hrs)	12/52 0.39 [0.23, 0.66]	NR	NR
Saravanakumar, 2014, RCT, 2/3arms Yoga	Y	M	11 / 33	Australia	85.2	88	10	Mild to moderate	Stand with support	Yes	Yes	14/52 group yoga program, TNP led, low intensity. (2/wk, 30min/session, 14 hrs)	26/52 0.47 [0.24, 0.91]	NR	NR
Saravanakumar, 2014, RCT, 2/3arms Tai Chi	Y	M	11 / 33	Australia	83.3	63.6	10	Mild to moderate	Stand with support	Yes	Yes	14/52 group tai chi program, TNP led, low intensity. (2/wk, 30min/session, 14 hrs)	26/52 0.52 [0.28, 0.98]	NR	NR
Sihvonen, 2004, RCT, 2 arms	NR	IC	28	Finland	81.7	100	2.6	Nil	Stand without staff assistance	Yes	NR	4/52 individual tailored and progressive balance exercise program using force platform. Moderate intensity. Program lead NR. (3/wk,30min/session, 6 hrs)	52/52 0.40 (0.17, 0.93)	52/52 0.77 (0.42, 1.42)	NR
Clinically but not statistically significant reduction in falls															
Cadore, 2014, RCT, 2 arms	Y	M	32	Spain	91.9	70	NR	Nil	Walk with and without staff assistance	Yes	NR	12/52 Individual, tailored, progressive strength, gait, balance and functional program. TNP led, moderate intensity. (2/wk, 40 min/session, 16 hrs)	NR	NR	IG: 0 fall, CG: 0.8/pt/ mnth Time*group interaction P<.001
Serra-Rexach, 2011, RCT, 2 arms	Y	HC	40	Spain	92	80	1.4	Mild to moderate	Walk with or without staff assistance	Yes	Nil	8/52 individual tailored, progressive strength, flexibility, cycling exercise, EP led, low to moderate intensity. (3/wk, 45min/session, 18 hrs)	NR	NR	IG:1.2 95% CI: 0.-3 fewer than control P.03
Toulotte, 2003, RCT, 2 arms	Y	M	20	France	81.4	NR	NR	Mild to moderate	Walk with or without staff assistance	NR	NR	16/52 progressive, tailored balance and seated strengthening, flexibility group program. GP led, low intensity. (2/wk, 45min/session, 24 hrs)	NR	NR	IG 0 fall, CG Part. 6 falls, no p value

Clinically significant but statistically non-significant reduction in falls (point estimate is 0.75 or less but the confidence interval crosses 1)															
Choi, 2005, Quasi RCT, 2 arms	Y	IC	59	Korea	77.	75	NR	Mild to moderate	Walk with and without staff assistance	Yes	NR	12/52 Tai Chi group exercise program. TNP led, low intensity. (3/wk, 35min/session, 21 hrs)	NR	52/52 0.6 (0.19, 1.87)	NR
Dhargrave 2020, RCT, 2 arms	Y	IC	163	India	74.6	53	NR	Mild	Walk without staff assistance	NR	NR	12/52 tailored, progressive flexibility, gait, balance, functional program and walking, PT led, moderate intensity. (7/wk., 30min/session, 42 hrs.)	12/52 0.72 (0.44, 1.17)	12/52 0.72 (0.39, 1.32)	NR
Imaoka, 2016, RCT, 4 arms	N	HC	91	Japan	84.3	76	NR	NR	NR	NR	NR	12/52 (1) strength and balance ex, x2/wk of individualised exercise, x1/wk group exercise (14 hrs) (2) the low exercise group control group minus group program (8 hrs) (3) nutrition group was given oral vitamin D, no ex. (4) low-level exercise and received vitamin (8 hrs)		12/52 0.48, (0.17, 1.3)	NR
Kovacs, 2012, 2 arms	N	IC	41	Hungary	69.2	100	2.3	NR	Walk with staff assistance	Yes	Nil	26/52 progressive tailored multimodal exercise program. PT led, moderate intensity (x2/wk, 30 min/session, 26 hrs)	NR	26/52 0.54 [0.29, 1.01]	NR
Kovacs, 2013, RCT, 2 arms	Y	IC	86	Hungary	77.8	81	2.4	Mild to moderate	Walk without staff assistance	Yes	NR	52/52 tailored, progressive gait, balance, functional and strength group program. PT led, moderate intensity. (2/wk, 60min/session, 104 hrs)	52/52 0.77 [0.37, 1.62]	52/52 0.67 (0.37, 1.23)	NR
Shimada 2004, RCT, 2 arms	N	IC	32	Japan	83.4	78	NR	Nil	Walk without staff assistance	NR	NR	26/52 Ind treadmill program lead NR, mod intensity (2/wk, 10min/session, 9 hrs)	26/52 0.42 (0.08, 2.06)	NR	NR
Tuunainen, 2013, RCT, 2/3 arms Gait, Bal., functional	N	HC	18 / 55	Finland	85	89	3.8	Mild, moderate, severe	Stand without staff assistance	NR	NR	13/52 Progressive gait, balance and functional group program, PT led, intensity NR. (2/wk, 60min/session, 26 hrs)	156/52 0.65 [0.4, 1.06]	NR	NR
Tuunainen, 2013, RCT, 2/3 arms Strength	N	HC	18 / 55	Finland	84.7	67	3.8	Mild, moderate, severe	Stand without staff assistance	NR	NR	13/52 Progressive strengthening group exercise program. PT led, intensity NR. (2/wk, 60min/session, 26 hrs)	156/52 0.74 [0.5, 1.1]	NR	NR

Varela, 2018, RCT, 2 arms	Y	HC	74	Spain	81.1	38	NR	Nil	Walk without staff assistance	No	NR	64/52 self-selected intensity cycling. Supervised by physio (7/wk, 15min/session, 112 hrs)	64/52 0.67 [0.3, 1.21)	NR	NR
Yokoi, 2015, Cluster RCT, 2 arms	Y	IC	105	Japan	79.3	60	3.9	Nil	Walk without staff assistance	Yes	Nil	26/52 individual seated physical activity exercise with traditional Japanese 'stick', TNP led, low intensity. (2/wk, 25min/session, 22 hrs)	NR	52/52 0.3 [0.07, 1.28]	NR
Significant effect on falls not detected or not present (point estimate between 0.75 and 1.25 regardless of confidence interval)															
Buckinx, 2014, RCT, 2 arms	Y	IC	62	Belgium	83.2	76	3	Mild to moderate	Stand without staff assistance	Yes	NR	26/52 individual whole body vibration program. PT/TNP led, low intensity. (3/wk, 1.25min/session, 1.5 hrs)	52/52 0.96 [0.58, 1.60]	52/52 0.88 [0.54, 1.43]	NR
Faber, 2006, RCT, 3 arms Tai Chi	Y	M	168	Nether-lands	84.4	79	NR	Mild to moderate	Walk without staff assistance	Yes	NR	20/52 Tai Chi group program TNP led, low intensity. (2/wk, 60min/session, 36 hrs)	52/52. 0.96 [0.77, 1.19]	52/52 1.19 (0.79, 1.79)	NR
Kerse, 2008, Cluster RCT, 2 arms	Y	IC	682	New Zealand	84.3	74	4.9	Mild	Walk without staff assistance	No	Nil	26/52 functional exercise program. TNP led, low intensity. (7/wk, 15min/session, 91 hrs)	52/52 1.11 [0.84, 1.45]	52/52 1.19 (0.94, 1.5)	NR
Nowalk, 2001, RCT, 3 arms	Y	M	110	USA	84	86	NR	NR	Walk without staff assistance	No	NR	52-104/52 Progressive, individualised strength ex. and physical activity (cycling, treadmill) or low intensity Tai Chi groups classes led by TNP (3/wk, ?/session, ? dose)	NR	NR	No signif-icant differ-ence p=0.27
Rosendahl, 2008, Cluster RCT, 2 arms	Y	M	191	Sweden	84.7	73	3.1	Mild to moderate	Stand with staff assistance	Yes	NR	12/52 progressive, strength, functional ex. and balance group ex. program based on high-intensity functional ex. PT led, high intensity. (2.5/wk, 45min/session, 22 hrs)	26/52 0.82 [0.44, 1.53]	26/52 1.05 (0.77, 1.44)	NR
Sakamoto, 2006, RCT, 2 arms	Y	IC	533	Japan	81.6	74	≥ 1	Mild to moderate	Stand without staff assistance	NR	NR	26/52 unipedal standing balance exercise. PT led, low intensity. (7/wk, 6min/session, 18 hrs)	26/52 0.82 [0.65, 1.04]	26/52 0.9 [0.65, 1.23]	NR
Toots, 2019, RCT, 2 arms	Y	HC	186	Sweden	85.1	76	3	Mild to moderate	Stand with or without staff assistance	Yes	Nil	16/52 progressive, strength, functional, balance group ex., high intensity, PT led. (2.5/wk, 45min/session, 30 hrs)	64/52 0.9 (0.5, 1.61)	64/52 0.97 (0.76. 1.22)	NR

Clinically and statistically significant increase in falls: point estimate greater than 1.25 and the CI does not cross 1														
Schoenfelder, 2000, RCT, 2 arms	NR[1]	HC	16	USA	82.8	75	NR	Mild	Walk without staff assistance	NR	NR	12/52 ankle strengthening and walking, NP led, low intensity. (3/wk, 20min/session, 12 hrs)	26/52 2.72 [1.42, 5.19]	NR	NR
Clinically significant but statistically non-significant increase in falls: if the point estimate is 1.25 or more but the CI crosses 1														
Faber, 2006, RCT, 3 arms Gait, balance, functional ex.	Y	M	154	Nether-lands	85.4	79	NR	Mild to moderate	Walk without staff assistance	Yes	NR	20/52 gait, balance and functional group program, TNP led, moderate intensity. (1-2/wk, 60min/session, 36 hrs)	52/52. 1.32 (1.09, 1.61)	52/52 1.31 (0.87, 1.98)	NR
Mulrow, 1994, 2 arms	Y	HC	194	USA	80.6	71	5.1	Mild to moderate	Walk with and without staff assistance	Yes	Nil	16/52 individual, tailored, progressive strength, balance, gait and functional ex. PT led, mainly low intensity (3/wk,30 min/session, 24 hrs)	16/52 1.32 [0.95, 1.85]	16/52 1.16 (0.83 to 1.62)	NR
Sitja Rabert, 2015, RCT, 2 arms	N	M	159	Spain	82	67	NR	Nil	Stand with assistance	Yes	Nil	6/52 progressive strength and balance exercise program with vibration platform therapy, low Intensity, program lead NR (3/wk, 30min/session, 9 hrs)	NR	1.28 (0.71, 2.31) NB: 6/12 FU	NR
Uncertain: insufficient data to make judgement														
Buettner 2002, RCT. 2 arms	Y	M	27	USA	83.3	48	NR	Severe, moderate or mild	Walk with staff assistance	NR	NR	12/52 group strengthening, balance and gait program. Recreation therapist led, low intensity. (3/wk, 60min, 36 hrs)	NR	NR	NR
Da Silva Borges, 2014, RCT, 2 arms	Y	IC	59	Brazil	67.5	NR	NR	Nil	Walk without staff assistance	NR	NR	12/52 group ball room dancing program. TNP led, high intensity. (3/wk, 50min/session, 30 hrs)	NR	NR	NR

NR = not reported, HC = high care facility, IC = intermediate care facility, M = mixed (IC and HC)

1: Routine or usual care Y =authors described the control group as usual or routine care such as seated range of movement exercises, N= authors described the control group as physical activity and exercise programs that include active exercise beyond routine or usual care

2: Attendance rate exceeded 50% and/or 75% or more of the participants attended 50% or more sessions

3: TNP = trained non-professional, EP = Exercise Professional, PT = Physiotherapist, GP = general practitioner

Supplementary material B: ProFaNE Components of the included trials

First author, year	Type of exercise (ex.) according to ProFaNE classification a							Duration in weeks	Total hours b	Delivery Mode c	Ex. supervised	Part. per group d	Program leader	Exercise tailored to individual	Exercise progressed	Exercise Intensity
	Gait, Balance functional	Strength/ resistance training	Flexibility training	3D ex.	General Physical Activity	Endur-ance exer.	Other exer.									
Arrieta, 2019	P	P	S					26	52	1	Y	NR	EP	Y	Y	Mod
Brett, 2021	P	P	S		S			12	9	1	Y	5	PT	Y	Y	Mod
Buckinx, 2014	S	S					P	26	1.5	2	Y	NA	PT	N	N	Low
Buettner 2002	P	P			P		S	12	24	1	Y	4	TNP	N	N	Low
Cadore 2014	P	P	S					12	16	2	Y	NA	TNP	Y	Y	Mod
Choi 2005				P				12	21	1	Y	29	TNP	N	N	Low
Da Silva Borges 2014			S	P				12	30	NR	Y	NR	NR	Y	Y	High
Dhargrave 2020	P	P	S		S			12	42	2	Partial	NA	PT	Y	Y	Mod
Faber 2006 – Functional walking	P	P						20	36	1	Y	12	TNP	Y	Y	Mod
Faber 2006 – In balance group				P				20	36	1	Y	12	TNP	Y	Y	Low
Fu 2015	P							6	18	NR	Y	NR	PT	Y	Y	NR
Hewitt 2018	P	P	S					52	76	1	Y	5	PT	Y	Y	Mod
Imaoka 2016	P	P						12	6	1	Y	NA	PT	Y	NR	Mod
Irez 2011	P	P	S					12	36	1	Y	NR	TNP	Y	Y	Mod

First author, year	Type of exercise (ex.) according to ProFaNE classification a							Duration in weeks	Total hours b	Delivery Mode c	Ex. supervised	Part. per group d	Program leader	Exercise tailored to individual	Exercise progressed	Exercise Intensity
	Balance, Gait or functional	Strength/ resistance Training	Flexibility training	3D ex.	General Physical Activity	Endur-ance ex.	Other ex.									
Jahanpeyma 2020	P	P	S		S			12	27	1	Y	9	TNP	Y	Y	Mod
Kerse 2008	P							26	91	2	Y	NA	TNP	Y	Y	Low
Kovacs 2012	P	P	S		P			26	52	1	Y	6	PT	Y	Y	Mod
Kovacs 2013	P	P	S		P			52	104	1	Y	4	PT	Y	Y	Mod
Mulrow 1994	P	P	S					16	24	2	Y	NA	PT	Y	Y	Low
Nowalk 2001 LL/TC				P				104	NR	NR	Y	NA	TNP	N	N	Low
Nowalk 2001 FNBF		P				P		104	NR	NR	Y	NA	EP	Y	Partial	Low
Rosendahl 2008	P	P						12	22	1	Y	9	PT	Y	Y	High
Sakamoto 2006	P							26	18	2	Y	NA	PT	N	N	Low
Saravanakumar 2014 Yoga				P				14	14	1	Y	11	TNP	Partial	N	Low
Saravanakumar 2014 Tai Chi				P				14	14	1	Y	11	TNP	Partial	N	Low
Schoenfelder 2000		P			P			12	12	2	Y	NA	TNP	N	Y	Low
Serra-Rexach 2011		P	S			P		8	18	2	Y	NA	TNP	Y	Y	Low to mod
Shimada 2004	P							6	10	2	Y	NA	NR	Y	Y	Mod
Sihvonen 2004	P							4	26	2	Y	NA	NR	Partial	N	Mod
Sitja Rabert 2015	P	P					P	9	6	1	Y	5	NR	N	Y	Low

First author, year	Type of exercise (ex.) according to ProFaNE classification a							Duration in weeks	Total hours b	Delivery Mode c	Ex. supervised	Part. per group d	Program leader	Exercise tailored to individual	Exercise progressed	Exercise Intensity
	Balance, Gait or functional	Strength/ resistance Training	Flexibility training	3D ex.	General Physical Activity	Endur-ance ex.	Other ex.									
Toots 2019	P	P						16	30	1	Y	NR	PT	Y	Y	High
Toulette 2003	P	P	P					16	24	1	Y	5	GP	N	N	Low
Tuunainen 2013	P	P	P					13	26	1	Y	5	PT	N	Y	High
Varela 2018						P		64	112	2	N	NA	Self	N	N	Low
Yokoi 2015					P			26	22	2	Y	NA	TNP	N	N	Low

a Classification (P = Primary; S = Secondary);
b Minimal dose
c Delivery mode (1 = Group, 2 = Individual, 3= combined);
d Maximum participants in a group
N = No, Y = Yes, NA = Not applicable, NR = Not reported, TNP = trained non-exercise professional, EP = exercise physiologist, PT = physiotherapist, GP = general practitioner

Supplementary Material C: Pedro Risk of Bias of included trials

First author Year	Pedro Score/ 10	Eligibility Criteria	Random allocation	Concealed Allocation	Baseline Compara -bility	Blind subjects	Blind therapists	Blind assessors	Adequate follow up	Intention to treat analysis	Between group compar.	Point est. & variability
Arrieta 2019	6	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes
Brett 2021	6	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes
~~Buckinx 2014~~	6	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes
Buettner 2002	1	Yes	Yes	No	No	No	No	No	No	No	No	No
Cadore 2014	6	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes
Choi 2005	5	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Da Silva Borges, 2014	5	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Dhargrave 2020	5	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Faber 2006	6	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Fu 2015	7	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Hewitt 2018	8	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Imaoka 2016	6	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Irez 2011	6	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes
Jahanpeyma 2020	6	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes
Kerse 2008	5	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes
Kovacs 2012	8	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes

Kovacs 2013	8	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Mulrow 1994	6	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Nowalk 2001	4	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Rosendahl 2008	7	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Sakamoto 2006	4	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes
Saravanakum 2014	6	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Schoenfelder 2000	4	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	No
Serra-Rexach, 2011	7	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes
Shimada 2004	4	No	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Sihvonen 2004	5	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Sitja Rabert 2015	7	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
Toots 2019.	8	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Toulotte 2003	3	No	Yes	No	No	No	No	Yes	No	No	No	Yes
Tuunainen 2013	4	Yes	Yes	No	No	No	No	No	Yes	No	Yes	Yes
Varela 2018	6	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes
Yokoi 2015	7	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes

Note: Eligibility criteria item does not contribute to total score

Supplementary File D: ICA Codebook – Fall prevention exercise in residential aged care

1. THEME 1: RIGHT EXERCISE

Subtheme 1: STRENGTH AND BALANCE 11 trials, 21 codes

1. Arrieta: Our participants, had high adherence to the multicomponent strength and balance exercise sessions, which proved to be well tolerated by those with lower physical function and enhanced their capacity to perform daily activities and avoid falls.
2. Arrieta: Individualised strength and balance moderate intensity exercise is safe for residents in nursing homes.
3. Arrieta: Multicomponent (strength and balance) interventions appear to be most effective for improving the overall physical status of older adults and preventing disability and other adverse outcomes.
4. Arrieta: Strength and balance program observed significant improvement in intervention and a marked decline in control in all assessed parameters.
5. Dhargave: Multicomponent exercise program focusing primarily on strength and balance training was the most effective strategy in managing falls in the elderly.
6. Dhargave: Strength and balance training in the elderly is successful in reducing episodes of falls.
7. Dhargave: Stronger muscles around the ankle are important for recovery of balance and near normal range of motion seems to be necessary for utilising better balance strategies and maintaining steady posture
8. Hewitt: Moderate intensity progressive resistance training and high level balance exercise can significantly reduce falls and improve physical performance in residents of long-term aged care facilities.
9. Kerse: Our study did not use a focused approach to intensively work on underlying impairments such as muscle weakness or balance problems.
10. Kerse: Residents with poor cognition did not benefit from functional training. Further refinement in potential interventions is needed for those with poor cognition.
11. Irez: Three months of Pilates exercise resulted in a decrease in the number of falls and an improvement in balance.

12. Irez: By performing designated strength and balance Pilates exercises within training program, improvements were seen amongst all dependent variables, including falls.
13. Jahanpeyma: Otago's strength and balance program saw a reduction in falls compared to control.
14. Jahanpeyma: Walking program alone may be insufficient to reduce the number of falls.
15. Jahanpeyma: Walking program supplemented with Otago strength and balance exercises strengthens lower extremities, thereby preventing falls.
16. Jahanpeyma: The Otago exercise program seems to improve balance and physical performance in older adults and thus may be an effective intervention for reducing and preventing falls in nursing home residents at high risk of falling.
17. Mulrow: Physiotherapy interventions that focus on strength and mobility have more value than range or motion exercises for many residents.
18. Rosendahl: In sub-group analysis, those who reduced falls benefitted from targeting balance and functional strength exercises such as sit to stand.
19. Sitja Rabert: Whole body vibration, together with a strength and balance exercise program, is a safe intervention, and its benefits in body balance, gait, functional mobility, and muscle strength are similar to those of strength and balance exercise alone in institutionalized elderly individuals.
20. Toots: High intensity strength and balance functional exercise improved balance in older persons with dementia living in residential care facilities but did not reduce falls.
21. Yokoi: Positive fall prevention effects were seen, as well as improvement in balance reaction and functional strength.

Subtheme 2: TAILORED EXERCISE 12 trials, 34 codes

1. Arrieta: Adherence to fall prevention programs could be influenced by residents with low physical function or severe cognitive deficit.
2. Arrieta: Important to account for differences in functional status to facilitate creating an optimal exercise program for older people
3. Arrieta: Previous trials have not considered the heterogeneity of physical function and personal skills to achieve optimal stimulus.
4. Arrieta: There were few significant intervention effects in participants with better mobility baseline scores on the SPPB. The lower efficacy of the program in participants with better functional status might be due to the insufficient exercise demands of this program for higher functioning older adults.
5. Dhargave: A well-designed tailored exercise program is advisable for elderly individuals to improve their gait and balance function and thus may reduce the episodes of falls and the risk of falls.
6. Dhargave: Residential aged care needs early admission to tailored exercise program for elderly to maintain balance and gait and prevent deterioration, which can predispose to falls.
7. Dhargave: Tailored exercise program was found to reduce falls and improvement in balance confidence and obstacle clearance.
8. Dhargave: This trial was designed by experienced nursing home physiotherapists and was targeted to the individuals' particular deficits.
9. Dhargave: Overall results showed that this particular Physical Therapy program aimed at very frail long-stay nursing home residents with disability due to multiple conditions led to modest improvements in mobility.
10. Dhargave: The results should not be generalised to less frail, long-stay residents.
11. Faber: Broad inclusion criteria resulted in a sample with a wide range of medical conditions, and functional limitations might explain the lack of significant reduction in falls
12. Faber: Exercise prescription must ensure interventions are challenging yet safe - more difficult in more frail groups.

13. Faber: Frail participants did not always succeed in performing exercises in the intended standing position and resorted to sitting position due to fatigue.
14. Faber: Functional walking and balance increased risk to becoming faller is significant in frail elderly without any sig changes to physical performance.
15. Fu: Tailoring different training modes and environments may been associated with significantly better performance in Wii Fit balance training than control.
16. Hewitt: Tailored strength and balance exercise program reduces falls
17. Kerse: This negative result highlights the importance of the specificity of training
18. Kerse: Low intensity functional training based on activities of daily living did not help to preserve physical function in frail elderly people with normal cognition in residential care and may have adversely affected those with poor cognition
19. Kovacs: Tailoring fall prevention exercise programs to those with physical abilities such as strength, balance and gait
20. Mulrow: These results, as well as others, suggest that strength and mobility deficits are common among nursing home residents, and interventions that focus on these deficits may be most beneficial
21. Nowalk: Fall prevention programs need to be tailored to suit individual seniors' changing needs, interests, physical, and cognitive capabilities.
22. Nowalk: Tai chi is not possible over a long intervention period due to the learning demands of cognitively impaired people.
23. Rosendahl: Fall prevention exercise is more likely to be successful if tailored to a broad spectrum of predisposing factors in older people.
24. Rosendahl: Previous successful fall prevention programs exclude people with dementia and poor balance.
25. Rosendahl: High intensity exercise may need to be included as part of a multifactorial fall prevention interventions due to comorbidities
26. Rosendahl: It seems important to investigate further what characterises people who are likely to respond to fall prevention exercise.

27. Sitja Rabert: Another factor that could influence the negative results in our study is the higher comorbidity and greater limitations in participants' autonomy.
28. Sitja Rabert: Another justification for the no difference in falls is that our intervention group included participants with higher cognitive impairment and a history of falls.
29. Toots: The results of this study support the notion that dementia should not be considered a single disease entity but rather constitutes separate disorders with clinical symptoms that may require different strategies to optimize symptom management.
30. Toots: Improvement in balance and attenuation of decline in ADL independence were exclusive to patients with non-Alzheimer's dementia.
31. Toots: Larger effect of exercise on balance seen in patients with higher cognitive function reinforces the potential moderating effect of cognitive function on fall prevention programs.
32. Toots: Different balance response between different types of dementia to high intensity functional fall prevention exercise programs
33. Toots: Physical function and clinical symptoms typical of certain dementia types may influence response to an exercise program
34. Toots: Dependence in ADLs is multifactorial, with various compositions and causes that may not be equally predisposed to change.

Subtheme 3: MODERATE INTENSITY 8 trials 21 codes

1. Arrieta: The primary finding in this study was that six months of individualized and progressive multicomponent exercise at moderate intensity composed of strength, balance, and walking recommendations in long-term nursing homes (LTNH) residents was effective in preventing falls and reducing frailty and mortality.
2. Arrieta: Individualised strength and balance moderate intensity exercise is safe for residents in LTNH.
3. Arrieta Multicomponent exercise interventions at moderate intensity could be efficient for improving gait, balance, strength and reducing frailty in older adults in LTNH, which aligns with previous results in other studies.
4. Arrieta: Attendance at moderate intensity exercise sessions in our study was higher (91%) than that found in similar studies that tested low intensity exercise.
5. Dhargave: Moderate to high intensity strengthening and endurance exercise program for 12 weeks will significantly improve the gait and balance in elderly.
6. Dhargave: The individuals enjoyed participating in the moderate intensity exercise program and didn't complain about any untoward incidents.
7. Faber: Absence of a significant reduction in falls could be attributed to the inadequacy of intensity, frequency, duration and/or specificity of exercise mode.
8. Faber: Frail elderly may need individual and more vigorous training approaches to reduce falls.
9. Faber: High-intensity individual training would make the program unsuitable for long-term incorporation into daily life.
10. Faber: Moderate intensity group exercise is preferred amongst the elderly as an opportunity to socialise is key element in sustaining participation.
11. Hewitt: This trial achieved a 55% fall rate reduction, a greater reduction than for any previous intervention in a residential aged care setting, potentially because it is the first to implement the published key components (strength and balance, moderate intensity) and dosage of successful falls prevention exercise programs.
12. Hewitt: Moderate-intensity progressive resistance training and high-level balance exercise can significantly reduce falls and improve physical performance in residents of long-term aged care facilities.

13. Hewitt: Outcomes differ from previous research that employed the use of seated, range of motion, light resistance or simple walking programs.
14. Hewitt: The intensity of the PRT in this trial that is 2 to 3 sets of 10 to 15 repetitions for each exercise at a perceived intensity of "moderate" using the Borg Scale of Perceived Exertion, also differs from prior research that advocated more intense training.
15. Kerse: Either a more intensive intervention or more effort in implementation would be needed to achieve functional improvement in this population.
16. Kerse: To be successful, fall prevention interventions may need a higher intensity of activity than low intensity exercise.
17. Rosendahl: Among older people living in residential care facilities, a high-intensity functional exercise program did not significantly reduce either the fall rate or proportion of participants who sustained a fall overall, compared with a control activity.
18. Sitja Rabert: Low intensity exercise on high physical functioning people in aged care is not effective.
19. Toots: High intensity exercise did not reduce falls in people with dementia in nursing homes.
20. Toots: Strength exercises were performed at moderate to high intensity levels.
21. Toots: High dose of exercise may be more important than exercise intensity for greater effects on falls

THEME 2: SUPPORTING EXERCISE ENGAGEMENT

Subtheme 1: SUFFICIENTLY RESOURCED 8 trials 17 codes

1. Arrieta: Routine multicomponent exercise intervention composed of resistance, balance, and gait exercises should be included for institutionalised older adults, as it seems to be effective for improving overall physical outcomes and preventing disability and other outcomes in this population.
2. Dhargave: The study identified an overall reduction in the risk of falls in individuals who underwent structured exercise programs, whereas we identified that those who were not provided with any of the supervised training had an increase in the risk of falls after the study period.
3. Dhargave: Strength and flexibility training needs to be part of a structured exercise program for elderly individuals.
4. Dhargave: Our study contributed to this gap by identifying the effect of structured exercise programs on elderly individuals staying at various geriatric homes in India.
5. Dhargave: Further studies consisting of a structured institutional-based supervised exercise program with equipment-assisted assessment protocols will give a better picture of the current study.
6. Hewitt: Increase in engagement due to resident wanting to spend time with specialised strength exercise equipment
7. Hewitt: Sunbeam findings suggest exercise dose of 30 or more hours produce outcomes similar to those with higher doses (e.g., 50 hours) previously recommended.
8. Hewitt: Reduced physiotherapy input reduced exercise engagement.
9. Irez: Buying balance and strengthening exercise equipment has a more significant impact on reducing falls.
10. Kerse: More effective reinforcement by care workers is required to reduce falls.
11. Kovacs: 12 monthly physio-led exercise programs provide better outcomes than six months.
12. Kovacs: Physiotherapy is more expensive to provide to frailer cohorts to improve mobility but needed.
13. Mulrow: Because it was based on standardised assessments and prioritized treatment plans, the therapy program was probably more consistent than what is generally practiced.

14. Mulrow: Funding sufficient physiotherapy delivers modest improvements in mobility amongst very frail nursing home residents with a disability.
15. Toots: Structured exercise programs are required to reduce falls regarding exercise mode, intensity and frequency.
16. Toots: The application of better balance to reduce the level of assistance required in ADLs relies on the responsiveness of care staff, and routines and time constraints may limit it.
17. Toots: The use of a structured exercise program improves the potential to replicate the results of this study clinically or for research purposes.

Subtheme 2: GROUP EXERCISE ALLOWING FOR SOCIALISATION 3 trials six codes

1. Faber: Another reason for preferring moderate intensity programs is that a key element in sustaining exercise participation of older people is the opportunity to socialise.
2. Faber: Moderate intensity group exercise is preferred amongst the elderly as an opportunity to socialise is a key element in sustaining participation.
3. Faber: Group exercise is feasible in frail nursing home residents.
4. Hewitt: Increase in attendance may be related to patients choosing to spend time attending classes in a known format using both gym equipment and physiotherapy nvolvement.
5. Sitja Rabert: Group exercise program was appropriate and enjoyable as compliance was more than 75%.
6. Sitja Rabert: Group exercise is a safe intervention.

Subtheme 3: STAFF AND RESIDENT EDUCATION 4 trials six codes

1. Fu: Real-time visual feedback to the participants would be expected to improve the training process as compared with conventional training.
2. Fu: Performance feedback as to the status and outcome of a response is generally accepted to be necessary for most forms of learning or skill acquisition, including the learning process that underlies rehabilitation.
3. Fu: Presentation of cuing stimuli that could be used for “error-free” learning approaches in rehabilitation scenarios.
4. Hewitt: Educating staff and residents on the potential benefits of progressive resistance training and balance training may have resulted in higher participation rates.
5. Kerse: The importance of specificity of training. The training approach in this study focused on practicing overall functional tasks embedded within daily activities facilitated by existing staff.
6. Nowalk: This program included an intensive team management approach to reducing falls through staff training, regular quality improvement meetings, enhanced basic programs for residents, and two exercise interventions.

TRIALIST'S METHODOLOGICAL COMMENTARY

SMALL SAMPLE SIZE 7 trials seven codes

1. Arrieta: In addition, the study length and sample size are one of the largest among studies focused on multicomponent exercise programs in LTNH.

2. Faber: Lack of a significant reduction in falls due to a study being underpowered.

3. Irez: Results showed no differences in described variables. This may be related to the small number of participants. In our study, the sample size was much larger than in the previously mentioned study.

4. Nowalk: A limitation of this study is the sample size.

5. Rosendahl: However, more participants or a longer follow-up period would certainly have been preferable in evaluating falls.

6. Sitja-Rabert: The main limitation of this study is that it did not have sufficient power to clinically detect relevant results in fall prevention.

7. Toots: Small sample size limited statistical power.

CONTROL GROUP NEEDS TO HAVE NO ACTIVE EXERCISE 5 trials six codes

1. Irez: Our study involved a control group of no active exercise, whilst alternate studies that were ineffective did not.
2. Jahanpeyma: Using active exercise in the control group reduces research outcomes.
3. Kovacs: Future research needs to ensure different types of exercise are compared to an inactive control group to better understand the most effective fall prevention exercise intervention.
4. Rosendahl: Physical activity in the control group could have explained non-significant fall outcomes between groups.
5. Sitja-Rabert: No difference between groups, could have been a result of the inclusion of active exercise in the control group.
6. Sitja-Rabert: One factor that could explain the differences in results in this study is the similar exercises in the control group.