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Multifactorial falls prevention programmes for older adults presenting to the Emergency Department with a fall: systematic review and meta-analysis

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ABSTRACT

Objective: To determine whether multifactorial falls prevention interventions are effective in preventing falls, fall injuries, ED re-presentations and hospital admissions in older adults presenting to the ED with a fall.

Design: Systematic review and meta-analyses of randomised controlled trials (RCTs).

Data sources: Four health-related electronic databases (Ovid MEDLINE, CINAHL, EMBASE and The Cochrane Central Register of Controlled Trials) were searched (inception to June 2018),

Study selection: RCTs of multifactorial falls prevention interventions targeting community dwelling older adults (≥ 60 years) presenting to the ED with a fall with quantitative data on at least one review outcome.

Data extraction: Two independent reviewers determined inclusion, assessed study quality and undertook data extraction, discrepancies resolved by a third.

Data synthesis: Twelve studies involving 3,986 participants, from six countries, were eligible for inclusion. Studies were of variable methodological quality. Multifactorial interventions were heterogeneous, though the majority included education, referral to healthcare services, home modifications, exercise, and medication changes. Meta-analyses demonstrated no reduction in falls (rate ratio=0.78; 95% CI 0.58, 1.05), number of fallers (risk ratio=1.02; 95% CI 0.88, 1.18), rate of fractured neck of femur (risk ratio=0.82; 95% CI 0.53, 1.25), fall-related ED presentations (rate ratio=0.99; 95% CI 0.84, 1.16), or hospitalisations (rate ratio=1.14; 95% CI 0.69, 1.89) with multifactorial falls prevention programmes.

Conclusions: There is insufficient evidence to support the use of multifactorial interventions to prevent falls or hospital utilisation in older people presenting to ED following a fall. Further research targeting this population group is required.

Keywords

Accidental falls, Systematic Review, Emergency department, Fall prevention, Elderly.

ABBREVIATIONS

ED Emergency department

RCT Randomised controlled trial

US United States

UK United Kingdom

MMSE Mini Mental State Examination

AMT Abbreviated Mental Test

NOF Neck of femur

CI Confidence interval

What is already know about this subject:

- Falls are a leading reason that older adults present to emergency departments (EDs).
- There is systematic review evidence for interventions to reduce falls in older people living in the community.
- When similar interventions are applied to those presenting to the ED with a fall, there is a lack of effectiveness.

What this study ads:

- There remains little evidence to support the use of multifactorial falls prevention programmes for older adults that present to ED with a fall.
- More studies in this complex population are required.

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INTRODUCTION

Falls are a leading cause of emergency department (ED) presentations in older adults[1,2]. In the United States (US), an older adult is treated in the ED for a fall every 15 seconds, and an older adult dies following a fall every 29 minutes[3]. It is estimated that £2.3 billion is spent annually on fall-related injuries in people over the age of 65 in the United Kingdom (UK)[4]. Age-standardised rates of hospitalised fall-related injury cases in older Australians are also steadily increasing[5]. Fall-related presentations to the ED are not isolated events; older patients frequently experience subsequent falls (46% to 56%)[6]; re-hospitalisation (49%)[7], and substantial functional decline[7] in the 12 months following ED presentation.

Clinical practice guidelines in the US, UK and Australia recommend the use of multifactorial interventions that involve an assessment of individual risk factors, followed by specific interventions targeted to those identified risk factors, to prevent falls in older adults living in the community[4,8,9]. A number of systematic reviews have also established evidence for the effectiveness of multifactorial interventions in reducing falls in community dwelling older adults[10-13]. However, there is conflicting evidence regarding the effectiveness of these interventions when applied specifically to those presenting to the ED with a fall, based on findings from a systematic review of available evidence until March 2007, conducted by Gates and colleagues[11]. Similarly, a more recent systematic review concluded that falls prevention interventions found to be effective in the general older population did not appear to be transferrable to those recently discharged from hospital[13]. These conflicting results are likely because of the different care needs of the populations concerned[14]. There is a lack of current evidence on the effectiveness of fall prevention interventions for older people presenting to the ED with a fall, who have different care needs to their community-dwelling peers and those who have been recently discharged from hospital[15].

An updated review of the effects of multifactorial interventions in people presenting to the ED is warranted, given the addition of new published trials, the increasing number of older people at risk[16], the major physical and psychological consequences associated with falls[17,18] and high associated healthcare costs[19]. The purpose of this review was to determine the effects of multifactorial falls prevention interventions on falls, fall injuries, fractures, ED presentations and hospitalisations in older adults presenting to the ED with a fall. The results will be of importance to healthcare services and policy makers considering the high cost of the associated injuries and management, and the costs associated with implementing such interventions[20].

METHODS

A systematic review and meta-analysis was performed according to the criteria of the Preferred Reporting Items for Systematic Reviews and Meta-analyses.[21]

Search strategy and selection criteria

Four electronic databases (Ovid MEDLINE, CINAHL, EMBASE and The Cochrane Central Register of Controlled Trials (CENTRAL)) were searched, from inception to June 2018. A sensitive search strategy was developed using medical subject heading (MESH) search terms and keywords (Appendix 1 outlines full Medline search strategy), and was customised to each database as needed. References of included studies were reviewed for further relevant literature.

Eligibility criteria

Study inclusion criteria: (1) randomised controlled trials (RCT) published in English; (2) included participants aged 60 years or older who presented to an ED after a fall; (3) the intervention included any multifactorial falls prevention intervention delivered to the target population (multifactorial interventions were defined as including two or more sub-domains of interventions provided to participants in any possible combination that addresses two or more individual risk factors for falls from assessment findings[22]); and (4) at least one fall or hospitalisation outcome was reported. Falls prevention interventions were classified according to the Prevention of Falls Network Europe (ProFaNE) taxonomy[22]. Fall outcomes included the number or rate of falls, fallers (number of people who experienced one or more falls in the follow-up period), fall-related injuries or fractures. Hospitalisation outcomes included ED re-presentations or hospital admissions. Studies that included participants who were recruited from an alternative setting (e.g. primary care or community setting) were excluded from this review.

Study selection and data extraction

Initially, two reviewers independently screened and excluded studies based on title and abstracts. For articles not excluded, full-text versions were independently assessed by both reviewers to determine if they met inclusion criteria. In the event of multiple reports from one trial, only the study with the most complete reporting was retained. Disagreements were resolved by a third reviewer if required. Reviewers independently extracted data from included studies. Demographic information (including country of origin, population specifications, sample size), definitions for fall and hospital outcomes and intervention characteristics (such as falls-risk assessments, healthcare professional undertaking the assessment, the intervention strategies used, timing and intensity of interventions offered, and participation) were extracted using a standardised data extraction form. Data available for all relevant outcomes were extracted and tabulated.

Methodological quality assessment

All included studies were assessed for methodological quality by the same reviewers using the PEDro scale[23]. This scale rates 11 aspects of methodological quality of RCTs as being either absent or present. A third reviewer was called upon if consensus could not be reached.

Data synthesis and meta-analysis

Study characteristics and demographic data, such as sample size, gender, and age of participants were reported using mean (SD), median (IQR) or frequency. Meta-analysis was conducted to assess the effect of multifactorial interventions on review outcomes. The rate ratio and 95% confidence interval (if available) was used to describe the treatment effect for falls, fractures, ED presentations and hospitalisations. For the outcome of faller versus non-faller, we used the risk ratio and 95% confidence interval as the treatment effect. If both adjusted and unadjusted effect estimates were reported, we used the unadjusted estimate unless the adjustment was for clustering. Effect estimates were manually calculated when needed. When a study reported

multiple effect estimates for an outcome, the follow up most comparable with other studies, or with the longest follow-up, or adjusted for the largest number of covariates was selected. We conducted two pre-planned subgroup analyses; 1) based on frequency of interventions (interventions with two or more interactions versus those that included less than two), and 2) type of interventions included (interventions including only referral based interventions versus those that included direct treatment to address risk factors).

As heterogeneity of data was anticipated, due to differences in study populations, follow-up duration and intervention components, a random effects model was used. An inverse variance method was also used to weight each estimate. Between-study variability was assessed using the I^2 statistic[24], where I^2 values greater than 50% were considered to have a high degree of statistical heterogeneity[25]. Where data was unable to be pooled in a meta-analysis due to heterogeneity of outcome measures, descriptive analysis was performed. All analyses were conducted with the use of Review Manager, version 5.2 (RevMan, The Cochrane Collaboration; Oxford, UK).

RESULTS

Search yield

The electronic search identified 851 potential studies for screening of eligibility, after duplicate studies were removed. Following screening of titles and abstracts and full-text review, 12 studies were retained for inclusion (Figure 1), based on our described inclusion and exclusion criteria. There were a total of 3,986 participants in the trials included. The median number of participants randomised per trial was 340 (range 109[26] to 712[6]). Mean age was 78 years and ranged across studies from 73[27] to 84[28] years. Average gender mix was 69% female (ranging from 55%[27] to 80[29]%).

<<Insert Figure 1>>

Study and sample characteristics

The 12 included studies were published between 1999 and 2018 and conducted in six countries (Table 1). Population age was specified as equal or greater than 65 years in all studies except two[6,27], which included those 60 years and above. Ten studies excluded participants with cognitive impairment, although definitions varied across studies. Five studies utilised the Mini Mental State Examination (MMSE) (score ranging from 16 to ≥25), three the Abbreviated Mental Test (AMT) (scores ranging from 4 to ≥7) and two did not use a validated tool (patients were excluded based on being described as having dementia in hospital records). Only one study included older people with cognitive impairment (MMSE <24)[29].

<<Insert Table 1>>

Methodological quality of included studies

Studies were of variable methodological quality (Table 1). Methodological strengths included allocation concealment and between-group comparisons for statistical analysis. Common limitations were the lack of blinding and inadequate follow-up of participants. The complete PEDro assessment of studies have been outlined in Appendix 2 in the supplementary data on the journal website.

Multifactorial falls assessment and interventions

All studies included an assessment of falls risk factors (Appendix 3 provides a detailed summary). Assessment tools and risk factors assessed varied considerably across studies, as did the type of healthcare professionals undertaking the assessments. The most common falls risk factors assessed were home environment (10 studies), mobility or gait (9 studies), vision (10 studies) and balance (7 studies). The time from index fall until baseline assessment was described in five studies, and ranged from within two weeks to one month after the fall-related ED presentation. Assessments were also undertaken in a variety of settings and on occasion by more than one health professional, including the participant's home (10 studies), an outpatient setting e.g. day hospital or clinic (4 studies) or as an inpatient (2 studies).

Table 2 provides a detailed summary of the interventions of included studies. Interventions were led by a variety of healthcare professionals, including occupational therapists, physiotherapists, registered nurses and medical professionals. The specific interventions delivered were highly variable, including education (11 studies), referral to healthcare services (11 studies), home modifications (8 studies), exercise (6 studies) and medication change (5 studies). Some studies provided only limited treatment options, such as education and referral to healthcare services, whilst others provided many potential intervention strategies. The time until delivery of intervention was reported in only six studies, and ranged from two to eight weeks after

completion of baseline assessment. Frequency of the recommended interventions varied from one to up to 16 sessions. Only six of the 12 included studies reported on patient uptake of referrals and/or fall prevention recommendations, ranging from 7%[6] to 100%[28].

<<Insert Table 2>

Outcome measures

A number of fall outcomes were captured across the 12 studies (Table 1). Studies used varying definitions for these outcomes, summarised in Appendix 4. All studies utilised falls calendars or diaries to record information on falls. Of these, 11 studies required participants to return the calendar regularly (weekly, monthly), nine contacted the participants monthly to verify/retrieve falls data from the calendar, whilst one collected data only on follow-up (12 months)[30]. All studies, except one[31] that included ED presentations and/or hospital admissions as an outcome measure, assessed medical records to confirm details. The length of follow up for studies was between six and 12 months.

Effectiveness of falls prevention interventions

Rate of falls and number of fallers

As shown in Figure 2a, there was no reduction in the rate of falls (rate ratio 0.78, 95% CI 0.58 to 1.05) with the use of multifactorial falls prevention programmes. Nor did the programmes significantly reduce the number of fallers (risk ratio 1.02, 95% CI 0.88 to 1.18; Figure 2b). Substantial statistical heterogeneity was noted between individual studies for both the rate of falls (I^2=94%) and the number of fallers (I^2=75%). Subgroup analyses demonstrated that studies that included two or more interactions in their multifactorial intervention programme had a significant reduction in the rate of falls (rate ratio 0.62, 95% CI 0.45 to 0.86) (Appendix 5). Similarly, studies which included treatment of risk factors, rather than just referral based

interventions, demonstrated a significant reduction in the rate of falls (rate ratio 0.78, 95% CI 0.58 to 0.93). No difference was observed for number of fallers in these subgroups.

Fall injuries and injurious falls

Meta-analyses were not performed for fall injuries and injurious falls, as the definitions were too heterogeneous across included studies (Appendix 4). However, of the eight studies that reported on either injurious falls or fall injuries, no study observed a statistically significant effect.

Number of fractures

Due to the variability in the type of fractures reported, only studies that reported on the same outcome of a fractured neck of femur (NOF) were included in this meta-analysis (3 studies). Multifactorial falls prevention programmes did not significantly reduce the number of fractured NOFs (risk ratio 0.82, 95% CI 0.53 to 1.25; Figure 2c). Of the remaining two studies that reported on other fractures, one[27] reported a reduction in the rate of fractures in the intervention group (incidence rate ratio 0.37, 95% CI 0.15 to 0.91). The other study[6] observed no effect on fractures.

Rate of fall-related ED presentations and hospitalisations

Due to the limited number of studies that reported all-cause ED presentations and hospitalisations, only fall-related ED presentation or hospitalisation outcomes are reported. The pooled data demonstrates no significant effect on the rate of fall-related ED presentations (rate ratio 0.99, 95% CI 0.84 to 1.16; Figure 2d), or fall-related hospitalisations (rate ratio 1.14, 95% CI 0.69 to 1.89; Figure 2e). Statistical heterogeneity was noted between individual studies for hospitalisations (I^2=58%). Of the three studies that reported all-cause ED presentations and/or hospitalisations, no study observed a statistically significant effect on either outcome. Subgroup

analyses did not identify any difference in the results for fractures, ED presentations or hospitalisations.

<<Insert Figure 2>>

DISCUSSION

This review extends upon previous reviews on the effect of multifactorial falls prevention programmes[10,12] focusing on the specific population of older adults who present to ED with a fall. It includes seven additional studies published since the review by Gates and colleagues in 2007[11]. We found that multifactorial intervention programmes did not reduce falls in older people who present to the ED with a fall, unless the programme included two or more interactions, or the treatment of risk factors, rather than referral-based interventions alone. No significant reductions were observed in the number of fallers, fractured NOFs, ED presentations or hospitalisations with the delivery of multifactorial falls prevention programmes. We were unable to synthesise data relating to rates of injuries, due to the variability in how this outcome was defined.

There are three key reasons that may have contributed to the limited findings of effect; heterogeneity of multifactorial interventions, poor tailoring of interventions to the ED population, and the inconsistent definition of outcomes between studies. The findings of this review are consistent with findings from the recently updated Cochrane systematic review which examined the efficacy of multifactorial interventions in community-dwelling older adults[12]. As observed by Hopewell et al. (2018), we noted substantial diversity between the multifactorial interventions delivered within studies included in our review. Some studies managed multiple risk factors with multiple intervention strategies from a variety of healthcare professionals over

numerous interactions, while others concentrated more on education and home modifications in a single interaction. Studies also used various suites of multifactorial interventions. Although the majority of studies included referral to relevant healthcare services and education, the location and mode of delivery of the interventions were different. Based on results from our subgroup analyses, programmes should at minimum include more than one interaction or actual treatment of one or more risk factor, and not be purely referral based. Meta-analyses of the number of fallers, rate of falls and rate of ED presentations showed significant statistical heterogeneity (I^2 58-94%). Whilst is it expected that multifactorial interventions will differ based on a person's individual risk factors, the low number of studies and the heterogeneity observed may have diluted any possible effects.

Many of the included interventions were not tailored specifically to the care needs of this population group but were generic interventions that can be implemented to community-dwelling older adults. People that present to the ED as a result of a fall, are generally older, frailer, have higher risk of subsequent falls, have more multi-morbidity, complex social issues and more severe injuries when compared to those who do not attend the ED[15,37]. The ED is a challenging environment in which to initiate falls prevention interventions as staff, workflows and processes are focused on managing the acute care needs of a patient (e.g. injury assessment and management) as opposed to prevention. The studies included in this review may not have sufficiently addressed these differences.

Finally, our outcomes of interest were rate of falls, rate of ED presentations and hospitalisations, number of fallers and number of fractures. Similar to the review by Hopewell and colleagues (2018), it was apparent in our review that these outcomes were defined inconsistently across the included studies. Definitions varied for falls and fall injuries. Some studies excluded specific types of falls (for example, those due to an acute medical event or in which the person came to

rest on furniture or a wall) whereas others included all falls. The rate of peripheral fractures has been recommended as the only robust and feasible measure of an injury[12,38]. However, only NOF fractures were able to be pooled in this review, due to varying definitions. As injuries related to falls contribute to the significant burden on the health of patients, and the healthcare system[19], it is important that these more robust outcome measures are consistently defined and reported to allow pooling of results in future reviews[10,38,39]. The lack of effect on hospitalisation outcomes may reflect the broader health concerns in this population.

Adherence to fall prevention recommendations and referrals is an important consideration when assessing the efficacy of a falls prevention programme, particularly when numerous interventions are being provided. However, we found adherence to be inconsistently reported. Previous studies have found that participation and engagement in falls prevention programmes in general community dwelling older adults is likely to be around 50% at 12 months[40]. A likely contribution to those that present to ED with a fall having poorer participation and engagement in fall prevention programmes may be their complex health needs. Poor adherence could also be explained by the "better for others than for me" phenomenon as described by Haines et al, where individuals at risk of falls can see benefits in falls prevention interventions generally, but do not adhere to these as they do not believe the interventions are relevant to them[41]. When developing new interventions it is important to consider the full range of factors that may influence the effectiveness of an intervention including factors that may limit engagement and participation[40]. Future research would benefit from exploring these factors this population group in more detail.

Study limitations

This review was undertaken using the robust methods recommended in the PRISMA statement. Limitations include the consideration of papers only published in English, potentially excluding

other high-quality studies, and the analysis of only objective outcomes (eg falls, fall injuries). Subjective information regarding fear of falling, falls self-efficacy and health related quality of life were not considered, which may have provided further insight into meaningful change in psychological consequences of falls, that contribute to the overall burden. The majority of studies also excluded older adults with significant cognitive impairment, which restricts generalisability of this review's findings to those with delirium or dementia. All studies only had a maximum follow-up period of 12 months. It is possible that different conclusions may result if a longer follow-up was applied for these less sensitive measures. Despite the limitations, this review reinforces the fact that falls prevention for this high-risk population is complicated and current guidelines regarding falls prevention practices may need to be targeted specifically for this population.

Conclusion

Falls and their sequelae are a significant health burden worldwide. This systematic review and meta-analysis of randomised controlled trials found little evidence to support the use of multifactorial falls prevention programmes for older adults that present to ED with a fall. More studies in this complex population are required. Studies with a reproducible type and dose of intervention, and powered to detect effects on fall injuries and fractures, are needed to resolve the uncertainty of effectiveness of intervening in this population group. Research with consistent definitions of fall outcomes, along with adequate reporting of intervention components, intensity and adherence are crucial.

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Table 1: Characteristics of included studies

Study ID	Population					Fall outcomes							PEDro score
First named author, year	Country	Sample size	Age, mean	Female (%)	Cognitive status	Follow-up (months)	Falls	Faller	Injurious falls	Fall injuries	Fractures	ED re-presentations	Hospital admissions	
Barker (2018)[27]	AUS	430	73	55	MMSE≥23	12	✓	✓	✓	✓	✓	✓	✓	8
Chu (2017)[30]	HK	198	78	71	MMSE>15	12	✓	✓				✓[a]	✓[a]	8
Close (1999)[31]	UK	397	78	68	AMT≥7	12	✓			✓[b]			✓	6
Davison (2005)[32]	UK	313	77	72	MMSE≥24	12	✓	✓			✓	✓[a]	✓[a]	7
Harper (2017)[26]	AUS	109	82	59	~	-		✓						5
Hendricks (2008)[33]	NL	333	75	68	AMT≥4	12	✓	✓	✓					7
Lightbody (2002)[34]	UK	348	75	74		6	✓	✓	✓	✓		✓[a]	✓[a]	5
Matchar (2017)[35]	SGP	354	78	75		9		✓	✓[c]					8
Russell (2010)[6]	AUS	698	75	70	AMT≥7*	12	✓	✓	✓[b]	✓	✓[d]	✓		8
Shaw (2003)[29]	UK	274	84	80	MMSE<24	12	✓	✓		✓[b]	✓[e]	✓[a]	✓[a]	7
Vind (2009)[28]	DM	392	74	74	~	12	✓	✓	✓[f]	✓	✓[e]	✓[a]	✓[a]	8
Whitehead (2003)[36]	AUS	140	78	71	MMSE≥25	6		✓						7

*Amended to allow those with AMT <7 if carer provided informed consent
~ No formal assessment tool used, based on medical history or hospital records
- Not reported
HK = Hong Kong; UK = United Kingdom; NL = Netherlands; AUS = Australia; DM = Denmark; SGP = Singapore; AMT = Abbreviated Mental Test; MMSE = Mini-Mental State Examination
[a]Fall related presentations or admissions only

[b]Major/serious injury only
[c]Injurious faller
[d]Peripheral fractures
[e]Fracture neck of femur
[f]Fall caused injury resulting in contact with a healthcare service

Table 2: Intervention characteristics of included studies

Study ID	Intervention characteristics										
	Timing (weeks)*	Setting	Intensity (number of sessions)	Duration	Education	Home modifications	Referral to other healthcare services	Exercise Prescription	Medication Change	Assistive devices/aids	Vitamin D
Barker (2018)[27]	≤2	Home, Tele	3+	6 months	✓		✓	✓	✓		✓
Chu (2017)[30]	≤8	Home, Tele	2+	2 months	✓	✓	✓			✓	
Close (1999)[31]	–	DH, Home	2	–	✓	✓	✓		✓	✓	
Davison (2005)[32]	–	IP, Home	2	–	✓	✓	✓	✓	✓	✓	
Harper (2017)[26]	–	DH, Home, Tele	3+	–	✓	✓	✓	✓		✓	
Hendriks (2008)[33]	≤4	DH, Home	2	–	✓	✓	✓				
Lightbody (2002)[34]	≤4	Home	1	–	✓	✓	✓				
Matchar (2017)[35]	–	Home, Group†	≤24	6 months	✓	✓	✓	✓			
Russell (2010)[6]	≤4	Home	1	–	✓		✓				
Shaw (2003)[29]	–	Home	–	3 months	✓	✓		✓	✓	✓	
Vind (2009)[28]	7	Falls Clinic	4+	–	✓		✓	✓	✓		✓

Whitehead (2003)[36]	–	Home	1	–	✓

* Longest time for ≥ 1 intervention to be delivered after baseline assessment

– Not reported

✓ Included as part of the fall prevention program

† Intervention completed at either setting

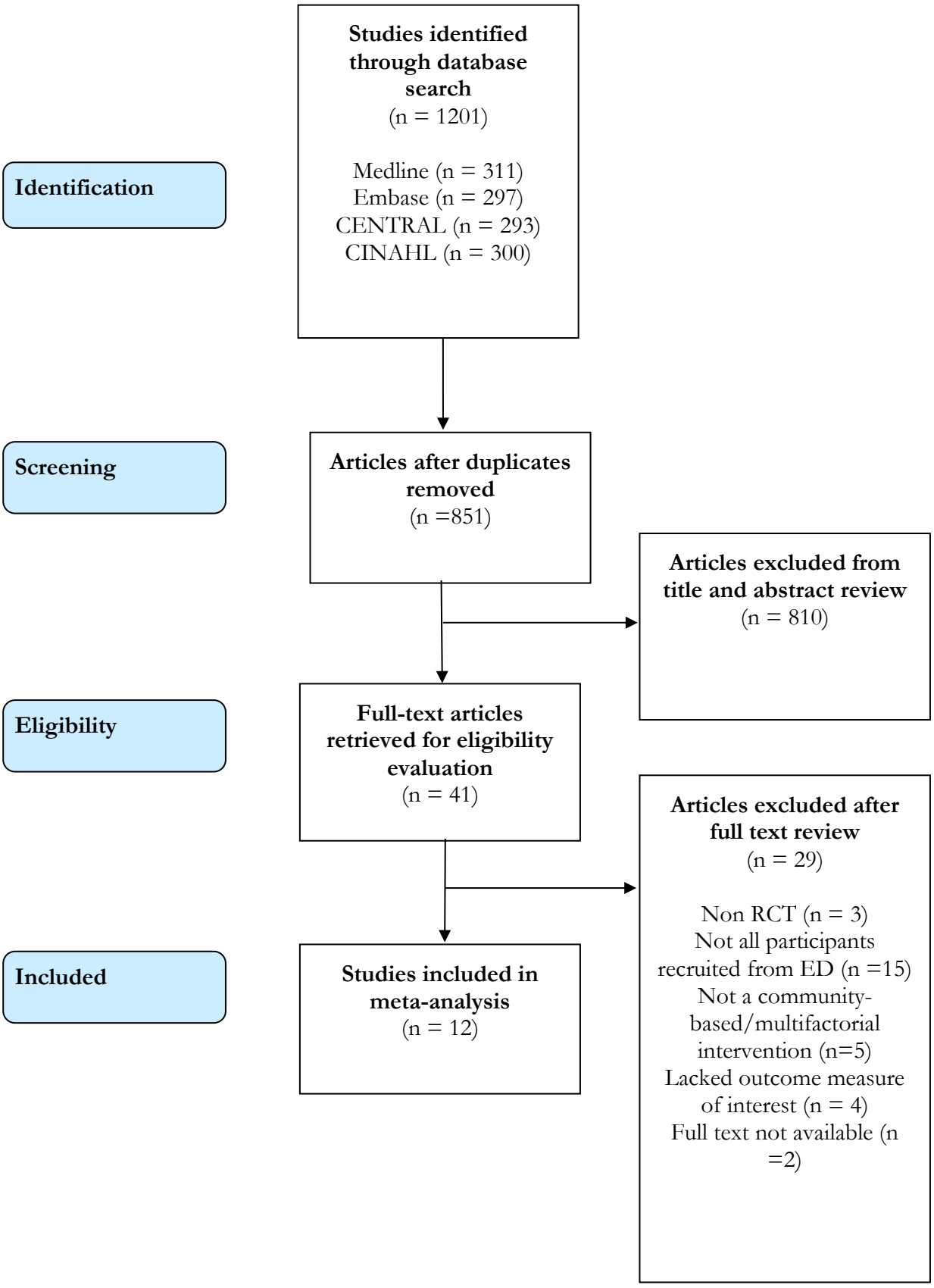


Figure 1: PRISMA flow diagram of study selection process

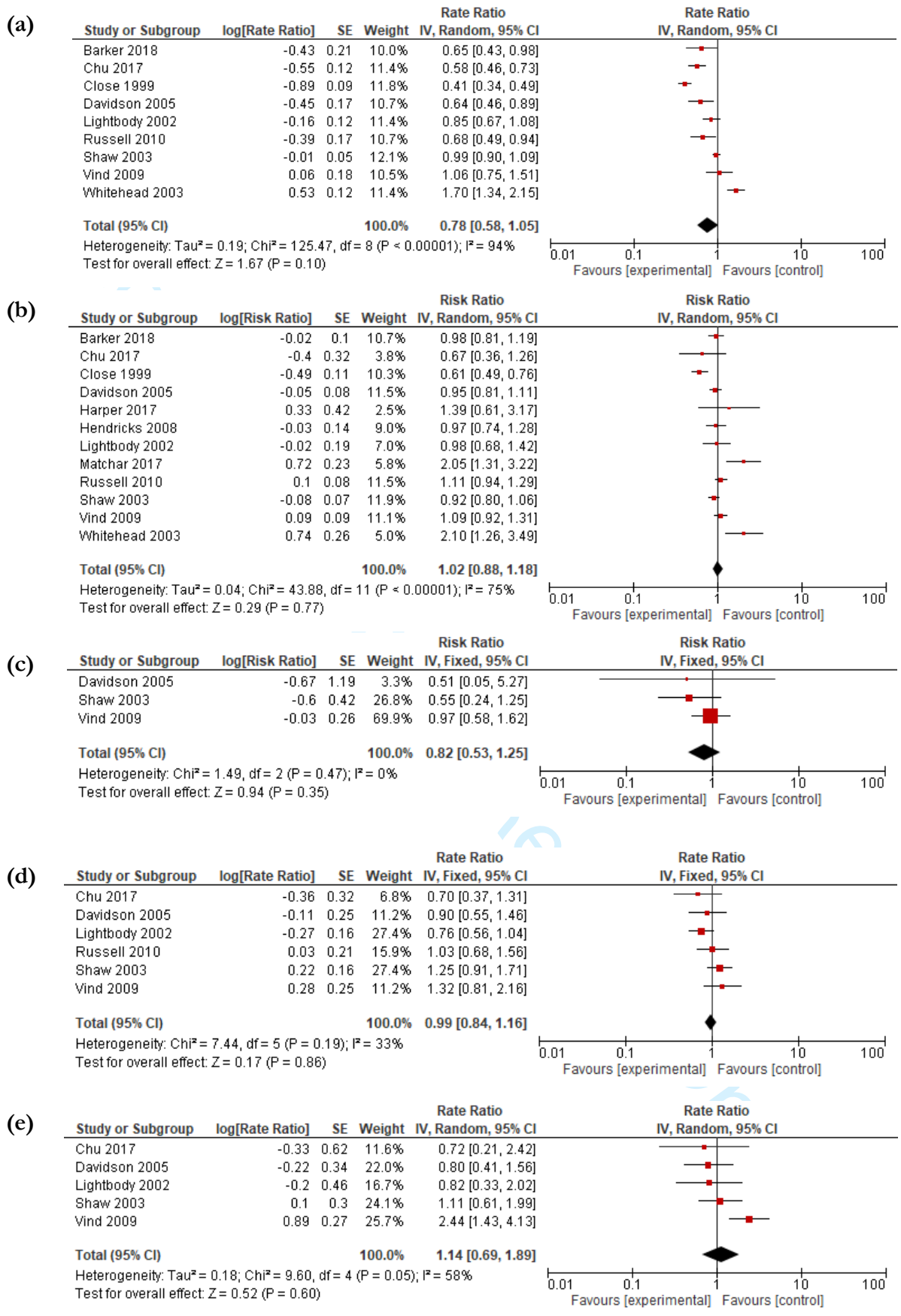


Figure 2: Meta-analysis of effect of multifactorial fall prevention programs on fall outcomes: (a) falls, (b) fallers, (c) neck of femur fractures, (d) fall-related emergency department presentations & (e) fall-related hospitalisations

APPENDICES

Multifactorial falls prevention programs for older adults presenting to the Emergency Department with a fall: systematic review and meta-analysis

Table of contents

Appendix 1: Medline Search Strategy

1: Accidental falls/ or fall*.tw.

2: (slip or slips or slipped or slipping).tw.

3: (trip or trips or tripped or tripping).tw

4: 1 or 2 or 3

5: Emergency Medical Services/ or Emergency Medicine/ or exp Emergency Service, Hospital/ or Emergency Treatment/ or Emergency Nursing/ or Emergencies/

6: (emergenc* or emergicient*).tw.

7: exp Hospitalization/ or hospitali*.tw.

8: 5 or 6 or 7

9: exp Aged/ or Health Services for the Aged/ or Homes for the Aged/ or Housing for the Elderly/ or Nursing Homes/

10: Geriatric Assessment/ or Geriatric Nursing/ or Geriatrics/

11: (elder* or older or aged or geriatric* or gerentol* or senior*).tw.

12: 9 or 10 or 11

13: 4 and 8 and 12

14: (controlled clinical trial or randomized trial).pt.

15: (random* or trial or placebo).tw. or clinical trial*.mp.

16: 14 or 15

17: 13 and 16

18: Accidental falls/ or fall*.tw.

19: exp Emergency Service, Hospital/ or Emergencies/ or emergenc*.tw.

20: exp Emergency Medical Services/ or exp Emergency Medicine/ or exp Emergency Treatment/ or exp Emergency Nursing/

21: exp Hospitalization/ or hospitali*.tw.

22: 19 or 20 or 21

23: exp Aged/

24: (elder* or older or aged or geriatric* or gerontol* or senior*).tw.

25: 23 or 24

26: 18 and 22 and 25

27: limit 26 to randomized controlled trial

28: randomi?ed controlled trial*.mp.

29: 26 and 28

30: 27 or 29

31: 17 not 30

32: limit 31 to english

Appendix 2: PEDro scale items

Author, year	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Subjects	Blinding Therapists	Assessors	Adequate follow-up	Intention-to-treat analysis	Between-group comparisons	Point estimates and variability	Total score
Barker 2018	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Chu 2017	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Close 1999	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	6
Davison 2005	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Harper 2017	Y	Y	Y	N	N	N	Y	Y	N	Y	N	5
Hendriks 2018	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	7
Lightbody 2002	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5
Matchar 2017	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Russell 2010	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Shaw 2003	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Vind 2009	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Whitehead 2003	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	7

Appendix 3: Risk factor assessment characteristics of included studies

Study ID	Risk factor assessment														
	Timing (days)†	Setting	Health professionals	Falls risk	Falls efficacy	Balance	Mobility/gait	Function/activity	Home environment	Hearing	Feet/footwear	Vision	Vestibular	Medications	Cardiac health
Barker (2018)[27]	≤14	Home	OT PT RN‡	FROP-Com	Short FES-I	FROP-Com	FROP-Com		FROP-Com		FROP-Com	FROP-Com		FROP-Com	
Chu (2017)[30]	≤14	Home	OT						WHSA						
Close (1999)[31]	—	DH Home	MD OT		FHI	~		MBI	Checklist			Snellen		~	OH
Davison (2005)[32]	—	IP Home	MD PT OT				POMS		USER		POMS	Snellen		~	OH
Harper (2017)[26]	—	ED	OT PT‡	FROP-Com§		FROP-Com	FROP-Com		FROP-Com		FROP-Com	FROP-Com		FROP-Com	
Hendricks (2008)[33]	≤30	DH Home	MD OT		FHI	Rhomberg	GnG	FAI GARS	CDC	Whisp	~	Snellen		~	OH
Lightbody (2002)[34]	14-28	Home	RN			Rhomberg	S-test		~	~	~	Snellen	~	~	ECG OH
Matchar (2017)[35]	—	DH Home	PT MD				SPPB		CDC			Snellen		~	~
Russell (2010)[6]	≤30	Home	MD OT PT RF‡	FROP-Com	MFES	FROP-Com	FROP-Com		FROP-Com		FROP-Com	FROP-Com		FROP-Com	~
Shaw (2003)[29]	—	Home	MD OT PT				mPOMA		Checklist×		~	Snellen VAA		~	OH

Vind (2009)[28]	–	Falls Clinic	MD RN PT	PPA		BBS	DGI TUG	30STS		VAA	~	ECG OH
Whitehead (2003)[36]	–	Home	–		~							

– Not reported
~ Included in assessment but no formal assessment tool used
† Time for assessment to delivered after fall/discharge from ED
‡ Assessment completed by one healthcare professional from one of the list professions
§ Two item screening tool was also used to assess falls risk

MD =Doctor; OT = Occupational Therapist; PT = Physiotherapist; MD = Medical doctor; RN = Registered Nurse; D = Dietitian; RF = Research Fellow
Home = Home visit or home based intervention; Tele = Telephone follow up calls; DH = Day Hospital; IP = Inpatient hospital; Group = Group program in out patient setting

FROP-Com = Falls Risk for Older People in the Community; Short FES-I = Falls Efficacy Scale–International (Short version); WHSA = Westmead Home Safety Assessment; Snellen = Snellen chart; FHI = Falls handicap inventory; Checklist = Environment hazards checklist designed by the Health and Safety Executive, UK; OH = orthostatic/postural hypotension; POMS = Performance Orientated Mobility Score; USER = User Safety and Environmental Risk checklist for home environment hazards; Romberg = The Romberg test of proprioception; FAI = Frenchay Activities Index; GnG = Get up and Go; GARS = Groningen Activity Restriction Scale; CDC = Centers for Disease Control and Prevention Home Checklist; Checklist^{x} = Assessment of Environmental fall hazards using a standard checklist; Whisp = Whisper voice test; S-test = The 'S' test for selecting mobility aids within an institutional setting; ECG = Electrocardiography; MFES = Modified version of the Falls Efficacy Scale; SPPB = Short Physical Performance Battery; mPOMA = modified version of the Performance Orientated Mobility Assessment; Checklist^{x} = Assessment of environmental fall hazards using a standard checklist; VAA = Visual acuity assessment; PPA = A physiological profile approach to fall risk assessment (short version); BBS = Berg Balance Scale; DGI = Dynamic Gait Index; TUG = Timed up and go; 30STS = Sit to stand in 30 seconds

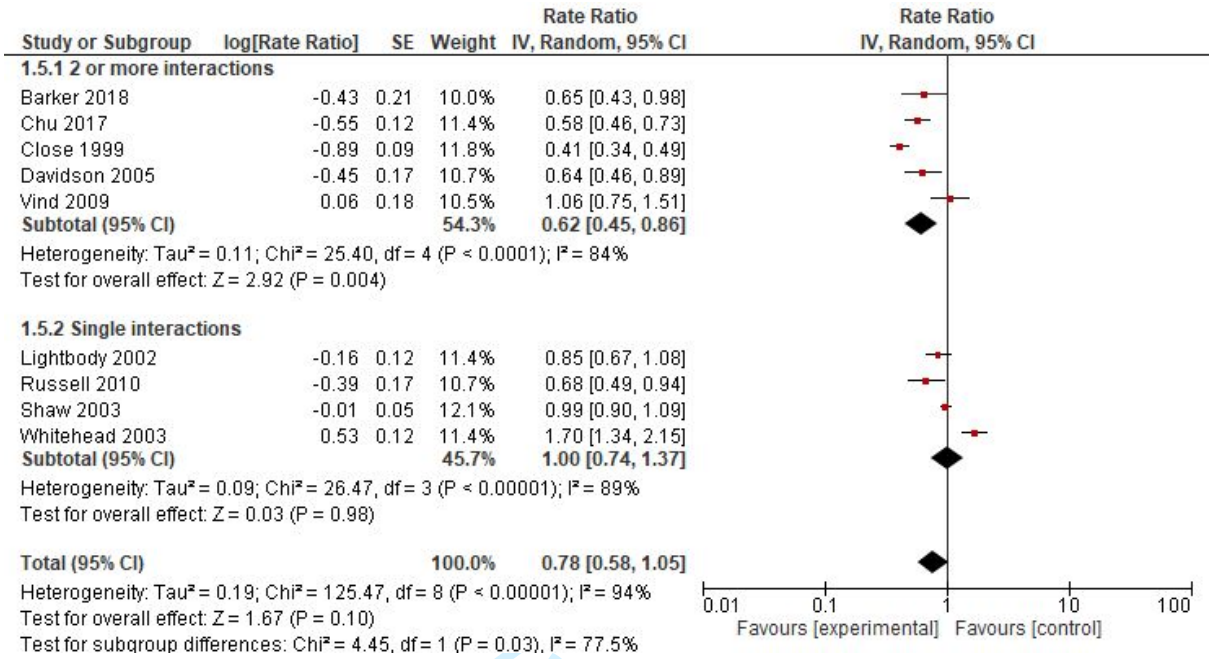
Appendix 4: Fall outcomes measured

Reference	Outcome measure collected	Definition of fall outcomes	Data collection mode
Barker 2018	**Primary outcomes** were falls and fall injuries per person-year over the 12-month study period. Falls may result in multiple injuries. As such, data on injurious falls (falls with at least one injury) were also recorded. **Secondary outcomes** included ED re-presentations, hospitalisations, fractures (confirmed by radiological investigation) and deaths per person-year over the 12-month study period.	**Fall**: an event resulting in a person coming to rest inadvertently on the ground, floor or other lower level. **Fall injury**: any physical harm resulting from a fall (including fractures, dislocations, sprain, skin tears and bruising), reported by study participants.	**Fall outcomes**: Self-reported via monthly fall calendars and blinded assessor telephone calls **Hospital utilisation**: Self-reported via monthly fall calendars and blinded assessor telephone calls and verified using hospital administrative datasets
Chu 2017	**Primary outcomes** included number of fallers and repeated fallers, number of falls and recurrent falls, time until first fall, number of ED visits because of falls, and length of hospital stays primarily due to falls in the 12-month follow-up period. **Secondary outcomes** included measurements during follow-up calls—telephone Barthel Index-50 (MBI), the Chinese version of the Frenchay Activities Index (FAI), and the Chinese version of the 4-item Geriatric Depression Scale (GDS).	**Fall:** an event that results in a person coming to rest inadvertently on the ground or hitting an object like a chair or stair. Individuals who fell because of excess alcohol intake or sustained a sudden blow or loss of consciousness or sudden onset of paralysis due to stroke or an epileptic seizure were excluded.	**Fall outcomes**: Self-reported via blinded assessor telephone calls to ask about subsequent falls
Close 1999	**Primary endpoint** was subsequent falls **Secondary outcomes** were death, major injury, moves to institutional care, functional status, and use of health care.	**Fall:** inadvertently coming to rest on the ground or other lower level with or without loss of consciousness and other than as a consequence of sudden onset of paralysis, epileptic seizure, excess alcohol intake, or overwhelming external force. **Fall injury:** the number of serious injuries (fracture or joint dislocation)	**Fall and healthcare utilisation outcomes**: Self-reported via monthly calendars

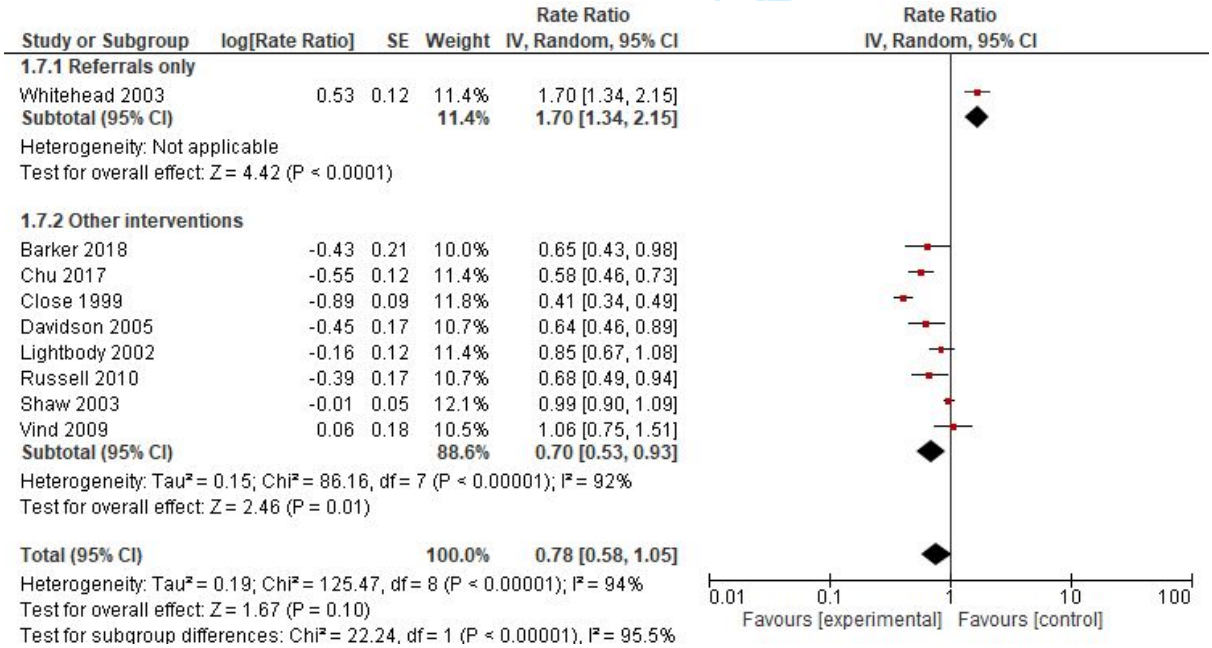
Davidson 2005	**Primary outcome** was the number of falls and the number of subjects who fell again during 1 year of follow-up. **Secondary outcome measures** were injury rates and fall-related hospitalisation, mortality, and changes in fall efficacy (Activities specific Balance Confidence Scale).	**Fall:** inadvertently coming to rest on the ground or other lower level with or without loss of consciousness or injury. **Fall injury:** not defined	**Fall outcomes**: Self-reported via monthly fall calendars and blinded assessor telephone calls **Hospital utilisation**: Self-reported via monthly calendars and blinded assessor telephone calls and verified with hospital records
Harper 2017	**Primary outcome** measure was the fall frequency among patients between ED discharge and commencement with the falls specific service. **Secondary outcomes** were time from discharge to next fall, attendance rates at the falls specific service, reason for nonattendance and death.	**Fall:** any presentation where patients had come to rest on the ground, floor, or lower level.	**Fall outcomes**: Self-reported via monthly fall calendars and blinded assessor telephone calls
Hendriks 2008	**Primary outcome** measures were falls (falls, recurrent falls, "injurious falls", and time to first fall) and daily functioning.	**Fall:** an event that results in a person coming to rest inadvertently on the ground or other lower level. **Injurious fall:** the percentage of participants who sought medical care after a fall.	**Fall outcomes**: Self-reported via monthly fall calendars and blinded assessor telephone calls
Lightbody 2002	**Primary outcome** was further falls, consequent injury and subsequent place of treatment were recorded. **Secondary outcome** were functional ability, re-attendance at the Accident and Emergency Department and admission to hospital.	**Fall:** patient failing to maintain a stable position and inadvertently coming to rest on the ground or lower level, with or without loss of consciousness, but not as the result of acute medical events or extraordinary environmental factors. Coming to rest against furniture or a wall was not deemed a fall. **Fall injury:** not defined	**Fall outcomes**: Self-reported via monthly fall calendars and blinded assessor telephone calls **Hospital utilisation**: Self-reported via monthly calendars and triangulated with hospital and GP records
Matcher 2017	**Primary outcome** measure was experiencing at least 1 fall during the 9-month study period. **Secondary outcome** measures were the occurrence of at least 1 injurious fall during the study period and a change in the Short Physical Performance Battery (SPPB) score.	**Fall:** an event which results in a person coming to rest inadvertently on the ground or floor or other lower level **Injurious fall:** a fall for which the participant sought medical attention or restricted his/her daily activities for at least 48 hours.	**Fall outcomes**: Self-reported via monthly fall calendars

Russell 2010	**Primary outcome** measures were falls and injuries as a result of these falls, over the 12-month follow-up period. **Secondary outcome** measures of serious injury (Abbreviated Injury Score >2) and peripheral fractures were summarised and compared using the same methods used for the primary outcomes.	**Fall:** based on the Kellogg International Working Group definition: ''an event which results in a person coming to rest inadvertently on the ground or some lower level, and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke or an epileptic seizure.'' **Injurious fall:** number of participants sustaining a fall or injury **Serious fall injury:** Injuries sustained as a result of falling were assessed for severity using the Abbreviated Injury Score. Serious fall injuries = Abbreviated Injury Score >2	**Fall outcomes**: Self-reported via monthly fall calendars and blinded assessor telephone calls **Hospital utilisation**: Self-reported via monthly calendars and blinded assessor telephone calls and verified with hospital records
Shaw 2003	**Primary outcome** measure was number of participants who fell at least once in the year after intervention. **Secondary outcome** measures were number of falls (corrected for diary returns), time to first fall, injury rates, fall related attendance at accident and emergency department, fall related hospital admissions, and mortality.	**Fall:** an event reported by either the person who fell or a witness, resulting in the patient inadvertently coming to rest on the ground or at another lower level with or without loss of consciousness or injury **Fall injury:** major injury or fractured neck of femur	**Fall outcomes**: Self-reported via weekly fall calendars and blinded assessor telephone calls **Hospital utilisation**: Hospital computerized records
Vind 2009	**Primary outcome** of the study was total number of falls. **Secondary outcome** measures were number of injurious falls, fallers, frequent fallers (>3 falls per year), time to first fall and first injury.	**Fall:** unintentionally coming to rest on the floor, ground, or other lower level. **Injurious fall:** fall caused injury resulting in contact with a general practitioner, emergency department or admission to the hospital.	**Fall outcomes**: Self-reported via weekly fall calendars and blinded assessor telephone calls **Hospital utilisation**: Hospital computerized records
Whitehead 2003	**Principal outcome** measure was the uptake of recommended evidence-based strategy at six months. Self-reported fall rate over the ensuing six month period was also assessed.	**Fall:** inadvertently coming to rest on the ground or other lower level with or without loss of consciousness and other than as a consequence of a major intrinsic or extrinsic event.	**Fall outcomes**: Self-reported via weekly fall calendars and blinded assessor telephone calls

Appendix 5: Sub-group analyses for falls



a) Meta-analysis by intensity of treatments



b) Meta-analysis by type of treatments i.e. referrals vs other