The effect of complex falls prevention interventions on falls in residential aged care settings: A systematic review

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Executive summary

Background

Preventing falls in the high risk residential aged care (RAC) population is a common global goal with acknowledged complexity. Previous meta-analyses have not specifically addressed complexity, as described by falls prevention intervention delivery at multiple levels of a residential aged care organization, to determine its effect on falls outcomes.

Objectives

The objective of this review was to synthesize the best available evidence for the effectiveness of complex falls prevention interventions delivered at two or more of the following levels: resident, facility or organization, on falls rates in the RAC population.

Inclusion criteria

Types of participants

The current review considered studies on participants who were aged 65 years and older residing in long-term care settings providing 24-hour supervision and/or care assistance.

Types of intervention(s)

Studies that evaluated complex falls prevention interventions delivered by single discipline or multidisciplinary teams across at least two or all of the following levels: residents, RAC facility and RAC organization were considered.

Types of studies

Experimental study designs including randomized controlled trials, controlled clinical trials and quasi-experimental trials were considered.

Types of outcomes

The current review considered studies that reported measures related to falls incidence namely rate

of falls (expressed as the number of falls per 1000 occupied bed days), the number of participants who became fallers (expressed as the number of participants who fell once or more) and the rate of injurious falls (expressed as the number of falls with injury per 1000 occupied bed days).

Search strategy

A three step search strategy was undertaken commencing with an initial scoping search of MEDLINE and CINAHL databases prior to an extensive search of all relevant published literature, clinical trial registries and gray literature.

Methodological quality

Two independent reviewers assessed selected studies for methodological validity using the standardized critical appraisal instrument from the Joanna Briggs Institute Meta-Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI).

Data extraction

Data were extracted from the selected studies using the standardized data extraction tool from JBI-MAStARI.

Data synthesis

Quantitative data were pooled in statistical meta-analysis for rate of falls, the number of participants who became fallers and the rate of injurious falls. Meta-analysis was conducted using a random-effect model with heterogeneity assessed using the standard Chi-squared and I^2 index. Where statistical pooling was not possible, study findings were presented in narrative form.

Results

Twelve studies were included in this review with seven being eligible for meta-analysis. Complex falls prevention interventions delivered at multiple levels in RAC populations did not show a significant effect in reducing falls rates [MD = -1.29; 95% CI (-3.01, 0.43)], or the proportion of residents who fell [OR = 0.76; 95% CI (0.42, 1.38)]. However, a sensitivity analysis suggested complex falls prevention interventions delivered with additional resources at multiple levels had a significant positive effect in reducing falls rates [MD = -2.26; 95% CI (-3.72, -0.80)].

Conclusions

Complex falls prevention interventions delivered at multiple levels in the RAC population may reduce falls rates when additional staffing, expertise or resources are provided. Organizations may need to determine how resources can be allocated to best address falls prevention management. Future research should continue to investigate which combinations of multifactorial interventions are effective.

Summary of findings

(see Table at end of doc)

Introduction

Background

Falls in the RAC sector are a major concern worldwide with rates reported to range between 3-13 falls per 1000 bed days.[1-5] One in two older people (residents) admitted to RAC have a fall within 12 months and 25%-30% of those sustain a physical injury.[3,6] Significant physical injuries, such as hip fracture, have an estimated incidence rate of between 3% and 5% annually.[7-9] These types of injuries frequently lead to a loss of independence. The psychological impact of falling can also result in loss of confidence and reduced quality of life, with researchers reporting that even with rehabilitation interventions, many older people who have fallen never regain their former level of confidence or independence.[3,5,10]

Falls prevention in any setting is challenging as it involves a number of interacting components making both intervention and evaluation complex.[11,12] Older people residing in aged care facilities are recognized as a population with high falls risk due to many individuals having a history of falls, activities of daily living disability, cognitive and visual impairments, multiple medications, pain, urinary incontinence and reduced strength and balance.[1,2,5,13] A European study of 57 long term care homes with over 4000 residents observed cognitive impairment in 68% of residents and activities of daily living disability in 81.3%,[14] suggesting that older people in residential care are particularly vulnerable and often lack the capability to reduce their risk of falling without prompting or assistance. The environment can also impact resident safety; with the highest incidence of falls occurring in residents bedrooms[4,15] or bathrooms.[4] Other factors within the RAC setting, such as staff and organizational philosophy and culture, can also influence resident safety.[16,17]

Researchers working in this field have trialed a range of different intervention approaches to address falls among this older population from single strategies, including exercise and medication review, to multifactorial approaches delivered by a multidisciplinary staff.[1,18,19] Two recent meta-analyses examining falls prevention programs in RAC populations showed different findings; the Cochrane systematic review[1] concluded that providing vitamin D supplementation for residents with low vitamin D levels reduced the rate of falls by 37%, 95% CI [0.46-0.86] but not an individual's risk of falling whilst Vlaeyen *et al*.[9] reported that multifactorial fall prevention interventions decreased falls by 33%, 95% CI [0.55-0.82] and the number of people with recurrent falls by 21% (95% CI 0.65-0.97). However whilst these systematic reviews focused on single, multiple or multifactorial intervention approaches their inclusion criteria differed; the former included some mixed population studies[1] whilst the latter included only nursing home populations and randomized or cluster randomized controlled designs.[9]

Since residents are frail and generally require assistance with activities of daily living, implementing falls prevention evidence-based practice into a RAC setting predominantly requires staff to master the content of such a program and apply it to the care of their residents.[12,20] Whilst the capacity to deliver organization wide approaches to address complex issues, such as effective falls prevention, is strongly influenced by an organization's leadership and culture to support change.[17,20] This requires connections between managers, staff and researchers to develop effective policy through interdisciplinary problem solving and discussion that in turn enables staff behavioral change.[21-23] Consequently some researchers have suggested that organizations need to make changes at multiple levels using a systematic approach to enable evidence to be translated into practice.[12,20,24-26] These interventions that are delivered across multiple levels have been characterized as complex.[12] For falls prevention interventions delivered in RAC settings these levels can be categorized as: resident, facility and organization and if at least two or all of these levels are targeted then the intervention can be considered complex. Resident level describes intervention delivery involving resident participation, such as the resident undertaking an exercise program, continence management, vitamin D supplementation, hip protectors or having a medication review. Facility level delivery describes interventions that target RAC staff, such as giving staff falls prevention education, environmental audits, referral to other health professionals or undertaking safety maintenance on patient equipment. Organization level describes interventions involving RAC management participation in bringing about practice change, such as revising professional staff roles, implementation of multidisciplinary falls prevention teams or committees and reviewing policy or processes around falls prevention. A limited number of studies have evaluated complex multiple level interventions that included elements that addressed aspects of organizational change including, reassignment of staff roles and adoption of best practice at a facility level.[15,27,28] Such studies include; a participatory action research design that trained a falls resource nurse to lead the implementation of evidence-based strategies resulting in a reduction in the proportion of fallers in RAC facilities[15] whilst a falls management program targeting cultural change and quality improvement had no effect on falls.[28] Another study, led by a falls coordinator in similar RAC settings, delivered tailored best practice falls prevention interventions and found that falls rates increased.[27] These variations in findings lead to uncertainty about the effectiveness of complex multi-level approaches.

Clinical care barriers that hinder the implementation of falls prevention evidence into practice in RAC settings have been identified. These included poor communication, staffing issues, staff concerns regarding their ability to control fall management and limited staff clinical knowledge and skills.[29] It has also been suggested that RAC facilities may require additional resources to facilitate translation of falls prevention evidence into practice,[30,31,32] this will be increasingly challenging due to the reported financial constraints of the RAC industry globally.[31-34]

To our knowledge there were no recent systematic reviews either published or underway that synthesized the evidence for effectiveness of complex falls prevention interventions delivered at multiple levels in the RAC population from searches of The Cochrane Database of Systematic

Reviews (The Cochrane Library, latest issue), The Joanna Briggs Institute of Systematic Reviews and Implementation Reports (JBISRIR), PROSPERO, MEDLINE and CINAHL. The absence of synthesized evidence for organization wide approaches to falls prevention in the RAC setting justifies this current review. Given that clinicians and falls researchers are now undertaking and evaluating complex multiple level interventions there is a need to combine these data systematically. This review was conducted according to an *a priori* published protocol.[35]

Objectives

The aim of this review was to synthesize the best available evidence for the effectiveness of complex falls prevention interventions, implemented at two or more of the following levels: resident, facility or organization, on falls in the RAC population.

Inclusion criteria

Types of participants

This review considered studies that included participants who were 65 years of age or older or the mean age of the group was over 65 years and they resided in long-term care accommodation (residential aged care) providing 24-hour supervision and/or care assistance.

Studies were excluded if they were conducted in a setting that was community-based, assisted living in retirement communities, retirement homes, continuing care retirement centers, hospitals or specialized care units; such as palliative care or transition care. In a deviation from our published protocol[35] we also excluded studies conducted solely on selected psychogeriatric wards as the intervention and resultant outcomes were specific to psychogeriatric patients. It has been found by other falls researchers that the participant characteristics and the environment differ between these settings and hence require different falls prevention interventions.[1] Studies using only samples of the RAC population defined by a diagnosis or event, e.g. dementia or residents who fell once or more times, were also excluded.

Types of intervention(s)

This review considered studies that evaluated complex falls prevention interventions. Complex falls prevention interventions were defined as those delivered across at least two or all of the following levels: resident, RAC facility and RAC organization. These levels were classified based on the adapted works of Wensing *et al.*[26] and Quigley *et al.*[36] Resident level described intervention delivery involving resident participation or compliance similar to Quigley *et al.*[36] Facility level delivery described interventions at a proxy level engaging RAC staff in undertaking falls prevention education or practice change to effect resident outcomes. We considered interventions such as modifying the environment layout and safety maintenance on patient equipment to be decided at facility level, involving RAC staff rather than organization level as described by Quigley *et al.*[36] At organizational level we considered Wensing et al.'s[26] focused review describing the organizational changes directed at staff practices to improve patient care a better fit for our review criteria, as they reflected management participation. Therefore, organization level described interventions involving RAC management participation in bringing about practice change. Interventions delivered at any of the levels included multiple or

multifactorial falls prevention interventions delivered by single discipline, multidisciplinary staff teams or quality improvement collaboratives.

Types of comparators

Studies were included that compared intervention complexity by delivery level, that is whether the interventions were delivered at resident, facility or organizational levels. Studies offering no comparison, a passive comparison (such as standard care) or an active comparison (such as variation of the intervention) were also considered.

Types of studies

The study designs considered were both experimental and quasi-experimental designs, including randomized controlled trials, controlled clinical trials, experimental studies where randomization had been used, comparative studies without randomization, cohort and pre post designs. Studies were only included if they contained repeated measures. Studies published in the English language from January 1 1990 to September 30 2017 were considered for inclusion as the incidence of falls in RAC settings and concepts to engage healthcare organizations and staff in falls prevention interventions to improve falls outcomes began to be addressed in published studies from around 1990 onwards.[35]

Types of outcomes

Studies were included if an outcome measure related to falls incidence was used and outcomes were measured before and after the intervention period. Outcome measures related to falls incidence included the number of falls, the rate of falls (expressed as the number of falls per 1000 occupied bed days) and the proportion of participants who fell (expressed as the number of participants who fell one or more times); the number of injurious falls, the rates of injurious falls (expressed as the number of falls with injury per 1000 occupied bed days). Studies that measured falls rates as secondary outcome measures were also included if they provided data from which the falls rate or injurious falls rate could be calculated.

Search strategy

This review used a three-step search strategy. An initial limited search of MEDLINE (Pubmed) and CINAHL Plus with full text (EBSCO) using initial key words falls, falls prevention, residential aged care and nursing homes was undertaken. Text words contained in the title and abstract of these identified studies together with index terms describing these studies were used to construct the second search step, undertaken in seven databases: The Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library), The JBI Database of Systematic Reviews and Implementation Reports (Implementation reports only), Medline, CINAHL, EMBASE, AMED and PsycINFO. The search for unpublished studies included an electronic search of: trials registers Current Controlled Trials (http://www.controlled-trials.com) and the National Institute of Health Clinical Database (http://clinicaltrials.gov), Universal Index of Doctoral Dissertations in Progress, Mednar, Grey Literature Report and Google. The third search step reviewed reference lists of all studies retrieved in

full text for any relevant additional studies not previously captured. The full search strategy is provided in Appendix I.

Method of the review

Critical appraisal

Papers selected for critical appraisal were assessed by two independent reviewers for methodological quality prior to inclusion in the review, using standardized critical appraisal instruments (checklists for randomized controlled trials and quasi-experimental trials) from the Joanna Briggs Institute Meta-Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI) as shown in the protocol.[35] Potential risk of bias was assessed by rating each item as yes, no or unclear and subsequently scoring the overall quality out of a total of 100%. Disagreement was resolved by discussion between the two independent reviewers. A third independent reviewer was available for arbitration should a consensus not have been reached.

Data extraction

Quantitative data were extracted from the selected studies by two independent reviewers using the standardized data extraction tool from the JBI-MAStARI as per protocol.[35] The data extracted included details about participants and setting, study design and duration, sample size and the level and type of interventions delivered; including whether interventions were delivered at resident, facility or organization level. Falls outcomes extracted included the number of falls, falls rates, the number of older people who fell, the number of injurious falls and injurious falls rates. Data were only extracted on injurious falls if soft tissue injuries and fractures were included.

Data synthesis

Quantitative data from eligible studies were pooled in statistical meta-analyses using Revman V5.3.4 (The Nordic Cochrane Centre, Cochrane, Copenhagen, Denmark). All results were subject to double data entry. Statistical analysis was undertaken for falls rates, number of fallers and injurious falls rates. All studies were analysed in terms of primary outcomes where data were available, regardless of their settings or combinations of intervention. Heterogeneity was assessed using a combination of visual inspection of the Forest plot along with consideration of the Chi-squared test and the I^2 statistic.[37] When the I^2 statistic was greater than 50% a random effects model was applied as authors were aware of the uncertainty of the homogeneity of RAC resident populations and interventions delivered. For continuous outcomes the mean difference, standard deviation and standard error were calculated using the inverse variance DerSimonian and Laird method.[38] The results for dichotomous outcomes (fallers) were analysed using Mantel-Haenszel's random effects model.[39] We explored heterogeneity by carrying out subgroup analyses based on whether additional staff or resources were allocated or obtained to participate in the intervention. Statistical significance was set at $p \leq .05$ for all

analyses (two-sided). Where statistical pooling was not possible the results were presented as a narrative synthesis.

Results

Description of studies

The three step search strategy identified 2488 studies for consideration with 28 studies retrieved for full text review. Twelve studies were included for critical appraisal and were subsequently included in the review; seven of those were eligible for meta-analysis (Figure 1). Excluded studies with reasons are shown in Appendix II.

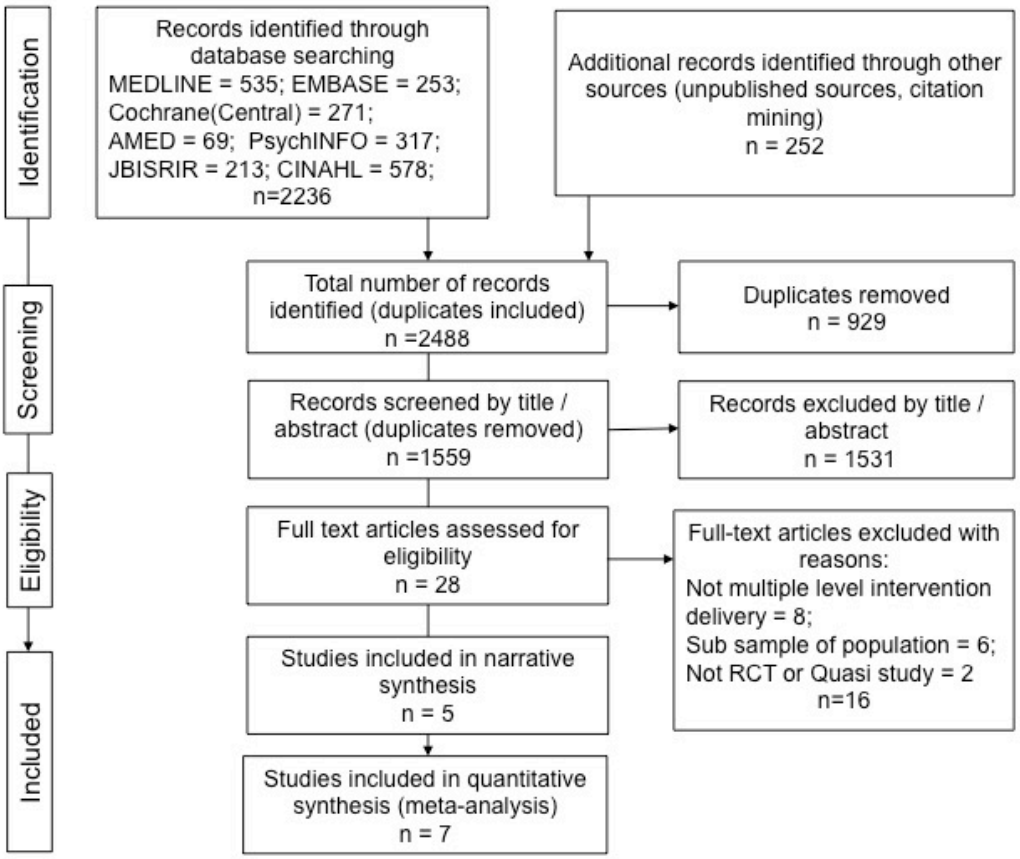

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Figure 1: Flow chart showing selection of studies included in the review

Characteristics of the 12 included studies are shown in Appendix III. Seven studies were cluster randomized controlled trials,[16,27,40-44] two were quasi-experimental pre-post with control group[6,28] and the remaining three quasi-experimental pre-post design.[15,21,45] Five studies were conducted in the USA, two in the UK, and the remainder in Australia, New Zealand, Canada, Germany and Sweden. The number of RAC facilities included in the 12 studies ranged from one to 112 with the mean age of

residents being greater than 80 yrs. Studies included were conducted in long term care facilities for older people providing 24-hour supervision and care assistance as assessed. Study follow up times ranged from 34 weeks[41] to 24 months.[15] Eight studies included a fall or injurious fall definition[15,27,28,40-44] and seven studies followed recommended methods for gathering falls data.[6,15,16,27,40-42]

Nine studies[6,15,21,27,40,41,43-45] delivered falls prevention interventions at three levels (resident, facility and organization). Three studies delivered falls prevention interventions at two levels; two delivered resident and facility level interventions[16,42] and one delivered facility and organization level interventions.[28] For example, resident level interventions included falls risk assessment, exercise program, medication review and provision of mobility aids or hip protectors. Facility level interventions included staff education, environmental modifications (audit, install or repair) and referral to a health professional or service. Organization level interventions included changes to falls or falls prevention policy. Comparisons of intervention complexity by delivery level i.e. whether the interventions were delivered at resident, facility and/or organization levels were undertaken for the 12 included studies.

Methodological quality

Assessment for risk of bias was completed for seven RCTs (Table 1). Two studies scored six out of 10,[42,43] four studies scored seven out of 10[16,40,41,44] and one study scored nine out of 10.[27] True random assignment to treatment groups was performed in five (71.4%) of the included studies,[16,27,40,43,44] four (57.1%) studies[16,27,41,44] concealed allocation to treatment from the allocator and six (85.7%) studies[16,27,40-42,44] described and included outcomes of people that withdrew in their analysis. In all seven studies (100%) the control and treatment groups were similar at entry, received identical treatment apart from the named intervention and measured outcomes in the same way for both groups. Measurement of outcomes was deemed reliable in six (85.7%) studies[16,27,40-43] with five (71.4%) using appropriate statistical analysis.[27,40,41,43,44] Blinding of assessors to treatment groups was reported in three (42.9%) studies[27,42,43] with none (0%) blinding participants to treatment allocation. Overall the seven studies scored above six out of 10 (≥60%) and were thus considered of an acceptable quality for inclusion in meta-analysis.[16,27,40-44]

Table 1: Results of critical appraisal of included randomized controlled trials

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Becker *et al.*[40]	Y	U	U	Y	N	Y	Y	Y	Y	Y
Dyer *et al.*[16]	Y	N	Y	Y	N	Y	Y	Y	Y	U

Jensen *et al.*[41]	U	N	Y	Y	N	Y	Y	Y	Y	Y
Kerse *et al.*[27]	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
McMurdo *et al.*[42]	U	U	U	Y	Y	Y	Y	Y	Y	N
Ray *et al.*[44]	Y	U	Y	Y	U	Y	Y	Y	N	Y
Ray *et al.*[43]	Y	N	U	N/A	Y	Y	Y	Y	Y	Y
%	71.43	0.00	57.14	100.00	42.86	100.00	100.00	100.00	85.71	71.43

Note. Y=Yes, N=No, N/A=Not applicable, U=Unclear

Assessment for risk of bias was also conducted on the five quasi-experimental designs (Table 2). Two studies scored seven[6] and eight[15] out of nine respectively, one scored five out of nine,[28] one scored three out of nine[45] and the other two out of nine.[21] All five studies (100%) clearly stated cause and effect, four (80%) studies provided treatment similarly other than the intervention and follow up was completed or strategies to deal with losses were employed.[6,15,21,28] Three (60%) studies reported participants under comparison were similar and measurement of outcomes was performed in the same way for all participants.[6,15,45] In two (40%) studies participants received similar treatments other than the intervention,[15,45] a control group was included,[6,28] multiple measurements of outcomes pre and post exposure were reported,[15,28] outcomes were measured reliably and appropriate statistical analysis was used.[6,15] These five studies with weaker designs, incomplete reporting and variable quality were considered ineligible for meta-analysis and were thus narratively synthesized.[6,15,21,28,45]

Table 2: Results of critical appraisal of included quasi-experimental studies

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Burland *et al.*[6]	Y	Y	U	Y	N	Y	Y	Y	Y
Colon-Emeric *et al.*[21]	Y	U	U	U	N	Y	N	N	U
Hofmann *et al.*[45]	Y	U	Y	N	N	U	Y	N	U

NItz *et al.*[15]	Y	Y	Y	N	Y	Y	Y	Y	Y
Rask *et al.*[28]	Y	Y	U	Y	Y	Y	N	N	N
%	100.00	60.00	40.00	40.00	40.00	80.00	60.00	40.00	40.00

Note. Y=Yes, N=No, N/A=Not applicable, U=Unclear

Findings of the review

The certainty of the evidence from the seven RCTs pooled[16,27,40-44] was summarized as moderate to low. The effectiveness of multiple level interventions on falls rates was examined first, which included three sensitivity analyses. The effectiveness of multiple level interventions on the outcomes of people who fell once or more, injurious falls rates and serious injurious falls rates were also reported.

Effectiveness of multiple level interventions on falls rates (Meta-analysis)

Some studies were not suitable for meta-analysis due to incomplete reporting. Falls rates from five RCTs were pooled for meta-analyses (shown in Figure 2).[16,27,40-42] Three studies provided a complex intervention with intervention delivery at all three levels[27,40,41] and two provided interventions delivered at two levels (resident and facility).[16,42] Overall there was no significant between group difference in the rate of falls [MD = -1.29; 95% CI (-3.01, 0.43)]. There was evidence of heterogeneity between the included studies (I^2 = 64%).

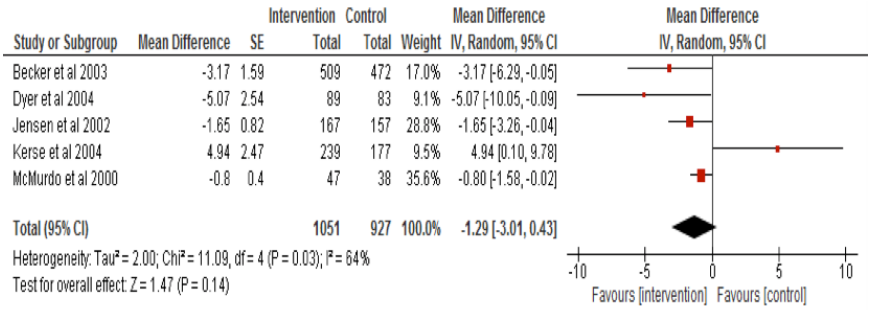

Figure 2 Forest plot of comparison: Intervention vs control for falls rates.

Sensitivity analysis

For the outcome rate of falls three sensitivity analyses were performed to explore differences in the delivery of the intervention. Three studies[16,40,41] that delivered their interventions using notable additional input from external experts and extra resources at two or three levels were effective in reducing falls rates [MD = -2.26; 95% CI (-3.72, -0.80)] (Figure 3).

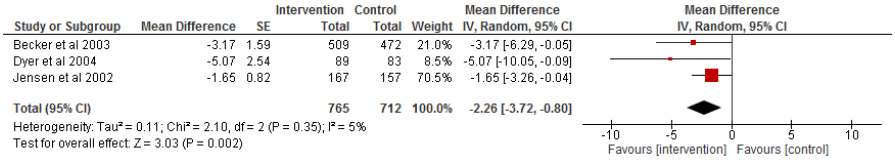

Figure 3 Forest plot of comparison: Intervention vs control for falls rates in studies with additional resource support in intervention delivery.

The two studies[27,42] that were removed delivered their multiple level interventions using existing RAC resources with no extra assistance. Removal of these two studies significantly reduced the heterogeneity (I^2 = 5%). Additionally, separate sensitivity analyses were performed, which pooled the studies that delivered interventions at two levels[16,42] (Figure 4) and those that delivered interventions at three levels[27,40,41] (Figure 5). Neither had a significant effect on falls rates [MD = -2.20, 95% CI (-6.13, 1.73)] and [MD = -0.56, 95% CI (-4.02, 2.90)] respectively and heterogeneity was high in both (I^2 = 64% and 75% respectively).

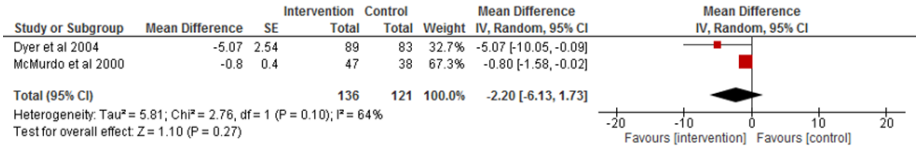

Figure 4 Forest plot of comparison: Intervention vs control for falls rates in studies with interventions delivered at two levels.

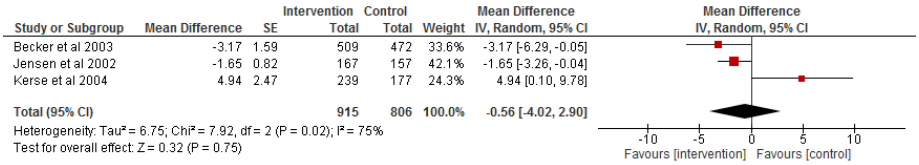

Figure 5 Forest plot of comparison: Intervention vs control for falls rates in studies with interventions delivered at three levels.

Five quasi-experimental studies reported data on falls rates.[6,15,21,28,45] Four of the studies[6,15,21,28] reported no significant change in falls rates at follow up compared to baseline. One study[45] reported a significant reduction in the number of falls; however, this study was of low quality and did not report or analyze falls rates according to the prevention of falls network Europe global recommendations of including a fall definition, undertaking prospective comparison and reporting on participant compliance.[46]

Effectiveness of multiple level interventions on fallers

The number of residents who fell (relative to all residents) from five RCTs[16,27,40-42] were pooled for meta-analysis (Figure 6). Overall there was no significant between group differences in fallers [OR =

0.76, 95% CI (0.42, 1.38)]. There was evidence of high heterogeneity between the included studies (I^2 = 88%).

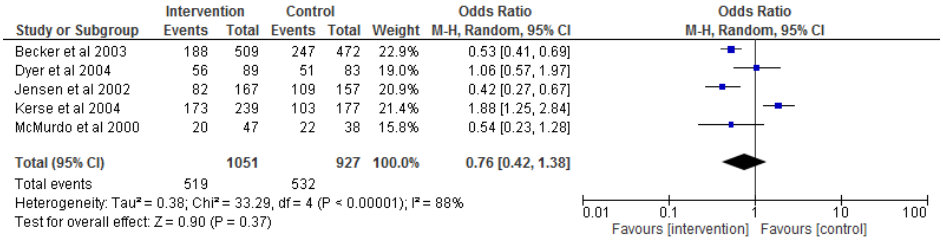

Figure 6 Forest plot of comparison: Intervention vs control for the proportion of residents who fell.

Two quasi-experimental studies reported data on the number of residents who fell.[15,21] One study reported no significant differences in the proportion of residents who fell pre and post intervention.[21] The other study showed a significant reduction in the proportion of fallers (residents who fell once or multiple times) [95% CI (-21.85, -0.28) p = .044] and single fallers (residents who fell only once) [95% CI (-15.03, -0.35) p = .040].[15]

Effectiveness of multiple level interventions on injurious falls rates

Data reporting injurious falls rates from two RCTs[27,41] were pooled for meta-analyses (Figure 7).

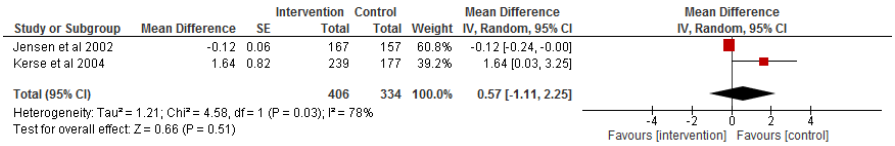

Figure 7 Forest plot of comparison: Intervention vs control for injurious falls rates.

These two studies delivered complex interventions at all three levels. There was no significant between group difference in the rate of injurious falls [MD = 0.57, 95% CI (-1.11, 2.25)] and heterogeneity was high (I^2 = 78%). A further two studies[43,44] were pooled separately as they classified injurious falls differently, using the prefix 'serious' to include only those injuries from falls that required hospital admission, emergency department or physician visit (Figure 8).

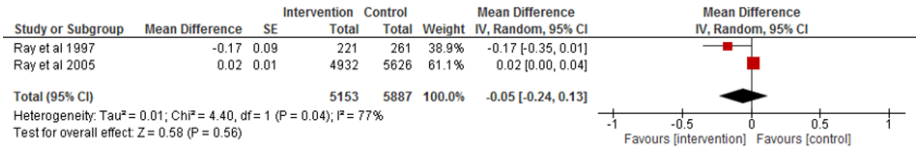

Figure 8 Forest plot of comparison: Intervention vs control for serious injurious falls rates.

These studies both provided interventions delivered at three levels (resident, facility and organization). Again there was no significant between groups differences in the rate of serious

injurious falls [MD = -0.05, 95% CI (-0.24, 0.13)]. There was also evidence of high heterogeneity in the serious injurious falls rates (I^2 = 77%).

Two quasi-experimental studies reported data on injurious falls[6,45] of which one only reported the number of falls that resulted in fracture.[45] Burland *et al*.[6] reported a significant reduction in injurious falls [adjusted RR = 0.79, 95% CI (0.67, 0.96) p = .022]. However this study compared injurious falls rates pre and post intervention between two different groups, meaning results may have been confounded.

Discussion

Complex interventions using a multiple level approach to prevent falls in RAC settings have been delivered at combinations of resident, facility and organizational levels. Synthesized results demonstrated no significant reduction in falls rates or the proportion of residents who fell when intervention delivery targeted combinations of resident, facility and organizational levels. High heterogeneity amongst the five included studies[16,27,40-42] was identified and deemed significant. A sensitivity analysis that pooled three studies[16,40,41] where interventions were delivered at either two or three levels and supported with additional resources, improved heterogeneity and showed a significant reduction in falls rates. These studies provided additional resources such as extra nursing staff to perform falls risk assessments, personal falls consultation for residents by external staff and extra physiotherapists employed part time during and following the intervention period. This may have enabled better intervention intensity and fidelity without compromise to RAC staff undertaking their usual duties.

Common intervention components provided in these three studies[16,40,41] were exercise programs for residents, education for staff and modifications to the environment. Targeting patients (or residents), staff and the environment have also previously been identified as domains' requiring simultaneous intervention to prevent falls amongst older people in hospital settings.[47,48] This indicates that complex settings require complex solutions, rather than single interventions for falls that have been established as effective for older community dwelling people.[49] A recent systematic review addressing the barriers and facilitators to implementing falls prevention interventions in RAC facilities identified determinants of success across a range of healthcare levels.[29]

Two meta-analyses[9,50] investigating the effectiveness of multifactorial fall prevention programs for older people in RAC showed more favorable results on falls outcomes but did not include the study by Kerse *et al*.[27] which we assessed as having low risk of bias, but showed a significant increase in falls outcomes. The meta-analysis of the effectiveness of multifactorial intervention studies by Cameron *et al*.[1] included five studies common to ours and showed similar non-significant findings.

The studies included in our review varied widely in terms of the type, intensity and level of the interventions delivered with some differences in setting. For example Becker *et al*.[40] provided residents with falls prevention education, hip protectors and balance and resistance exercises twice weekly for 75 minutes, staff received falls education (60 minutes presentation and written material) and monthly feedback on falls outcomes, modifications to the environment that included appropriate lighting, chair and bed height and additional safety rails combined with revision of nursing roles to lead falls prevention at their facility. In contrast Hofmann *et al*.[45] implemented a restorative activity program for residents that was entertainment based, repositioned or removed furnishings within the environment, formed a falls committee and changed staff rostering to cover periods identified as high risk for fall occurrence. Other systematic reviews have also noted that multifactorial interventions vary widely in their components in terms of, the duration, intensity of the intervention and its implementation, which makes interpretation of findings difficult.[1,9,50] Researchers have also suggested that the philosophy of the RAC facility (or organization), including that of individual staff members,[16] staff communication, knowledge and skills[29] may influence whether a falls prevention program is successful. This supports the need for more multiple level multifactorial approach investigations.

Limitations

This systematic review was only able to consider studies written in English, thus results may be subject to language and publication bias. Only a small number of studies (n=7) were eligible for meta-analysis and the overall quality of the pooled evidence was summarized as moderate to low, therefore the results must be interpreted with caution. We were not able to account for the heterogeneity of resident case-mix and staffing in these RAC settings in our analyses. In a deviation from our published protocol[35] we excluded one study[51] as it was conducted solely on selected psychogeriatric wards meaning the intervention and resultant outcomes were specific to psychogeriatric patients. Psychogeriatric settings are known to have higher falls rates and greater challenges to intervention compliance compared with the broader RAC population.[52,53] Therefore we felt this study was not representative of falls prevention programs delivered across the broader RAC population. Consideration should also be given to intervention fidelity and intensity. These complex interventions delivered at multiple levels incorporated a range of different strategies, making it difficult to attribute the beneficial outcomes to individual components or levels. Variations in the methods of gathering, reporting and analyzing falls data were also noted. Thus careful descriptions of intervention components, intensity and fidelity and adherence to falls reporting recommendations are required for better comparisons in the future.

Conclusion

Implementing multifactorial falls prevention programs across multiple levels is challenging in RAC settings. There are limited resources to provide falls prevention interventions for a frail population with

complex needs. The best available evidence indicates that multifactorial interventions delivered at resident, facility and organization levels can be effective in reducing falls rates in the RAC population when additional external expertise and resources are provided in the short term.

Implications for practice

Investment in interventions to reduce falls may contribute to prolonged independence and a better quality of life for residents, in addition to cost savings per person fall.[54,55,56] Our finding regarding the requirement of additional intervention resources to achieve a significant reduction in falls rates poses a problem in an industry faced with resource constraints. It has previously been suggested that interventions in RAC facilities need to be delivered with existing resources due to the financial constraints of the RAC sector.[31,32] Peak bodies representing the RAC sector have recently reported they have serious concerns regarding their ability to provide high quality care because of limited RAC funding. Changes to the funding criteria in Australia are estimated to cost the RAC sector over $1.6 billion over the next four years.[57] Similarly in the United States and Europe trends in the demand for long-term care for the ageing population threaten service provision, care quality and health outcomes in the absence of appropriate funding.[34,58,59] However current evidence supports delivery of multifactorial falls prevention interventions to improve falls outcomes which is of benefit to residents as it assists to avoid negative outcomes such as physical injury. Therefore we concur with other researchers in stating that assisting RAC organizations to find a sustainable means of achieving this is of primary importance.[6,9,15,31] JBI Grade B evidence.[60]

Implications for research

More high quality studies investigating complex multiple level interventions are required. In addition, there is a need for trials to determine how RAC organizations can facilitate sustainable delivery of evidence-based falls prevention interventions with existing resources. When large research studies using external resources have been conducted it is not known if the positive outcomes reported are sustained in the longer term, as RAC facilities may return to their usual operation conditions when the additional resources are withdrawn. Hence trials should measure outcomes over longer follow up periods to determine the ongoing intervention effect.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

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Appendix I: Search strategy (January 1990 to Sept 2017)

MEDLINE		Results
1	Accidental fall*.mp	20996
2	Fall* prevention.mp	2861
3	Faller*.mp	3654
4	1 OR 2 OR 3	23984
5	programme*.mp	200394
6	program*.mp	1184184
7	Intervention*.mp	915733
8	Quality improvement.mp	40744
9	Best practi?e.mp	17160
10	Multifactorial.mp	35687
11	Collaborative*.mp	79686
12	Community of practice.mp	3131
13	Communities of practice.mp	485
14	Organi?ation and management.mp	35940
15	5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14	2104327
16	Nursing home*.mp	44281
17	Residential aged care.mp	810
18	Residential facilit*.mp	5882
19	Residential facility.mp	330
20	Residential home.mp	321
21	Skilled nursing facilities.mp	4531
22	Long term care.mp	39435
23	Home* for the aged.mp	13811
24	16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23	85843
25	4 AND 15 AND 24	629

26	Limit 25 to (humans and English language and yr="1990-current")	535
CINAHL		Results
1	"Accidental fall*"	16192
2	(MH "Accidental falls/PC")	16234
3	(MH "Accidental falls/EV")	16229
4	"Falling"	6085
5	"Faller*"	870
6	Fall* prevention	8030
7	1 OR 2 OR 3 OR 4 OR 5 OR 6	21,819
8	"programme*"	49006
9	"program*"	366535
10	"Intervention*"	300951
11	"Quality improvement"	49108
12	"Best practi?e"	7960
13	"Multifactorial"	5254
14	"Collaborative"	20182
15	"Community of practice"	10831
16	"Communities of practice"	10831
17	Organi?ation and management.mp	21061
18	(MH "Quality Management, Organizational")	997
19	(MH "Evaluation and Quality Improvement Program")	652
20	8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19	681657
21	"Nursing home*"	45787
22	"Residential aged care"	833
23	"Residential facilit*"	4919
24	"Residential home*"	1526
25	"Long term care"	30040

26	“Home* for the aged”	2869
27	21 OR 22 OR 23 OR 24 OR 25 OR 26	72226
28	7 AND 20 AND 27	598
29	Limiters – Publication Year: 1990-2016, English language	578
EMBASE		Results
1	Accidental fall*.mp	1907
2	Falling/pc [Prevention]	2932
3	Falls prevention.mp	1315
4	1 OR 2 OR 3	5674
5	programme*.mp	228320
6	program*.mp	1216132
7	Intervention*.mp	1114160
8	Quality improvement.mp	39377
9	Best practi?e.mp	15942
10	Multifactorial.mp	47043
11	Collaborative*.mp	63104
12	Organization and management.mp	472642
13	5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12	2650145
14	Nursing home*.mp	58159
15	Residential aged care.mp	867
16	Residential facilit*.mp	1198
17	Residential facility.mp	415
18	Residential home/	6614
19	Skilled nursing facilities.mp	1340
20	Long term care.mp	121003
21	Home* for the aged	11437
22	14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21	180311

23	4 AND 13 AND 22	292
24	Limit 23 to (human and English language and yr="1990-current")	253
AMED		Results
1	Accidental fall*.mp	2038
2	Fall.mp	1732
3	Falls.mp	2667
4	Fall* prevention.mp	302
5	Faller*.mp	241
6	Falling*.mp	862
7	1 OR 2 OR 3 OR 4 OR 5 OR 6	3780
8	programme*.mp	4721
9	program*.mp	20360
10	Intervention*.mp	22897
11	Quality improvement.mp	263
12	Best practice.mp	320
13	Multifactorial.mp	377
14	Collaborative*.mp	1064
15	Community of practice.mp	59
16	Communities of practice.mp	25
17	Organization and management.mp	200
18	Organisation and management.mp	55
19	8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19	39891
20	Nursing home*.mp	1562
21	Residential aged care.mp	35
22	Residential facilities.mp	694
23	Residential facility.mp	30
24	Residential home.mp	26

25	Skilled nursing facilities.mp	81
26	Long term care.mp	1248
27	Home* for the aged.mp	280
28	20 OR 21 OR 22 OR 23 OR24 OR 25 OR 26 OR 27	3358
29	7 AND 19 AND 28	71
30	Limit 29 to (English language and yr="1990-current")	69
PsycINFO		Results
1	Accidental fall*.mp	178
2	Falls.mp	10104
3	Faller*.mp	462
4	Falling.mp	8095
5	Fall* prevention.mp	833
6	Exp Falls/	2313
7	1 OR 2 OR 3 OR 4 OR 5 OR 6	17168
8	programme*.mp	38453
9	program*.mp	378656
10	Intervention*.mp	330172
11	Quality improvement.mp	4001
12	Best practice*.mp	13236
13	Multifactorial.mp	3924
14	Collaborative*.mp	35872
15	Community of practice.mp	2074
16	Communities of practice.mp	1791
17	Exp "Communities of practice"/	633
18	Organization and management.mp	18649
19	Organisation and management.mp	1961
20	8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19	681688

21	Nursing home*.mp	11827
22	Residential aged care.mp	357
23	Residential facilities.mp	859
24	Residential facility.mp	623
25	Residential home.mp	205
26	exp Residential care institutions/	38193
27	Skilled nursing facilities.mp	255
28	Long term care.mp	7845
29	Home* for the aged.mp	989
30	21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29	48538
31	7 AND 20 AND 30	344
32	limit 31 to (human English language and yr="1990-current")	317
Cochrane Central Registry of Controlled Trials		Results
1	"Fall*":ti,ab,kw	13502
2	"accidental fall*":ti,ab,kw	1200
3	"Faller*":ti,ab,kw	349
4	Fall* prevention:ti,ab,kw	2936
5	1 OR 2 OR 3 OR 4	13794
6	"program*":ti,ab,kw	73392
7	"Intervention*":ti,ab,kw	147194
8	"Quality improvement" :ti,ab,kw	16915
9	"Best practi?e":ti,ab,kw	2456
10	"Multifactorial":ti,ab,kw	1444
11	"Collaborative":ti,ab,kw	4119
12	"Community of practice":ti,ab,kw	4885
13	"Organi?ation and management":ti,ab,kw	3468
14	6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13	204034

15	“Nursing home”:ti,ab,kw	4116
16	“Residential aged care”:ti,ab,kw	491
17	“MH Residential facilities”:ti,ab,kw	312
18	“Residential home*”:ti,ab,kw	533
19	“Long term care facilities”:ti,ab,kw	451
20	15 OR 16 OR 17 OR 18 OR 19	5140
21	5 AND 14 AND 20	270
22	Limit publication year from 1990 to 2016	271
JBI Database of Systematic Reviews and Implementation Reports		Results
1	Accidental fall*.mp	26
2	Fall.mp	338
3	Falls.mp	348
4	Faller*.mp	39
5	Falling.mp	176
6	Fall* prevention.mp	82
7	1 OR 2 OR 3 OR 4 OR 5 OR 6	630
8	programme*.mp	603
9	program*.mp	2354
10	Intervention*.mp	3949
11	Quality improvement.mp	248
12	Best practice*.mp	3855
13	Multifactorial.mp	132
14	Collaborative*.mp	365
15	Community of practice.mp	20
16	(Organization and management).mp	664
17	(Organisation and management).mp	262
18	8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 16 OR 17	5610

19	Nursing home*.mp	461
20	Residential aged care.mp	255
21	Residential facilit*.mp	49
22	Residential home.mp	8
23	Skilled nursing facilities.mp	18
24	Long term care.mp	358
25	Home* for the aged.mp	42
26	19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25	693
27	7 AND 18 AND 26	213
Note. ab=abstract, kw=keyword, MH=mesh heading, mp=multi-purpose, ti= title		

Results for additional searches:

Current Controlled trials

“Falls prevention” = 40

National Institute of Health Clinical Database

Falls = 2

Falls + prevention = 27

Falls + nursing homes = 7

Universal Index of Doctoral Dissertations in Progress

“Falls” = 2

Mednar

“Prevent falls” = 97

Grey Literature Report (GreyLit.org)

“Falls” AND Prevent* = 51

Google

"Falls prevention in aged care" = 6

"Falls prevention in aged care facilities" = 5

"Falls prevention program residential aged care" = 2

"Nursing home fall prevention program" = 1

Citation mining

Reference lists of relevant articles = 9

Appendix II: Excluded studies

Beasley K. Benefits of implementing an interdisciplinary and multifactorial strategy to falls prevention in a rural, residential aged-care facility. *Int J Evid Based Healthc* 2009; 7(3): 187-92.

Reason for exclusion: Selection bias, sub sample of RAC population, limited measurement data from which the falls rate or injurious falls rate could be calculated.

Bonner A, MacCulloch P, Gardner T, Chase CW. A student-led demonstration project on fall prevention in a long-term care facility. *Geriatr Nurs* 2007; 28(5): 312-8.

Reason for exclusion: Intervention not broadly delivered at multiple levels. Setting does not match inclusion criteria.

Bouwen A, Lepeleire J, Buntinx F. Rate of accidental falls in institutionalised older people with and without cognitive impairment halved as a result of a staff-oriented intervention. *Age Ageing* 2008; 37: 306-10.

Reason for exclusion: Intervention not broadly delivered at multiple levels. Falls outcome was a sub group of falls with medical consequences.

Colon-Emeric CS, McConnell E, Pinheiro SO, Corazzini K, Porter K, Earp KM, Landerman L, Beales J, Lipscomb J, Hancock K, Anderson RA. CONNECT for better fall prevention in nursing homes: results from a pilot intervention study. *J Am Geriatr Soc* 2013; 61: 2150-9.

Reason for exclusion: Intervention not broadly delivered at multiple levels.

Cox H, Puffer S, Morton V, Cooper C, Hodson J, Masud T, Oliver D, Preedy D, Selby P, Stone M, Sutcliffe A, Torgerson D. Educating nursing home staff on fracture prevention: a cluster randomised trial. *Age Ageing* 2008; 37: 167-72.

Reason for exclusion: Intervention not broadly delivered at multiple levels.

Crotty M, Whitehead C, Rowett D, Halbert J, Weller D, Finucane P, Esterman A. An outreach intervention to implement evidence based practice in residential care: a randomized controlled trial [ISRCTN67855475]. *BMC Health Serv Res* 2004; 4: 6.

Reason for exclusion: Intervention not broadly delivered at multiple levels, limited measurement data from which the falls rate or injurious falls rate could be calculated.

Fitzgerald TD, Hadjistavropoulos T, Williams J, Lix L, Zahir S, Alfano D, Scudds R. The impact of fall risk assessment on nurse-led fears, patient falls and functional ability in long term care. *Disabil Rehabil* 2016; 38(11): 1041-52.

Reason for exclusion: Only included residents with a diagnosis of dementia, intervention not broadly delivered at multiple levels.

Gama ZA, Medina-Mirapeix F, Saturno PJ. Ensuring evidence-based practices for falls prevention in a nursing home setting. *J Am Med Dir Assoc* 2011; 12(6): 398-402.

Reason for exclusion: Selection bias, sub sample of population, limited measurement data from which the falls rate or injurious falls rate could be calculated.

Kaleta J. Improving LTC safety to reduce falls injuries. *Canadian Nursing Home* 2009; 20(3): 11-3.

Reason for exclusion: Publication is a magazine. Report only. Not an intervention study.

Lannering C, Ernsth M, Johansson L. Prevention of falls, malnutrition and pressure ulcers among older persons - Nursing staff's experiences of a structured preventative care process. *Health Soc Care Community* 2017; 25(3): 1011-1020.

Reason for exclusion: No quantitative measurement data from which the falls rate or injurious falls rate could be calculated.

Neyens JC, Dijcks BP, Twisk J, Schols JM, Haastregt JC, Heuvel WJ, Witte LP. A multifactorial intervention for the prevention of falls in psychogeriatric nursing home patients, a randomised controlled trial (RCT). *Age Ageing* 2009; 38: 194-9.

Reason for exclusion: The study was conducted on selected psychogeriatric wards within the participating nursing homes and included only residents with psychiatric conditions, the intervention was specifically tailored for the needs of this cohort and was not representative of the broader RAC population.

Rubenstein LZ, Robbins AS, Josephson KR, Schulman BL, Osterweil D. The value of assessing falls in an elderly population. A randomized clinical trial. *Ann Intern Med* 1990; 113(4): 308-16.

Reason for exclusion: Intervention not broadly delivered at multiple levels.

Teresi JA, Ramirez M, Remler D, Ellis J, Boratgis G, Silver S, Lindsey M, Kong J, Eimicke JP, Dichter E. Comparative effectiveness of implementing evidence-based education and best practices in nursing homes: Effects on falls, quality-of-life and societal costs. *Int J Nurs Stud* 2013; 50: 448-63.

Reason for exclusion: Intervention not broadly delivered at multiple levels.

Uymaz PE, Nahcivan NO. Evaluation of a nurse-led fall prevention program in Turkish nursing home residents. *Educ Gerontol* 2016; 42(5): 299-309.

Reason for exclusion: Not a representative RAC sample, excluded residents with selective disabilities and cognitive impairment (MMSE<25).

Walker GM, Armstrong S, Gordon AL, Gladman J, Robertson K, Ward M, Conroy S, Arnold G, Darby J, Frowd N, Williams W, Knowles S, Logan PA. The falls in care home study: A feasibility randomized controlled trial of the use of a risk assessment and decision support tool to prevent falls in care homes. *Clin Rehabil* 2016; 30(10): 972-83.

Reason for exclusion: Population included people under 65 yrs of age, care homes for people with learning disabilities and only people who had already fallen.

Ward JA, Harden M, Gibson RE, Byles JE. A cluster randomised controlled trial to prevent injury due to falls in a residential aged care population. *Med J Aust* 2010; 192(6): 319-22.

Reason for exclusion: Intervention not broadly delivered at multiple levels.

Appendix III: Characteristics of included studies

Criteria	Included studies
	Becker *et al.*[40]
Title	Effectiveness of a multifaceted intervention on falls in nursing home residents
Methods	Prospective cluster randomized controlled trial
Setting	6 nursing homes, Germany
Participants	981 residents >60 yrs, Mean Age yrs (*SD*) 83.5(7.5) intervention group, 84.3(6.9) control group
Intervention	Multifaceted, 12 months. Additional resources provided during intervention (staffing and environmental)
Resident level	Resident education on fall prevention, Exercise (progressive balance and resistance 75 minutes x 2 weekly), Hip protectors. Residents chose any combination of interventions for any selected duration
Facility level	Staff education on fall prevention (60 minutes) and monthly feedback on falls outcomes, environmental modification (76 items audited)
Organizational level	Trained nurses from within participating nursing homes. Telephone hotline to experts.
Control	No specific falls prevention program activities
Falls outcome measures	Falls ✓ fallers ✓ injurious falls ✘ (also measured recurrent fallers and hip fractures only)
Key results	Significant reduction in falls rates (p<.001), residents that fell (p = .038) and residents that fell more than twice (p = .015)
Notes	Included a fall definition.
	Burland *et al.*[6]
Title	The evaluation of a fall management program in a nursing home population
Methods	Quasi-experimental, pre-post, comparison group design
Setting	12 nursing homes, Canada
Participants	5 intervention nursing homes (196 beds) 7 control (200 beds), 1046 residents
Intervention	Fall management program (site level), 3 years
Resident level	Falls risk assessment, restraint minimization, prompted voiding, exercise, nutrition and medication reviews, education
Facility level	Environmental audits, assistive devices, staff education
Organizational level	New tools and processes including: program guide, assessment tools, checklists, educational resources and a post-fall protocol
Control	Usual care (no formal falls management program in place)
Falls outcome measures	Falls ✓ fallers ✘ injurious falls ✓

Criteria	Included studies
Key results	Falls rates trended upwards in the intervention group pre and post measures but did not reach significance, injurious falls remained unchanged and hospitalized falls decreased significantly. Intervention group had significantly less injurious falls in post intervention period (p = .022)
Notes	No site fall definition included but fall data extraction defined by data set codes. Intervention delivered using existing resources
	Colon-Emeric *et al.*[21]
Title	Translating evidence-based falls prevention into clinical practice in nursing facilities: results and lessons learned from a quality improvement collaborative
Methods	Naturalistic quasi-experimental pre/post design
Setting	36 nursing homes, USA
Participants	36 nursing homes with 353 non-participating nursing homes considered as controls
Intervention	“Change package”, 9 months
Resident level	Falls risk assessment, medication review, supplemented vitamin D and calcium, correction of orthostatic hypotension, hip protectors, post fall assessment
Facility level	Staff education, monthly environmental assessment including equipment repair, labeling high risk residents and PT referral.
Organizational level	2 to 3 nursing home staff became QIC members, Tool kit to support change
Control	Usual care (not participating in QIC)
Falls outcome measures	Falls ✓ fallers ✓ injurious falls ✘ (primarily measured changes in clinical practice)
Key results	No significant change in falls rates or proportion of residents who fell. Self-reported falls rates showed a decline from 6.1 to 5.6/1000 resident days (p = .31) but falls rates measured by chart abstraction increased slightly (p = .17). There was no significant association between the proportion of fallers and level of site participation. Compliance with screening, labeling, risk assessment and medication review showed only moderate improvement (evidenced by chart abstraction). Significant increase in vitamin D prescription (p = .03) and decrease in sedative hypnotics prescribed (p = .04). No change in benzodiazepine, neuroleptic or calcium use.
Notes	Participating facilities used a variety of fall definitions but none were reported. Some self report and chart abstraction from MDS, no raw falls data
	Dyer *et al.*[16]
Title	Falls prevention in residential care homes: a randomized controlled trial
Methods	Cluster randomized trial
Setting	20 residential care homes, England
Participants	196 residents, Mean Age yrs (*SD*) 87.4(6.9) intervention group, 87.2(6.9) control group

Criteria	Included studies
Intervention	Multifactorial program for three months, follow up 12 months, additional resources provided during intervention (staffing and environmental)
Resident level	Risk factor and medical assessment, progressive group exercise program 3 x 40 minutes per week for 3 months (83 participants), or individual program for frailer/cognitively impaired residents, medication review
Facility level	Environmental modifications, staff education, referral to optician and podiatrist
Organizational level	✘
Control	No intervention, visit by researcher every 3 weeks to collect data only
Falls outcome measures	Falls ✓ fallers ✓ injurious falls ✘ (also measured recurrent fallers and fractures only)
Key results	Modest reduction in falls rates in intervention group but not statistically significant (p = .27), no significant difference in the proportion of residents who fell (p = .94)
Notes	No fall definition included.
	Hofmann *et al.*[45]
Title	Decreasing the incidence of falls in the nursing home in a cost-conscious environment: a pilot study
Methods	Prospective time-services study
Setting	1 nursing home, USA
Participants	120 residents
Intervention	Combined interventions
Resident level	Restorative activity program (entertainment based), hip protectors, provision and repair of mobility aids, medication review
Facility level	Staff education, environmental modifications, repair of mobility aids
Organizational level	Multidisciplinary falls committee formed. Shift changes to increase staffing at times of high fall occurrence (no additional staff members), OT to provide post fall assessment, Post fall conferences.
Falls outcome measures	Falls ✓ fallers ✘ injurious falls ✓ (measured hip fractures only)
Key results	A significant reduction in number of falls was reported (p<.001) and falls resulting in fracture trended downwards but the difference was not significant. Post intervention falls on evening and night shifts reduced significantly (p<.001)
Notes	No fall definition. Retrospective comparison, information on resident compliance with the intervention was not available
	Jensen *et al.*[41]
Title	Fall and injury prevention in older people living in residential care facilities a cluster randomized trial
Methods	Cluster randomized trial
Setting	9 residential care facilities, Sweden

Criteria	Included studies
Participants	402 residents >65 yrs, Mean Age yrs (range) 83(65-97) intervention group, 84(65-100) control group
Intervention	11 week multidisciplinary program, follow up 34 weeks. Additional resources provided (8 physiotherapy staff employed during intervention (200 hrs/wk) and 3 during follow up period (10 hrs/wk)
Resident level	Individualized exercise program 2-3 x per week, assistive device prescription, medication review, hip protectors
Facility level	Staff falls prevention education, environmental modifications, assistive device repairs
Organizational level	Implementation of falls team meeting and post fall conference
Control	Received usual care only
Falls outcome measures	Falls ✓ fallers ✓ injurious falls ✓ (also measured recurrent fallers)
Key results	Total number of falls and number of residents who fell reported as significantly decreased (no p values were reported)
Notes	Included a fall and injurious fall definition.
	Kerse *et al.*[27]
Title	Fall prevention in residential care: A cluster, randomized, controlled trial
Methods	Cluster randomized controlled trial
Setting	14 residential care homes in New Zealand
Participants	617 residents, Mean Age yrs (*SD*) 83.2(10.6)
Intervention	Falls risk management program, 12 months
Resident level	Falls risk assessment with individualized care plan strategies targeting identified risk factors
Facility level	Reminder logos for risk level and strategy adoption, environmental assessment, referral to relevant health professionals
Organizational level	Falls coordinator appointed, falls risk assessment tool and falls/injury prevention manual implemented
Control	Usual care, monthly visit by researcher to audit fall surveillance
Falls outcome measures	Falls ✓ fallers ✓ injurious falls ✓ (also measured recurrent fallers)
Key results	Falls rates increased significantly in the intervention program homes compared with control group homes and the proportion of residents who fell also increased significantly (p<.018) following adjustment for clustering, baseline fall rate, site dependency level. There was no statistically significant difference in injurious fall rates between the two groups
Notes	Included a fall and injurious fall definition, utilized existing resources to deliver the intervention
	McMurdo *et al.*[42]
Title	A randomized controlled trial of fall prevention strategies in old peoples' homes

Criteria	Included studies
Methods	Cluster randomized controlled trial
Setting	9 nursing homes, UK
Participants	133 residents, Mean Age yrs (*SD*) 84(7)
Intervention	Multifactorial, 12 months follow up
Resident level	Falls risk assessment including medication review and visual acuity test, supervised exercises (not tailored individually): seated balance exercises, strength and flexibility 30 minutes x 2 weekly for 6 months
Facility level	Environmental modification (lighting levels), optometry referral
Organizational level	✘
Control	Received reminiscence therapy (targeting social interaction) twice weekly for six months
Falls outcome measures	Falls ✓ fallers ✓ injurious falls[a] ✓ (also measured recurrent fallers)
Key results	No significant differences in falls rates (p = .165) or proportion of residents who fell (p = .088)
Notes	Included a fall definition, high drop out rate compromised power to detect an effect, excluded residents with higher levels of cognitive impairment (MMSE <12), utilized existing resources
	Nitz *et al.*[15]
Title	Outcomes from the implementation of a site-specific evidence-based falls prevention intervention program in residential aged care
Methods	Prospective cohort study pre/post design
Setting	9 residential aged care facilities, Australia
Participants	670 residents (650 staff)
Intervention	External project team facilitated an action research approach to deliver multifactorial interventions that varied dependent on the needs of the participating facilities, 24 months (included a 6 month pre-intervention phase). Additional resources provided: staffing 0.2FTE and equipment budget funded during intervention
Resident level	Prioritized strategies identified at audit e.g. hip protectors
Facility level	Falls prevention activity audit, low-low beds and other prioritized strategies identified at audit including environmental modification, staff education
Organizational level	A falls resource nurse was trained to lead the project at their site, falls prevention action research group formed and met fortnightly at each site
Falls outcome measures	Falls ✓ fallers ✓ injurious falls ✘ (also measured recurrent fallers)
Key results	Reduction in the proportion of fallers (p = .044) and single fallers (p = .04), no effect on number of falls due to confounding by residents who fell multiple times, variation in positive outcomes from interventions by site

Criteria	Included studies
Notes	Included fall definition.
	Rask *et al.*[28]
Title	Implementation and evaluation of a nursing home fall management program
Methods	Quality improvement project
Setting	19 nursing homes, USA within single organization
Participants	All residents of 19 participating nursing homes (convenience sample), 23 non-intervention nursing homes considered controls
Intervention	Falls management program (quality improvement and culture change) Additional external resources utilized (Advanced practice nurse or expert consult).
Resident level	✘
Facility level	Intensive staff education including problem solving and safety culture training
Organizational level	Advanced practice nurse consultation, falls nurse coordinator and interdisciplinary falls team elected at participating facilities, extensive falls prevention tools (manuals, video, forms and brochures)
Falls outcome measures	Falls ✓ fallers ✘ injurious falls[a] ✓ (primarily measured process of care documentation including restraint use)
Key results	No significant difference in falls rates in intervention homes (p = .59), fall related care process documentation improved significantly and restraint use decreased (p<.001), serious fall injuries only were reported with no significant difference (p = .79)
Notes	Fall and injurious fall defined
	Ray *et al.*[44]
Title	A randomized controlled trial of a consultation service to reduce falls in nursing homes
Methods	Cluster randomized controlled trial
Setting	14 nursing homes, USA
Participants	482 residents, Mean Age 83 yrs
Intervention	External falls consultation service (multidisciplinary assessment) with 12 month follow up. Additional resources (external staff) employed in intervention delivery.
Resident level	Comprehensive individual falls risk assessment including medication review, gait and transfer safety training
Facility level	Environmental modification
Organizational level	Falls coordinator appointed at participating sites
Control	Usual care
Falls outcome measures	Falls ✘ fallers ✘ injurious falls[b] ✓ (also measured recurrent fallers)

Criteria	Included studies
Key results	A non-significant trend towards a reduction in the rate of serious injurious falls (p = .220) was observed between groups
Notes	Included a fall definition, only falls injuries leading to hospital admission, ED or physician visit were included. High falls risk residents who had fallen only were included
	Ray *et al.*[43]
Title	Prevention of fall-related injuries in long-term care randomized
Methods	Cluster randomized controlled trial
Setting	112 aged care facilities, USA
Participants	10,558 residents >65 yrs (not bedridden) mean age 84 yrs
Intervention	Intensive 2 day safety training program with 12 month follow up
Resident level	Medication review, transfers and ambulation
Facility level	Environmental modification, equipment review (wheelchairs and walking aids), staff training
Organizational level	Falls team coordinated by a nurse appointed at participating sites, training resources implemented (manual, video, assessment tools), telephone calls to falls team coordinator (mean of 24 calls per site)
Control	Usual care
Falls outcome measures	Falls ✘ fallers ✘ injurious falls[b] ✓ (also measured recurrent fallers)
Key results	There was a trend towards an increase in serious fall related injuries but the difference was not significant (p = .84)
Notes	Included serious injurious fall definition

Note. QIC = Quality improvement collaborative, MDS = Minimum data set, ✓ = Presence of outcome measurement, X = Absence of outcome measurement

[a] serious fall injuries only were reported, [b] only falls injuries leading to hospital admission, ED or physician visit were included.

Summary of Findings

Author(s): Jacqueline Francis-Coad, Christopher Etherton-Beer, Elissa Burton, Chiara Naseri & Anne-Marie Hill

Date: October 10 2017

Question: What is the effect of complex falls interventions implemented at two or more of the following levels: resident, facility or organization compared to usual care on falls in the residential aged care population

Setting: Residential Aged Care Facilities

Bibliography: Becker *et al.*[40], Dyer *et al.*[16], Jensen *et al.*[41], Kerse *et al.*[27], McMurdo *et al.*[42], Ray et al.[44], Ray et al.[43]

Certainty assessment							№ of patients		Effect		
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Complex falls interventions	Usual care	Absolute (95% CI)	Certainty	Importance
What is the effect of complex falls interventions implemented at two or more of the following levels: resident, facility or organization compared to usual care on falls rates (follow up: range 6 months to 12 months; assessed with: per 1000 occupied bed days; Scale from: -5.07 to 4.94) Bibliography: Becker *et al.*[40], Dyer *et al.*[16], Jensen *et al.*[41], Kerse *et al.*[27], McMurdo *et al.*[42]											
5	randomised trials	serious [a]	serious [b]	not serious	not serious	none	1051	927	MD 1.29 lower (3.01 lower to 0.43 higher)	⨁⨁◯◯ LOW	CRITICAL
What is the effect of complex falls interventions delivered with additional resource support and implemented at two or more of the following levels: resident, facility or organization compared to usual care on falls rates (follow up: range 6 months to 12 months; assessed with: per 1000 occupied bed days; Scale from: -5.07 to -1.65) Bibliography: Becker *et al.*[40], Dyer *et al.*[16], Jensen *et al.*[41]											
3	randomised trials	serious [c]	not serious	not serious	not serious	none	765	555	MD 2.26 lower (3.72 lower to 0.8 lower)	⨁⨁⨁◯ MODERATE	CRITICAL
What is the effect of complex falls interventions implemented at two of the following levels: resident, facility or organization compared to usual care on falls rates (follow up: mean 12 months; assessed with: per 1000 occupied bed days; Scale from: -5.07 to -0.80) Bibliography: Dyer *et al.*[16], McMurdo *et al.*[42]											
2	randomised trials	serious [c]	not serious	not serious	serious [d]	none	136	121	MD 2.2 lower (6.13 lower to 1.73 higher)	⨁⨁◯◯ LOW	CRITICAL
What is the effect of complex falls interventions implemented at three levels: resident, facility and organization compared to usual care on falls rates (follow up: range 6 months to 12 months; assessed with: per 1000 occupied bed days; Scale from: -3.17 to 4.94) Bibliography: Becker *et al.*[40], Jensen *et al.*[41], Kerse *et al.*[27]											
3	randomised trials	serious [c]	serious [e]	not serious	not serious	none	915	806	MD 0.56 lower (4.02 lower to 2.9 higher)	⨁⨁◯◯ LOW	
What is the effect of complex falls interventions implemented at two or more of the following levels: resident, facility or organization compared to usual care on the proportion of residents who fell (follow up: range 6 months to 12 months; assessed with: Number of people who fell) Bibliography: Becker *et al.*[40], Dyer *et al.*[16], Jensen *et al.*[41], Kerse *et al.*[27], McMurdo *et al.*[42]											

Certainty assessment							№ of patients		Effect	Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Complex falls interventions	Usual care	Absolute (95% CI)		
5	randomised trials	serious [a]	serious [b]	not serious	not serious	none	1051/1978 (53.1%)	927/1978 (46.9%)	**67 fewer per 1,000** (from 80 fewer to 198 more)	⨁⨁◯◯ LOW	CRITICAL
What is the effect of complex falls interventions implemented at two or more of the following levels: resident, facility or organization compared to usual care on injurious falls rates (follow up: range 6 months to 12 months; assessed with: per 1000 occupied bed days; Scale from: -0.12 to 1.64) Bibliography: Jensen *et al.*[41], Kerse *et al.*[27]											
2	randomised trials	serious [c]	serious [b]	not serious	not serious	none	406	334	MD 0.57 higher (1.11 lower to 2.25 higher)	⨁⨁◯◯ LOW	CRITICAL
What is the effect of complex falls interventions implemented at two or more of the following levels: resident, facility or organization compared to usual care on serious injurious falls rates (follow up: mean 12 months; assessed with: per 1000 occupied bed days; Scale from: -0.17 to 0.02) Bibliography: Ray *et al.*[44], Ray *et al.*[43]											
2	randomised trials	serious [c]	serious [b]	not serious	not serious	none	5153	5887	MD 0.05 lower (0.24 lower to 0.13 higher)	⨁⨁◯◯ LOW	CRITICAL

CI: Confidence interval; **MD:** Mean difference

Explanations

a. Lack of allocation concealment or blinding. Incomplete accounting of patients or outcome events

b. Heterogeneity may be explained by the differences in characteristics of the population, content and/or duration of the interventions across studies

c. Lack of blinding

d. Small sample < 200 per group

e. No overlap of confidence intervals suggesting variation is more than what one would expect by chance alone

GRADE Working Group grades of evidence High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. Very low quality: We are very uncertain about the estimate.

The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

GRADEpro GDT: GRADEpro Guideline Development Tool [Software]. McMaster University, 2015 (developed by Evidence Prime, Inc.). http://www.gradepro.org. [Accessed 5th October 2017]