An economic evaluation of community and residential aged care falls prevention strategies in NSW

NSW GOVERNMENT | Health

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CHERE is an independent research unit affiliated with the University of Technology, Sydney. It has been established since 1991, and in that time has developed a strong reputation for excellence in research and teaching in health economics and public health and for providing timely and high quality policy advice and support. Its research program is policy-relevant and concerned with issues at the forefront of the sub-discipline.

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Abbreviations and acronyms

ABS	Australian Bureau of Statistics
AIHW	Australian Institute of Health and Welfare
CHERE	Centre for Health Economics Research and Evaluation
ED	Emergency department
FICSIT	Fraility and Injuries: Cooperative Studies and Intervention Techniques
ICER	Incremental cost effectiveness ratio
QALY	Quality adjusted life year
QOL	Quality of life
RAC	Residential aged care
RACF	Residential aged care facility

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Executive summary

Falls are a major cause of harm to older people and fall-related injuries impose a substantial burden on the health and aged care systems. Falls resulting in injury or hospitalisation can lead to a reduction in both length and quality of life. Research has shown that many falls can be prevented. Fall prevention strategies lead to reductions in the number of individuals who fall, which consequently reduces the number of individuals injured or hospitalised due to a fall. The key objective of this project was to evaluate the cost effectiveness of strategies designed to prevent falls among people aged 65 and over living in the community and in residential aged care facilities.

Meta-analysis results of community dwelling interventions

We undertook a systematic review of fall prevention interventions in community dwelling older people. Concurrently a 2009 Cochrane systematic review on the same topic was conducted.[1] Results from both reviews informed our economic evaluation. Interventions that significantly reduced the risk of falling (based on the numbers of falls) were: group exercise, tai chi, home hazard modification, psychotropic medication withdrawal, expedited cataract surgery, cardiac pacing, multiple interventions and multi-factorial interventions. Home exercise was significant in the Cochrane review only.

Table 1: Community dwelling meta-analysis results (CHERE and Cochrane)

Intervention	Indication/group	CHERE rate ratio* (95% CI)	Cochrane rate ratio† (95% CI)
All exercise	Population >65	**0.80 (0.71, 0.90)**	-
Group exercise	-	**0.76 (0.66, 0.87)**	**0.78 (0.71, 0.86)**
>75	-	**0.85 (0.75, 0.96)**	-
<75	-	**0.65 (0.54, 0.79)**	-
Home exercise	-	0.81 (0.58, 1.14)	**0.66 (0.53, 0.82)**
Stepping On Program	-	**0.69 (0.50, 0.96)**	-
Tai chi	Low/medium risk of falling	**0.66 (0.57, 0.77)**	**0.63 (0.52, 0.78)**
Vitamin D and Calcium	Population >65	0.95 (0.85, 1.07)	0.95 (0.80, 1.14)
Education	Population >65	0.85 (0.65, 1.11)	0.33 (0.09, 1.20)
Home hazard assessment	Medium/ high risk of falling	**0.70 (0.56, 0.88)**	0.90 (0.79, 1.03)
Hip protectors	High risk of falling	1.23 (1.12, 1.36)	-
Psychotropic medication withdrawal	Patients currently on psychotropic medication	**0.40 (0.23, 0.70)**	**0.34 (0.16, 0.73)**
Medication review	Taking multiple medications	Not estimable	Not estimable
Expedited cataract surgery	Patients with cataracts currently on waiting list	**0.66 (0.49, 0.90)**	**0.66 (0.45, 0.75)**
Vision and eye exam	Population >65	1.57 (1.39, 1.76)	1.57 (1.19,2.06)
Cardiac pacing	Patients with carotid hypersensitivity	**0.33 (0.28, 0.38)**	**0.42 (0.23, 0.75)**
Multiple interventions	Population >65	0.80 (0.70, 0.90)	-
Exercise and home safety	Population >65	**0.76 (0.65, 0.90)**	-
Exercise and falls advice	Population >65	0.86 (0.71, 1.03)	-
Exercise and supplementation	Population >65	0.57 (0.27, 1.20)	-
Multi-factorial interventions	Population >65	**0.72 (0.62, 0.84)**	**0.75 (0.65, 0.86)**
Assessment and referral	Population >65	**0.81 (0.72, 0.92)**	**0.84 (0.72, 0.98)**
Assessment and active intervention	Population >65	**0.67 (0.52, 0.85)**	**0.70 (0.55, 0.90)**

Sources:* systematic review conducted by CHERE; † Gillespie et al (2009)[1]
Note: Numbers in bold indicate a significant reduction in the number of people that fell; dashes indicate data not available

Meta-analysis results of residential aged care facilities

We undertook a review and meta-analysis of fall prevention interventions in residential aged care facilities. No complete systematic review was available on this topic at the time of writing.

Table 2: Residential aged care meta-analysis results

Intervention	Indication/group	CHERE rate ratio* (95% CI)
Exercise	Population >65y	0.79 (0.56, 1.11)
Tai chi	Population >65y	0.96 (0.79, 1.17)
Vitamin D and Calcium	Population >65y	**0.86 (0.83, 0.90)**
Hip protectors	Medium/high risk of falling	**0.78 (0.73, 0.84)**
Medication review	Population >65y	**0.59 (0.49, 0.70)**
Multiple interventions	Population >65y	**0.52 (0.47, 0.57)**
Multi-factorial interventions	Population >65y	**0.76 (0.59, 0.97)**
Assessment and referral		1.34 (1.06, 1.69)
Assessment and active intervention		**0.68 (0.53, 0.87)**

Source:* systematic review conducted by CHERE
Note: Numbers in bold indicate a significant reduction in the number of people that fell

Cost effectiveness of falls prevention strategies

A reduction in the number of individuals who fall or are injured after a fall, may result in improvements measured in quality adjusted life years (QALYs). QALYs represent the most acceptable outcome for use in an economic evaluation. We adopted this approach as the results of such an analysis (termed a cost-utility analysis) can be compared across interventions and settings.

A decision analytical model was constructed to perform the economic evaluation. The model included five Markov states: 1) low risk (individuals who have never fallen); 2) medium risk (individuals who have previously fallen but incurred no injury); 3) high risk (previously injured faller); 4) residential aged care; and 5) death.

Individuals move between each state by following a multiple event decision tree. The transition probabilities were determined through a literature search of event data. The cycle length of the model was one year.

Table 3 describes the cost effectiveness of community dwelling programs. Only those interventions that had a statistically significant reduction in the fall rate were modelled. The results are based on a cohort of 75 year old community residents over a 10 year period.

Table 3: Cost effectiveness of community dwelling interventions

Intervention	Average		ICER
	Cost ($)	QALY	Cost/QALY ($)
Population >65y			
No intervention (all groups)	4,532	4.628	
Group exercise	5,003	4.634	72,006
Home exercise	5,481	4.638	93,847
Stepping On program*	5,187	4.637	71,104
No intervention (low/med)	4,495	4.638	
Tai chi	4,990	4.649	45,083
No intervention (med/high)	4,913	4.606	
Home hazard assessment*	5,291	4.615	40,073
Multiple interventions*	5,848	4.613	123,814
Multi-factorial – referral	5,679	4.611	152,151
Multi-factorial – active	6,169	4.615	133,083
Population specific			
No intervention	5,153	4.927	
Cataract surgery†	5,188	4.936	3,505
No intervention	4,913	4.606	
Psychotropic medication withdrawal†	5,245	4.626	20,848
No intervention	4,913	4.606	
Cardiac Pacing†	15,560	4.743	77,520

Source: Unless indicated the effectiveness data is taken from Gillespie et al (2009)[1]
Note: ICER = Incremental cost effectiveness ratio; QALY = Quality adjusted life year
*Effectiveness taken from the meta-analysis presented in this report
†Only patient specific populations benefit from this intervention

Table 4 describes the cost effectiveness of residential aged care programs. These results are based on a cohort of 75 year old aged care residents followed for 10 years. Medication review and hip protectors were only assumed to be given to medium and high risk groups whereas vitamin D/calcium, multiple and multi-factorial interventions were given to all risk groups. The baseline for no intervention differs between these different treatment groups.

Table 4: Cost effectiveness of residential aged care interventions

Intervention	Average Cost ($)	Average QALY	ICER
			Cost per QALY ($)
Total population >65y			
No intervention	1,757	1.563	
Vitamin D	1,911	1.584	7,316
Multiple	3,619	1.634	26,300
Multi-factorial	4,234	1.610	52,066
Med/high risk groups			
No intervention	1,942	1.547	
Medication review	1,821	1.612	Dominant
Hip protectors	2,006	1.582	1,838

Note: Dominant = the intervention is less costly and more effective than no intervention; ICER = Incremental cost effectiveness ratio; QALY = Quality adjusted life year

Conclusions

The most cost-effective interventions in community dwelling older people are:

- expedited cataract surgery
- psychotropic medication withdrawal
- tai chi
- group-based exercise

Home hazard assessment, expedited cataract surgery and psychotropic medication withdrawal are both specific to certain patient populations, and consequently are not suitable for every older person in NSW.

The most cost-effective interventions in the residential aged care setting are:

- medication review
- hip protectors
- vitamin D supplementation

Medication review dominates the 'do nothing' alternative (this means it is more effective and less costly than no intervention), in that it is both cost-saving and beneficial in terms of QALYs gained. Hip protectors and vitamin D supplementation are both relatively low cost, which is the main reason they appear cost-effective when considered at a threshold between $50,000 and $60,000 per QALY.

The economic model is sensitive to a number of model inputs, in particular the quality of life decrement associated with fear of falling. The model is also sensitive to the effectiveness and cost of each intervention, however there is more certainty regarding these estimates.

Note that the incremental cost relates to the additional cost of providing the intervention. This includes the actual cost of providing the intervention less the cost of avoided medical treatment due to falls averted. The 'do nothing' option incurs the maximum fall-related treatment costs.

SECTION 1

Introduction

Falls are a major cause of harm to older people and fall-related injuries impose a substantial burden on the health and aged care systems. Research has shown that many falls can be prevented. The key objective of this project was to evaluate the cost effectiveness of strategies designed to prevent falls among people aged 65 and over living in the community and in residential aged care facilities (RACFs). An additional objective was to systematically review the literature on community–dwelling and RACF interventions aimed to reduce the risk of falling, the number of those who fall and fall related injuries.

This cost effectiveness study commenced before the 2009 release of the Cochrane Collaboration's review of interventions for preventing falls in older people living in the community.[1] A Cochrane review of falls prevention interventions for older people living in RACFs was also not available at the time the study was conducted. The economic evaluation task therefore required a systematic review of interventions and a meta-analysis to be undertaken for the two settings. In addition, costs and resource use data were collected.

The meta-analysis pooled the results from a selection of studies for each intervention. Note that pooling the data from studies that use a similar method (such as the administration of Vitamin D and Calcium) allows the estimation of a more precise measure of the effectiveness of the intervention compared with multi-factorial or multiple interventions where each study differs widely in the design of the intervention. The Cochrane Collaboration's review of the efficacy of interventions for falls prevention in community settings was released part way through this research and these results have also been modelled.

A decision analytic model was created to evaluate the costs and outcomes of a range of falls prevention strategies in both settings. Within each setting, the costs and outcomes of each strategy were compared. The relative strengths and weaknesses of each strategy/intervention relative to the others was evaluated and issues such as the impact of the assumptions on the results, the timing of costs and benefits. Where possible a societal and health care perspective was taken into consideration when applying costs in the model.

Background information about falls in older people

A fall is defined as an unexpected event in which the person comes to rest on the ground, floor or lower level.[2] Falls are common among older people with up to one in three people aged 65 years or over falling at least once a year, with many falling more than once.[3] Falls are even more common among residents of RACFs, with up to half of all residents falling at least once a year.[4]

Fall-related injury is a major cause of morbidity and mortality for older people. In Australia in 2003-04 there were over 100,000 fall-related hospitalisations in people aged 65 years and over.[5] In the same year there were at least 1,660 deaths due to falls in those aged 65 years and over.[6] In NSW each year, falls lead to about 30,000 hospitalisations and at least 300 deaths in people aged 65 years and over. Even non-injurious falls can have negative impacts such as loss of confidence and activity restriction, and falls are the most commonly reported adverse event among hospital inpatients.

Falls generate substantial costs for the health care and aged care systems. In Australia in 2003-04, fall-related hospitalisations (n=100,000) represented 4.3 per cent of all hospitalisations among people aged 65 years and older. Due to the long length of stay that can result from fall-related injuries, these hospitalisations represented 10 per cent of all hospital bed days in this age group.[5] Hospital stays and rehabilitation can be long and expensive[7] and having had a recent fall is one of the leading reasons for premature admission to permanent residential aged care (RAC).[8] No other single injury cause, including road trauma, costs the heath system more than injuries resulting from falls.[9]

The burden from fall-related harm among older people is likely to increase unless action is taken. Projections indicate that without preventive action, and assuming that individuals continue to fall and be injured at the current rate, the costs to the health system from injurious falls are likely to escalate due to the expected future increase in the number of older people in NSW. In 2004, it was estimated that the Australian direct medical costs were $500 million per annum and the total cost to Australian society was $1- $2 billion per year.[10] In NSW alone, the total cost of falls for people aged 65 and over was estimated at $334.4 million in the financial year of 1998/99[11] and current research indicates this figure is expected to have at least doubled within 10 years. It is projected that by 2056, between 23 and 25 per cent of the Australian population will be 65 years or older. During the same period, the proportion of those aged 85 years and older is expected to increase to between 5 and 7 per cent compared to 1.6 per cent in 2007. In NSW, it is projected that the group aged 85 and older will increase eightfold over 2002 numbers.[12]

Risk factors for falls among older people

Among older people, falls are more common with advancing age, with substantially higher rates in those aged over 85 as compared to those aged 65. One of the strongest predictors of future falls is past falls.

Risk factors for falls can be considered intrinsic (relating to a person's health status and behaviour) or extrinsic (factors external to the person, such as the environment). 'Intrinsic' risk factors for falls among older people include gait and balance deficits, impaired vision, impaired peripheral sensation, use of certain medications such as psychotropic medications, and less common disorders causing syncope such as neurocardiogenic syncope and carotid sinus syndrome.[13] Older people with cognitive impairment are also often at higher risk of falls. There are multiple potential underlying causes for each of these health states, for example gait and balance can be impaired due to musculoskeletal problems (eg arthritis), peripheral neuropathy (eg caused by diabetes), neurological disorders such as Parkinson's disease and impairments caused by previous stroke. Transient states such as acute illness can also increase the risk of falling, particularly in frail older people.

'Extrinsic' risk factors may include home hazards, hazards in the external environment, poor footwear, and inappropriate glasses (eg multi-focal glasses when walking). However extrinsic factors often only cause increased falls risk in combination with frailty and other intrinsic risk factors.[14] Among older people there may often be multiple and interacting factors increasing the risk of falling.

Note that a person's health status in older age is likely to have been influenced by past events and lifestyles choices. For example exposure to risk factors for the development of chronic disease, can in turn cause the problems pre-disposing the older person to falls. Broader social and cultural factors influence a person's health experience across their lifetime.[15]

Falls prevention interventions

Interventions for community dwelling older people

A systematic review of randomised controlled trials assessing interventions for preventing falls in community dwelling older people[1] identified the following as effective interventions:

- certain exercise programs:
  - home exercise program including balance retraining and muscle strengthening such as the Otago exercise program,[16] individually prescribed by a trained health professional
  - certain forms of Tai chi group exercise
  - group exercise programs that include balance retraining and muscle strengthening, with sufficient frequency and intensity (as described below)
- multi-factorial interventions, which include assessment of falls risk factors followed by individualised intervention/s, usually involving a multi-disciplinary team
- home hazard assessment and modification that is professionally prescribed (such as by an occupational therapist) among older people at high risk of falls or with severe visual impairment
- gradual withdrawal of psychotropic medication
- a prescribing modification program for general practitioners
- pacemakers for those with carotid sinus hypersensitivity
- expedited cataract surgery

The NSW Ministry of Health also commissioned the development of recommendations for physical activity to prevent falls in older people,[17] based on a recent meta-analysis of exercise interventions for falls prevention.[18] The recommendations are (Sherrington et al, 2008:4):[17]

- "Exercise which has a focus on balance training has the greatest effect on falls
- Programs of at least 2 hours exercise per week for 6 months or more are more effective in preventing falls than lower dose programs
- Walking or strength training programs as single interventions do not appear to prevent falls
- More active people experience fewer falls but there is no evidence that we can prevent falls simply by encouraging older people to be more active
- Falls can be prevented by a range of exercise programs which target balance and provide ongoing exercise – these include the Otago Exercise Program of home-based balance and strength training, group-based tai-chi and other group-based balance and strengthening exercise programs
- Programs should be designed according to the needs of the target population to ensure they provide exercise that is challenging yet safe"

A Cochrane systematic review of population-based interventions for preventing falls in older people is also available.[19] The authors characterise population-based interventions as programs that "share ownership of the injury problem with the whole community, experts and community members" and where "joint responsibility is taken for determining priorities and appropriate interventions are widely promoted" (McClure et al, 2005:2).[19] The programs evaluated for this review were diverse in approach. The six evaluation studies included in the review showed reductions in fall-related injuries in intervention communities. The methodological limitations of the study designs used needs to be considered in interpreting the result, and contextual factors may influence generalisability of the findings.

Interventions in residential aged care facilities

A Cochrane library systematic review of interventions for preventing falls in older people identified only one type of intervention as effective in RACF, specifically multidisciplinary, multi-factorial, risk factor screening and intervention programs.[20] These programs provide interventions tailored to each person's risk factors, but often include exercise, review of medications, and provision of vitamin D supplementation, and may also include changes to organisational practices. Such programs may require sufficient time to become established before benefits become visible, for example six months was required before significant reductions in falls were achieved in one successful trial.[21]

Vitamin D supplementation has been shown in some studies to reduce falls[22] and fractures[23] in older people in RAC. There is debate as to whether calcium supplementation should also accompany vitamin D supplementation.

Table 5 describes the falls prevention interventions that were included in this report.

Table 5: Falls prevention interventions

Single Interventions	
Exercise	Exercise interventions improve bone/muscle strength, balance, flexibility and aerobic capacity. Examples include home and group exercise programs, brisk walking, resistance training and strength and balance exercises.
Tai chi	Tai chi is a Chinese martial art that can improve strength, balance and flexibility. It is based on slow flowing movements and shifts of balance. The forms emphasise weight shifting, postural alignment, coordinated movements and synchronised breathing.
Vitamin D and Calcium	Vitamin D is essential for the absorption of calcium in the body and needed for bone growth and bone remodelling. These supplements increase the bone mineral density in the body and increase muscle strength. Interventions use either a combination of Vitamin D and Calcium or each supplement alone.
Hip protectors	Hip protectors are a specially designed undergarment containing pads that cover and protect the hip area in the case of a fall. They are designed to absorb energy and reduce the impact of falls with the overall aim to mitigate the incidence of hip fractures.
Home hazard assessment and modification	Home hazard assessment and modification involves a home visit to the patient (for example by an occupational therapist), an assessment to identify hazards, and recommendation/s to reduce risk of falling and modification of the home. These recommendations would be in relation to safety issues such as electrical cords, floor mats and footwear and modifications such as hand rails and bathroom modifications, stair railings and ramps for example.
Clinical medication review	A patient using multiple medications can increase the risk of adverse drug reactions and inadvertently, the risk of falling. The review is performed by a pharmacist and the recommended treatment adjustments are provided to the patient's GP.
Psychotropic medication withdrawal	Psychotropic drugs can cause sedation, impaired balance and postural hypotension. The four main psychotropic medications are antidepressants, antipsychotics, benzodiazepines and sedatives-hypnotics. The intervention involves reducing the active ingredient/s gradually over a specified period of time.
Vision and eye exams	Poor vision is an established risk factor for falls. Participants in this intervention are assessed by an optometrist and adjustments in prescriptions are given to improve visual acuity.
Expedited cataract surgery	Cataracts are a common cause of poor vision in older people. The routine waiting period for this surgery is 12 months. The intervention reduces the wait for surgery to one month from referral.
Cardiac pacing	Cardiac pacing is used in patients with carotid sinus hypersensitivity (CSH) as this sensitivity can cause large changes in heart rate and/or blood pressure which can lead to syncope (fainting or passing out) causing falls and fall-related injuries. Cardiac pacing involves the use of an artificial pacemaker to regulate the heartbeat.
Falls risk screening and falls risk assessment	Falls risk screening is a process that identifies risk factors for falling usually by the use of a tool. The risk factors may include previous history of a fall, the use of four or more medications, mental status (confusion, disorientation, agitation), vision (glasses, blurred, cataracts, glaucoma, macular degeneration), mobility (independent, needs assistance), ability to transfer (with or without assistance). From this, a falls risk score 'low-high' can be allocated (in some tools). The assessment is intended to provide guidance about the range of falls interventions that could be implemented.
Falls prevention education	Education programs involve educating the elderly concerning the severity of falls and educating individuals about exercise, home hazards, footwear, safety etc. Educating the older population about falls prevention can either be provided via a comprehensive program conducted over time or a minimal information session/information booklet.
Multiple interventions	
A multiple intervention is a fixed set of intervention components delivered to participants. Examples include: a combination of an exercise component with Vitamin D supplementation or psychotropic medication withdrawal; or an exercise component combined with psychotropic medication withdrawal and home hazard assessment and modification.	
Multi-factorial interventions	
Multi-factorial interventions offer each individual a tailored intervention, that is, a tailored suite of intervention components. Intervention components are selected from an established set, and matched to participants following the assessment of a range of risk factors affecting participants on an individual basis. Examples of intervention components are: education and training; exercise programs; safe footwear and clothing recommendations; home hazards assessment and modification; vision or medication adjustments; and recommendations for behavioural change or home-based physical therapy.	

SECTION 2

Review of the literature

A systematic review of the relevant literature was undertaken. Articles were retrieved if they met the inclusion criteria outlined below. Two reviewers independently applied the inclusion criteria and any differences were resolved by discussion. The bibliographies of all retrieved publications were hand-searched for any relevant references missed in the database search (pearling).

Search strategy

Searches were conducted in a number of electronic databases to identify the relevant studies. These databases included PubMed (Medline and PreMedline), EMBASE, the Cochrane Library, the Centre for Reviews and Dissemination (CRD) databases [Database of Abstracts of Reviews of Effects (DARE), National Health Service Economic Evaluation Database (NHS EED), Health Technology Assessment database] and Web of Science.

All searches were conducted from 1990 onwards. Results were limited to those studies published in English, in humans and in study populations with a mean age greater than 65.

A comprehensive search string was executed in both PubMed and EMBASE databases, with search terms limited to the title and/or abstract:

(elderly OR aged OR 'older adult') AND fall* AND (prevention OR intervention OR strategy OR program* OR service* OR system* OR care OR management OR guideline* OR 'tai chi' OR 'occupational therapy' OR OT OR physiotherapy OR balance OR strength* OR exercise OR movement OR 'home hazard*' OR 'home modification*' OR psychotropic OR medication* OR screening OR 'risk assessment' OR 'cardiac pacing' OR 'cataract surgery' OR 'hip protector*' OR supplements OR calcium OR 'vitamin D' OR cost OR costs OR effect* OR consequence* OR outcome* OR benefit* OR resource* OR hospitalisation OR hospitalization OR economic* OR burden OR risk* OR morbidity OR mortality OR prevalence OR incidence OR epidemiology OR evaluation OR QALYs OR 'quality adjusted life years' OR QOL OR 'quality of life' OR 'health related quality of life' OR HRQL OR HRQOL OR 'life years gained' OR 'life years saved' OR LYG OR LYS OR measurement* OR measuring OR scale*) AND (community OR residential OR nursing OR facility OR facilities OR hospital*) AND (Australia OR 'New Zealand' OR 'North America' OR 'United States' OR US OR Canada OR Europe [MeSH])

Appendix A provides the complete search string.

Simpler search strings were constructed for the remaining databases (Cochrane, CRD etc) due to the fewer number of results generated. Country search terms were removed in these databases and searches were generally limited to title only (with the exception of the Cochrane database which was title, abstract or keywords). The same time limits and English language requirements were applied. Appendix B details the total search results for each database.

Study inclusion and exclusion criteria

The inclusion and exclusion criteria were determined through discussion with the advisory panel. Table 6 details the inclusion and exclusion criteria used. Additional papers were identified by hand-searching the reference lists of those studies meeting the inclusion criteria.

Types of studies

The studies included in this review were each assigned a 'level of evidence'. These are set levels, developed by the National Health and Medical Research Council which: (1) indicate the study design used by the investigators to assess intervention effectiveness; and (2) reflect the degree to which bias has been eliminated by the study design. The levels of evidence and their appropriate study design are summarised in Table 7.

Table 6: Selection criteria

Inclusion criteria	Exclusion criteria
Population mean age ≥65	Non relevant population (mean age <65)
Community dwelling or residential aged care facility residents (private homes, retirement villages, hostels, nursing homes, etc) including those attending accident and emergency, outpatient clinics and hospital rehabilitation wards	Hospital inpatient population
Relevant final outcome measures (falls and fallers); new fractures in subpopulations with a prior history of fractures	Irrelevant intermediate outcome measures (fear of falling, falls self-efficacy, fall risk, balance, strength, mobility, etc)
Australia, New Zealand, Canada, United States, United Kingdom, Scandinavia, Japan, Taiwan, Korea and developed European countries	Irrelevant and developing countries
Systematic reviews of randomised controlled trials (RCTs), single RCTs, and pseudo-RCTs (Level I, II, III-1 evidence, see Table 7)	Comparative studies, with and without concurrent control groups, and case series studies (Level III-2, III-3 and IV evidence, see Appendix D); population-based studies, pilot studies and method studies
English full text papers	Papers published in non English language without an English abstract
Study data collected after 1990	Study data collected prior to 1990
	Number of trial participants <20

Table 7: Designation of levels of evidence

Level of evidence	Study design
I	Systematic review of level II RCTs
II	RCT
III-1	Pseudo-RCT (ie alternate allocation or some other method)
III-2	Comparative study with concurrent controls: ▪ non randomised, experimental trial ▪ cohort study ▪ case-control study ▪ Interrupted time series with a control group
III-3	Comparative study without concurrent controls: ▪ historical control study ▪ two or more single arm study ▪ interrupted time series without a parallel control group
IV	Case series with either post-test or pre-test/post-test outcomes

Types of participants

Studies were included if the mean age of participants was greater than or equal to 65, and if the population group was either community dwelling (private homes, retirement villages) or RAC residents (hostels, nursing homes). Community dwelling populations were also included if the study recruitment was conducted in emergency department (ED) outpatients clinics and hospital rehabilitation wards. Studies conducted with hospital inpatient populations were excluded. Only studies with a sample size of 20 participants were included in the analysis.

Types of interventions

Studies were included if the comparator was placebo, usual care, or another control. Studies comparing multiple interventions were also included. Studies included were based on either single, multiple or multi-factorial interventions. Single interventions usually address one risk factor. Multiple interventions address two or more risk factors on an untargeted (group) basis. Multi-factorial interventions address two or more risk factors on a targeted (individual) basis. Those given single or multiple interventions receive the same intervention as the entire group, whereas each individual in a multi-factorial intervention receive a tailored intervention or a combination of possible interventions based on each individual's risk factors.

Types of outcome measures

Studies were included if the number of fallers or falls were reported. Other outcomes included the number of fallers injured or number of falls resulting in injury and the number of fallers/falls requiring medical attention or hospitalisation. Those studies only reporting fear of falling, fall risk, balance, strength, mobility etc. were excluded from the analysis. However data extracted from these studies were used to populate the economic model.

Data extraction

Data were extracted by one researcher and checked by a second using standardised data extraction tables developed a priori. Data were only recorded if clearly indentified in the text, tables, graphs or figures of the article, or if they could be accurately extrapolated from the data presented. If no data were reported for a particular outcome then no value was tabulated. Descriptive statistics were extracted or calculated for all effectiveness outcomes in the individual studies, this included numerator and denominator information.

Meta-analysis

Overall, 131 studies matched the inclusion criteria. Details of each included study by population, study design, intervention and outcome measures can be found in Appendix C. Studies excluded from the analysis and the reasons for their exclusion can be found in Appendix D.

Data from each study were extracted to obtain a pooled measure of effectiveness for each intervention. The analysis was based on an 'intention to treat' principle, following the rule that "once randomised, always analysed" (Petitti, 1994:82).[24] Data were entered into Excel and transformed into the required input for statistical analysis. The pooled statistical analysis was conducted using Review Manager 5 (RevMan), a meta-analysis software available through the Cochrane Collaboration.

Statistical methods

Number of fallers

Data for the following outcome measures were analysed dichotomously using the RevMan default Mantel-Haenszel method: number of fallers; number of fallers with injury; number of hospitalised fallers; and number of fallers requiring medical attention. The number of fallers and the total number of participants (taking into account intention to treat) were entered into RevMan to obtain the pooled relative risk ratio, the 95 per cent confidence interval (95%CI) and any tests for heterogeneity. If necessary a random effects method was applied.

Number of falls

Dichotomous data (fall/no fall) were not reported in some studies. Any study reporting only the total number of falls was treated as rate data, where an event may occur more than once in a given period, for example the number of falls in 12 months. We calculated the rate ratio (RR), which is the ratio of the rate in the intervention group to the rate in the control group as described in the Cochrane handbook.[25] This is calculated as:

$$= \frac{\dfrac{(\#falls)}{(\text{\#of participants} - \text{follow up months}/12)_{\text{intervention}}}}{\dfrac{(\#falls)}{(\text{\#of participants} - \text{follow up months}/12)_{\text{control}}}}$$

When the number of months of follow up is the same for both the intervention and control arms of the studies, the time unit becomes irrelevant as it is cancelled out of the rate ratio equation. The natural log of each rate ratio and the standard error were then calculated in Excel and these values were then entered into RevMan using the generic inverse variance method.

Standard error is calculated as:

$$\left(\frac{1}{\#falls_{intervention}} + \frac{1}{\#falls_{control}}\right)^{1/2}$$

If statistical heterogeneity was present a random effects method was applied. The pooled rate ratio, with 95% CI, was estimated for each intervention.

Heterogeneity

When pooling data from multiple studies, inherently heterogeneity will exist between studies, especially with interventions where intensity, duration and frequency can vary. Evidence of heterogeneity was assessed using the chi^2 test with a p-value greater than 0.10 for statistical significance and the I^2 statistic. A low p value (or inversely a large chi^2 statistic relative to its degree of freedom) provides evidence of heterogeneity. The chi^2 statistic measures the amount of variation among studies and tests that this would be more than just chance. The I^2 statistic explains the proportion of variability explained by heterogeneity instead of chance.

If the I^2 statistic is between 30 and 60 per cent, this may represent moderate heterogeneity, between 50 and 90 per cent may represent substantial heterogeneity and greater than 75 per cent may represent considerable heterogeneity is present. If the I^2 statistic was greater than 50 per cent a random effects model was used for the results. In a random effects model, the standard error is based on sampling variation between the studies as well as within the study, as opposed to a fixed effect which only measures the sampling variation within the study.

Although a random effects model will widen the confidence intervals and allow for a better statistical fit of the data, it does not explain where the heterogeneity arises between the studies. One solution is to use subgroup analysis which was done if enough data were available. For example, given the large number of studies within the exercise group, it was possible to pool those studies on a group or home basis as well as the mean group age of participants.

The Cochrane meta-analysis

During this project, a meta-analysis conducted by the Cochrane Collaboration, titled *Interventions for preventing falls in older people living in the community* (Gillespie et al, 2009) was released.[1] The results of the Cochrane review were compared with the results of the meta-analysis obtained in this report in terms of both qualitative and quantitative differences. In general, there was strong agreement between the results of both meta-analyses. The main differences were due to slightly different inclusion/exclusion criteria and in some cases the interpretation of intention-to-treat. An analysis of the differences between the Cochrane and our meta-analysis is included in Appendix E. Given that the results of the meta-analyses were similar, and the Cochrane review was published, the effectiveness estimates used in the economic evaluation were derived from the Cochrane review. However in some cases, such as multiple interventions, the Cochrane review did not attempt an analysis, therefore the results of the meta-analysis conducted in this project were used.

The data used in the economic analysis for RACF were taken entirely from the results of the CHERE meta-analysis presented in this report. A Cochrane meta-analysis for interventions aimed at preventing falls in RACF and hospitals was not available at the time of writing but was due for release in late 2010.

Community dwelling meta-analysis results

This section describes the results of the meta-analysis for community dwelling fall prevention strategies and the Cochrane review. Table 8 summarises the results for single interventions and Table 9 for multiple and multi-factorial interventions. Appendix F provides the complete list of forest plots for community dwelling interventions. Interventions that significantly reduced the risk of falling (based on the numbers of falls) were: home exercise (Cochrane), group exercise, tai chi, home hazard modification, psychotropic medication withdrawal, expedited cataract surgery, cardiac pacing, multiple interventions and multi-factorial interventions (shown in bold). Note that home exercise was significant in the Cochrane review but was insignificant in this meta-analysis because of the exclusion of the study by Ebrahim et al (1997).[26] It was included in the CHERE review as the mean age of study participants was greater than 65 whereas the Cochrane review excluded because of age range.

Within the multiple intervention category, interventions that comprised of exercise and a form of supplementation appeared to be more effective. However, with overlapping confidence intervals for the education, exercise and safety interventions, this finding is uncertain. Within the multi-factorial category, interventions that included a risk assessment and an active component appeared to be more effective at reducing falls compared to those with just an assessment and referral, but again there are overlapping confidence intervals.

Table 8: Results of community dwelling meta-analysis: single interventions

Intervention	CHERE rate ratio* (95% CI)	Cochrane rate ratio† (95% CI)
All exercise	**0.80 (0.71, 0.90)**	-
Group exercise	**0.76 (0.66, 0.87)**	**0.78 (0.71, 0.86)**
>75y	**0.85 (0.75, 0.96)**	-
<75y	**0.65 (0.54, 0.79)**	-
Home exercise‡	0.81 (0.58, 1.14)	**0.66 (0.53, 0.82)**
Stepping On program	**0.69 (0.50, 0.96)**	-
Tai chi	**0.66 (0.57, 0.77)**	**0.63 (0.52, 0.78)**
Vitamin D and Calcium	0.95 (0.85, 1.07)	0.95 (0.80, 1.14)
Education	0.85 (0.65, 1.11)	-
Home hazard assessment	**0.70 (0.56, 0.88)**	0.90 (0.79, 1.03)
Hip protectors	1.23 (1.12, 1.36)	-
Psychotropic medication withdrawal	**0.40 (0.23, 0.70)**	**0.34 (0.16, 0.73)**
Medication review‡	Not estimable	Not estimable
Expedited cataract surgery	**0.66 (0.49, 0.90)**	**0.66 (0.45, 0.75)**
Vision and eye exam	1.57 (1.39, 1.76)	-
Cardiac pacing	**0.33 (0.28, 0.38)**	**0.42 (0.23, 0.75)**

Sources: * systematic review conducted by CHERE; † Gillespie et al (2009)[1]
Note: Numbers in bold indicate a significantly reduced risk of falling; dashes indicate data not available
‡The rate ratio was not estimable as studies in this category did not report number of falls, only number of fallers.

Table 9: Results of community dwelling meta-analysis: multiple and multi-factorial interventions

Intervention	CHERE rate ratio* (95% CI)	Cochrane rate ratio† (95% CI)
Multiple interventions	**0.80 (0.70, 0.90)**	-
Exercise and home safety	**0.76 (0.65, 0.90)**	-
Exercise and falls advice	0.86 (0.71, 1.03)	-
Exercise and supplementation	0.57 (0.27, 1.20)	-
Multi-factorial interventions	**0.72 (0.62, 0.84)**	**0.75 (0.65, 0.86)**
Assessment and referral	**0.81 (0.72, 0.92)**	**0.84 (0.72, 0.98)**
Assessment and active intervention	**0.67 (0.52, 0.85)**	**0.70 (0.55, 0.90)**

Sources:* systematic review conducted by CHERE; † Gillespie et al (2009)[1]
Note: Numbers in bold indicate a significantly reduced risk of falling; dashes indicate data not available

Exercise interventions

Thirty-two studies examined the effectiveness of community dwelling exercise programs to prevent falls. When all studies were pooled the likelihood of falling for all exercise interventions was significantly lower when compared to no intervention (RR=0.80; 95%CI 0.71, 0.90).

The large number of publications meant that the studies could be categorised according to location of exercise program (home or group based), the age of the study population (greater than or less than 75) and the type of exercise program. Each sub-group was analysed separately to allow for the heterogeneity in the different types of exercise programs.

All studies were separated into two age groups (mean age less than 75 and mean age greater than 75) to identify whether the age of the participants affected the success of exercise programs. The likelihood of falling was significantly lower in both age groups when compared to control. The likelihood of falling was 0.85 (95%CI 0.75, 0.96) in the study populations with a mean age of less than 75, and 0.65 (95%CI 0.54, 0.79) for those greater than 75 when compared to control.

The location of the exercise programs were categorised as being group-based programs or individual-based programs conducted in a person's home. The results from the meta-analysis indicated that the incidence of falls is significantly lower only for group based exercises compared to the control [group-based RR= 0.76 (95% CI 0.66, 0.87) and home-based RR= 0.81 (95%CI 0.58, 1.14)].

Exercise studies were categorised according to the emphasis of the program, such as those that specifically target balance, strength, or flexibility. Additionally exercise programs that emphasised walking as a means of preventing falls were also grouped together. In all categories, there was a statistically significant lower incidence of falls in the intervention group when compared to control: balance RR= 0.75 (95%CI 0.67, 0.84); strength RR= 0.74 (95%CI 0.64, 0.85); flexibility RR= 0.68 (95%CI 0.59, 0.79); and walking RR= 0.76 (95%CI 0.65, 0.87). These groups were not considered as mutually exclusive and consequently some studies may have been included in more than one group.

Tai chi

Four studies examined tai chi community dwelling exercise programs to prevent falls. One study used both the FICSIT (Fraility and Injuries: Cooperative Studies and Intervention Techniques) and ATLANTA definitions to define falls and measure the incidence of falls in the study populations.[27] The meta-analysis took this into account by using each of the two sets of results in two separate meta-analyses. Both analyses found a significantly lower risk of falling in the intervention when compared to control which included stretching exercises or no intervention. In the analyses that incorporated the FICSIT and ATLANTA data the likelihood of falling in the intervention group were 0.66 (95%CI 0.57, 0.77) and 0.67 (95%CI 0.57, 0.79) respectively, when compared to control.

Vitamin D and calcium

Fourteen studies examined the effect of vitamin D and/or calcium to prevent falls. Overall there was no benefit, in terms of reduction in falls, based on ten studies (RR=0.95; 95%CI 0.85, 1.07). The results were further analysed to compare vitamin D only to placebo (RR= 0.87; 95%CI 0.75, 1.02) and vitamin D and calcium with placebo (RR=1.13; 95%CI 0.95, 1.35) however both were insignificant. This result was expected since the aim of vitamin D and calcium interventions is to prevent fall-related injuries rather than prevent falls.

Falls prevention education

Four studies examined the impact of education on falls. Overall falls prevention education was found to have an insignificant impact on the incidence of falls when compared to control (RR = 0.85; 95%CI 0.65, 1.11).

Home hazard assessment

Seven studies examined the effect of home hazard assessments on the rate of falls. Overall, the likelihood of falling was lower in the intervention groups than in the control groups (RR= 0.70; 95%CI 0.56, 0.88).

Hip protectors

Three studies examined the use of hip protectors in the community. However, only one study was included in the analysis.[28] In this study the incidence of falls was greater for the intervention group than the control group (RR= 1.23; 95%CI 1.12, 1.36).

Psychotropic medication withdrawal

One study examined the effect of psychotropic medication withdrawal on the number of falls experienced by study participants.[16] There was a significantly lower likelihood of falling in the intervention group when compared to the control (RR=0.40; 95%CI 0.23, 0.70).

Clinical medication review

All of the studies included in the clinical medication review only had data on the number of fallers and not the number of falls. The resulting risk ratio for the number of fallers was insignificant RR=0.98 (95%CI 0.84, 1.15).

Vision and eye exams

One study compared comprehensive vision and eye examinations to a control group of usual care.[29] The study found a higher incidence of falls in the intervention group (RR=1.57; 95%CI 1.39, 1.76).

Expedited cataract surgery

Two studies examined the use of expedited cataract surgery (within one month) compared to routine surgery (12 months). The first study[30] examined the use of cataract surgery in the first eye, while the second study[31] examined the use of cataract surgery in the second eye. About half of the study population from the first study was also used in the second study. When each study was considered separately, the likelihood of falling was significantly lower when the first eye was expedited (RR= 0.66; 95%CI 0.45, 0.95). However this benefit was not maintained when the second eye was expedited (RR=0.68; 95%CI 0.39, 1.17). The pooling of the results from both studies found a significantly lower likelihood of falling after expedited cataract surgery when compared to the control of routine surgery (RR=0.66; 95%CI 0.49, 0.90).

Cardiac pacing

One study examined whether use of a cardiac pacemaker in older people with carotid sinus hypersensitivity would affect the incidence of falls. The study found a significantly lower likelihood of falls in the intervention group compared to the control group (RR=0.33; 95%CI 0.28, 0.38).

Multiple interventions

Nine studies examined a combination of two or more of the single-component interventions that have been reported above. The pooled analysis of all studies found a lower likelihood of falls in the intervention groups compared to the control (RR=0.79; 95%CI 0.70, 0.89). The studies were separated into two groups according to interventions used: 1) exercise plus education and safety (RR=0.84; 95%CI 0.73, 0.96); and 2) exercise and nutritional supplementation (RR=0.66; 95%CI 0.52, 0.85). Both types of multiple interventions had a significant effect on the incidence of falls.

Multi-factorial interventions

The combined effect of multi-factorial interventions over control was 0.72 (95%CI 0.62, 0.83). The studies were separated into two groups according to the specific components of the multiple intervention programs. Studies that comprised falls screening, assessment and referral had a significantly lower likelihood of falls when compared to the control group (RR=0.81; 95%CI 0.72, 0.92). Likewise, those that were based on active participation also had a significant reduction (RR=0.67; 95%CI 0.52, 0.85).

Residential aged care meta-analysis results

This section describes the results of the meta-analysis for RACF fall prevention strategies. Table 10 summarises the findings and Appendix G provides the complete Forest plots. Interventions that significantly reduced the risk of falling were: vitamin D, hip protectors, medication review, multiple interventions and multi-factorial interventions.

Table 10: Results of residential aged care meta-analysis

Interventions	CHERE rate ratio* (95% CI)
Exercise	0.79 (0.56, 1.11)
Tai chi	0.96 (0.79, 1.17)
Vitamin D and Calcium	**0.86 (0.83, 0.90)**
Hip protectors	**0.78 (0.73, 0.84)**
Medication review	**0.59 (0.49, 0.70)**
Multiple interventions	**0.52 (0.47, 0.57)**
Multi-factorial interventions	**0.76 (0.59, 0.97)**
Assessment and referral	1.34 (1.06, 1.69)
Assessment and active intervention	**0.68 (0.53, 0.87)**

Source:* systematic review conducted by CHERE
Note: Numbers in bold indicate a significantly reduced risk of falling

Exercise

Eight studies examined exercise programs compared to a control of usual care. The likelihood of having a fall in the intervention group was lower than in the control group, but this result was insignificant (RR=0.79; 95%CI 0.56, 1.11).

Tai chi

One study compared tai chi to usual care, however the intervention was insignificant at reducing falls (RR=0.96; 95%CI 0.79, 1.17).[32]

Vitamin D and calcium

Four studies examined the effect of vitamin D to prevent falls. Three studies compared a Vitamin D regimen to placebo. One study[33] compared a regimen of Vitamin D plus calcium to a control group of calcium alone. The likelihood of falling in the intervention group was significantly lower when compared to the control group (RR= 0.86; 95%CI 0.83, 0.90). This result is mostly driven by the Law et al (2006)[34] study with 3,717 participants. The mode of administration for this study was ergocalciferol 2.5mg which is equivalent to a dose of 1,100 IU of Vitamin D.

Hip protectors

Three studies examined the use of hip protectors in RAC. The number of falls were reduced with the use of hip protectors, denoted by a significant rate ratio of 0.78 (95%CI 0.73, 0.84).

Clinical medication review

Three studies were identified, but only one study contained information pertaining to the number of falls.[35] The result from this study showed a reduction in the number of falls after a medication review (RR= 0.59; 95%CI 0.49, 0.70).

Multiple interventions

Three studies were identified. The pooled results showed a significant reduction in the number of falls favouring the multiple interventions (RR=0.59; 95%CI 0.49, 0.70).

Multi-factorial interventions

The overall pooled result for all multi-factorial interventions in RACF was a rate ratio favouring the intervention (0.76; 95%CI 0.59, 0.97). With regards to assessment and referral, only one study contained falls information. In this study the rate ratio favoured the control group (1.34; 95%CI 1.06, 1.69). Those studies which included an assessment and active component had a pooled rate ratio of 0.68 (95%CI 0.53, 0.87).

Economic modelling of falls prevention

Introduction to economic evaluation

Economic evaluation of new health care technologies or interventions is important when determining whether the new initiative offers additional benefits and at what cost, that is, its relative value for money. Economic evaluations are able to determine whether the new initiative is dominated by (or dominates) the existing approach, such that the costs are higher (lower) and the effectiveness is less (greater). Economic evaluation is particularly important where the new initiative offers health benefits at additional costs. Within a constrained health care budget, determining the additional cost that would be paid for a given health gain is important when ascertaining whether such incremental costs represent value for money.

The usual approach to economic evaluation is first to determine the incremental effectiveness, which is measured as the additional benefits associated with the new intervention relative to current practice (eg does the falls prevention intervention lead to a reduction in falls?). Second, to determine the incremental costs, that is the difference in costs between the new initiative and the comparator. Finally, the incremental cost effectiveness ratio (ICER) can be calculated using the ratio:

$$ICER = \frac{Cost_{New} - Cost_{Comparator}}{Effectiveness_{New} - Effectiveness_{Comparator}}$$

It is preferable for an economic evaluation to take the form of a cost-utility analysis to allow comparison of effectiveness across interventions (eg falls prevention strategies with obesity prevention strategies or cardiac surgery) and/or across settings (community or hospital). A cost-utility analysis generates an ICER as described above, using a generic outcome measure, defined as one which can be utilised in different areas of healthcare. The most common generic outcome measure is the quality-adjusted life year (QALY). This is a measure of effectiveness which combines morbidity and mortality dimensions into one composite measure of outcome. The use of cost-utility analysis, while preferable to disease-specific outcome measures, is reliant on appropriate published data. This includes generic quality of life (QOL) measures, such as the SF-6D or the EQ-5D. While these are the gold standard for economic evaluations, outcomes such as life years gained are also widely used as they provide an output which can be compared across different interventions and avoid the difficulties in estimating and applying utility weights.

Decision analytical modelling

The key purpose of economic evaluation is to inform decision-makers about the consequences and efficient allocation of health care resources. Economic evaluation focuses on the expected cost and effects, and uncertainty in those values. Relying upon a single source of information, such as a randomised clinical trial, is often impossible or undesirable because of data limitations. For this reason economic evaluation usually draws upon a range of data sources. For example the clinical effectiveness may be obtained from a randomised clinical trial, but other clinical outcomes, costs and health-related QOL may be derived from other sources, such as surveys or cohort studies. Decision analytical models provide a method of bringing this evidence together.

Decision analytic modelling provides a framework for decision making under conditions of uncertainty. Economic models are simplifications of reality and it is impossible for a model to include all possible ramifications of a particular option being considered. The purpose is to provide a structure that is consistent with the key features of the economic evaluation, such as the perspective, time horizon and measure of outcome.

Most decision models adopt an ‘average patient’ approach, by exploiting the fact that similar patients within a population share the same characteristics. These models are referred to as cohort models. More advanced designs that focus on variability between patients are referred to as micro simulation models. The two most common forms of cohort models are the decision tree and the Markov model.

The decision tree

The decision tree is probably the most common model used in health care evaluation. It provides a schematic representation showing a series of pathways, or possible prognoses that represent the experience of a typical patient during and after an intervention. The decision tree consists of decision nodes, chance nodes and branch probabilities. Decision nodes, usually positioned at the start of a tree, indicate a decision point between alternative options. Chance nodes show a point where two or more alternatives for a patient are possible. Branch probabilities attached to a chance node represent the likelihood of an event occurring.

A key concept in decision analysis that is fundamental to identifying the preferred alternative is the expected value. Each intervention along the pathway of the tree has an expected cost and benefit associated with it. These represent the sum of the costs (and benefits) of each event a patient experiences in that pathway. Expected values are based on the summation of the pathway values weighted by the pathway probabilities.

There are two main limitations of decision trees. First, time is not explicitly defined within the tree. Therefore those elements of an economic evaluation that are time dependant are difficult to implement and would require additional branches. Second, and related to the first limitation, decision trees can become complex (or bushy) when they are used to model complicated long-term prognoses. This is particularly true of chronic conditions, where the patient is at risk of multiple events for many years. In this case the tree would contain numerous mutually exclusive pathways that would be difficult to compute and analyse.

The Markov model

The limitations of the decision tree are the main motivation for using a Markov model. Markov models are commonly used where: 1) the time at which costs and outcomes are accrued is important and 2) there is a multiplicity of possible consequences. Such models are commonly used in the evaluation of screening tests and diagnostic technologies. Markov models are based on a series of mutually exclusive disease states that a patient can occupy at any point in time. Instead of disease progression being modelled by movement along a large number of possible pathways, as in a decision tree, a more complex prognosis can be produced as a set of possible transitions between these disease states. Time elapses explicitly in a Markov model, and is represented by a patient occupying a given disease state for a discrete time period (or cycle). The length of each cycle depends upon the disease and intervention under investigation, but is often a month or a year. The speed at which a patient moves between states in the model is determined by a set of transition probabilities. Costs and outcomes are incorporated into these models as a mean value per state per cycle. Expected values are calculated by adding the costs and outcomes across states and weighting these according to the time the patient is expected to be in each state.

Although a Markov model provides greater flexibility than a decision tree, it is also limited in terms of accurately reflecting complex prognoses. The Markov assumption, or 'memoryless' feature of Markov models, means that the probability of a given transition in the model is independent of the nature or timing of earlier events. In other words, the model cannot remember where a patient came from and treats all patients within a given state as homogenous. With no memory, it is difficult to build history into the model; this is important in diseases where future events are dependent upon past events. Fortunately these issues can be negated by adding 'memory' states, albeit by adding another level of complexity, to the model.

Limitations of economic modelling

All models are only as good as the evidence that underpins them. Inevitably, individual patients will differ in terms of events, outcomes and costs. Uncertainty around the precision of each parameter input (eg probability of an event, a mean cost or a mean utility) is inherent due to the fact that input parameters are estimated for populations on the basis of limited available information. Whilst parameter uncertainty can be reduced by acquiring additional evidence, variability in individual patient outcomes cannot. However, heterogeneity, or intra-patient variability that may be explained by one or more patient characteristics, can be accounted for by estimating input parameters conditional on a patient's characteristics, that is, by performing subgroup analysis. *Methods for the Economic Evaluation of Health Care Programmes* provides a detailed discussion of decision analytical modelling.[36]

Falls prevention model

The falls prevention interventions assessed in this economic evaluation are:

- no intervention – maintenance of the status quo, which would see the continuation of current practice in falls prevention
- each intervention discussed in section 1 given to a group of 75 years olds to determine the effects over their remaining lifetime.

The rationale for the cost effectiveness analysis was that falls prevention interventions lead to reductions in the number of individuals who fall and this consequently leads to reductions in the number of individuals injured or hospitalised due to a fall. Falls resulting in injury or hospitalisation can lead to a reduction in both length of life and QOL. In reducing the number of individuals who fall or are injured after a fall, it may be possible to observe an improvement in the QALYs for those who avoid a fall.

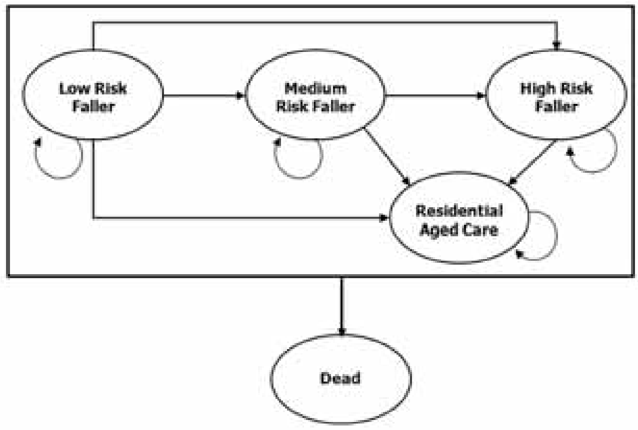
The additional cost of each intervention indicates that any health benefits will be gained at additional cost. However, the costs of some interventions may be offset by a reduction in health care costs due to fewer injuries, less serious injuries and/or reduction in hospitalisations. If the number of injuries avoided is large, falls prevention may be cost saving to society.

The meta-analysis results indicated interventions that are effective at reducing falls in the community setting include: exercise, tai chi, home hazard assessment, psychotropic medication withdrawal, expedited cataract surgery, cardiac pacing, multiple and multi-factorial interventions. Interventions in RAC that are effective at reducing falls include: vitamin D, hip protectors, medication review, multiple and multi-factorial interventions. Only interventions that have a statistically significant reduction in the number of falls compared to control were modelled in the decision analytic model.

Markov model for falls prevention

The Markov model contains five states: 1) low risk (individuals who have never fallen); 2) medium risk (individuals who have previously fallen but incurred no injury); 3) high risk (previously injured faller); 4) RAC; and 5) death (Figure 1).

Figure 1: Markov model: community dwelling



The cycle length for the model is one year, therefore an individual can only transition to another state once a year. These transitions are denoted by the arrows and each transition has a probability or (risk) of moving from one state to another. The box surrounding the four states indicates that the transition to death can occur from any of the other four states. The model assumes that there are five outcomes for individuals with no previous falls (starting at low risk):

- do not fall (remain in low risk)
- fall and do not suffer injuries or suffer minor injuries (transition to medium risk)
- fall and are hospitalised due to injuries (transition to high risk)
- fall and are admitted to or transition to RAC from other causes (transition to RAC)
- fall and die or die from 'all causes' death (transition to death).

Once a person has fallen they are unable to return to being a low risk faller and either continue to fall (which increases their risk of falling) or remain in medium or high risk states.

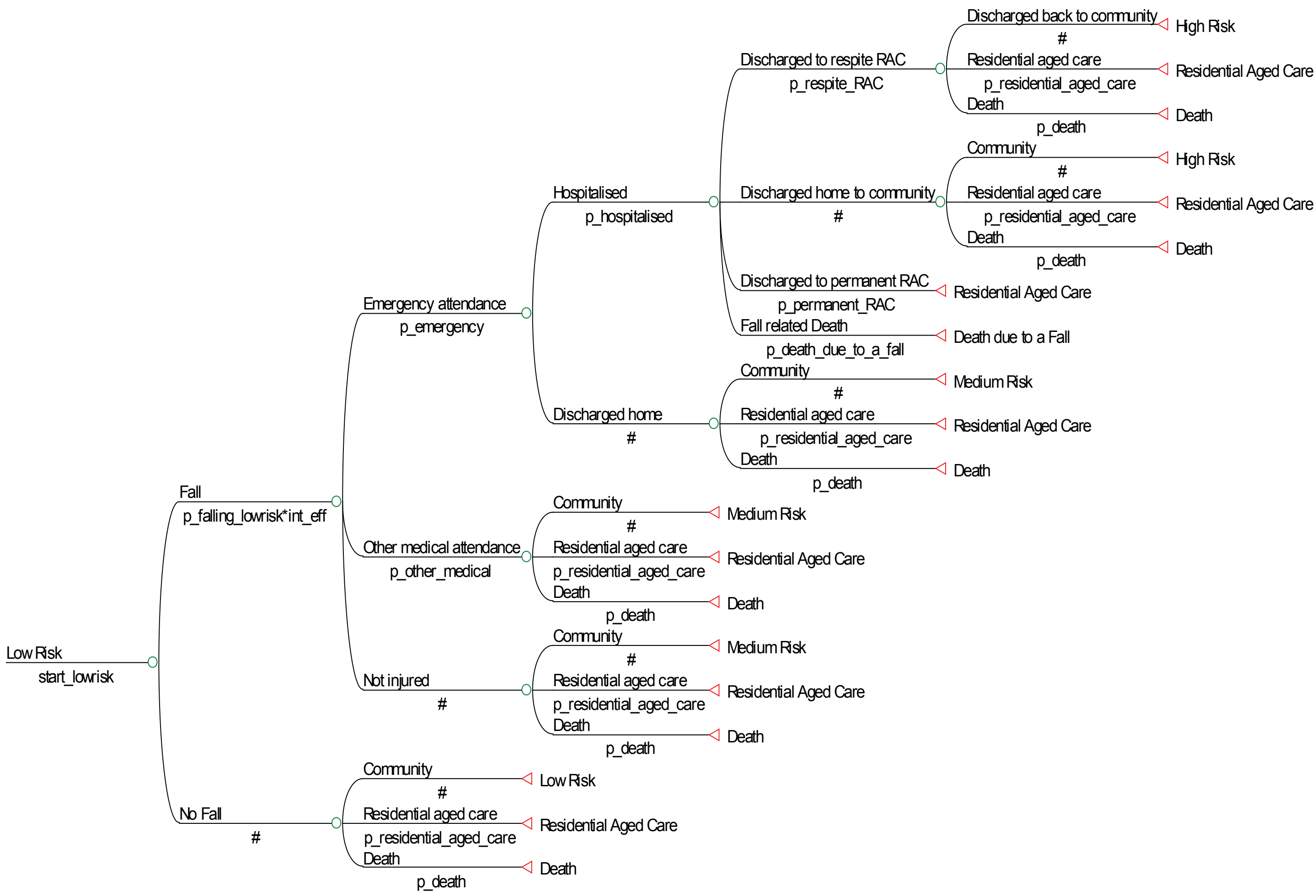
The Markov model for those living in RAC is similar to that for the community setting. The only difference is the omission of the RAC state, since all individuals are now in this state. Those in RAC will transition from low risk to medium or high risk based on their probability of falling once in RAC.

Markov model analysis

A Markov model was built using TreeAge Pro Suite 2009. A decision tree was embedded between each Markov state (Figure 2). Within the decision tree the probability of transitioning to another state depended on the occurrence of various events, such as presenting at the ED and being admitted to hospital. The end of each possible outcome is associated with one of the Markov states. States such as Death and RAC are called absorbing states. Once the individual enters this state they are unable to exit. In the example of death, no further costs or benefits are accumulated, whereas in RAC state, they either transition to death or stay in long term care and incur a cost, as well as the disutility associated with long term care.

The decision tree illustrates the possible decision options available to an individual in the low risk group. The outcomes for a low risk faller are to: remain a low risk faller; transition to being a medium or high risk faller; enter into RAC or death. At each decision node, the probability of going down one branch versus another is dependent upon age as well as the risk of falling.

Figure 2: Decision tree: community dwelling



Assumptions made in the model:

- Individuals who fall (fallers) have a fall rate multiplier applied to each fall because some people fall multiple times in one year.
- The death rate by age is applied at each chance node to represent death from all causes. Death due to falls is also included.
- Once an individual enters RAC they can remain in this state or transition to death (exit from the community).
- Those who fall and are uninjured are assumed to incur no costs.
- Those who fall and do not go to the ED incur the cost of seeking other medical attention.
- The utility loss due to fear of falling is applied to the medium and high risk fallers at the beginning of each stage. The disutility associated with fear of falling is applied for one year only.
- Once an individual enters into RAC, this is a terminal state. This is based on the fact that only 4.1 per cent of permanent aged-care residents return to the community.[37]
- A discount rate of five per cent is applied to both costs and benefits, which is tested in the sensitivity analysis.
- The perspective of the cost analysis is limited to the costs incurred by the health care system due to falls as well as RAC costs that are fall related.

The assumptions for the RAC model are the same as the community model, except for those who attend the ED and are later discharged back to RAC as a high risk faller (Figure 3). In the RAC model, there is one less state so fallers transition through the different risk states or die.

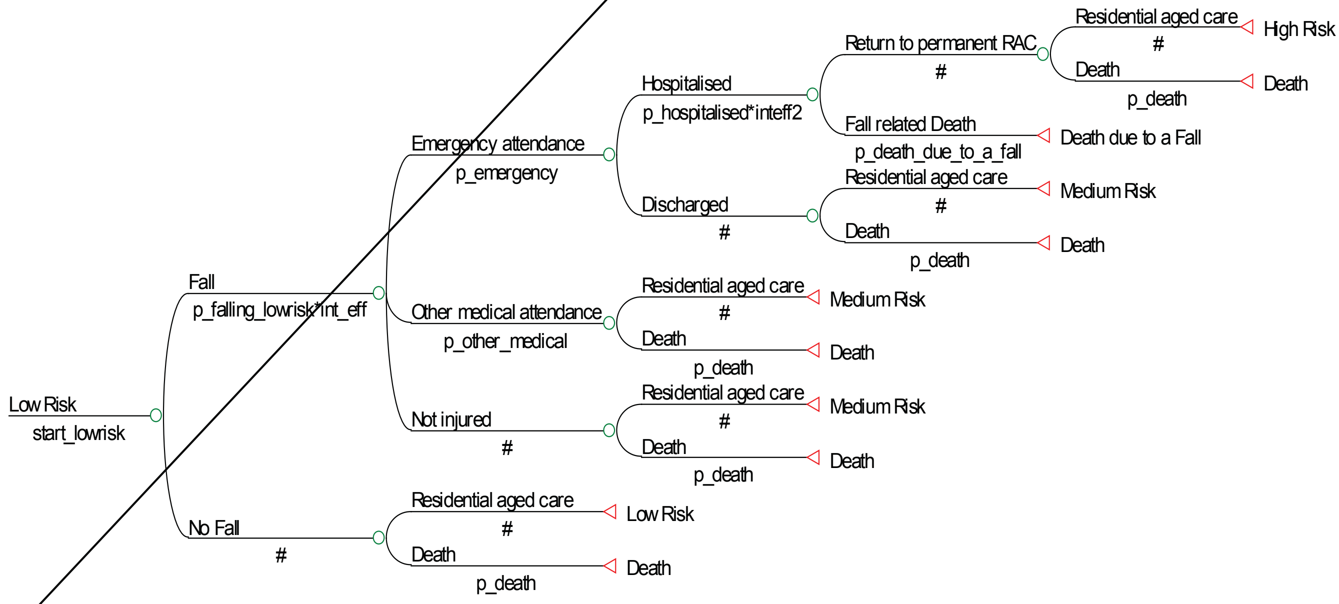
Table 11 provides an overview of the possible transitions from each state.

Table 11: Risk state transitions in the model

Risk state	Description of individual	Possible Transitions
Low risk	Has not previously fallen	Medium risk High risk Residential aged care* Death due to a fall Death
Medium risk	Has previously fallen but did not suffer a serious injury	Medium risk High risk Residential aged care* Death due to a fall Death
High risk	Has previously fallen and suffered a serious injury that required hospitalisation	High risk Residential aged care* Death due to a fall Death
Residential aged care	Entered into residential aged care due to a fall or natural transition	Residential aged care* Death
Death due to a fall	Died due to a fall	Absorbing state
Death	Died from all causes†	Absorbing state

* community model only
†All cause death is calculated directly from the ABS lifetables, therefore this value contains a small number of fall-related deaths. However since the proportion is small it does not impact the economic model

Figure 3: Decision tree: residential aged care



Model inputs

The data used in the model were obtained from different sources, including: published literature on falls prevention; expert opinions; the ABS; the AIHW; and NSW Government released reports, specifically Watson et al (2010).[38] In the absence of suitable data, assumptions were made and tested in the sensitivity analysis.

Starting points

The initial distribution in year zero between low, medium and high risk groups in the model were derived from Lord et al (1993)[39] (Table 12). The proportion of each age group who had never fallen was assumed for the low risk fallers. The percentage of high risk fallers was calculated using the hospitalisation rate for community dwelling older people who have fallen, from the Watson et al (2010) report.[38] This is based on the assumption that individuals in the high risk group have previously been admitted to hospital due to a fall and are still living in the community. The medium risk fallers are then considered to be the remainder, as this group is considered to be those who have previously fallen but were not seriously injured.

Table 12: Initial starting points for community dwelling by age groups (%)

Age group	Low risk*	Medium risk*	High risk†
65-69	74.0	25.2	0.8
70-74	67.5	31.3	1.2
75-79	60.0	37.9	2.1
80-84	56.5	39.8	3.7
85-89	52.0	41.8	6.2
90-94	44.4	45.3	10.4
95+	40.7	45.7	13.6

Sources: *based on Lord et al (1993)[39]; †based on Watson et al (2010)[38]

For RAC, the initial distribution was not adjusted for age. The following proportions were used for the initial distribution: low risk 49.5 per cent (based on Delbaere et al, 2008);[40] medium risk 39.5 per cent (based on Rubenstein et al, 1994);[41] and the remainder were high risk (11 per cent).

Target risk groups

Some interventions only target particular risk groups. For instance, tai chi is only suitable for low and medium risk groups, whereas home hazard assessment is only suitable for those who had a history of falling and therefore would only be applicable to the medium and high risk groups. Table 13 shows the assumptions regarding which risk groups would be targeted for particular interventions, based on expert opinion (personal communication with Professor Stephen Lord, October 28, 2009).

Table 13: Target risk groups by interventions

Intervention	Community	Residential
Exercise	All	All
Tai chi	Low/med risk	All
Vitamin D and Calcium	All	All
Home hazard assessment	Med/high risk	-
Hip protectors	Med/high risk	Med/high risk
Clinical medication review	Med/high risk	Med/high risk
Psychotropic medication withdrawal*	Med/high risk	-
Expedited cataract surgery*	All	-
Vision and eye exam	All	-
Cardiac pacing*	Med/high risk	-
Falls prevention education	All	All
Multiple	Med/high risk	All
Multi-factorial	Med/high risk	All

Source: personal communication with Professor Stephen Lord, October 28, 2009
Note: Dashes indicate intervention is not available in RACF
*Does not include entire community/residential population; only benefit certain patient populations

Risk of falling

The probability of falling for those living in the community in the medium risk cohort was based on expert opinion, (personal communication with Professor Stephen Lord, May 26, 2009) (Table 14). The probability of falling in the low and high risk groups were extrapolated from the estimates of the medium risk group. They were adjusted to take into account that the absolute risk of being a faller if you fell in the past year was 71 per cent, compared to 32 per cent if you had no falls in the past year.

The probability of falling in RAC was based on 50 per cent falling per year (Table 15). The probably of falling was adjusted for age and risk group as described for the community setting.

Table 14: Probability of falling: community dwelling

Age group	Low risk	Medium risk*	High risk
65-69	0.18	0.25	0.39
70-74	0.18	0.25	0.39
75-79	0.23	0.35	0.50
80-84	0.26	0.40	0.57
85+	0.31	0.50	0.68

Source: personal correspondence with Professor Stephen Lord, May 26, 2009.
*Based on estimate that the absolute risk of being a faller if you fell in the past year was 71% and 32% if you had not fallen in the past year.

Table 15: Probability of falling: residential aged care

Age group	Low risk	Medium risk	High risk
65-69	0.26	0.36	0.57
70-74	0.26	0.36	0.57
75-79	0.32	0.50*	0.72
80-84	0.37	0.57	0.82
85+	0.44	0.71	0.97

Source: *Norton and Butler (1997).[4] All other probabilities derived from proportional risk in community dwelling probability of falling.

Transition probabilities

The probabilities of injury and all possible outcomes once an individual has fallen in the model were taken from the report by Watson et al (2010)[38] (Tables 16 and 17). The probability of having an ED attendance is the estimated number of falls requiring an ED attendance divided by the number of falls by each age group. The same calculation is used to derive those cases that used other medical services. The probability of being admitted to hospital was calculated as the number of fall admissions out of the total number of ED attendances. Note that the number of fall related admissions that were later discharged to permanent RACF, respite care or resulting in death were taken out of the total number of hospital admissions.

Table 16: Transition probabilities: community dwelling

Age group	Emergency attendance	Other medical	Admitted to hospital	Death due to fall*	Discharge to RACF	Discharge to respite
65-69	0.05	0.14	0.45	0.008	0.007	0.004
70-74	0.05	0.14	0.54	0.013	0.015	0.010
75-79	0.07	0.16	0.61	0.022	0.027	0.020
80-84	0.11	0.16	0.70	0.033	0.051	0.028
85-89	0.11	0.24	0.74	0.051	0.081	0.032
90-94	0.16	0.19	0.74	0.067	0.104	0.041
95+	0.13	0.37	0.69	0.111	0.119	0.041

Source: Derived from Watson et al (2010)[38]
*Personal correspondence with Dr. Wendy Watson, July 6, 2010
Note: RACF = residential aged care facility

Table 17: Transition probabilities: residential aged care

Age group	Emergency attendance	Other medical	Admitted to hospital	Death due to a fall*
65-69	0.04	0.44	0.57	0.008
70-74	0.06	0.43	0.47	0.013
75-79	0.10	0.38	0.47	0.022
80-84	0.13	0.35	0.45	0.033
85-89	0.17	0.3	0.46	0.051
90-94	0.19	0.29	0.45	0.067
95+	0.26	0.33	0.41	0.111

Source: Derived from Watson et al (2010)[38]
* Personal correspondence with Dr. Wendy Watson, July 6, 2010

Health care costs

Only direct health care costs were considered in the economic evaluation. All costs were taken from the report by Watson et al (2010)[38] (Tables 18 and 19). The costs included in the model are the average health care costs for a fall-related incident for individuals aged 65 and older, divided into five year age groups. The severity of injuries is not modelled specifically, however all different outcomes resulting from a fall are averaged in the final inputs used in the model. All costs are applied on a per fall basis in the cycle in which they occur. The only exception is those admitted to a RACF because of a fall, this cost is only incurred once and is calculated as the total lifetime of a fall-related RACF admission. Note that the figures for those discharged to permanent RACF are based on the average length of stay in RAC. In the model this cost is applied on a per faller basis as opposed to a per fall basis, therefore they only acquire this cost once (as discussed in the section *Decision analytical modelling).*

Table 18: Estimated average annual health care costs: community dwelling ($)

Age group	Hospital ED attendances discharged home (all costs)	Admitted to hospital (Ambulance/ ED & inpatient costs)*	Discharged to permanent RACF (RACF costs only)†	Discharged to respite RACF (RACF costs only)†	Discharged home after admission (all post-hospital costs)†	Other medical attendances (all costs)
65-69	2,074	9,057	272,296	3,947	1,821	318
70-74	3,210	12,031	235,906	3,814	1,805	396
75-79	3,496	11,875	183,595	3,812	1,228	476
80-84	3,282	13,233	146,990	3,793	1,627	523
85-89	3,487	13,694	114,177	3,793	2,089	554
90-94	4,495	14,231	83,078	3,768	1,701	477
95+	4,455	14,599	62,658	3,817	1,822	314

Source: Watson et al (2010)[38]
Note: ED = Emergency Department; RACF = residential aged care facility
*Costs do not include RACF, respite or post-hospital costs as in Watson (2010)[38]
† Personal correspondence with Dr. Wendy Watson, July 6, 2010

Table 19: Estimated average annual health care costs: residential aged care ($)

Age group	Hospital ED attendances (all costs)	Admitted to hospital (Ambulance/ED & inpatient costs)	Other medical attendances (all costs)
65-69	4,463	13,431	162
70-74	4,150	13,977	176
75-79	2,033	11,567	135
80-84	1,908	11,002	163
85-89	1,901	11,223	236
90-94	1,867	10,909	248
95+	1,756	10,549	250

Source: Watson et al (2010)[38]
Note: ED = Emergency Department

Intervention costs

Most of the intervention costs were estimated from a recent paper entitled *Modelling the impact, costs and benefits of falls prevention measures to support policy-makers and program planners*[42] (Tables 20 and 21). This report modelled some of the interventions presented here, therefore some of the costs that were estimated in this paper were deemed appropriate for use in our model. All other costs were based on data from the literature and the Department of Veteran Affairs, if available. In the case of Vitamin D and Hip protectors, the costs were based on yearly supply of the intervention. A further breakdown of each of the costs can be found in Appendix H: Cost estimates.

Table 20: Costs of interventions for community dwellers

Intervention	Cost ($)*
Home exercise	1,091
Group exercise	563
Tai chi	648
Stepping On program	785
Home hazard assessment	502
Psychotropic medication withdrawal	604
Cardiac pacing	13,526
Expedited cataract surgery	2,050
Multiple interventions	1,034
Multi-factorial – assessment & referral	832
Multi-factorial – assessment & active	1,380

Note: *See Appendix H for full explanation of costs

Table 21: Costs of interventions in residential aged care

Intervention	Cost ($)*
Vitamin D	138
Hip protectors	166
Medication review	228
Multiple interventions	775
Multi-factorial – assessment & active	1,023

Note: *See Appendix H for full explanation of costs

Utility data

Utility weights were used to quantify the gains in QOL by avoiding a fall, to estimate the benefit derived from the different falls prevention interventions (Table 22). The model assumes individuals in the low risk group (never fallen) have a utility value associated with full health, adjusted for age. This is based on the UK Population Norms for the EQ-5D.[43]

Table 22: Utility values of low risk fallers

Age group	Utility
65-69	0.806
70-74	0.747
75-79	0.731
80-85	0.699
85+	0.676

Source: Brazier et al (2002)[43]

The population QOL measures were multiplied by a fracture multiplier, which reflects a loss of QOL associated with either a hip, wrist or vertebral fracture (Table 23). It was assumed that a hospitalised fall would be considered either a hip fracture or vertebral fracture. Going to ED only would be a wrist fracture, given that wrist and proximal humerus were the same value. These values were then averaged over the age groups to determine the QOL decrement.

For hospitalised fallers, these averages were weighted by the likelihood of either a hip (94%) or vertebral fracture (6%), taken from Peel et al (2002).[44] In the first year the QOL decrement for a hospitalised faller was calculated as -0.144. Based on estimates for subsequent years, the utility decrement for subsequent years was calculated as -0.072.[45] This QOL decrement in subsequent years was included in the model to high risk fallers. The utility decrement for a wrist fracture was calculated as -0.014. It is assumed that the utility decrement for an ED visit only occurs in the year of the ED visit with no decrement in subsequent years. There are no studies to suggest that a wrist fracture would have any effect on QOL in the long term.[43, 46]

Table 23: Quality of life multipliers for associated fractures

Fracture	First year*	Subsequent years†
Hip fracture	0.797	0.9
Vertebral fracture	0.909	0.93
Wrist fracture	0.981	1
Proximal humerus	0.981	1

Sources:*Brazier et al (2002)[43]; †Strom et al (2006)[45]

As an individual moves throughout the model and falls, becomes injured or goes to RAC, a QALY decrement is accrued in that Markov cycle. In a population-based study of hospitalised fall-related injuries in people older than 65, 89 per cent (1,566) of fall-related injury admissions had a fracture.[44] It was therefore assumed that a decrement for being in a fracture state would be incurred once someone was admitted to hospital for a fall-related injury.

The following utility decrements were used in the model:

- -0.06 (CI 0.03-0.94) for RAC[47]
- -0.014 for ED attendance (assumed those who discharged from ED suffered a small loss in QOL, equivalent to a wrist fracture)
- -0.144 for fracture state (assumed those hospitalised suffered a fracture, either vertebral or hip)
- -0.072 for a previous fracture (assumed those previously hospitalised incurred a QOL decrement for years after the fracture).

Fear of falling

The advisory panel decided to include fear of falling in the model. Fear of falling can lead to depression and mobility restrictions[48] and reduced activities of daily living[49] leading to reductions in QOL. The results from a recent paper suggest that the main burden to an individual's QOL is due to the fear of falling rather than falls or fractures due to falls.[50] Based on these data an average fear of falling was added to the model.

An average fear of falling decrement was calculated to be 0.045 (CI 0.03 to 0.06). Three studies estimated 'fear of falls'. These studies categorised fear of falling into six distinct groups: none of the time; a little of the time; some of the time; a good bit of the time; most of the time; and all of the time. The average fear of falling decrement was based on the weighted proportion in each of six categories over the three studies. The same method was applied to calculate the upper and lower confidence intervals. This result is comparable with other studies. Salkeld et al (2000)[51] used a time trade off study to estimate the QOL related to fear of falling and hip fracture. The mean utility given to someone with a fear of falling for ages 75-84 was 0.7 (compared with 0.731 with no fear of falling) and the mean utility for someone 85+ was 0.62 (compared with 0.676 with no fear of falling). Therefore the fear of falling decrement used in the model was 0.045 with the 95%CI tested in the sensitivity analysis.

Effectiveness data

The effectiveness of each intervention was based on the pooled rate ratio obtained from the meta-analysis and the Cochrane review.[1] Only interventions with a significant reduction in the relative risk of falling were included in the model.

Death rates

Death rates were calculated from ABS life tables and an estimated probability of dying due to 'all causes' at each age was included in the model (Table 24). The probability of dying due to a fall was modelled separately and the incidence was based on data from the Injury Risk Management Research Centre, NSW. The death rates for RAC were calculated from a paper using Australian mortality data.[52]

Table 24: Probability of death

Age	Probability of death	Age	Probability of death	Age	Probability of death	Age	Probability of death
65	0.009	75	0.026	85	0.082	95	0.222
66	0.010	76	0.029	86	0.092	96	0.238
67	0.011	77	0.032	87	0.102	97	0.253
68	0.012	78	0.036	88	0.115	98	0.269
69	0.014	79	0.041	89	0.128	99	0.285
70	0.015	80	0.046	90	0.144	100	0.301
71	0.017	81	0.052	91	0.160		
72	0.018	82	0.058	92	0.176		
73	0.020	83	0.065	93	0.192		
74	0.023	84	0.073	94	0.207		

Source: ABS Life Tables Australia 2006-2007[53]

Admission to residential aged care and respite care

The probability of being admitted to RAC from 'all causes' was based on a study by Wang et al (2001)[54] (Table 25). Based on Australian data, the study reported six year cumulative crude incidence rates for nursing home placement. These six year probabilities were then transformed into a one year rate using the formula: $tp_1 = 1 - (1 - tp_t)^{1/t}$ where tp_1 is the yearly transition probability we wish to estimate and tp_t is the overall probability over time period t.[55]

Table 25: Six year cumulative crude incidence rates for nursing home placement

Age group	Six year cumulative incidence rate	One year probability
65-69	0.024 (1.2, 3.7)	0.004
70-74	0.039 (2.2, 5.6)	0.007
75-79	0.090 (6.1, 11.8)	0.016
80-84	0.183 (13.1, 23.5)	0.033
85+	0.349 (26.6, 43.1)	0.069

Source: Estimated from Wang et al (2001)[54]

An AIHW report *Residential Aged Care in Australia 2007-08: A statistical overview* estimated the average length of stay in RAC to be 147.8 weeks. Only three per cent of residents in 2007-08 returned to the community.[37] Therefore we assumed that once someone is admitted to RAC, they will stay in RAC for the rest of the model and this becomes a terminal state.

The average time spent in respite care during 2007-2008 was 3.3 weeks in NSW.[37] Therefore we assumed that during a one year cycle, all of those in respite care would either return to the community, die or be admitted to a RACF. Therefore, respite care is not a state within the model.

Those who enter respite care due to a fall will incur the average cost of respite care for fall-related injuries. Seventy seven per cent of those in respite care were discharged back into the community in 2007-2008.[37] Our model assumed they would then either transition into the high risk group, be admitted to RAC, or die.

Discount rate

It is important in economic models to allow for the fact that costs or benefits occurring immediately are valued more highly than those occurring in the future. In the model all costs and utilities were discounted at five per cent, in line with the current Australian Health Technology Assessment guidelines. Discount rates were also tested in the sensitivity analysis.

Cost effectiveness of falls interventions

The base case

One of the problems with modelling a number of disparate falls interventions is that the accrual of costs and benefits will be time dependent. Three possible scenarios were identified:

- All costs occur in the first year, but the benefits in terms of falls avoided occur every year.
- All costs occur in the first year and the benefits only occur in the first year.
- Cost and benefits occur indefinitely until the intervention is stopped.

Each of the interventions can be modelled using one or more of the three possible scenarios. For example, if an exercise program followed scenario 1, it is assumed that the costs of running the program occur only in the first year, such as a 12 week instructor led course, but the benefits of the program will be maintained indefinitely or as long as the model is run. In this scenario, it is assumed that the individual maintains the exercise program and hence continues to receive the benefit. This assumption may be too strong. A conservative option is scenario 2, where the benefits occur in the first year only and thereafter the individual is at the normal risk of falling. Finally in scenario 3, it is assumed that the individual receives the instruction led course every year, therefore the costs and benefits of the exercise program will occur every year.

Not all interventions can be modelled using the three scenarios. For example, in the case of cataract surgery and cardiac pacing, the costs of the procedure only occur in the first year; however the benefits can be expected to last beyond the first year. Therefore scenario 2 and 3 may not be appropriate for these interventions.

Given that the average length of follow up of participants in the studies is 11 months and in the absence of any evidence to the contrary, model 2 was used as the base case scenario for: exercise; tai chi; home hazard modification; psychotropic medication withdrawal; multiple and multi-factorial interventions. Model 3 was used for interventions such as medication review, hip protectors and Vitamin D, as these interventions were more likely to be used in the RAC setting and it was assumed that each year a cost would be incurred together with a reduction in the fall rate. Model 1 was used for cardiac pacing and expedited cataract surgery as these interventions have a high upfront cost, however the benefits can be expected to

Table 26: Cost and benefits

Intervention	Model 1	Model 2	Model 3
	C=1, B= ∞	C=1, B=1	C=∞, B=∞
Exercise	✓	✓*	✓
Tai chi	✓	✓*	✓
Home hazard assessment	✓	✓*	✗
Psychotropic medication withdrawal	✓	✓*	✗
Expedited cataract surgery	✓*	✗	✗
Cardiac pacing	✓*	✗	✗
Hip protectors	✗	✓	✓*
Vitamin D and Calcium	✓	✓	✓*
Medication review	✓	✓	✓*
Multiple interventions	✓	✓*	✓
Multi-factorial interventions	✓	✓*	✓

Note: B = Benefits; C = Costs; * models analysed in this report; ✓= possible scenario, ✗= scenarios that are probably not realistic.

last for as long as the model is run. Table 26 summarises this information. The ticks indicate a possible scenario, the asterisks indicate the scenario chosen for the base case analysis and the crosses represent scenarios that are probably not realistic.

Community dwelling interventions

Cost per fall avoided

Table 27 summarises the cost effectiveness results for community dwelling interventions in terms of cost per fall avoided. The incremental cost and incremental falls avoided are presented per 10,000 NSW older population over a 10 year period. By using a common denominator, interventions aimed at the general population can be compared with interventions aimed at specific patient groups.

Note the incremental cost relates to the additional cost of providing the intervention. This includes the actual cost of providing the intervention less the cost of avoided medical treatment due to falls averted. In this respect the 'do nothing' option is not costless because this option incurs the maximum fall-related treatment costs.

There are a number of issues to note. First, all interventions are more costly than the 'do nothing' option (seen as a positive incremental cost), that is, the additional cost of providing the intervention is not fully offset by cost-savings due to falls avoided. The interventions with the lowest incremental costs are home hazard assessment ($3.78M/10,000) and group exercise ($4.71M/10,000). The intervention with the highest incremental cost is cardiac pacing ($106M/10,000 treated).

Second, all interventions have a positive benefit in terms of falls avoided. The most efficacious are cardiac pacing and psychotropic medication withdrawal with an additional 22,734 and 2,893 falls avoided per 10,000 patients respectively over a 10 year period when compared to no intervention. Finally, in terms of incremental cost per falls avoided, the most cost-effective interventions are expedited cataract surgery and psychotropic medication withdrawal. In the general population the most cost-effective options are tai chi, group exercise and home hazard assessment.

Cost per hospitalisation avoided

Table 28 summarises the cost effectiveness results for community dwelling interventions in terms of incremental cost per fall-related hospitalisation avoided. The incremental cost and incremental hospitalisation avoided are presented per 10,000 NSW older population over a 10 year period.

Cardiac pacing and cataract surgery are the most efficacious, in terms of hospitalisations avoided. The most cost-effective programs are expedited cataract

Table 27: Community dwelling interventions: incremental cost per fall avoided per 10,000 NSW older population over a 10 year period

Intervention	Incremental cost/10,000 population ($)	Incremental falls avoided*/10,000 population	Incremental cost per fall avoided ($)
All			
Group exercise	4,710,000	928	5,075
Home exercise	9,490,000	1,434	6,618
Stepping On program	6,560,000	1,307	5,019
Tai chi	4,950,000	1,548	3,198
Home hazard assessment	3,780,000	1,315	2,875
Multiple	9,350,000	1,052	8,888
Multi-factorial - referral	7,660,000	701	10,923
Multi-factorial - active	12,560,000	1,315	9,552
Population specific			
Expedited cataract surgery	350,000	1,390	252
Psychotropic medication	3,320,000	2,893	1,148
Cardiac pacing	106,470,000	22,734	4,683

* Multiple falls can occur each year

Table 28: Community dwelling interventions: incremental cost per fall-related hospitalisation avoided per 10,000 NSW older population over a 10 year period

Intervention	Incremental cost/10,000 population ($)	Incremental hospitalisation avoided/10,000 population	Incremental cost per hospitalisation avoided ($)
All			
Group exercise	4,710,000	42	112,143
Home exercise	9,490,000	66	143,788
Stepping On program	6,560,000	60	109,333
Tai chi	4,950,000	71	69,718
Home hazard assessment	3,780,000	56	67,500
Multiple	9,350,000	45	207,799
Multi-factorial - referral	7,660,000	30	255,359
Multi-factorial - active	12,560,000	56	223,311
Population specific			
Expedited cataract surgery	350,000	64	5,469
Psychotropic medication	3,320,000	124	26,831
Cardiac pacing	106,470,000	1467	72,577

surgery and psychotropic medication withdrawal. In the general population the most cost-effective options are tai chi and group exercise.

Cost per quality adjusted life years gained

Presenting the results as incremental cost per fall avoided or hospitalisation avoided is useful if the decision maker has already decided to invest in a fall prevention strategy. In this case choosing the program with the lowest incremental cost per fall or hospitalisation avoided would represent the best value for money. However, using surrogate outcomes makes it difficult to judge whether an intervention represents value for money in terms of the total health care budget. In order to make this decision it is necessary to value society's willingness-to-pay to avoid a fall or a hospitalisation. Alternatively, a generic outcome measure such as life years gained or QALYs gained, could be used. The advantage of using the latter approach is that interventions for different health conditions (not just falls prevention) can be compared, and the most cost-effective interventions can be adopted.

This section presents the data in terms of QALYs gained. The cost effectiveness of community based exercise programs are summarised in Table 29. These results are based on a cohort of 75 year olds followed for 10 years. The average patient will cost $4,532 in fall-related medical expenses and RACF fees and will expect to gain 4.628 QALYs over a 10 year period for the no intervention option (do nothing). The values for the 'do nothing' option are different for some interventions because the starting population are different. For example, a group exercise program can be offered to the entire population aged less than 75 but expedited cataract surgery can only be offered to a specific patient population.

The most cost-effective exercise-based intervention is group-based exercise. The main reason for this is that group-based exercise is significantly cheaper than home-based exercise, yet only marginally less effective.

Additional analyses not presented in this report revealed that providing group-based exercise appears more cost-effective in a younger cohort ($77,000 per ICER as opposed to $117,000 per ICER). This result is based on pooling the studies into a mean age greater and less than 75 (which is the average age of an over 65 year old in NSW). The rate ratio indicates that exercise programs are less effective in populations over 75 years than populations under 75 years.

Tai chi, home hazard assessment (home hazard assessment results from the meta-analysis presented in this report) and group exercise are the most cost-effective of the other interventions available to the total population. The reason that multiple and multi-factorial interventions do not appear to be cost-effective is that despite these interventions being relatively effective, both are expensive.

Table 29: The cost effectiveness of community dwelling programs: incremental cost per quality adjusted life year saved

Intervention	Average cost ($)	Incremental cost ($)	Average QALY	Incremental QALY	ICER cost per QALY ($)
Population >65					
No intervention (all groups)	4,532		4.628		
Group exercise	5,003	471	4.634	0.0065	72,006
Home exercise	5,481	949	4.638	0.0101	93,847
Stepping On program*	5,187	656	4.637	0.0092	71,104
No intervention (low/med)	4,495		4.638		
Tai chi	4,990	495	4.649	0.0110	45,083
No intervention (med/high)	4,913		4.606		
Home hazard assessment*	5,291	378	4.615	0.0094	40,073
Multiple interventions*	5,848	935	4.613	0.0076	123,814
Multi-factorial – referral	5,679	766	4.611	0.0050	152,151
Multi-factorial – active	6,169	1,120	4.615	0.0094	133,083
Population Specific					
No intervention	5,153		4.927		
Expedited cataract surgery†	5,188	35	4.936	0.0096	3,505
No intervention	4,913		4.606		
Psychotropic medication withdrawal†	5,245	332	4.626	0.0207	20,848
No intervention	4,913		4.606		
Cardiac Pacing†	15,560	10,647	4.743	0.1373	77,520

Source: Unless indicated the effectiveness data is taken from Gillespie et al (2009)[1]; *Effectiveness taken from the meta-analysis present in this report; †Only patient specific populations benefit from this intervention; Note: ICER = Incremental cost effectiveness ratio; QALY = Quality adjusted life year

Finally, expedited cataract surgery and psychotropic medication withdrawal are the most cost-effective of the population-specific interventions. This conclusion is driven mainly by the effectiveness of these interventions.

Residential aged care interventions

Table 30 summarises the cost effectiveness results for RAC interventions in terms of cost per fall avoided. The incremental cost and incremental fall avoided are presented per 10,000 NSW RAC population over a 10 year period.

Medication review is cost-saving relative to ‘do nothing’. This is because the cost of an annual medication review is low and is offset by the avoided costs associated with the falls averted. Since the number of falls avoided is positive and the incremental cost is negative, it is normal to say that this intervention dominates the ‘do nothing’ alternative.

Multiple interventions and medication review are the most efficacious in terms of falls avoided. The most cost-effective programs are medication review, hip protectors and vitamin D supplementation.

Table 30: Residential aged care interventions: incremental cost per fall avoided

Intervention	Incremental cost/ 10,000 population ($)	Incremental falls avoided/ 10,000 population	Incremental cost per fall avoided
Total population >65			
Vitamin D	1,530,000	3751	$408
Multiple	18,620,000	12643	$1,473
Multi-factorial	24,770,000	8502	$2,914
Med/high risk groups			
Medication review	-1,210,000*	11584	dominant
Hip protectors	650,000	6236	$104

*cost-saving

Table 31: Residential aged care interventions: incremental cost per fall-related hospitalisation avoided

Intervention	Incremental cost/ 10,000 population ($)	Incremental hospitalisations avoided/ 10,000 population	Incremental cost per hospitalisation avoided
Total population >65			
Vitamin D	1,530,000	201	$7,627
Multiple	18,620,000	676	$27,552
Multi-factorial	24,770,000	455	$81,507
Med/high risk groups			
Medication review	-1,210,000*	615	Dominant
Hip protectors	650,000	331	$1,964

*cost-saving

Table 31 summarises the cost effectiveness results for RAC interventions in terms of cost per fall-related hospitalisations avoided. The incremental cost and incremental hospitalisations avoided are presented per 10,000 of the NSW RAC population over a 10 year period.

Medication review is cost-saving and beneficial in terms of hospitalisations avoided, therefore this option dominates 'do nothing'. Multiple interventions and medication review are the most efficacious in terms of hospitalisations avoided. The most cost-effective programs are medication review, hip protectors and vitamin D supplementation.

The cost effectiveness of RAC based programs are summarised in Table 32. The average patient will cost $1,757 in fall-related medical expenses and RACF fees and will expect to gain 1.552 QALYs over a 10 year period for the no intervention option (do nothing). As expected this is significantly lower than in the community based setting because of lower life expectancy among this group.

The most cost-effective (dominant) intervention is medication review, which is cost saving and beneficial in terms of QALYs gained. Hip protectors ($1,838 per QALY gained) and vitamin D ($7,316 per QALY gained) are other interventions that also have relatively low ICERs.

Note that medication review is likely to dominate all other interventions, with the exception of multiple interventions. This is because it offers more benefits at lower cost. Therefore, compared to medication review the other interventions are unlikely to ever be cost-effective options. Multiple interventions do offer some benefits over medication review (average QALY gained 1.634 versus 1.612) however, the incremental cost of multiple interventions relative to medication review means that this option is unlikely to ever be cost-effective at any acceptable level.

Table 32: The cost effectiveness of residential aged care interventions: incremental cost per quality adjusted life year saved

Intervention	Average cost ($)	Incremental cost ($)	Average QALY	Incremental QALY	ICER cost per QALY
Total Population >65					
No intervention	1,757		1.563		
Vitamin D	1,911	153	1.584	0.021	$7,316
Multiple	3,619	1,862	1.634	0.071	$26,300
Multi-factorial	4,234	2,477	1.610	0.048	$52,066
Med/high risk groups					
No intervention	1,942		1.547		
Medication review	1,821	-121	1.612	0.065	Dominant
Hip protectors	2,006	65	1.582	0.035	$1,838

Note: ICER = Incremental cost effectiveness ratio; QALY = Quality adjusted life year

Sensitivity analysis

All results have been presented based on average parameter inputs and model assumptions described earlier. These inputs and assumptions were tested in the sensitivity analysis.

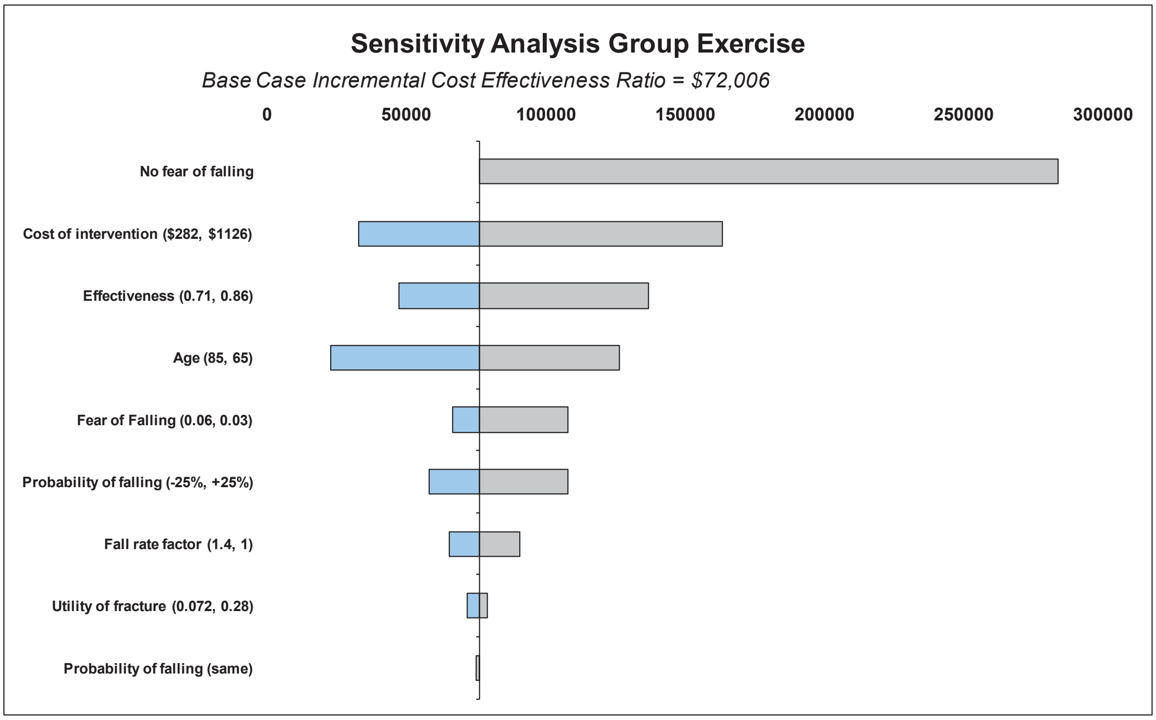
Sensitivity of group exercise

The sensitivity analysis was used to test the robustness of the model parameters and any assumptions made. A detailed one-way sensitivity analysis was undertaken, given the uncertainty in a number of the parameters in the model. Using group exercise as the base case, each possible parameter was tested using a confidence interval if available and if unavailable, using the best estimate of possible ranges. For the probability of falling, the parameter was adjusted up and down by 25 per cent. The results of adjusting each of these parameters is displayed in the form of a tornado plot in Figure 4. The vertical axis on the graph represents the base case ICER of exercise which is $72,006 per QALY. The blue bars represent a reduction in the ICER based on the first value in the brackets and the grey bars represent an increase in the ICER based on the second value in the brackets.

It is apparent which parameters are key drivers in the model from Figure 4. Fear of falling is the biggest driver in the model. This is expected because every time a fall is avoided the QALY decrement associated with a fall is also avoided. Removing the fear of falling QALY decrement changes the ICER from about $70,000 per QALY to greater than $250,000 per QALY gained.

The other key drivers are the costs and effectiveness of the interventions. This is also expected as these are the main inputs into the model. Age also has an effect, with interventions more cost-effective in the older age groups. The other parameters had little effect on the overall cost effectiveness ratio denoting that any uncertainty around utility decrements for fractures or the probability of falling has little effect on the underlining result.

Figure 4: Tornado plot

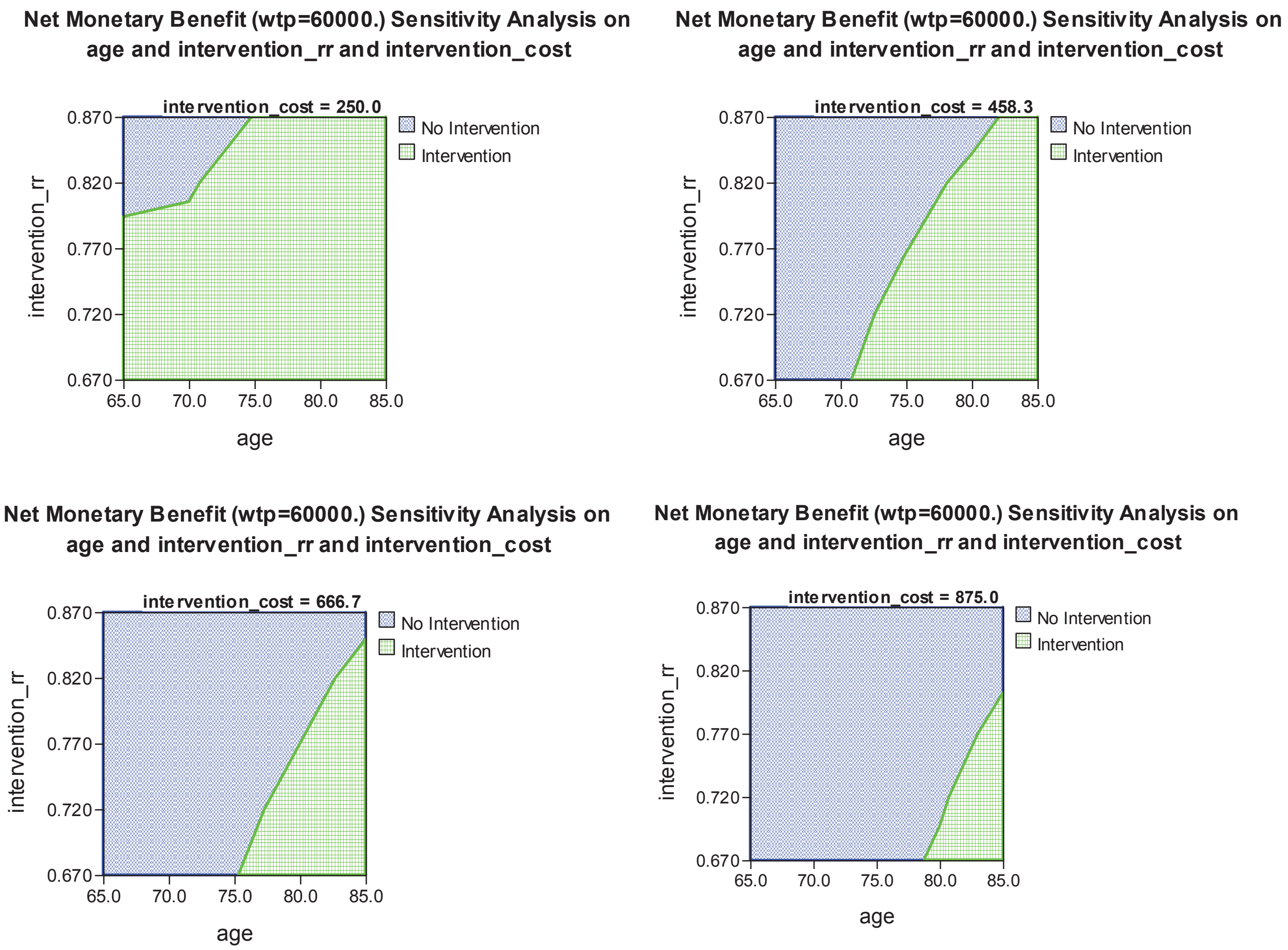


Threshold analysis

Conducting a threshold sensitivity analysis is another method of evaluating the effect of differences in age groups, cost and effectiveness of the exercise program. Figure 5 displays the relative cost effectiveness as an exercise program increases in cost. The basis of this analysis is that a willingness-to-pay threshold of $60,000 per QALY is applied. For example, if one is willing to pay $60,000 per QALY, and the exercise program is estimated to cost $250 per participant, the intervention would be cost-effective across all age groups. However, if the program cost $460 it would only be cost-effective in the over 75 group. Once the intervention costs increase to about $875 it would only be cost-effective in those older than 85. Any increases in exercise costs beyond this would mean that the intervention would not be considered cost-effective.

Table 33 provides an alternative analysis in the absence of a determined threshold. The cost per QALY over both a range of costs and effectiveness is presented. These ICERs are based on 75 year olds receiving the intervention for one year, and the resulting benefits of the intervention over 10 years. Group exercise becomes more cost-effective when the cost of the intervention is low and the effectiveness is high.

Figure 5: Threshold analysis



Note: wtp = willingness to pay; intervention_rr = the relative risk of the intervention over control; intervention_cost = cost of the intervention per participant

Table 33: Estimating the impact of different costs and effectiveness on the incremental cost per quality adjusted life year gained: a 75 year old for 10 years ($)

Intervention (incidence risk ratio)	Cost of group exercise intervention ($)					
	250	563	750	1,000	1,250	1,500
0.71	14,961	51,242	72,918	101,896	130,875	159,853
0.75	19,264	60,934	85,829	119,111	152,394	185,676
0.78	24,181	**72,006**	100,579	138,778	176,977	215,176
0.82	33,327	92,604	128,018	175,363	222,708	270,054
0.86	46,009	121,163	166,063	226,090	286,117	346,144

Note: Bold figure indicates the base case ICER for group exercise

Discussion and conclusions

This report adds to the falls prevention literature in a number of ways. It is the first to use the effectiveness data from the most recent community dwelling falls prevention Cochrane review and it is the first report to convert falls avoided and hospitalisations avoided into QALYs gained, the most commonly used outcome measure in economic evaluation.

Other reports have limited the outcomes reported in the economic evaluation to incremental cost per fall avoided or hospitalisation avoided. Whilst these measures are useful if the decision maker has already decided to invest in a falls prevention strategy, because the lowest incremental cost per fall or hospitalisation avoided can be identified, there are limitations to such an approach. In particular, using these surrogate outcomes makes it difficult to judge whether an intervention represents value for money in terms of the total health care budget. An alternative approach is required unless we know the value society is willing to pay to avoid a fall or a hospitalisation. The approach taken in this report was to use QALYs gained, which is a generic outcome measure. The advantage of using QALYs is that interventions for different health conditions (not just falls prevention) can be compared, providing information for decision makers to use when choosing which intervention(s) to recommend and/or fund.

Another advantage of using QALYs is that other factors considered important can be added to the model. Fear of falling is an important parameter to consider. The fear of falling decrement used in the model captures anxiety and loss of confidence that may occur subsequent to a fall. Fear of falling was a significant driver of the cost effectiveness results in the model. Without the inclusion of fear of falling, it is unlikely that any of the community dwelling interventions would be considered cost-effective at any acceptable threshold.

There is debate in Australia on whether a cost effectiveness threshold exists. Implicitly a threshold of between $50,000 and $60,000 per QALY gained is often mentioned as being appropriate. The Pharmaceutical Benefits Advisory Committee does not work with an explicit cost effectiveness threshold. "However, there is a relationship between cost per QALY gained and the probability of rejection of a drug. Between 1994 and 2003, the highest cost per QALY at which a drug was recommended for listing by the committee was $52,400" (Henry et al, 2005:2631).[56] If this threshold does represent society's willingness-to-pay, the following community dwelling interventions would be considered cost-effective: expedited cataract surgery; psychotropic medication withdrawal; tai chi; and home hazard assessment (home hazard assessment results from the meta-analysis presented in this report). Group-based exercise would be approaching cost-effective. The following RAC interventions would be considered cost-effective: medication review; hip protectors and vitamin D supplementation, multiple interventions and multi-factorial interventions.

Caution is required when interpreting cost effectiveness results in this way for a number of reasons. The cost effectiveness ratios reported here are all relative to the 'do nothing' alternative. Interventions should be compared with each other in order to determine the real cost effectiveness. They should be ranked according to their ICERs and dominated and extendedly dominated alternatives removed. This step was not undertaken in this project because of the degree of uncertainty already introduced into the model. Also, incremental analysis may not be applicable because not all groups are in the same populations. For example, patients with cataracts are a distinctly different population than those requiring vitamin D.

Specific populations versus general populations

One of the interesting findings that emerged from this project is that interventions targeting specific patient populations, such as expedited cataract surgery and cardiac pacing appear to be the most cost-effective. The main reason is that the benefits associated with both are generally large and occur for a number of years. The model does not capture all the benefits associated with these interventions. For example, expedited cataract patients will receive a large improvement in QOL simply because their vision has been restored. Therefore the cost effectiveness of this intervention is likely to be improved further. The downside is obvious; these interventions are only relevant to specific populations and therefore not available to everyone.

Age versus cost effectiveness

The results of the sensitivity analysis show that age plays a role in determining the cost effectiveness of each intervention. That is, the intervention is more cost-effective if it is applied to the older population. However, although it is rational to suggest that these interventions should only be implemented in the oldest age group, this recommendation is predicated on an assumption that the interventions are as effective in these older age groups as in younger age groups, which may not be the case. Any relaxation in this assumption will remove the cost effectiveness advantage for the older age groups. Therefore this assumption is uncertain.

Meta-analysis and heterogeneity

The point estimates used in the economic model are based on the results of the meta-analysis. Therefore they do not take into account the heterogeneity between similar interventions. For example, the pooled cost and pooled effectiveness estimates may mask the fact that high cost interventions (eg exercise three times a week compared to once a week) are more effective relative to the cheaper equivalent. A random effects model, which generally widens the confidence around a particular parameter, was used to explain statistical heterogeneity. However, this method does not explain all heterogeneity that exists between the studies and at times the pooling of studies may be inappropriate.

Falls versus injuries

Some interventions specifically targeted falls prevention, whilst others prevent fall-related injuries. The economic model was designed to capture both factors. However, the evidence for reduced fall-related injuries is limited, since most clinical trials have insufficient power to detect differences in such rare events. Several studies do report lower fall-related injuries, however these are usually insignificant once the number of falls have been taken into account.

Intervention costs

It was difficult to estimate the exact cost of an intervention in many cases, due to a lack of reporting in studies. Much of the sensitivity analysis focused on the cost of the intervention. Costs may differ depending on: the intervention setting (urban or rural); staff who deliver the intervention; and the frequency or duration of the intervention. We recommend better reporting of costs (or resource use) in studies, to facilitate improved cost estimates.

Clinical trial versus real world settings

One of the limitations when using clinical trial data is the transferability of the results into a real world setting. First, selection bias may influence the results, as those who enter into clinical trials may be more willing to participate in an intervention and adhere to the intervention. Second, the population characteristics of the study group may differ from those of the intended population. Finally, the costs of giving an intervention in the real world setting may differ from within the trial.

There are also some issues with data collection within a clinical trial. Some studies rely on recall or diaries. Within the falls context, particularly the age of the population, this could cause some inconsistencies in the actual number of falls that have occurred. In addition, high drop-out rates increase uncertainty.

Conclusions

The most cost-effective interventions in the community dwelling setting are:

- expedited cataract surgery
- psychotropic medication withdrawal
- tai chi
- home hazard assessment (results from the meta-analysis presented in this report)
- group-based exercise.

Expedited cataract surgery and psychotropic medication withdrawal are both specific to certain patient populations and consequently are not suitable for every older person in NSW.

The most cost-effective interventions in the RAC setting are:

- medication review
- hip protectors
- vitamin D supplementation.

Medication review dominates the ‘do nothing’ alternative, that is, it is both cost-saving and beneficial in terms of QALYs gained. Hip protectors and vitamin D supplementation are both relatively low cost, which is the main reason that these interventions are relatively cost-effective at normal thresholds.

The economic model is sensitive to a number of model inputs, in particular the key driver appears to be the QOL decrement associated with fear of falling. Other parameters that drive the model, but that can be controlled to a certain extent, include the effectiveness and cost of each intervention. The duration of the benefits and costs can also be adjusted within the model to better reflect real world situations for each intervention.

Appendix A

Search strategy

Search string:

fall OR falls
AND
(elderly OR aged OR 'older adult' OR 'older adults' OR 'older person' OR 'older persons' OR senior OR seniors)
AND
(prevention OR intervention OR strategy OR program OR programs OR programme OR programmes OR service OR services OR system OR systems OR care OR management OR guideline OR guidelines OR 'tai chi' OR 'occupational therapy' OR OT OR physiotherapy OR 'physical therapy' OR balance OR strength OR exercise OR movement OR 'home hazard' OR 'home hazards' OR 'home modification' OR 'home modifications' OR 'home safety' OR psychotropic OR medication OR medications OR screening OR assessment OR multifactorial OR multidisciplinary OR multidimensional OR vision OR 'visual correction' OR 'cardiac pacing' OR 'cataract surgery' OR 'hip protector' OR 'hip protectors' OR supplements OR calcium OR 'vitamin D' OR drug OR drugs OR bisphosphonate OR bisphosphonates OR cost OR costs OR effect OR effects OR consequence OR consequences OR outcome OR outcomes OR benefit OR benefits OR resource OR resources OR hospitalisation OR hospitalization OR economic OR economics OR burden OR risk OR risks OR morbidity OR mortality OR prevalence OR incidence OR epidemiology OR evaluation OR QALYs OR 'quality adjusted life years' OR QOL OR 'quality of life' OR 'health related quality of life' OR HRQL OR HRQOL OR 'life years gained' OR LYS OR LYG OR measurement OR measurements OR measuring OR scale OR scales)
AND
(community OR residential OR nursing OR facility OR facilities OR hospital OR hospitals)
AND
(Australia OR 'New Zealand' OR 'North America' OR 'United States' OR US OR Canada OR Japan OR Scandinavia OR Europe [MeSH])

Search limits:

- Title/abstract
- 1990 –
- Humans
- English

Appendix B

Databases and search results

Database	Results
PUBMED (Medline and PreMedline)	445
The Cochrane Library	307
Web of Science	207
MEDLINE, EMBASE, CINAHL and PsycINFO*	191
NHS EED	79
DARE	54
HTA	11
Total hits	1,294†
Total inclusions	131

*Search conducted through OVID †Figure does not include number of hand searched papers

Appendix C

Included studies at Level II full text review

Key to Appendix C tables:

A&E=accident & emergency; ADL=activities of daily living; BMC=bone mineral content; BMD = bone mineral density; ECG=electrocardiogram; FICSIT = Frailty and Injuries: Cooperative Studies and Intervention Techniques; FITNESS = The Frailty Interventions Trial in Elderly Subjects; GP = general practice; HMO= health maintenance organisation; HRQL=health related quality of life; MMSE=Folstein mini-mental state examination; NR = not reported; OT=occupational therapist; PPA=physiological profile assessment; PT= physical therapist; QOL = quality of life; RCT = randomised controlled trial; SAFE = Study of Accidental Falls in the Elderly; SIP= sickness impact profile; VIP = visual impairment.

Countries: AU=Australia; CA=Canada; CH=Switzerland; CL=Chile; DE=Germany; FI = Finland; FR=France; GB=United Kingdom; JP=Japan; NL=Netherlands; NO = Norway; NZ = New Zealand; SE=Sweden; TH=Thailand; TW=Taiwan; US=United States.

Table 34: Exercise intervention trials: community dwelling (n=32)

Study	Design	Population	Intervention and control	Outcome measures
Ballard et al, 2004[57]	RCT (II)	n=40 Older women Mean ages 73.4 (intervention) and 72.4 (control) Community dwelling residents Tyler, Texas, US	15 week intervention (1) Intervention group:15 week exercise training program targeting balance and leg strength (n=20) (2) Control group: 2 week exercise program (n=20)	1 year follow-up Balance; strength; falls
Barnett et al, 2003[58]	RCT (II)	n=163 People ≥ 65 years Community dwelling residents South Western Sydney, AU	1 year intervention (1) Intervention group: community based weekly group exercise program with ancillary home exercises and falls prevention information (n=83) (2) Control group: falls prevention information only, no exercise (n=80)	6 and 12 month follow-up Physical performance; general health status (SF-36); falls; fall-related injuries
Buchner et al, 1997[59]	RCT (II) FICSIT	n=105 People aged 68-85 Community dwelling residents Seattle, Washington, US	24 to 26 week intervention (1) Intervention group I: endurance training (ET) using bikes (n=25) (2) Intervention group II: strength training (ST) using weights (n=25) (3) Intervention group III: combination training of ST and ET (n=25) (4) Control group: usual activity (n=30)	Up to 25 month follow-up (falls) 6 and 9 month follow-up (all other measures) Gait; balance; physical health status; falls; resource use; costs
Bunout et al, 2005[60]	RCT (II)	n=298 Older people, mean age 75 Community dwelling residents CL	1 year intervention (1) Intervention group: exercise group, attended bi-weekly training sessions of weight-bearing exercises, exercises with Thera Bands and walking. (n=149) (2) Control group: No intervention (n=149)	Falls; muscle strength; walking capacity; body composition
Campbell et al, 1997[61]	RCT (II)	n=233 Older women ≥ 80 years Community dwelling residents GP patients Dunedin, NZ	1 year intervention (1) Intervention group: individually tailored home exercise program (n=116) (2) Control group: usual care and social visits at home (n=117)	6 month and 1 year follow-up Falls; fall-related injuries; compliance; muscle strength; balance
Campbell et al, 1999[16]	RCT (II)	n=93 Older people ≥ 65 years Community dwelling residents GP (n=17) Dunedin, NZ	14 week intervention (1) Intervention group I: psychotropic medication withdrawal and exercise program (n=24) (2) Intervention group II: psychotropic medication withdrawal and no exercise program (n=24) (3) Intervention group III: original medication and exercise program (n=21) (4) Control group: original medication and no exercise program (n=24)	44 week follow-up Falls

Study	Design	Population	Intervention and control	Outcome measures
Campbell et al, 2005[62]	RCT (II) VIP trial	n=391 Older people ≥ 75 years with severe VIP Community dwelling residents Dunedin and Auckland, NZ	12 month intervention (1) Intervention group I: home safety assessment and modification program (n=100) (2) Intervention group II: home exercise program and vitamin D supplementation (n=97) (3) Intervention group III: both interventions 1 and 2 (n=98) (4) Control group: social visits (n=96)	1 year follow up falls; fall-related injuries; home safety program implementation costs
Carter et al, 2002[63]	RCT (II)	n=80 Older women 65-74 years, with osteoporosis Community dwelling residents Vancouver, CA	20 week intervention (1) Intervention group: community based exercise program (n=40) (2) Control group: usual activity (n=40)	20 week follow-up Static balance; dynamic balance; knee extension strength; QOL; falls
Day et al, 2002[64]	RCT (II)	n=1,107 Older people ≥ 70 years Community dwelling residents Melbourne, AU	Intervention period NR (1) Intervention group I: group-based exercise program of strength and balance (n=135) (2) Intervention group II: home hazard management (n=136) (3) Intervention group III: vision improvement (n=139) (4) Intervention group IV: exercise and vision improvement (n=136); (5) Intervention group V: exercise and home hazard management (n=135) (6) Intervention group VI: vision improvement and home hazard management (n=137) (7) Intervention group VII: exercise, vision improvement and home hazard management (n=135) (8) Control group: no intervention (n=137)	18 month follow-up Falls; time to first fall; changes in targeted risk factors (strength, balance, vision and number of hazards)
Ebrahim et al, 1997[26]	RCT (II)	n=97 Older women, post-menopausal and post-fracture, mean age 66.4 A&E department attendees Hospital outpatient setting GB	2 year intervention (1) Intervention group: self-paced brisk walking (n=49) (2) Placebo group: upper limb exercises (n=48)	1 and 2 year follow-up Bone mineral density; falls; fractures
Hauer et al, 2001[65]	RCT (II)	n=57 Older women ≥ 75 years Acute care or inpatient rehabilitation patients Outpatient geriatric rehabilitation unit intervention setting DE	12 week intervention (1) Intervention group: exercise training targeting strength, functional performance and balance (n=31) (2) Control group: physiotherapeutic treatment excluding strength and balance training (n=26)	3 month post-intervention follow-up Strength; functional ability; motor function; psychological parameters; falls
Helbostad et al, 2004[66]	RCT (II)	n=77 Older people ≥ 75 years Community dwelling residents Trondheim, NO	12 week intervention (1) Intervention group I: home training comprising functional strength + balance exercises, and 3 group meetings (n=38) (2) Intervention group II: group training and home-based exercises (n=39)	3, 9 and 12 month follow-up Walking measures; strength; balance; falls; compliance
Korpelainen et al, 2006[67]	RCT (II)	n=160 Older women with low BMD Mean age, 73 years Community dwelling residents FI	30 month intervention (1) Intervention group: supervised, home-based impact exercise training (n=84) (2) Control group: no intervention (n=76)	12 and 30 month follow-up BMD; BMC; falls; fractures
Latham et al, 2003[68]	RCT (II) 2x2 factorial design FITNESS	n=222 Older people ≥ 65 years Hospital discharge patients Auckland, NZ Sydney, AU	10 week intervention (1) Intervention group I: home-based quadriceps resistance exercise (n=112) (2) Intervention group II: exercise control through telephone calls and home visits by the PT (n=110) (3) Intervention group: vitamin D3 (calciferol; n=108) (4) Placebo group (n=114)	3 and 6 month follow-up Physical health (SF-36); falls; physical performance; self-rated function
Lin et al, 2007[69]	RCT (II)	n=150 Older people ≥ 65 years Community- dwelling residents Taichung county, TW	4 month intervention (1) Intervention group I: falls prevention education (n=50) (2) Intervention group II: home safety assessment and modification (n=50) (3) Intervention group III: home-based training program (n=50)	2, 4 and 6 month follow-up QOL; function balance and gait; fear of falling; depression; falls (6 month follow-up)

Study	Design	Population	Intervention and control	Outcome measures
Liu-Ambrose et al, 2004[70]	RCT (II)	n=98 Older women ≥ 75 years, with low bone mass Community dwelling residents Vancouver, CA	25 week intervention (1) Intervention group I: resistance training (n=32) (2) Intervention group II: agility training (n=34) (3) Intervention group III: stretching (sham) exercises (n=32)	13 and 25 week follow-up Fall risk; ankle dorsiflexion strength; foot reaction time; community balance and mobility scale score; falls
Lord et al, 2003[71]	RCT (II)	n=551 Older people ≥ 62 years, mean age 79.5 Self and intermediate-care retirement village (RACF) residents Sydney and Wollongong, AU	12 month intervention (1) Intervention group: weight-bearing group-based exercises (n=280) (2) Control group: flexibility and relaxation (sham) exercises (n=271)	Accidental falls; choice stepping reaction time; reaction time; 6 minute walk distance postural sway; leaning balance; simple reaction time; lower limb muscle strength
Lord et al, 1995[72]	RCT (II) Randwick Falls and Fractures Study	n=197 Older women Mean age 71.6 Community dwelling residents Sydney, AU	12 month intervention (1) Intervention group: community based exercise program (n=100) (2) Control group: no intervention (n=97)	22 week and 12 month follow-up Accidental falls; postural sway; reaction time; neuromuscular control; lower limb muscle strength
Luukinen et al, 2007[73]	RCT (II)	n=555 Older people ≥ 85 years Community dwelling residents Oulu, FI	5-6 month intervention period (1) Intervention group: exercise program (home exercise, walking exercise, group exercise and self-care exercise; n=243) (2) Control group: routine care (n=243)	16 month median follow-up Falls; physical performance; health service use
McMurdo et al, 1997[74]	RCT (II)	n=118 Older women Mean age, 65 years Community dwelling residents Dundee, Scotland, GB	2 year intervention (1) Intervention group I: calcium supplementation (n=48) (2) Intervention group II: calcium and weight bearing exercise (n=44)	2 year follow-up BMD; BMC; falls; fractures
Means et al, 2005[75]	RCT (II)	n=238 Older people ≥ 65 years Community dwelling residents Central Arkansas, US	6 week intervention (1) Intervention group: balance rehabilitation intervention with supervised stretching, balance, endurance, coordination and strengthening exercises (n=144) (2) Control group: attended a series of non health related seminars (n=94)	6 month follow-up Functional obstacle; falls; fall-related injuries; activity, range of motion, muscle strength and symptoms of balance dysfunction
Morgan et al, 2004[76]	RCT (II)	n=294 Older people ≥ 60 years Mean ages 81.0 (intervention) and 80.1 (control) Community dwelling residents Miami, South Florida, US	8 week intervention (1) Intervention group: low intensity exercise 'physical restoration' intervention targeted at neuromuscular functioning, balance and gait (n=119) (2) Control group: usual activity (n=110)	1 year follow-up Gait and balance measures; self-reported physical function; number of medications; falls
Nitz and Choy, 2004[77]	RCT (II)	n=73 Older people Mean ages, 75.9 (intervention) and 79.7 (control) Community dwelling residents Queensland, AU	10 week intervention (1) Intervention group: balance training program delivered via workstation format (n=37) (2) Control group: fall risk education booklet (n=36)	3 month follow-up Falls; comorbidities; medications; community services and activity level; functional motor ability; balance; fear of falling
Reinsch et al, 1992[78]	RCT (II)	n=230 Older people ≥ 60 years Mean ages 74.1 (intervention) and 74.2 (control) Community dwelling residents Orange and Los Angeles counties, US	1 year intervention (1) Intervention group I: 'Senior Body Program' consisting of ≥ 1 health and fitness evaluation(s), exercise information, accident and fall prevention information, and healthy living discussions (n=57) (2) Intervention group II: cognitive behavioural intervention (n=51) (3) Intervention group III: exercise-cognitive intervention (n=72) (2) Control group: discussion control group (n=50)	12 month follow-up Falls; fallers; time to first fall; injury severity; musculoskeletal function; cognitive measures

Study	Design	Population	Intervention and control	Outcome measures
Robertson et al, 2001[79]	RCT (II)	n=211 Older people ≥ 75 years Community dwelling residents West Auckland, NZ	8 week intervention with a 6 month 'booster' (1) Intervention group: nurse delivered home-based exercise program through muscle strengthening and balance retraining exercises, and a walking plan (n=121) (2) Control group: usual care (n=119)	1 year follow-up Falls; fall-related injuries; program implementation costs; hospital costs
Rubenstein et al, 2000[80]	RCT (II)	n=59 Older men ≥ 70 years, with chronic impairments Community dwelling residents Ambulatory care centre patients Sepulveda, California, US	12 week intervention (1) Intervention group: low-medium intensity group exercise program using strength, endurance, mobility and balance (n=31) (2) Control group: usual care (n=28)	Within 1 week post-intervention follow-up Isokinetic strength and endurance; physical performance; self-reported physical functioning (SF-36); health perception (SF-36); activity level; falls
Sherrington et al, 2004[81]	RCT (II)	n=120 Older people aged 57-95 Average age 79 Community dwelling residents Previous hip fracture AU	(1) Weight bearing exercise group (n=35) (2) Non-weight bearing exercise group (n=37) (3) Control group: no intervention (n=36)	Fallers (given by authors)
Shigematsu et al, 2008[82]	RCT (II)	n=63 Older people ≥ 65 years Community dwelling residents Local health centre setting Kawage, Mie, Japan (JP)	12 week intervention (1) Intervention group: square-stepping exercise (n=32) (2) Control group: walking (n=31)	8 month follow-up Falls; physical function
Skelton et al, 2005[83]	RCT (II)	n=81 Older women ≥ 65 years Community dwelling residents London, GB	36 week intervention (1) Intervention group: Individualised, tailored group and home exercise program, falls management exercise intervention (n=50) (2) Control group: no intervention (n=31)	Mean follow up, 49.7 weeks Falls; fall-related injuries; death; institutionalisation
Steadman et al, 2003[84]	RCT (II)	n=133 Older people ≥ 60 years Multidisciplinary falls clinic patients Community dwelling residents GB	6 week intervention (1) Intervention group: enhanced balance training (n=69) (2) Control group: usual care (n=64)	24 week follow-up Balance; falls; mobility; balance; QOL (EQ-5D)
Steinberg et al, 2000 [85]	RCT (II)	n=252 (year 1) n=243 (year 2) Older people ≥ 50 years Mean age 69 Community dwelling residents Brisbane, AU	2 year intervention (1) Intervention group I: information session only (control group, n=63) (2) Intervention group II: information and exercise sessions (n=69) (3) Intervention group III: information and exercise sessions, and home safety assessment (n=61) (4) Intervention group IV: information and exercise sessions, home safety assessment and clinical assessment/medical risk factor advice (n=59)	1 and 2 year follow-up Slips; trips; falls
Suzuki et al, 2004[86]	RCT (II)	n=52 Older people ≥ 73 years Community dwelling residents Tokyo, JP	6 month intervention (1) Intervention group: exercise classes aimed at improving leg strength, balance and walking ability, supplemented by a home based exercise program (n=28) (2) Control group: pamphlet and advice on falls prevention (n=24)	20 month follow-up Attendance rate; physical function; falls
Wolf et al, 1996[27]	RCT (II) Atlanta FICSIT	n=200 Older people ≥ 70 years Community dwelling residents Atlanta, US	15 week intervention (1) Intervention group I: tai chi (n=72) (2) Intervention group II: computerised balance training (n=64) (3) Control group: education (n=64)	4 month follow-up Biomedical, functional and psychosocial indicators of frailty; falls

Table 35: Exercise intervention trials: residential aged care (n=8)

Study	Design	Population	Intervention and control	Outcome measures
Buettner, 2002[87]	RCT (II)	n=27 Older people Mean age 83.3 Intermediate and nursing care facility residents Oxford, Boston and Palo Alto, US	2 month intervention (1) Intervention group: falls prevention program consisting of 3 therapeutic recreational programs: walking group, exercise for function and sensory air mat therapy; aiming to increase strength, endurance and flexibility (n=13) (2) Control group: usual care provided by the nursing facility program (n=14)	2 month follow-up Falls; injuries; costs
Faber et al, 2006[32]	RCT (II)	n=278 Older people Mean age, 85 ± 6 years Nursing and retirement residents Amsterdam, Netherlands (NL)	20 week intervention (1) Intervention group I: functional walking program using mobility exercises (n=66) (2) Intervention group II: balance program using tai chi exercises (n=80) (3) Control group: usual care (n=92)	52 week follow-up Falls; performance oriented mobility assessment; physical performance; self-reported disability
Kerse et al, 2008[88]	RCT (II)	n=682 Older people ≥ 65 years Low level dependency residential care homes 2 cities in NZ	Intervention period NR (1) Intervention group: 'Promoting independence in residential care' intervention comprising an individualised functional activity program (n=330) (2) Control group: social group offered usual care and 2 social visits (n=352)	12 month follow-up Function; QOL; falls; depressive symptoms; hospital admissions
Mulrow et al, 1994[89]	RCT (II)	n=194 Older people Mean ages 79.7 (intervention) and 81.4 (control) Nursing home residents San Antonio, Texas, US	4 month intervention (1) Intervention group: tailored one-on-one physical therapy sessions targeting range of motion, strength, balance, transfer and mobility exercises (n=97) (2) Control group: friendly visits (n=97)	Bi-monthly, 1 year follow-up Physical disability index; SIP; ADL; geriatric depression scale; MMSE; falls (4 month follow-up)
Nowalk et al, 2001[90]	RCT (II) The FallsFREE program	n=110 Older people Mean age 84 Senior housing community residents (independent and skilled nursing care) US	24 month intervention (1) Intervention group I: resistance/endurance and basic enhanced programming (n=37) (2) Intervention group II: tai chi and basic enhanced programming (n=38) (3) Control group: basic enhanced programming only involving a comprehensive approach to falls prevention through team management and 3 educational programs (n=35)	6, 12 and 24 month follow-up Cognitive and physical functioning; falls
Shimada et al, 2004[91]	RCT (II)	n=26 Older people Age range 66-98 Long term care facility residents and geriatric health service facility outpatients undergoing rehabilitation JP	6 month intervention (1) Intervention group: treadmill exercise group (n=15) (2) Control group: usual exercise (n=11)	6 month follow-up Number of falls; time to first fall; balance function; gait function; reaction time
Sakamoto et al, 2006[92]	RCT (II)	n=527 Older people Mean age 81.6 Outpatient rehabilitation centre attendees, community dwelling and nursing care residents JP	6 month intervention (1) Intervention group: uni-pedal standing balance exercise (n=315) (2) Control group: no intervention (n=212)	6 month follow-up Falls; hip fractures
Sihvonen et al, 2004[93]	RCT (II)	n=27 Older women ≥ 70 years Mean ages 80.7 (exercise) and 82.9 (control) Residential care residents FI	4 week intervention (1) Intervention group: exercise group including individualised visual feedback based balance training (n=20) (2) Control group: no intervention (n=7)	1 year follow-up Falls; balance

Table 36: Tai Chi intervention trials: community dwelling (n=4)

Study	Design	Population	Intervention and control	Outcome measures
Li et al, 2005*[94]	RCT (II)	n=256 Older people ≥ 70 years Community dwelling residents Portland, Oregon, US	6 month intervention (1) Intervention group: tai chi program (n=125) (2) Control group: stretching exercises (n=131)	3 and 6 month, and 6 month post-intervention follow-up Falls; fall-related injuries; functional balance; physical performance; fear of falling
Voukelatos et al, 2007*[95]	RCT (II)	n=702 Older people Mean age 69 Community dwelling residents Sydney, AU	16 week intervention (1) Intervention group: community based tai chi program (n=347) (2) Control group: no intervention (n=337)	16 and 24 week follow up Falls
Wolf et al, 2003[96]	RCT (II)	n=311 Older people 70-97 years Congregate living facility (retirement village) residents Atlanta, US	48 week intervention (1) Intervention group I: intense tai chi exercise program (n=145) (2) Intervention group II: wellness education program (n=141)	48 week follow-up Falls; functional measures; SIP; depression, balance and confidence and falls efficacy scales; adherence to interventions
Wolf et al, 1996*[27]	RCT (II) Atlanta FICSIT	n=200 Older people ≥ 70 years Community dwelling residents Atlanta, US	15 week intervention (1) Intervention group I: tai chi (n=72) (2) Intervention group II: computerised balance training (n=64) (3) Intervention group III: education (n=64)	4 month follow-up Biomedical, functional and psychosocial indicators of frailty; falls

*Study included in Table 34

Table 37: Tai Chi intervention trials: residential aged care (n=2)

Study	Design	Population	Intervention and control	Outcome measures
Faber et al, 2006*[32]	RCT (II)	n=278 Older people Mean age 85 ± 6 Long term care residents Amsterdam, NL	20 week intervention (1) Intervention group I: functional walking program using mobility exercises (n=66) (2) Intervention group II: in balance program using tai chi exercises (n=80) (3) Control group: usual care (n=92)	52 week follow-up Falls; performance oriented mobility assessment; physical performance; self-reported disability
Nowalk et al, 2001*[90]	RCT (II) The FallsFREE program	n=110 Older people Mean age 84 Senior housing community residents (independent and skilled nursing care) US	24 month intervention (1) Intervention group I: resistance/endurance and basic enhanced programming (n=37) (2) Intervention group II: tai chi and basic enhanced programming (n=38) (3) Control group: basic enhanced programming only involving a comprehensive approach to falls prevention through team management and 3 educational programs (n=35)	6, 12 and 24 month follow-up Cognitive and physical functioning; falls

* Study included in Table 35

Table 38: Vitamin D and/or calcium intervention trials: community dwelling (n=14)

Study	Design	Population	Intervention and control	Outcome measures
Bischoff-Ferrari et al, 2006*[97]	RCT (II)	n=445 Older people ≥ 65 years Community dwelling residents US	3 year intervention (1) Intervention group: vitamin D_3 (700 IU cholecalciferol) and calcium citrate malate (500 mg) (n=219) (2) Placebo group (n=226)	3 year follow-up Falls; change in plasma 25-hydroxyvitamin D (25-OHD)
Dhesi et al, 2004[98]	RCT (II)	n=139 Older people ≥ 65 years Community dwelling residents GB	6 month intervention (1) Intervention group: vitamin D_2 (600,000 IU shot of ergocalciferol, n=70) (2) Placebo group (n=69)	6 month follow-up Neuromuscular function; functional performance; choice reaction time; postural stability; falls; fallers; QOL (SF-36)
Dukas et al, 2005*[99]	RCT (II)	n=378 Older people ≥ 70 years Community dwelling residents Basel, Switzerland CH	36 week intervention (1) Intervention group: vitamin D (1 ug of alfacalcidol, n=191) (2) Placebo group (n=187)	12, 24 and 36 week follow-up Falls; fallers; (results stratified by creatinine clearance levels)
Dukas et al, 2004*[100]	RCT (II)	n=378 Older people Mean age 75 Community dwelling residents Basel, CH	36 week intervention (1) Intervention group: vitamin D (1 ug of alfacalcidol, n=191) (2) Placebo group (n=187)	12, 24 and 36 week follow-up Falls; fallers; (results stratified by total calcium intake)
Gallagher et al, 2001[101]	RCT (II)	n=489 Older women ≥ 65 years Community dwelling residents Omaha, Nebraska, US	3 year intervention (1) Intervention group I: vitamin D (0.50 ug calcitriol, n=123) (2) Intervention group II: hormone replacement therapy or estrogen replacement therapy (HRT/ERT) (n=121) (3) Intervention group III: (0.50 ug calcitriol + HRT/ERT (n=122) (4) Placebo group (n=123)	3 year follow-up BMD; biochemistry; fractures; falls; AEs and side effects
Grant et al, 2005[†] (The RECORD Trial Group)[102]	RCT (II)	n=5,292 Older people ≥ 70 years Community dwelling residents GB	24 to 62 month intervention (1) Intervention group I: vitamin D and calcium (n=1,306) (2) Intervention group II: vitamin D (n=1,343) (3) Intervention group III: calcium (n=1,311) (4) Placebo group (n=1,332)	24 to 62 month mean follow-up Fractures; falls; QOL (EQ-5D); deaths
Harwood et al, 2004*[103]	RCT (II)	n=150 Older women Mean age 81.2 Post-hip fracture surgery patients Orthogeriatric rehabilitation ward setting Nottingham, GB	1 year intervention (1) Intervention group I: injected vitamin D_2 (n=38) (2) Intervention group II: injected vitamin D_2 and calcium (n=36) (3) Intervention group III: oral vitamin D_3 and calcium (n=39) (4) Control group: no treatment (n=37)	1 year follow-up Bone biochemical markers; BMD; falls
Ishida and Kawai, 2004[104]	RCT (II)	n=396 Post-menopausal women, aged 50 to 75, Mean age range 68-71(intervention and control groups) Hospital patients Residency status NR Tsushimi, JP	2 year intervention (1) Intervention group I: hormone replacement therapy (n=66) (2) Intervention group II: etidronate (n=66) (3) Intervention group III: calcitonin (n=66) (4) Intervention group IV: vitamin D (alfacalcidol, n=66) (5) Intervention group V: vitamin K (n=66) (6) Control group: no treatment (n=66)	2 year follow-up BMD; vertebral fractures; new vertebral fractures; bone turnover markers
Latham et al, 2003*[68]	RCT (II) 2x2 factorial design FITNESS	n=222 Older people ≥ 65 years Hospital discharge patients Auckland, NZ Sydney, AU	10 week intervention (1) Intervention group I: home based quadriceps resistance exercise (n=112) (2) Intervention group II: exercise control through telephone calls and home visits by the PT (n=110) (3) Intervention group: vitamin D_3 (calciferol; n=108) (4) Placebo group (n=114)	3 and 6 month follow-up Physical health (SF-36); falls; physical performance; self-rated function

Study	Design	Population	Intervention and control	Outcome measures
Pfeifer et al, 2000*[105]	RCT (II)	n=148 Older women ≥ 70 years Ambulatory, community dwelling residents Bad Pyrmont and Hameln, Lower Saxony, DE	8 week intervention (1) Intervention group: calcium and vitamin D_3 (cholecalciferol, n=74) (2) Intervention group II: calcium monotherapy (n=74)	8 week and 1 year follow-up Intact parathyroid hormone; bone turnover markers; body sway; falls; fractures
Porthouse et al, 2005*[106]	RCT (II)	n=3,314 Older women ≥ 70 years Primary care practice nurse-led clinic patients England, GB	18 month intervention (1) Intervention group: calcium and vitamin D_3 (cholecalciferol, n=1,321) (2) Control group: falls prevention advice (n=1,993)	25 month median follow-up Fractures; treatment adherence; falls; QOL (SF-12 and EuroQol); death; resource use (GP visits and hospital admissions); fear of falling
Prince et al, 2008*[107]	RCT (II)	n=302 Older women Age range 70-90 Community dwelling residents Perth, AU	1 year intervention (1) Intervention group: vitamin D_2 (ergocalciferol) and calcium citrate (n=151) (2) Placebo group: calcium citrate alone (n=151)	1 year follow up Falls
Smith et al, 2007[108]	RCT (II)	n=9,440 Older people ≥ 75 years Community dwelling residents Central Southern England, GB	3 year intervention (1) Intervention group: vitamin D_2 (ergocalciferol) i.m. (n=4,727) (2) Placebo group (n=4,713)	3 year follow-up Fractures; falls
Tilyard et al, 1992†[109]	RCT (II)	n=622 Older women with post-menopausal osteoporosis Mean ages 63.6 (calcitriol) and 63.8 (calcium) Residency status NR NZ	3 year intervention Intervention group I: vitamin D (calcitriol, n=314) Intervention group II: calcium (n=308)	1, 2 and 3 year follow-up New vertebral fractures; biochemical measures

* Studies measuring the primary prevention of falls and/or fractures † Studies measuring the secondary prevention of fractures per se

Table 39: Vitamin D and/or calcium intervention trials: residential aged care (n=4)

Study	Design	Population	Intervention and control	Outcome measures
Bischoff et al, 2003[33]	RCT (II)	n=122 Older women Mean age 85.3 Long stay geriatric care residents CH	12 week intervention (1) Intervention group I: vitamin D_3 (800 IU cholecalciferol tablet) and calcium (1200 mg) (n=62) (2) Intervention group II: calcium (n=60)	3 month follow-up Falls; fallers; strength and functional measures
Broe et al, 2007*[110]	RCT (II)	n=124 Older people Mean age 89 Nursing home residents US	5 month intervention (1) Intervention group I: vitamin D (200IU tablet, n=26) (2) Intervention group II: vitamin D (400IU tablet, n=25) (3) Intervention group III: vitamin D (600 IU tablet, n=25) (4) Intervention group IV: vitamin D (800 IU tablet, n=23) (5) Placebo group (n=25)	5 month follow-up Falls; fallers
Flicker et al, 2005*[111]	RCT (II)	n=625 Older people Mean age 83.4 Hostels and nursing home residents 3 states in AU	2 year intervention (1) Intervention group: vitamin D_2 (10,000 IU ergocalciferol tablet, n=313) (2) Placebo group (n=312)	1 and 2 year follow-up Falls; fractures
Law et al, 2006*[34]	RCT (II)	n=3,717 Older people ≥ 60 years Mean age 85 Residential care home residents GB	3 month treatment intervals (1) Intervention group: vitamin D_2 (2.5 mg ergocalciferol tablet; n=1,762) (2) Control group: no vitamin D_2 (n=1,955)	10 month median follow-up Falls; non-vertebral fractures

Table 40: Home hazard assessment and modification intervention trials: community dwelling (n=8)

Study	Design	Population	Intervention and control	Outcome measures
Campbell et al, 2005[62]	RCT (II) VIP trial	n=391 Older people ≥ 75 years with severe visual impairment Community dwelling residents Dunedin and Auckland, NZ	12 month intervention (1) Intervention group I: home safety assessment and modification program (n=100) (2) Intervention group II: home exercise program and vitamin D supplementation (n=97) (3) Intervention group III: both interventions 1 and 2 (n=98) (4) Control group: social visits (n=96)	12 month follow up Falls; fall related injuries; home safety program implementation costs
Cumming et al, 1999[112]	RCT (II)	n=530 Older people ≥ 65 years Mean age 77 Community dwelling residents Discharged hospital inpatients Sydney, AU	12 month intervention (1) Intervention group: home visit by an OT to assess the home for environmental hazards and facilitate necessary home modifications (n=264) (2) Control group: usual care (n=266)	12 month follow-up Falls
Day et al, 2002[64]	RCT (II)	n=1,107 Older people ≥ 70 years Community dwelling residents Melbourne, AU	Intervention period NR (1) Intervention group I: group-based exercise program of strength and balance (n=135) (2) Intervention group II: home hazard management (n=136) (3) Intervention group III: vision improvement (n=139) (4) Intervention group IV: exercise and vision improvement (n=136); (5) Intervention group V: exercise and home hazard management (n=135) (6) Intervention group VI: vision improvement and home hazard management (n=137) (7) Intervention group VII: exercise, vision improvement and home hazard management (n=135) (8) Control group: no intervention (n=137)	18 month follow-up Falls; time to first fall; changes in targeted risk factors (strength, balance, vision and number of hazards)
Lin et al, 2007[69]	RCT (II)	n=150 Older people ≥ 65 years Community- dwelling residents Taichung county, TW	4 month intervention (1) Intervention group I: falls prevention education (n=50) (2) Intervention group II: home safety assessment and modification (n=50) (3) Intervention group III: home based training program (n=50)	2, 4 and 6 month follow-up QOL; function balance and gait; fear of falling; depression; falls (6 month follow-up)
Nikolaus and Bach, 2003[113]	RCT (II) Home Intervention Team (HIT) trial	n=360 Frail older people Mean age 81.5 Community dwelling residents Geriatric clinic inpatients with home-based intervention Southern DE	Intervention period NR (1) Intervention group: comprehensive geriatric assessment (CGA) and diagnostic home visit by the HIT, n=181) (2) Control group: CGA and usual care, no HIT (n=179)	1 year follow-up Falls; fall-related injuries; home modification type; compliance
Pardessus et al, 2002[114]	RCT (II)	n=60 Older people ≥ 65 years Mean age 83.5 Community dwelling residents Geriatric hospital inpatients with home-based intervention Lille, France (FR)	Intervention period NR (1) Intervention group: home visit by an OT and ergotherapist to assess environmental hazards and recommend modifications (n=30) (2) Control group: no intervention (n=30)	12 month follow-up Falls; autonomy; hospitalisation for falling; institutionalisation; deaths
Peel et al, 2000[115] (see Steinberg et al, 2000)[85]	RCT (II)	n=252 (year 1) n=243 (year 2) Older people Mean age 69 Community dwelling residents Brisbane, AU	Intervention period NR (1) Intervention group: home assessment group (n=99) (2) Control group: no home assessment (n=96)	1 and 2 year follow-up Falls; treatable injurious falls
Stevens et al, 2001[116]	RCT (II)	n=1,737 Older people ≥ 70 years Community dwelling residents Perth, AU	Intervention period NR (1) Intervention group: home visit by a nurse to include home hazard assessment, installation of free safety devices and education (n=570) (2) Control group: no intervention (n=1,167)	1 year follow-up Falls

Table 41: Hip protectors intervention trials: community dwelling (n=3)

Study	Design	Population	Intervention and control	Outcome measures
Birks et al, 2004[117]	RCT (II)	n=4,169 Older women ≥ 70 years Community dwelling raesidents Aberdeen, Hertfordshire, Newcastle, North Cumbria and York, GB	12 month intervention (1) Intervention group: hip protectors (n=1,388) (2) Control group: information leaflet only (n=2,781)	28 month median follow-up (range, 24 to 42 months) Compliance; hip fractures; non-hip fractures; falls
Cameron et al, 2003[28]	RCT (II)	n=600 Older women ≥ 74 years Community dwelling residents NSW, AU	2 year intervention (1) Intervention group: hip protectors and contact with an 'adherence' nurse (n=302) (2) Control group: no intervention (n=298)	2 year follow-up Hip protector adherence; falls; hip fractures and other injuries; adverse events
Kannus et al, 2000[118]	RCT (II)	n=1,801 Older people ≥ 70 years Community dwelling residents Southern and central FI	18 month intervention (1) Intervention group: hip protectors (n=653) (2) Control group: no intervention (n=1,148)	18 month follow-up Fractures; falls

Table 42: Hip protectors intervention trials: residential aged care (n=3)

Study	Design	Population	Intervention and control	Outcome measures
Cameron et al, 2001[119]	RCT (II)	n=174 Older women ≥ 75 years Hostel and nursing home residents NSW, AU	18 month intervention (1) Intervention group: external hip protectors (n=86) (2) Control group: no intervention (n=88)	2 week and 2, 10 and 18 month follow - up Falls; fall injuries; hip protector use and adherence
Harada et al, 2001[120]	RCT (II)	n=164 Older women Mean age 83.2 Nursing home residents JP	1 and 2 year intervention (1) Intervention group: hip protectors (n=88) (2) Control group: no hip protectors (n=76)	377 day mean follow-up Compliance; anthropometric measurement; ultrasonic bone assessment; falls; hip fractures
Meyer et al, 2003[121]	RCT (II)	n = 733 Older people ≥ 70 years Nursing home residents Hamburg, DE	18 month intervention (1) Intervention group: external hip protectors plus information session (n=459) (2) Control group: usual care and information on hip protectors (n=483)	15 month mean follow up – intervention 14 month mean follow up - control Hip fractures; other fractures; falls; hospital admissions; hip protector use and adherence

Table 43: Clinical medication review intervention trials: community dwelling (n=4)

Study	Design	Population	Intervention and control	Outcome measures
Meredith et al, 2002[122]	RCT (II)	n=259 Older people ≥ 65 years Community dwelling residents US	(1) Intervention group: medication improvement program (n=130) (2) Control group: usual care (n=129)	Between 6 and 12 week follow-up Improvement in medication use; falls
Pit et al, 2007[123]	RCT (II)	n=849 Older people ≥ 65 years Community dwelling residents Hunter region NSW, AU	(1) Intervention group: provision of prescribing information/feedback information, medication risk assessment, facilitation of medication review, and doctor financial incentives (n=452) (2) Control group: no intervention (n=397)	4 and 12 month follow-up Medication use; use of medication reviews; falls; QOL (SF-12, EQ-5D)
Weber et al, 2008[124]	RCT (II)	n=620 Older people ≥ 70 years Community dwelling residents Central and North-eastern Pennsylvania, US	15 month intervention (1) Intervention group: electronic medical record based clinical medication review intervention (n=413) (2) Control group: usual care (n=207)	1, 3, 6, 9, 12, 15 month follow up Medication use; intervention medical costs; falls
Zermansky et al, 2006[35]	RCT (II)	n=661 Older people ≥ 65 years Elderly care home residents (nursing, residential and mixed) Leeds, GB	28 day intervention (1) Intervention group: clinical medicine review (n=331) (2) Control group: usual care (n=330)	6 month follow-up Primary: number of changes in medication per patient; Secondary: number and cost of repeat, medicines per participant, medication review rate, mortality, falls, hospital admissions, GP consultations, Barthel index, standardised MMSE

Table 44: Clinical medication review intervention trials: residential aged care (n=3)

Study	Design	Population	Intervention and control	Outcome measures
Crotty et al, 2004[125]	RCT (II)	n=110 Older people Mean age 82.7 Hospital discharge patients Long-term care facility residents Adelaide, AU	28 day intervention (1) Intervention group: 'pharmacist transition coordinator' services including medication management transfer summaries from hospitals, timely coordinated medication reviews by accredited community pharmacists, and case conferences with physicians and pharmacists (n=56) (2) Control group: usual care (usual hospital discharge process, n=54)	8 week follow-up Quality of prescribing; A&E visits; hospital readmissions; adverse drug events; falls; worsening mobility; worsening behaviours; increased confusion; worsening pain
Crotty et al, 2004a[126]	RCT (II) Strokes And Falls In Residential care Evaluation (SAFIRE) project	n=715 Older people Mean ages 83.4 (control) and 84.7 (intervention) Hostel and nursing home residents Adelaide, AU	Intervention period NR (1) Intervention group: outreach visits program conducted by a pharmacist targeting falls reduction and stroke prevention (n=381) (2) Control group: no intervention (n=334)	3, 7 and 12 month follow-up Falls; injurious falls; fall risk; use of psychotropic medications
Zermansky et al, 2006[35]	RCT (II)	n=661 Older people ≥ 65 years Elderly care home residents (nursing, residential and mixed) Leeds, GB	28 day intervention (1) Intervention group: clinical medicine review (n=331) (2) Control group: usual care (n=330)	6 month follow-up Primary: number of changes in medication per patient; Secondary: number and cost of repeat, medicines per participant, medication review rate, mortality, falls, hospital admissions, GP consultations, Barthel index, standardised MMSE

Table 45: Psychotropic medication withdrawal intervention trials: community dwelling (n=1)

Study	Design	Population	Intervention and control	Outcome measures
Campbell et al, 1999[127]	RCT (II)	n=93 Older people ≥ 65 years Community dwelling residents GP (n=17) Dunedin, NZ	14 week intervention (1) Intervention group I: psychotropic medication withdrawal and exercise program (n=24) (2) Intervention group II: psychotropic medication withdrawal and no exercise program (n=24) (3) Intervention group III: original medication and exercise program (n=21) (4) Control group: original medication and no exercise program (n=24)	44 week follow-up Falls

Table 46: Expedited cataract surgery intervention trials: community dwelling (n=2)

Study	Design	Population	Intervention and control	Outcome measures
Foss et al, 2006[31]	RCT (II)	n=239 Older women ≥ 70 years Hospital ophthalmology department patients Nottingham, GB	1 month intervention (1) Intervention group: expedited second eye cataract surgery (4 weeks, n=120) (2) Control group: 'waiting list' group, routine surgery (12 months, n=119)	3, 6, 9 and 12 month follow-up Falls; visual function; visual disability; handicap; confidence
Harwood et al, 2005[30]	RCT (II)	n=306 Older women ≥ 70 years Consultant ophthalmologist or cataract clinic patients Nottingham, GB	1 month intervention (1) Intervention group: expedited first eye cataract surgery (4 weeks, n=154) (2) Control group: routine surgery (12 months, n=152)	3, 6, 9 and 12 month follow-up Falls; visual function; activity anxiety; depression; confidence; visual disability; handicap

Table 47: Vision and eye examination intervention trials: community dwelling (n=1)

Study	Design	Population	Intervention and control	Outcome measures
Cumming et al, 2007[29]	RCT (II)	n=616 Frail older people ≥ 70 years Community dwelling residents Sydney, AU	Intervention period NR (1) Intervention group: comprehensive vision and eye examinations by an optometrist (n=309) (2) Control group: usual care (n=307)	12 month follow-up Falls; fractures

Table 48: Cardiac pacing intervention trials: community dwelling (n=1)

Study	Design	Population	Intervention and control	Outcome measures
Kenny et al, 20011[28]	RCT (II) SAFE PACE	n=175 Older people with carotid sinus hypersensitivity Mean age 73 A&E department attendees Newcastle-upon-Tyne, GB	Intervention period NR (1) Intervention group: dual-chamber pace-maker, 'pacing' group (n=87) (2) Control group: no pacing intervention (n=88)	12 month follow-up Falls; syncope events; injurious events

Table 49: Falls prevention education intervention trials: community dwelling (n=4)

Study	Design	Population	Intervention and control	Outcome measures
Kerse et al, 2005[129]	RCT (II)	n=270 Older people ≥ 65 years Primary care practices Community dwelling residents Waikato, NZ	3 month intervention (1)Intervention group: 'Green Prescription' physical activity counselling program (n=130) (2) Control group: usual care (n=140)	12 month follow-up Physical activity; energy expenditure; systolic and diastolic blood pressure; HRQL (SF-36); musculoskeletal injuries; falls; hospitalisations
Lord et al, 2005[130]	RCT (II)	n=620 Older people ≥ 75 years Community dwelling residents Hospital falls clinic patients Sydney, AU	12 month intervention (1) Intervention group I: extensive intervention comprising a PPA report outlining falls risk, with specific recommendations and interventions to prevent falls (n=210) (2) Intervention group II: minimal intervention through brief advice (n=206) (3) Control group: no intervention (n=204)	6 and 12 month follow-up Falls; physical functioning; vision
Robson et al, 2003[131]	RCT (II)	n=660 Older people > 65 years Community dwelling residents Edmonton, Alberta, CA	4 month intervention (1) Intervention group: multifactorial program 'Steady as you go' (SAYGO) given as two 90 minute group sessions held 1 month apart (n=235). (2) Control group: no program activities. Falls monitored for 4 months and client called who fell. SAYGO program given to control group after 4 month follow up period (n=236).	1 month and 4 month follow-up Falls; risk of falling
Ryan and Spellbring, 1996[132]	RCT (II)	n=45 Older women Mean age 78 Community dwelling residents US	(1) Intervention group I: group based falls prevention program (n=16) (2) Intervention group II: one-on-one falls prevention program delivered by a nurse (n=14) (3) Control group: health promotion presentation, no falls prevention information (n=15)	3 month post-intervention follow-up Falls

Table 50: Multiple intervention trials: community dwelling (n=9)

Study	Design	Population	Intervention and control	Outcome measures
Assantachai et al, 2002[133]	RCT (II)	n=1043 Older people Urban area community–dwelling residents Bangkok, TH	12 month intervention (1)Intervention group: leaflet identifying risk factors for falls and appropriate way to modify, correct or cope and assessment to geriatric clinic at a hospital (n=585) (2)Control group: Postcard asking about falls and a telephone call if postcard not returned (n=458)	1 year follow up Fallers
Campbell et al, 2005[62]	RCT (II) VIP trial	n=391 Older people ≥ 75 years with severe VIP Community dwelling residents Dunedin and Auckland, NZ	12 month intervention (1) Intervention group I: home safety assessment and modification program (n=100) (2) Intervention group II: home exercise program and vitamin D supplementation (n=97) (3) Intervention group III: both interventions 1 and 2 (n=98) (4) Control group: social visits (n=96)	1 year follow up Falls; fall-related injuries; home safety program implementation costs
Clemson et al, 2004[134]	RCT (II)	n=310 Older people ≥ 70 years Community dwelling residents Sydney, AU	14 month intervention (1)Intervention group: 'Stepping On' multi-faceted, community based group program involving lower limb balance and strength, home and community environmental and behavioural safety, encouraging regular visual screening, making adaptations to low vision, and encouraging medication review (n=157) (2) Control group: social visits (n=153)	14 month follow-up Falls
Day et al, 2002[64]	RCT (II)	n=1,107 Older people ≥ 70 years Community dwelling residents Melbourne, AU	Intervention period NR (1) Intervention group I: group based exercise program of strength and balance (n=135) (2) Intervention group II: home hazard management (n=136) (3) Intervention group III: vision improvement (n=139) (4) Intervention group IV: exercise and vision improvement (n=136); (5) Intervention group V: exercise and home hazard management (n=135) (6) Intervention group VI: vision improvement and home hazard management (n=137) (7) Intervention group VII: exercise, vision improvement and home hazard management (n=135) (8) Control group: no intervention (n=137)	18 month follow-up Falls; time to first fall; changes in targeted risk factors (strength, balance, vision and number of hazards)
Hill et al, 2000[135]	RCT (II)	n=100 Older people Mean age 78.5 Nurse-led falls assessment clinic setting Community dwelling residents GB	3 month intervention (1) Intervention group: daily exercise and individualised falls prevention advice (n=40) (2) Control group: standard falls prevention advice (n=38)	6 month follow-up Falls; mobility; ADL
Reinsch et al, 1992[78]	RCT (II)	n=230 Older people ≥ 60 years Mean ages 74.1 (intervention) and 74.2 (control) Community dwelling residents Orange and Los Angeles counties, US	1 year intervention (1) Intervention group I: 'Senior Body Program' consisting of ≥ 1 health and fitness evaluation, exercise information, accident and fall prevention information, and healthy living discussions (n=57) (2) Intervention group II: cognitive behavioural intervention (n=51) (3) Intervention group III: exercise-cognitive intervention (n=72) (2) Control group: discussion control group (n=50)	12 month follow-up Falls; fallers; time to first fall; injury severity; musculoskeletal function; cognitive measures
Shumway-Cook et al, 2007[136]	RCT (II)	n=453 Older people ≥ 65 years Community dwelling residents Washington, US	12 month intervention (1) Intervention group: multifactorial intervention involving group exercise, fall prevention education and falls risk assessment (n=226) (2) Control group: written material on falls prevention (n=227)	12 month follow-up Falls; leg strength; balance; mobility

Study	Design	Population	Intervention and control	Outcome measures
Steinberg et al, 2000[85]	RCT (II)	n=252 (year 1) n=243 (year 2) Older people ≥ 50 years Mean age 69 Community dwelling residents Brisbane, AU	2 year intervention (1) Intervention group I: information session only (control group; n=63) (2) Intervention group II: information and exercise sessions (n=69) (3) Intervention group III: information and exercise sessions, and home safety assessment (n=61) (4) Intervention group IV: information and exercise sessions, home safety assessment and clinical assessment/medical risk factor advice (n=59)	1 and 2 year follow-up Slips; trips; falls
Swanenburg et al, 2007[137]	RCT(II)	n=24 Independently living elderly females ≥65 years Mean age 71 Zurich, CH	3 month intervention (1) Intervention: Exercise training (balance, endurance, strength), protein supplement, Calcium and Vitamin D (n=12) (2) Calcium and Vitamin D (n=12)	12 month follow-up Falls

Table 51: Multiple intervention trials: residential aged care (n=3)

Study	Design	Population	Intervention and control	Outcome measures
Becker et al, 2003[21]	RCT (II)	n=981 Older people Mean age 85 Nursing home residents DE	12 month intervention (1) Intervention group: staff and resident education on falls prevention, advice on environmental adaptations, progressive balance and resistance training, and hip protectors (n=509) (2) Control group (n=472)	12 month follow-up Falls; fallers; fractures
Evans et al, 1997[138]	RCT (II)	n=643 Older people ≥ 60 years Mean ages 83.6 (intervention) and 83.8 (control) Nursing home residents Philadelphia, US	6 month intervention (1) Intervention group I: restraint education by gerontologic nurse specialist (GNS) to increase staff awareness of restraint hazards and knowledge of assessing and managing resident behaviours (n=184) (2) Intervention group II: restraint education with GNS consultation 12 hours per week to discuss 'clinically challenging' resident behaviour (n=127) (3) Control group (n=184)	6, 9 and 12 month post-trial follow-up Restraint status; staff levels; psychoactive drug use; falls; serious injuries
Schnelle et al, 2003[139]	RCT (II)	n=190 Older people with incontinence Mean ages 87.3 (intervention) and 88.6 (control) Long-stay nursing home residents Los Angeles, US	8 month intervention (1) Intervention group: 'FIT intervention' consisting of low-intensity exercise and incontinence care (n=92) (2) Control group: usual care (n=98)	8 month follow-up Functional outcomes; acute conditions (including falls and injuries); costs

Table 52: Multi-factorial intervention trials: community dwelling (n=28)

Study	Design	Population	Intervention and control	Outcome measures
Carpenter and Demopoulos, 1990[140]	RCT (II)	n=539 Older people ≥ 75 years Community dwelling residents Andover, GB	3 year intervention (1) Intervention group: regular, at-home, surveillance of activities of daily living and referral to GP where appropriate (n=272) (2) Control group: pre and post-intervention visits (n=267)	39 month follow-up Mortality; ADL; number of institutionalisation days; resource use; falls
Close et al, 1999[141]	RCT (II) Prevention of falls in the elderly trial (PROFET)	n=397 Older people ≥ 65 years Community dwelling residents A&E attendees GB	Intervention period NR (1) Intervention group: bi-disciplinary medical patient assessment and OT assessment via home visit, with referral to relevant services if indicated (n=184) (2) Control group: usual care (n=213)	12 month follow-up Falls; death; major injury; institutionalisation; functional status; resource utilisation
Coleman et al, 1999[142]	RCT (II)	n=169 Older people ≥ 65 years Primary care practice patients Seattle, Washington, US	Intervention period NR (1) Intervention group: half-day 'Chronic Care Clinics' consisting of an extended (30 minute) visit by a physician and nurse dedicated to planning chronic disease management, a pharmacist visit emphasising reduction of polypharmacy and high-risk medication, and a patient self-management/ support group (n=96) (2) Control group: usual care (n=73)	24 month follow-up Urinary incontinence; falls; depressive symptoms; physical function; satisfaction

Study	Design	Population	Intervention and control	Outcome measures
Davison et al, 2005[143]	RCT (II)	n=313 Older people ≥ 65 years A&E department attendees Newcastle, North Tyneside and Gateshead, GB	1 year intervention (1) Intervention group: multifactorial (medical, physiotherapy and OT) post-fall assessment and intervention (n=159) (2) Control group: conventional care (n=154)	1 year follow-up Falls; fallers; injury rates; fall related A&E attendances; fall related hospital admissions; mortality; fear of falling
Elley et al, 2008[144]	RCT (II)	n=312 Older people ≥ 75 years Community dwelling residents Wellington, NZ	(1) Intervention group: home based nurse assessment of falls/fracture related risk factors and home hazards, referral to community interventions, and strength + balance exercise program (n=155) (2) Control group: social visits (n=157)	1 year follow-up Falls; muscle strength; balance; fear of falling; QOL (SF-36)
Fabacher et al, 1994[145]	RCT (II)	n=254 Older people ≥ 70 years Community dwelling residents Los Angeles, US	Intervention period NR (1) Intervention group: home visit by a physician's assistant to screen for medical, functional and psychological problems and GP recommendations made where appropriate (n=131) (2) Control group: follow-up telephone interviews to collect outcomes data only (n=123)	1 year follow-up Compliance with recommendations; mortality; medication usage; functional status; immunisation rates; nursing home and hospital utilisation; falls
Gallagher and Brunt, 1996[146]	RCT (II)	n=100 Older people ≥ 60 years Mean ages 73.8 (control) and 75.4 (intervention) Community dwelling residents Victoria, British Colombia, CA	Intervention period NR (1) Intervention group: comprehensive falls risk assessment, individualised feedback and counselling, and a video/print educational package (n=50) (2) Control group: no intervention (n=50)	6 month follow-up Falls; fear of falling; self-efficacy; social function; health services; QOL
Gill et al, 2002[147]	RCT (II)	n=188 Older people ≥ 75 years Community dwelling residents Connecticut, US	6 month intervention (1) Intervention group: home-based intervention program including a PT assessment for potential impairments in physical abilities and a home environment assessment (n=94) (2) Control group: educational program designed to provide attention and health education (n=94)	3, 7 and 12 month follow-up Disability scores; admission to nursing home; days spent in nursing home; falls and fall-related fractures (reported as adverse events)
Hendrks et al. 2008[148]	RCT (II)	n=333 Older people ≥ 65 years Community dwelling residents A&E attendees NL	12 month intervention (1) Intervention group: medical and OT assessment to evaluate and address risk factors for recurrent falls, followed by recommendations and referral if indicated (n=166) (2) Control group: usual care (n=167)	4 and 12 month follow-up Falls; Injurious falls; daily functioning; recuperation from the index fall; health complaints; perceived health (SF-36); ADL; instrumental ADL disability; mental health; fear of falling; activity avoidance; social participation; QOL
Hogan et al, 2001[149]	RCT (II)	n=163 Older people ≥ 65 years Ambulatory, community dwelling residents Calgary, CA	Intervention period NR (1) Intervention group I: in-home assessment, an individualised treatment plan and exercise (n=84) (2) Control group: usual care (n=84)	1 year follow-up Falls; A&E visits; hospital admissions
Hornbrook et al, 1994[150]	RCT (II) SAFE	n=3,185 Older people ≥ 65 years Community dwelling residents Kaiser Permanente's Northwest Region HMO Portland, Oregon/Vancouver, Washington metropolitan areas	Intervention period NR (1) Intervention group: comprehensive falls intervention model targeting intrinsic/extrinsic risk factors (removal of home falls hazards, reducing risk-taking behaviours, improving fitness through exercise intervention group, n=1,611) (2) Control group: minimum treatment through a consumer safety booklet and information about potential safety hazards in the home, with no repair advice given (n=1,571)	2 year follow-up Falls; fall-related fractures; fall-related medical care; fall-related hospitalisations

Study	Design	Population	Intervention and control	Outcome measures
Huang and Acton, 2004[151]	RCT (II)	n=120 Older people ≥ 65 years Community dwelling residents Northwest TW	4 month intervention (1) Intervention group: multifactorial program based on individualised risk assessment (environmental hazards + medications) and standardised + individualised falls prevention teaching (n=60) (2) Control group: standardised falls prevention information (n=60)	4 month follow-up 2 month post-intervention follow-up (falls incidence) Knowledge of medication safety; environmental hazards; falls self-efficacy; falls
Huang and Liang, 2005[152]	RCT(II)	n=126 Hip fracture patients > 65 years TW	3 month intervention (1)Intervention: individualised discharge plan with home nurse visit, telephone support, brochures, monitoring progress and collaboration with physicians (2)Control: routine hospital discharge planning	3 month follow-up Falls; length of hospital stay; rate of readmission
Jitapunkul, 1998[153]	RCT (II)	n=142 Older people ≥ 70 years Community dwelling residents Bangkok, TH	3 year intervention (1) Intervention group: home visiting program involving screening, nurse/geriatrician assessment, referral and appropriate management (n=70) (2) Control group (n=72)	3 year follow-up Falls; resource use
Lightbody et al, 2002[154]	RCT (II)	n=348 Older people ≥ 65 years Community dwelling residents A&E attendees Liverpool, GB	4 week intervention (1) Intervention group: nurse-led falls prevention program including a home visit to assess risk factors: medication, ECG, blood pressure, cognition, visual acuity, hearing, vestibular dysfunction, balance, mobility, feet and footwear; and make subsequent referral (n=171) (2) Control group: advice and education about general home safety (n=177)	6 month follow-up Further falls; functional ability; A&E re-attendances; resource use
Lord et al, 2005[130]	RCT (II)	n=620 Older people ≥ 75 years Community dwelling residents Hospital falls clinic patients Sydney, AU	12 month intervention (1) Intervention group I: extensive intervention comprising a PPA report outlining falls risk, with specific recommendations and interventions to prevent falls (n=210) (2) Intervention group II: minimal intervention through brief advice (n=206) (3) Control group: no intervention (n=204)	6 and 12 month follow-up Falls; physical functioning; vision
Mahoney et al, 2007[155]	RCT (II)	n=349 Older people ≥ 65 years Community dwelling residents Kenosha country, Wisconsin, US	2 year intervention (1) Intervention group: multifactorial intervention with in-home multifactorial risk assessment, referrals for physical therapy, follow up calls and a balance exercise plan (n=174) (2) Control group: in-home safety assessment visit by an OT, limited to home safety recommendations and advice to see their doctor about falls (n=175)	2 year follow-up Falls; hospitalisations; hospital days; nursing home admissions; depression and functional status
McMurdo et al, 2000[156]	RCT (II)	n=133 Older people Mean age 84 Community dwelling residents Dundee, GB	6 month intervention (1) Intervention group: falls risk factor assessment and modification, and seated balance exercise training (n=77) (2) Control group: reminiscence therapy (n=56)	7 to 12 month follow-up (falls and fractures) 6 month follow up (fall risk factors and functional measures) Falls; fractures; fall risk factors; functional measures
Newbury et al, 2001[157]	RCT (II)	n=100 Older people ≥ 75 years Community dwelling residents Adelaide, AU	Intervention period NR (1) Intervention group: health assessment (HA) using the 75+HA and SF-36 instruments, with problems identified and reported to a GP (n=50) (2) Control group: SF-36 and usual care (n=50)	1 year follow-up Problems; mortality; physical function; psychological function and geriatric depression scale; falls; admission to institution
Rubenstein et al, 2007[158]	RCT (II)	n=792 Older people ≥ 65 years Community dwelling residents Los Angeles, US	Intervention period NR (1) Intervention group: structured telephone geriatric assessment, individualised referrals and recommendations (n=380) (2) Control group: no intervention (n=412)	1, 2 and 3 year follow-up Target conditions (falls, depression, cognitive impairment, functional impairment and urinary incontinence); health perceptions (SF-36); functional status; hospitalisation

Study	Design	Population	Intervention and control	Outcome measures
Schrijnemaekers and Haveman, 1995[159]	RCT (II)	n=222 Older people > 75 Community dwelling residents (65%) Residential home (35%) Sittard, NL	Intervention period NR (1) Intervention group: outpatient geriatric unit who observe, assess, evaluate and advise both GP and patient concerning treatment and support (n=110) (2) Control group: not invited to visit the outpatient geriatric unit but could apply for and use all regular services as before (n=112)	6 month follow-up Falls; mortality; physical limitations
Spice et al, 2008[160]	RCT (II)	n=505 Older people ≥ 65 years Community dwelling residents Mid Hampshire, GB	Mean duration assessment and referral time: 71 minute (intervention group I) and 121 minute (intervention group II) (1) Intervention group I: primary care group receiving nurse-led assessment and community referral (n=136) (2) Intervention group II: secondary care group attending a day-hospital 'one-stop' multi-disciplinary clinic for assessment, with referral for investigations, followed by the appropriate interventions (n=210) (3) Control group: usual care (n=159)	1 year follow-up Falls; fractures; fall-related hospitalisation; institutionalisation; mortality
Tinetti et al, 1994[161]	RCT (II) Yale FICSIT trial	n=301 Older people ≥ 70 years Community dwelling residents HMO enrolees Southern Connecticut, US	Intervention period NR (1) Intervention group: individualised multiple risk factor abatement intervention strategy through medication adjustment, behavioural instructions and exercise programs (n=153) (2) Control group: usual care and social visits (n=148)	1 year follow-up Falls; cost effectiveness (cost per fall prevented)
van Haastregt et al, 2000[162]	RCT (II)	n=316 Older people ≥ 70 years Community dwelling residents Hoensbroek, NL	12 month intervention (1) Intervention group: multifactorial home visits by a community nurse involving screening for medical, environmental and behavioural factors, advice and recommendations (n=159) (2) Control group: usual care, no intervention (n=157)	18 month follow-up Falls; mobility impairments
Vetter et al, 1992[163]	RCT (II)	n=863 Older people ≥ 70 years GP patients Community dwelling residents GB	4 year intervention (1) Intervention group: 'Health visitor' employed to perform household visits, patient assessment and correction of risk factors targeting 4 areas: nutrition, medical conditions, environment and fitness/muscle tone (n=350) (2) Control group: no intervention (n=324)	4 year intervention Fractures; falls
Wagner et al, 1994[164]	RCT (II)	n=1,559 Older people ≥ 65 years Ambulatory HMO enrolees Western Washington, US	Intervention period NR (1) Intervention group I: nurse assessment visit and follow up interventions targeting risk factors for disability and falls (n=635) (2) Intervention group II: general health promotion nurse visit (n=317) (3) Control group: usual care (n=607)	12 and 24 month follow-up Disability days; physical function; falls; hospitalisations
Whitehead et al, 2003[165]	RCT (II)	n=123 Older people ≥ 65 years Community dwelling and low care residential care (ie hostel accommodation) residents A&E fall-related attendance Adelaide, AU	22 week intervention (1) Intervention group: falls risk assessment and writing of an individualised evidence-based prescription by a GP (n=58) (2) Control group: usual care (n=65)	6 month follow-up Intervention uptake; self-reported fall rate
Wyman et al, 2005 (published abstract)[166]	RCT(II)	n=272 Older women < 70 years Community dwelling Mean age 79 Minnesota, US	12 week intervention (1) Intervention: Walking with weighted balance, coordination exercises, education and risk reduction counselling (2) Control: health education *numbers for each group not given, assumed equal split	1 year follow-up Falls

Table 53: Multi-factorial intervention trials: residential aged care (n=9)

Study	Design	Population	Intervention and control	Outcome measures
Dyer et al, 2004[167]	RCT (II)	n=196 Older people ≥ 60 years Mean ages 87.2 (intervention) and 87.4 (control) Residential care residents Western Wiltshire, GB	3 month intervention (1) Intervention group: multifactorial falls prevention program including gait and balance training, staff education, environmental modification, medication review, podiatry and optometry (n=102) (2) Control group: no intervention (n=94)	1 year follow-up Falls; recurrent falls per person; number of medications per person; gait and balance
Jensen et al, 2003[168]	RCT (II)	n=378 Older people ≥ 65 years Aged care facility residents High versus low levels of cognition subgroup Umeå, SE	11 week intervention (1) Intervention group: multifactorial program comprising staff education, environmental adjustment, exercise, drug review, aids, hip protectors and post-fall problem-solving conferences (n=186) (2) Control group: usual care (n=192)	34 week follow-up Falls; fall-related injuries
Jensen et al, 2002[169]	RCT (II)	n=402 Older people ≥ 65 years RACF residents Umeå, SE	11 week intervention (1) Intervention group: multi-disciplinary program comprising educating staff, modifying the environment, exercise, supplying and repairing aids, reviewing drug regimens, free hip protectors, post-fall problem solving conferences and guiding staff (n=194) (2) Control group: usual care (n=208)	34 week follow-up Falls; fall-related injuries
Kerse et al, 2004[170]	RCT (II)	n=547 Older people Mean ages 83.0 (intervention) and 83.6 (control) Residential care residents Auckland, NZ	Intervention period NR (1) Intervention group: falls prevention program using a systematic individualised falls risk assessment, high risk logo and referral to services to address identified risks (n=309) (2) Control group: usual care and participated in falls surveillance (n=238)	12 month follow-up Fallers; falls; injurious falls
Rapp et al, 2008[171]	RCT (II)	n=725 Older people Median age 86 Long-stay residents Ulm, DE	12 month intervention (1) Intervention group: staff and resident fall prevention education, environmental regulations advice, recommendations to wear hip protectors, and progressive balance and resistance training (n=143) (2) Control group: no intervention (n=189)	12 month follow-up Time to first fall; falls
Ray et al, 1997[172]	RCT (II)	n=482 Older people ≥ 65 years Nursing home residents Tennessee, US	Intervention period NR (1) Intervention group: falls consultation service, an intensive multifactorial intervention involving individual safety assessment and treatment planning, environmental and personal safety, wheelchairs, psychotropic drugs, transferring and ambulation, facility interventions and compliance with recommendations and facility-wide interventions (n=221) (2) Control group: no program activities (n=261)	12 month follow-up Falls; recurrent fallers
Rubenstein et al, 1990[173]	RCT (II)	n=160 Older people Mean age 87 Long-term care residents Los Angeles, US	3 week (average) intervention (1) Intervention group: comprehensive post-fall assessment including physical examination, environmental assessment, and GP referral (n=79) (2) Control group: usual care (n=81)	2 year follow-up Hospitalisations; hospital days; mortality; falls
Shaw et al, 2003[174]	RCT (II)	n=274 Older people ≥ 65 years with cognitive impairment and dementia Hospital A&E attendees Newcastle-upon-Tyne, GB	Intervention period NR (1) Intervention group: multifactorial risk assessment program including medical, cardiovascular and physiotherapy patient assessments (n=130) (2) Control group: conventional care (n=144)	1 year follow-up Number of fallers; falls; time to first fall; injury rates; fall-related A&E attendances; fall-related admissions; mortality
Whitehead et al, 2003[165]	RCT (II)	n=123 Older people ≥ 65 years Community dwelling and low care residential care (ie hostel accommodation) residents A&E fall-related attendance Adelaide, AU	22 week intervention (1) Intervention group: falls risk assessment and writing of an individualised evidence-based prescription by a GP (n=58) (2) Control group: usual care (n=65)	6 month follow-up Intervention uptake; self-reported fall rate

Appendix D

Excluded studies at Level II full text review (n=102)

Study	Reasons for exclusion
Ashburn et al, 2007[175]	Non Relevant subgroup (Parkinson's disease)
Avenell et al, 2004[176]	Methods study (comparison of RCT methods)
Becker et al, 2003[21]	Methods study (development of a screening algorithm)
Bogaerts et al, 2007[177]	Falls not an outcome measure
Brown, 2002[178]	PhD Thesis - No falls data
Bruyere et al, 2005[179]	Falls not an outcome measure
Cameron et al, 2000[180]	Falls not an outcome measure
Campbell et al, 1999[16]	Extension of Campbell 1997 paper
Cerny et al, 1998[181]	Falls not an outcome measure
Chapuy et al, 2002[182]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Chen et al, 2005[183]	Not a RCT or pseudo-RCT (prospective cohort study)
Choi et al, 2005[184]	Quasi-experimental trial design with non-equivalent control group
Ciaschini et al, 2008[185]	Study protocol
Cornillon et al, 2002[186]	Not English language paper
Crotty et al, 2002[187]	Comparison of intervention settings (home versus hospital), rather than intervention types
Cumming et al, 2008[188]	Inpatient hospital setting
Dawson-Hughes et al, 1997[189]	Falls (or new fractures) not an outcome measure
Delbaere et al, 2008[40]	Methods study (development and validation of fall risk screening tool)
Di Monaco et al, 2008[190]	Inpatient population
Diener and Mitchell, 2005[191]	Not a RCT or pseudo-RCT (non randomised, comparative study)
Donald et al, 2000[192]	Inpatient hospital setting
Ekman et al, 1997[193]	Not a RCT or pseudo-RCT
El-Faizy and Reinsch, 1994[194]	Not a RCT or pseudo-RCT (descriptive study)
Fiatarone et al, 1997[195]	No falls data
Fleming et al, 2008[196]	Not a RCT or pseudo-RCT (cohort study)
Fletcher, 1998[197]	Non systematic review
Freiberger et al, 2007[198]	Not a RCT or pseudo-RCT (non randomised, comparative study)
Gorai et al, 1999[199]	Falls not an outcome measure
Graafmans et al, 2003[200]	Not a RCT or pseudo-RCT (cross-sectional study)
Graafmans et al, 1996[201]	Trial data collected prior to 1990 (1989-1994)
Green et al, 2002[202]	Non relevant subgroup stroke patients)
Greenspan et al, 2005[203]	Hormone replacement therapy not an intervention in our analysis
Gray-Donald et al, 1995[204]	Nutritional Supplement not an intervention in our analysis
Hakim et al, 2007[205]	Falls not an outcome measure
Haumschild et al, 2003[206]	Not a RCT or pseudo-RCT (retrospective observational study)

Study	Reasons for exclusion
Hendriks et al, 2005[207]	Study protocol
Holland et al, 2005[208]	Falls not an outcome measure
Inokuchi et al, 2007[209]	Not a RCT or pseudo-RCT (non randomised, multi-centre controlled trial)
Kato et al, 2006[210]	Not a RCT or pseudo-RCT (non randomised, quasi-experimental study)
Kenny, 1999[211]	Study protocol
Kiely et al, 1998[212]	Methods study (development of a fall risk model)
Kingston et al, 2002[213]	Falls not an outcome measure
Komulainen et al, 1998[214]	Mean age <65 years
Lannin et al, 2007[215]	Trial participants <20
Larsen et al, 2004[216]	Population-based study
Larsen et al, 2005[217]	Population-based study
Lauritzen et al, 1993[218]	Data collection prior to 1990
Lips et al, 1996[219]	Falls (or new fractures) not an outcome measure
Madureira et al, 2007[220]	Non relevant country (Brazil)
Mayo et al, 1994[221]	ID bracelets not an included intervention
McKiernan, 2005[222]	Gait-stabilising devices not an intervention in our analysis
Meunier et al, 1994[223]	Non systematic review
Meunier, 1996[224]	Non systematic review
Meyer et al, 2002[225]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Mudge et al, 2008[226]	Inpatient hospital setting
Neyens et al, 2006[227]	Methods study (development of a fall risk tool)
O'Halloran et al, 2004[228]	Policy evaluation RCT (not intervention effectiveness)
Oliver et al, 1997[229]	Methods study (development of a risk assessment tool)
Voshaar et al, 2006[230]	Falls not an outcome measure
Peacock et al, 2000[231]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Perell et al, 2001[232]	Non systematic review
Pereira et al, 1998[233]	Mean age ≤65 at baseline; original data collection prior to 1990
Prince et al, 2006[234]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Ray et al, 2005[235]	Falls not an outcome measure
Resnick, 2002[236]	Trial participants < 20
Robitaille et al, 2005[237]	Falls not an outcome measure
Rubenstein et al, 2001[238]	Non systematic review (narrative review)
Sambrook et al, 2004[239]	Falls not an outcome measure
Sato et al, 1999[240]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Sato et al, 1999[241]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Sattin et al, 2005[242]	Falls not an outcome measure
Schoenfelder, 2000[243]	Pilot study
Scott et al, 2007[244]	Systematic review of methods studies (fall risk assessment tools)
Sherrington and Lord, 1997[245]	Falls not an outcome measure
Shumway-Cook et al, 1997[246]	Falls not an outcome measure

Study	Reasons for exclusion
Sjosten et al, 2007[247]	Study protocol
Sjosten et al, 2008[248]	Falls not an outcome measure
Stein et al, 1999[249]	Not a RCT or pseudo-RCT (retrospective cross-sectional study)
Stenvall et al, 2007[250]	Inpatient hospital setting
Tennstedt et al, 1998[251]	Falls not an outcome measure
Thapa et al, 1995[252]	Fear of falling (primary outcome measure); irrelevant population subgroup
Thapa et al, 1995[252]	Not a RCT or pseudo-RCT (prospective cohort study)
Tideiksaar et al, 1993[253]	Bed alarms not an included intervention
Tinetti et al, 1992[254]	Not a RCT or pseudo-RCT (prospective cohort study)
Toulotte et al, 2003[255]	No falls data
Trivedi et al, 2003[256]	Falls (or new fractures in a population with a previous history of fractures) not an outcome measure
Tromp et al, 2001[257]	Not a RCT or pseudo-RCT (prospective cohort study)
Ushiroyama et al, 2001[258]	Falls not an outcome measure
van Rossum et al, 1993[259]	Falls not an outcome measure
van Schoor et al, 2003[260]	Not a RCT or pseudo-RCT (retrospective study)
Vu et al, 2004[261]	Non systematic review
Waddington and Adams, 2004[262]	Pilot study
Weerdesteyn et al, 2006[263]	Not a RCT or pseudo-RCT (non-randomised experimental study)
Wijlhuizen et al, 2007[264]	Not a RCT or pseudo-RCT (non-randomised experimental study)
Wilder, 2001[265]	No falls data
Wilkins et al, 2003[266]	Non systematic review
Wolf et al, 2003 (reprinted from JAGS 1996) [267]	Falls not an outcome measure
Wolfson et al, 1995[268]	Non systematic review
Woo et al, 2007[269]	Non relevant country (China)
Yardley and Nyman, 2007[270]	Falls not an outcome measure
Yates and Dunnagan, 2001[271]	Falls not an outcome measure
Zijlstra et al, 2006[272]	Methods study

Comparison to the Cochrane Review (Gillespie et al, 2009)

Community dwelling: exercise

- Ebrahim (1997)[26] was included in our meta-analysis as the mean age of participants was greater than 65.
- Steinberg (2000) was included in our meta-analysis as the study uses an add-on approach to their intervention. We used the arm of exercise plus education versus education in the exercise category.
- Ashburn (2007),[26] Cerny (1998),[181] Green (2002),[202] Cornillon (2002),[186] Fiatorone (1997),[195] Weerdesteyn (2000),[263] Pereira (1998),[233] Resnick (2002),[236] and Brown (2002),[178] were all excluded from our meta-analysis but included in the Cochrane review for various reasons as outlined in Appendix D.
- The rate ratio for Robertson (2001)[79] was 0.72 (0.54, 0.96) in our meta-analysis but 0.54 (0.32, 0.90) in the Cochrane review. We based our rate ratios off the intention to treat numbers.
- Rate ratios in our meta-analysis from Barnett (2003),[58] Bunout (2005),[60] Lord (1995),[130] Skelton (2005),[83] Suzuki (2004),[86] and Latham (2003),[68] were all calculated using number of participants at randomisation hence the difference between the Cochrane review numbers.
- The rate ratio for Campbell (1997) in our analysis was 0.58 (0.45, 0.75) calculated from the number of falls, compared to the Cochrane review value of 0.68 (0.51, 0.89) which was the relative hazard for the first 4 falls as reported in the study.
- The rate ratios for Liu-Ambrose (2004)[70] differ as we used the reported number of falls to calculate the rate ratio. Verification of the Cochrane review values was not possible.

Community dwelling – tai chi

- Rate ratios for Li (2005),[94] Voukelatos (2007)[95] and Wolf (2003)[96] were derived from the intention to treat numbers in our meta-analysis.
- For example: from Li (2005)[94] we used N=125 for the intervention group and N=131 for the control group as opposed to the Cochrane review which used N=95 and N=93. These are the numbers from the follow-up group and not after randomisation.

Community dwelling – home hazard assessment

- In the Cochrane review Nikolaus (2003)[113] was included in the multi-factorial analysis but upon further review, this paper was kept in our analysis in the home hazard assessment group.
- Peel (2000)[115] was a part of a multi-factorial study which has an 'add' on approach for each arm of the study and this paper only reported the home assessment and modification portion on the trial. This study is one section of the Steinberg (2000)[85] study, so it was included in our analysis.
- Lannin (2007)[215] was not included in the analysis as the number of participants fell short of our inclusion criteria.
- McKiernan (2005)[222] did not show up in our search and was also not included in our analysis.
- Campbell (2005)[62] was also not separated out as in the Cochrane review. If this paper is taken out the result is RR= 0.79 (0.66, 0.93) which is still significant.

Community dwelling – education

- We included the same two studies that the Cochrane review used: Robson (2003)[131] and Ryan (1996).[132]
- We added two other studies into the education group, Kerse (2005)[129] and Lord (2005)[130] as these two papers we deemed as having an education component. Kerse (2005)[129] evaluated the use of a green-prescription that used exercise specialists, telephone support and education materials and newsletters. Lord (2005)[130] participants received a report outlining their falls risk, recommendations, instructions and home exercises.
- Both estimates are however insignificant.

Community dwelling – cardiac pacing

- The Kenny (2001)[128] study is the only one that assessed the effectiveness of this intervention.
- We used the actual numbers of falls from the paper instead of using the reported odds ratio as per the Cochrane review; hence we have a lower rate ratio for the number of falls.

Community dwelling – psychotropic medication withdrawal

- The estimated rate ratio in our analysis is higher than that of the Cochrane review as we used the actual number of falls to estimate the rate ratio whereas they used the reported hazard ratio from the paper.

Community dwelling – multi-factorial interventions

- Davison (2005)[143] was calculated using intention to treat resulting in a different rate ratio to that of the Cochrane review. Two outliers were also excluded from the analysis as done in the paper.
- For Elley (2008),[144] the risk ratio presented in the paper was used to calculate the rate ratio.
- Davison (2005)[143] was analysed using the number of participants after randomisation, thus our rate ratios are different than the Cochrane review.
- The actual number of falls reported and intention to treat numbers were used in the analysis of Hogan (2001).[149] The paper found no significant differences between the control and the intervention for falls, fallers or mean number of falls. The Cochrane review reported a much lower rate ratio and a significant result.
- Lord (2005)[130] compared the use of a minimal intervention and intensive intervention versus control. Our analysis used the results from the intensive program against control giving slightly different numbers than that of the Cochrane review.
- McMurdo (2000)[156] was not included in the Cochrane review but was used in our analysis under the assessment and referral category.
- Salminen (2008) was not included in our study as it was unpublished data.
- It is assumed that the Cochrane review had access to unpublished data and were able to estimate the rate ratio for Rubenstein (2007).[158]

Meta-analysis results: community dwelling

Figure 6: Exercise vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
1.15.1 All Groups				
Ballard 2004	-0.97	0.59	0.9%	0.38 [0.12, 1.20]
Barnett 2003	-0.46	0.19	4.2%	0.63 [0.44, 0.92]
Buchner 1997	-0.5	0.26	3.1%	0.61 [0.36, 1.01]
Bunout 2005	0	0.28	2.8%	1.00 [0.58, 1.73]
Campbell 1997	-0.54	0.13	5.3%	0.58 [0.45, 0.75]
Campbell 1999b	-0.16	0.24	3.4%	0.85 [0.53, 1.36]
Campbell 2005	-0.24	0.12	5.5%	0.79 [0.62, 1.00]
Carter 2002	-0.13	0.52	1.1%	0.88 [0.32, 2.43]
Day 2002	0	0		Not estimable
Ebrahim 1997	0.52	0.25	3.2%	1.68 [1.03, 2.75]
Hauer 2001	0	0		Not estimable
Helbostad 2004	0.09	0.21	3.8%	1.09 [0.72, 1.65]
Korpelainen 2006	-0.24	0.15	4.9%	0.79 [0.59, 1.06]
Latham 2003	0.12	0.11	5.7%	1.13 [0.91, 1.40]
Lin 2007	-0.41	0.32	2.4%	0.66 [0.35, 1.24]
Liu-Ambrose 2004	0.03	0.44	1.5%	1.03 [0.44, 2.44]
Liu-Ambrose 2004	0.59	0.39	1.8%	1.80 [0.84, 3.87]
Lord 1995	-0.42	0.2	4.0%	0.66 [0.44, 0.97]
Lord 2003	-0.23	0.1	5.9%	0.79 [0.65, 0.97]
Luukinen 2007	-0.07	0.07	6.5%	0.93 [0.81, 1.07]
McMurdo 1997	-0.69	0.31	2.5%	0.50 [0.27, 0.92]
Means 2005	-0.9	0.18	4.4%	0.41 [0.29, 0.58]
Morgan 2004	0	0		Not estimable
Nitz 2004	-0.11	0.4	1.7%	0.90 [0.41, 1.96]
Reinsch 1992	0	0		Not estimable
Robertson 2001	-0.33	0.15	4.9%	0.72 [0.54, 0.96]
Rubenstein 2000	-0.18	0.39	1.8%	0.84 [0.39, 1.79]
Sherrington 2004	0	0		Not estimable
Skelton 2005	-0.5	0.15	4.9%	0.61 [0.45, 0.81]
Steadman 2003	0	0.18	4.4%	1.00 [0.70, 1.42]
Steinberg 2000	-0.1	0.19	4.2%	0.90 [0.62, 1.31]
Suzuki 2004	-1.2	0.47	1.3%	0.30 [0.12, 0.76]
Wolf 1996	0.17	0.22	3.7%	1.19 [0.77, 1.82]
Subtotal (95% CI)			**100.0%**	**0.80 [0.71, 0.90]**
Total (95% CI)			**100.0%**	**0.80 [0.71, 0.90]**

Subtotal: Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 72.00$, df = 27 ($P < 0.00001$); $I^2 = 62\%$
Test for overall effect: $Z = 3.76$ ($P = 0.0002$)

Total: Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 72.00$, df = 27 ($P < 0.00001$); $I^2 = 62\%$
Test for overall effect: $Z = 3.76$ ($P = 0.0002$)

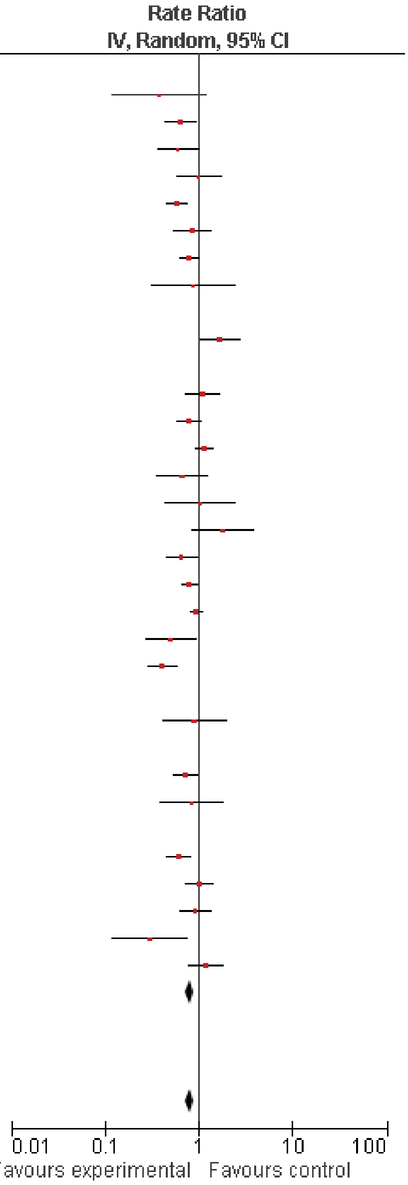


Figure 7: Group exercise vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
1.11.1 Group Exercise				
Ballard 2004	-0.97	0.59	1.3%	0.38 [0.12, 1.20]
Barnett 2003	-0.46	0.19	6.4%	0.63 [0.44, 0.92]
Buchner 1997	-0.5	0.26	4.6%	0.61 [0.36, 1.01]
Bunout 2005	0	0.28	4.2%	1.00 [0.58, 1.73]
Campbell 1997	-0.54	0.13	0.0%	0.58 [0.45, 0.75]
Campbell 1999b	-0.16	0.24	0.0%	0.85 [0.53, 1.36]
Campbell 2005	-0.24	0.12	0.0%	0.79 [0.62, 1.00]
Carter 2002	-0.13	0.52	1.7%	0.88 [0.32, 2.43]
Day 2002	0	0		Not estimable
Ebrahim 1997	0.52	0.25	0.0%	1.68 [1.03, 2.75]
Hauer 2001	0	0		Not estimable
Helbostad 2004	0.09	0.21	5.8%	1.09 [0.72, 1.65]
Korpelainen 2006	-0.24	0.15	7.6%	0.79 [0.59, 1.06]
Latham 2003	0.12	0.11	0.0%	1.13 [0.91, 1.40]
Lin 2007	-0.41	0.32	0.0%	0.66 [0.35, 1.24]
Liu-Ambrose 2004	0.03	0.44	2.2%	1.03 [0.44, 2.44]
Liu-Ambrose 2004	0.59	0.39	2.6%	1.80 [0.84, 3.87]
Lord 1995	-0.42	0.2	6.1%	0.66 [0.44, 0.97]
Lord 2003	-0.23	0.1	9.3%	0.79 [0.65, 0.97]
Luukinen 2007	-0.07	0.07	10.2%	0.93 [0.81, 1.07]
McMurdo 1997	-0.69	0.31	3.7%	0.50 [0.27, 0.92]
Means 2005	-0.9	0.18	6.7%	0.41 [0.29, 0.58]
Morgan 2004	0	0		Not estimable
Nitz 2004	-0.11	0.4	2.5%	0.90 [0.41, 1.96]
Reinsch 1992	0	0		Not estimable
Robertson 2001	-0.33	0.15	0.0%	0.72 [0.54, 0.96]
Rubenstein 2000	-0.18	0.39	2.6%	0.84 [0.39, 1.79]
Sherrington 2004	0	0		Not estimable
Shigematsu 2008	-0.35	0.57	0.0%	0.70 [0.23, 2.15]
Skelton 2005	-0.5	0.15	7.6%	0.61 [0.45, 0.81]
Steadman 2003	0	0.18	6.7%	1.00 [0.70, 1.42]
Steinberg 2000	-0.1	0.19	6.4%	0.90 [0.62, 1.31]
Suzuki 2004	-1.2	0.47	2.0%	0.30 [0.12, 0.76]
Wolf 1996	0.17	0.22	0.0%	1.19 [0.77, 1.82]
Subtotal (95% CI)			**100.0%**	**0.76 [0.66, 0.87]**
Heterogeneity: Tau² = 0.05; Chi² = 43.81, df = 19 (P = 0.001); I² = 57%				
Test for overall effect: Z = 3.85 (P = 0.0001)				
Total (95% CI)			**100.0%**	**0.76 [0.66, 0.87]**
Heterogeneity: Tau² = 0.05; Chi² = 43.81, df = 19 (P = 0.001); I² = 57%				
Test for overall effect: Z = 3.85 (P = 0.0001)				

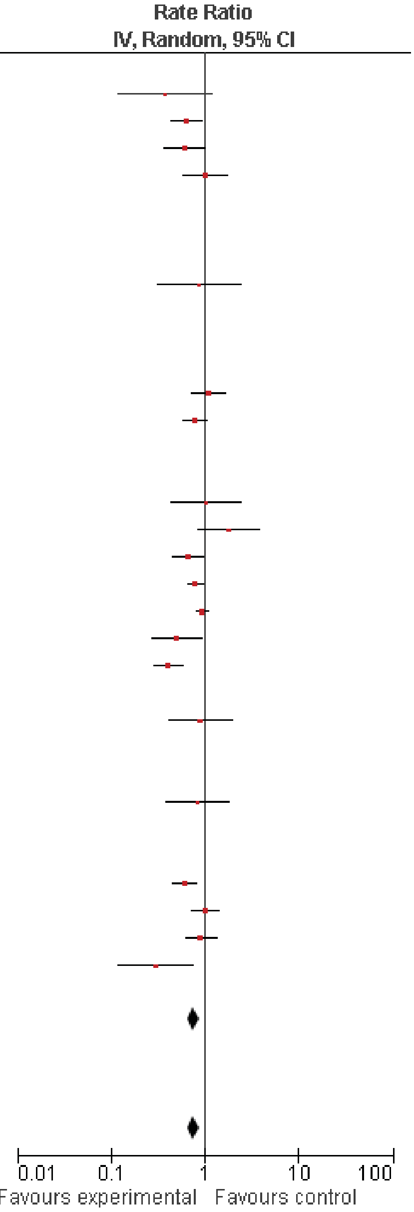


Figure 8: Home exercise vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
1.11.2 Home based Exercise				
Ballard 2004	-0.97	0.59	0.0%	0.38 [0.12, 1.20]
Barnett 2003	-0.46	0.19	0.0%	0.63 [0.44, 0.92]
Buchner 1997	-0.5	0.26	0.0%	0.61 [0.36, 1.01]
Bunout 2005	0	0.28	0.0%	1.00 [0.58, 1.73]
Campbell 1997	-0.54	0.13	25.0%	0.58 [0.45, 0.75]
Campbell 1999b	-0.16	0.24	18.6%	0.85 [0.53, 1.36]
Campbell 2005	-0.24	0.12	0.0%	0.79 [0.62, 1.00]
Carter 2002	-0.13	0.52	0.0%	0.88 [0.32, 2.43]
Day 2002	0	0		Not estimable
Ebrahim 1997	0.52	0.25	18.0%	1.68 [1.03, 2.75]
Hauer 2001	0	0		Not estimable
Helbostad 2004	0.09	0.21	0.0%	1.09 [0.72, 1.65]
Korpelainen 2006	-0.24	0.15	0.0%	0.79 [0.59, 1.06]
Latham 2003	0.12	0.11	0.0%	1.13 [0.91, 1.40]
Lin 2007	-0.41	0.32	14.5%	0.66 [0.35, 1.24]
Liu-Ambrose 2004	0.03	0.44	0.0%	1.03 [0.44, 2.44]
Liu-Ambrose 2004	0.59	0.39	0.0%	1.80 [0.84, 3.87]
Lord 1995	-0.42	0.2	0.0%	0.66 [0.44, 0.97]
Lord 2003	-0.23	0.1	0.0%	0.79 [0.65, 0.97]
Luukinen 2007	-0.07	0.07	0.0%	0.93 [0.81, 1.07]
McMurdo 1997	-0.69	0.31	0.0%	0.50 [0.27, 0.92]
Means 2005	-0.9	0.18	0.0%	0.41 [0.29, 0.58]
Morgan 2004	0	0		Not estimable
Nitz 2004	-0.11	0.4	0.0%	0.90 [0.41, 1.96]
Reinsch 1992	0	0		Not estimable
Robertson 2001	-0.33	0.15	23.9%	0.72 [0.54, 0.96]
Rubenstein 2000	-0.18	0.39	0.0%	0.84 [0.39, 1.79]
Sherrington 2004	0	0		Not estimable
Shigematsu 2008	-0.35	0.57	0.0%	0.70 [0.23, 2.15]
Skelton 2005	-0.5	0.15	0.0%	0.61 [0.45, 0.81]
Steadman 2003	0	0.18	0.0%	1.00 [0.70, 1.42]
Steinberg 2000	-0.1	0.19	0.0%	0.90 [0.62, 1.31]
Suzuki 2004	-1.2	0.47	0.0%	0.30 [0.12, 0.76]
Wolf 1996	0.17	0.22	0.0%	1.19 [0.77, 1.82]
Subtotal (95% CI)			**100.0%**	**0.81 [0.58, 1.14]**
Heterogeneity: $Tau^2 = 0.10$; $Chi^2 = 14.66$, df = 4 (P = 0.005); $I^2 = 73\%$				
Test for overall effect: Z = 1.22 (P = 0.22)				
Total (95% CI)			**100.0%**	**0.81 [0.58, 1.14]**
Heterogeneity: $Tau^2 = 0.10$; $Chi^2 = 14.66$, df = 4 (P = 0.005); $I^2 = 73\%$				
Test for overall effect: Z = 1.22 (P = 0.22)				

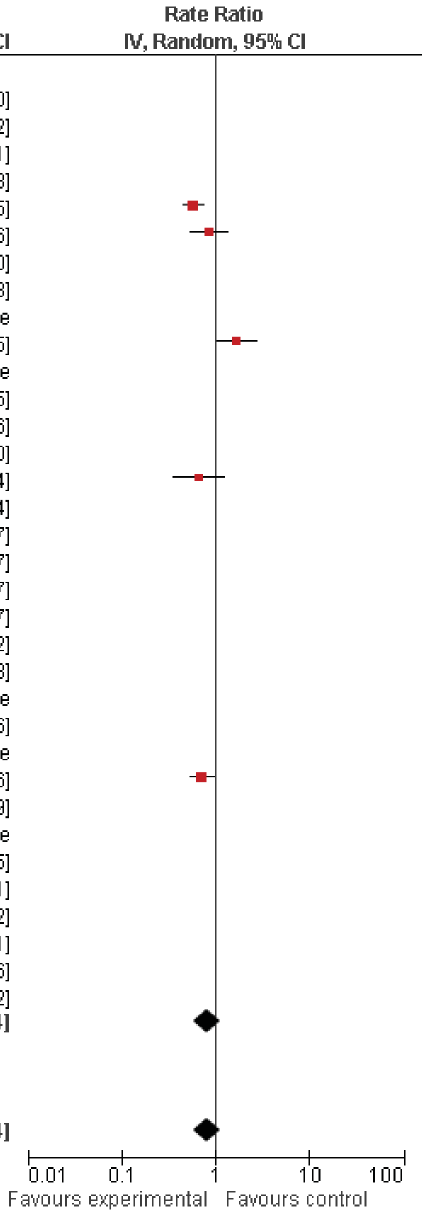


Figure 9: Tai chi vs control: community dwelling

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Fixed, 95% CI
2.2.1 Rate of Falls (FICSIT def)				
Li 2005	-0.95	0.28	4.1%	0.39 [0.22, 0.67]
Voukelatos 2007	-0.39	0.14	16.3%	0.68 [0.51, 0.89]
Wolf 1996	-0.44	0.18	9.9%	0.64 [0.45, 0.92]
Wolf 2003	-0.32	0.12	22.2%	0.73 [0.57, 0.92]
Subtotal (95% CI)			**52.4%**	**0.66 [0.57, 0.77]**
Heterogeneity: Chi² = 4.33, df = 3 (P = 0.23); I² = 31%				
Test for overall effect: Z = 5.29 (P < 0.00001)				
2.2.2 Rate of Falls (ATLANTA def)				
Li 2005	-0.95	0.28	4.1%	0.39 [0.22, 0.67]
Voukelatos 2007	-0.39	0.14	16.3%	0.68 [0.51, 0.89]
Wolf 1996	-0.36	0.25	5.1%	0.70 [0.43, 1.14]
Wolf 2003	-0.32	0.12	22.2%	0.73 [0.57, 0.92]
Subtotal (95% CI)			**47.6%**	**0.67 [0.57, 0.79]**
Heterogeneity: Chi² = 4.33, df = 3 (P = 0.23); I² = 31%				
Test for overall effect: Z = 4.91 (P < 0.00001)				
Total (95% CI)			**100.0%**	**0.67 [0.60, 0.74]**
Heterogeneity: Chi² = 8.67, df = 7 (P = 0.28); I² = 19%				
Test for overall effect: Z = 7.22 (P < 0.00001)				
Test for subgroup differences: Chi² = 0.01, df = 1 (P = 0.92), I² = 0%				

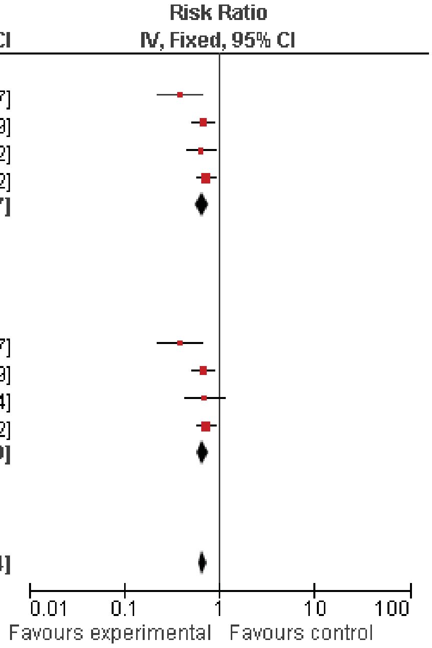


Figure 10: Vitamin D and Calcium vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
7.3.1 Vitamin D and calcium vs. Placebo				
Bischoff-Ferrari 2006	0.12	0.09	40.8%	1.13 [0.95, 1.35]
Grant 2005	0	0		Not estimable
Subtotal (95% CI)			**40.8%**	**1.13 [0.95, 1.35]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 1.33 (P = 0.18)				
7.3.4 Vitamin D and calcium vs. Calcium				
Pfeifer 2000	-0.57	0.3	3.7%	0.57 [0.31, 1.02]
Prince 2008	0	0		Not estimable
Subtotal (95% CI)			**3.7%**	**0.57 [0.31, 1.02]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 1.90 (P = 0.06)				
7.3.6 Vitamin D vs. Placebo				
Dhesi 2004	-0.48	0.33	3.0%	0.62 [0.32, 1.18]
Dukas 2004	-0.13	0.2	8.3%	0.88 [0.59, 1.30]
Gallagher 1996	-0.47	0.14	16.9%	0.63 [0.48, 0.82]
Grant 2005	0	0		Not estimable
Latham 2003	0.11	0.11	27.3%	1.12 [0.90, 1.38]
Smith 2007	0	0		Not estimable
Subtotal (95% CI)			**55.5%**	**0.87 [0.75, 1.02]**
Heterogeneity: Chi² = 11.78, df = 3 (P = 0.008); I² = 75%				
Test for overall effect: Z = 1.74 (P = 0.08)				
Total (95% CI)			**100.0%**	**0.95 [0.85, 1.07]**
Heterogeneity: Chi² = 19.54, df = 5 (P = 0.002); I² = 74%				
Test for overall effect: Z = 0.81 (P = 0.42)				
Test for subgroup differences: Chi² = 7.76, df = 2 (P = 0.02), I² = 74.2%				

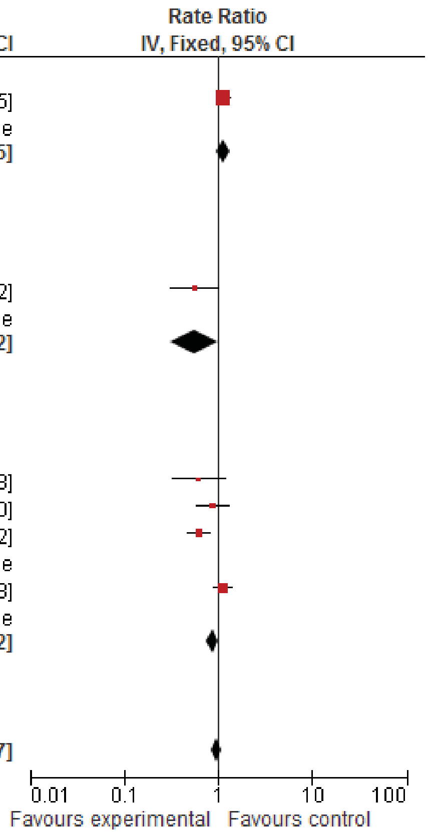


Figure 11: Education vs control: community dwelling

Study or Subgroup	log[]	SE	Weight	IV, Fixed, 95% CI
8.3.1 Education				
Kerse 2005	0	0		Not estimable
Lord 2005	-0.12	0.14	32.2%	0.89 [0.67, 1.17]
Robson 2003	0	0		Not estimable
Ryan 1996	-1.1	0.65	1.5%	0.33 [0.09, 1.19]
Subtotal (95% CI)			**33.7%**	**0.85 [0.65, 1.11]**
Heterogeneity: Chi² = 2.17, df = 1 (P = 0.14); I² = 54%				
Test for overall effect: Z = 1.19 (P = 0.23)				
8.3.2 Education - Material Only				
Kerse 2005	0	0		Not estimable
Lord 2005	-0.12	0.14	32.2%	0.89 [0.67, 1.17]
Subtotal (95% CI)			**32.2%**	**0.89 [0.67, 1.17]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 0.86 (P = 0.39)				
8.3.3 Education - Taught sessions				
Robson 2003	0	0		Not estimable
Ryan 1996	-1.1	0.65	1.5%	0.33 [0.09, 1.19]
Subtotal (95% CI)			**1.5%**	**0.33 [0.09, 1.19]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 1.69 (P = 0.09)				
8.3.4 Education - Group sessions only				
Kerse 2005	0	0		Not estimable
Lord 2005	-0.12	0.14	32.2%	0.89 [0.67, 1.17]
Robson 2003	0	0		Not estimable
Ryan 1996	-1.86	1.08	0.5%	0.16 [0.02, 1.29]
Subtotal (95% CI)			**32.7%**	**0.86 [0.66, 1.13]**
Heterogeneity: Chi² = 2.55, df = 1 (P = 0.11); I² = 61%				
Test for overall effect: Z = 1.07 (P = 0.28)				
Total (95% CI)			**100.0%**	**0.85 [0.73, 1.00]**
Heterogeneity: Chi² = 6.91, df = 5 (P = 0.23); I² = 28%				
Test for overall effect: Z = 2.00 (P = 0.05)				
Test for subgroup differences: Chi² = 2.18, df = 3 (P = 0.54), I² = 0%				

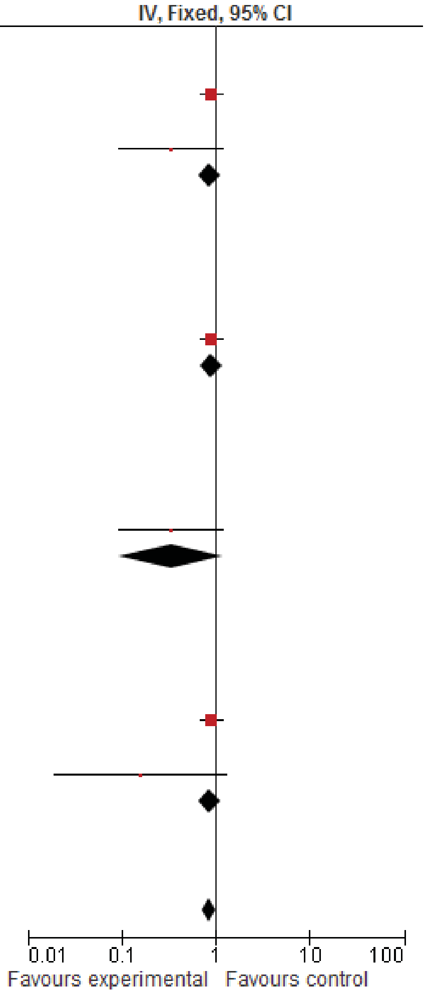


Figure 12: Home hazard assessment vs control: community dwelling

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI
Campbell 2005	-0.9	0.15	15.1%	0.41 [0.30, 0.55]
Cumming 1999	-0.41	0.09	17.9%	0.66 [0.56, 0.79]
Lin 2007	-0.78	0.36	6.9%	0.46 [0.23, 0.93]
Nikolaus 2003	-0.24	0.11	17.0%	0.79 [0.63, 0.98]
Pardessus 2002	-0.19	0.3	8.7%	0.83 [0.46, 1.49]
Peel 2000	-0.18	0.14	15.5%	0.84 [0.63, 1.10]
Stevens 2001	-0.05	0.06	19.0%	0.95 [0.85, 1.07]
Total (95% CI)			**100.0%**	**0.70 [0.56, 0.88]**
Heterogeneity: Tau² = 0.07; Chi² = 35.41, df = 6 (P < 0.00001); I² = 83%				
Test for overall effect: Z = 3.04 (P = 0.002)				

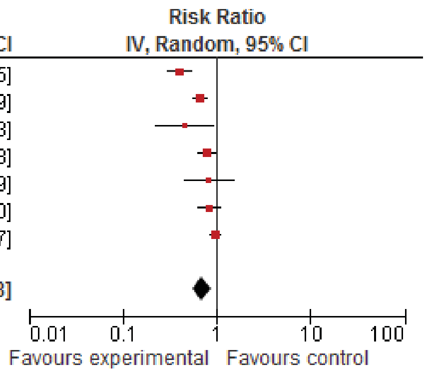


Figure 13: Hip protectors vs control: community dwelling

Study or Subgroup	log[Risk Ratio]	SE	Weight	Risk Ratio IV, Random, 95% CI
Birks 2004	0	0		Not estimable
Cameron 2003	0.21	0.05	100.0%	1.23 [1.12, 1.36]
Kannus 2000	0	0		Not estimable
Total (95% CI)			**100.0%**	**1.23 [1.12, 1.36]**

Heterogeneity: Not applicable
Test for overall effect: Z = 4.20 (P < 0.0001)

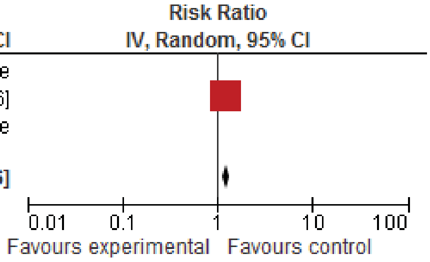


Figure 14: Psychotropic medication withdrawal vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Campbell 1999b	-0.92	0.29	100.0%	0.40 [0.23, 0.70]
Total (95% CI)			**100.0%**	**0.40 [0.23, 0.70]**

Heterogeneity: Not applicable
Test for overall effect: Z = 3.17 (P = 0.002)

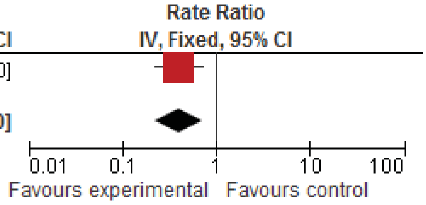


Figure 15: Expedited cataract surgery vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Foss 2006	-0.39	0.28	31.5%	0.68 [0.39, 1.17]
Harwood 2005	-0.42	0.19	68.5%	0.66 [0.45, 0.95]
Total (95% CI)			**100.0%**	**0.66 [0.49, 0.90]**

Heterogeneity: $Chi^2 = 0.01$, df = 1 (P = 0.93); $I^2 = 0\%$
Test for overall effect: Z = 2.61 (P = 0.009)

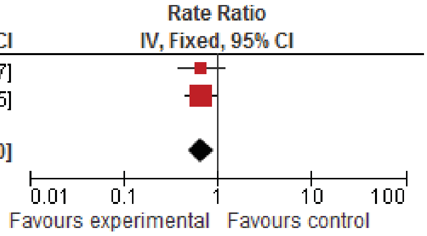


Figure 16: Vision and eye exams vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Cumming 2007	0.45	0.06	100.0%	1.57 [1.39, 1.76]
Total (95% CI)			**100.0%**	**1.57 [1.39, 1.76]**

Heterogeneity: Not applicable
Test for overall effect: Z = 7.50 (P < 0.00001)

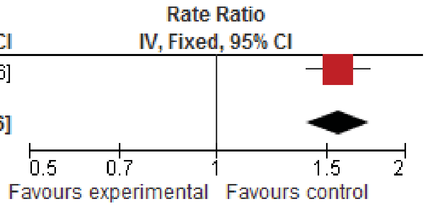


Figure 17: Cardiac pacing vs control: community dwelling

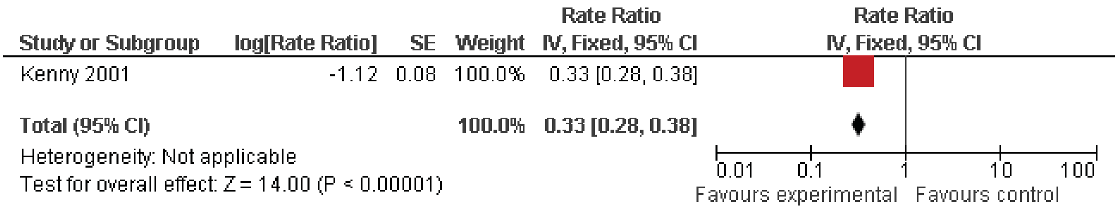


Figure 18: Multiple interventions vs control: community dwelling

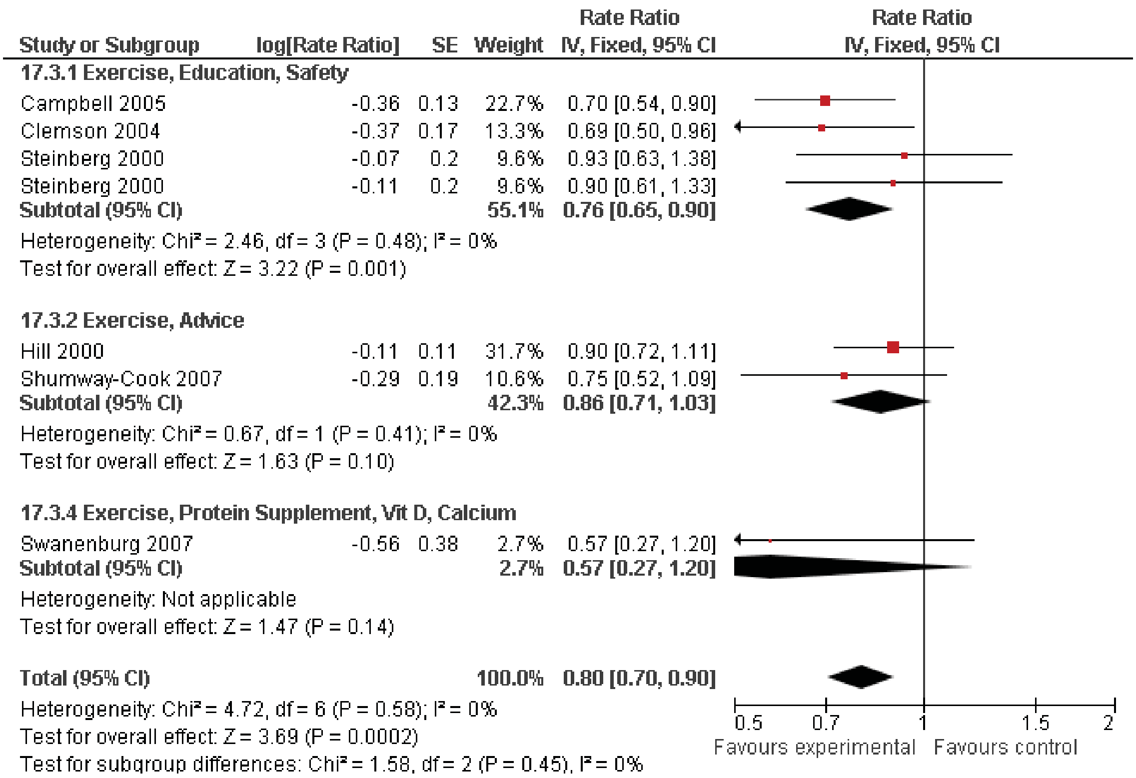
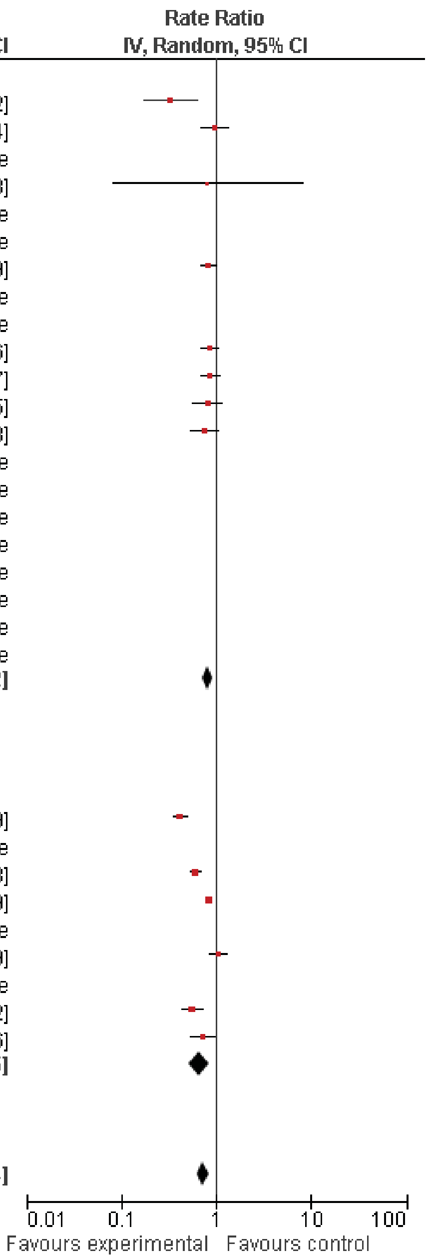


Figure 19: Multi-factorial interventions vs control: community dwelling

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
19.11.1 Referral				
Carpenter 1990	-1.12	0.33	3.4%	0.33 [0.17, 0.62]
Elley 2008	-0.04	0.17	6.6%	0.96 [0.69, 1.34]
Fabacher 1994	0	0		Not estimable
Gallagher 1996	-0.21	1.17	0.4%	0.81 [0.08, 8.03]
Gill 2002	0	0		Not estimable
Hendriks 2008	0	0		Not estimable
Hogan 2001	-0.19	0.09	8.8%	0.83 [0.69, 0.99]
Huang 2004	0	0		Not estimable
Jitapunkul 1998	0	0		Not estimable
Lightbody 2002	-0.16	0.11	8.3%	0.85 [0.69, 1.06]
Lord 2005	-0.15	0.11	8.3%	0.86 [0.69, 1.07]
Mahoney 2007	-0.21	0.18	6.4%	0.81 [0.57, 1.15]
McMurdo 2000	-0.3	0.17	6.6%	0.74 [0.53, 1.03]
Newbury 2001	0	0		Not estimable
Rubenstein 2007	0	0		Not estimable
Schrijnemaekers 1995	0	0		Not estimable
Spice 2008	0	0		Not estimable
van Haastegt 2000	0	0		Not estimable
Vetter 1992	0	0		Not estimable
Wagner 1994	0	0		Not estimable
Whitehead 2003	0	0		Not estimable
Subtotal (95% CI)			**48.8%**	**0.81 [0.72, 0.92]**
Heterogeneity: Tau² = 0.01; Chi² = 9.35, df = 7 (P = 0.23); I² = 25%				
Test for overall effect: Z = 3.28 (P = 0.001)				
19.11.2 Active				
Close 1999	-0.88	0.09	8.8%	0.41 [0.35, 0.49]
Coleman 1999	0	0		Not estimable
Davison 2005	-0.5	0.06	9.4%	0.61 [0.54, 0.68]
Hornbrook 1994	-0.18	0.03	9.9%	0.84 [0.79, 0.89]
Huang 2005	0	0		Not estimable
Lord 2005	0.04	0.11	8.3%	1.04 [0.84, 1.29]
Spice 2008	0	0		Not estimable
Tinetti 1994	-0.59	0.13	7.7%	0.55 [0.43, 0.72]
Wyman 2005	-0.33	0.15	7.2%	0.72 [0.54, 0.96]
Subtotal (95% CI)			**51.2%**	**0.67 [0.52, 0.85]**
Heterogeneity: Tau² = 0.09; Chi² = 83.07, df = 5 (P < 0.00001); I² = 94%				
Test for overall effect: Z = 3.21 (P = 0.001)				
Total (95% CI)			**100.0%**	**0.72 [0.62, 0.84]**
Heterogeneity: Tau² = 0.06; Chi² = 95.37, df = 13 (P < 0.00001); I² = 86%				
Test for overall effect: Z = 4.31 (P < 0.0001)				



Meta-analysis results: residential aged care

Figure 20: Exercise vs control: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
Buettner 2002	-0.62	0.23	15.0%	0.54 [0.34, 0.84]
Faber 2006	0.2	0.1	18.9%	1.22 [1.00, 1.49]
Kerse 2008	0	0		Not estimable
Mulrow 1994	0.28	0.17	16.9%	1.32 [0.95, 1.85]
Nowalk 2001	-0.04	0.28	13.3%	0.96 [0.55, 1.66]
Sakamoto 2006	-0.47	0.13	18.1%	0.63 [0.48, 0.81]
Shimada 2004	-0.57	0.46	8.5%	0.57 [0.23, 1.39]
Sihvonen 2004	-0.96	0.42	9.4%	0.38 [0.17, 0.87]
Total (95% CI)			**100.0%**	**0.79 [0.56, 1.11]**

Heterogeneity: $Tau^2 = 0.15$; $Chi^2 = 32.38$, df = 6 ($P < 0.0001$); $I^2 = 81\%$
Test for overall effect: $Z = 1.34$ ($P = 0.18$)

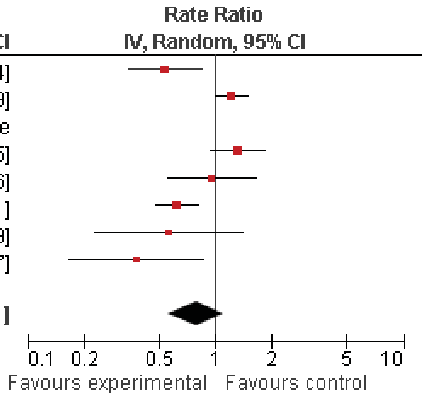


Figure 21: Tai chi vs control: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Faber 2006	-0.04	0.1	100.0%	0.96 [0.79, 1.17]
Nowalk 2001	0	0		Not estimable
Total (95% CI)			**100.0%**	**0.96 [0.79, 1.17]**

Heterogeneity: Not applicable
Test for overall effect: $Z = 0.40$ ($P = 0.69$)

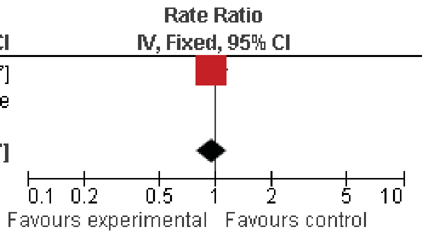


Figure 22: Vitamin D vs control: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
3.2.1 Vitamin D vs. Placebo				
Broe 2007	0.1	0.41	0.2%	1.11 [0.49, 2.47]
Broe 2007	-1.27	0.51	0.1%	0.28 [0.10, 0.76]
Broe 2007	0.05	0.69	0.1%	1.05 [0.27, 4.06]
Broe 2007	0.19	0.39	0.3%	1.21 [0.56, 2.60]
Law 2006	-0.14	0.02	96.3%	0.87 [0.84, 0.90]
Subtotal (95% CI)			**97.1%**	**0.87 [0.84, 0.90]**
Heterogeneity: Chi² = 6.04, df = 4 (P = 0.20); I² = 34%				
Test for overall effect: Z = 7.03 (P < 0.00001)				
3.2.2 Vitamin D + Calcium vs. Calcium				
Bischoff 2003	-0.82	0.24	0.7%	0.44 [0.28, 0.70]
Subtotal (95% CI)			**0.7%**	**0.44 [0.28, 0.70]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 3.42 (P = 0.0006)				
3.2.3 Vitamin D + Calcium vs. Placebo + Calcium				
Flicker 2005	-0.31	0.13	2.3%	0.73 [0.57, 0.95]
Subtotal (95% CI)			**2.3%**	**0.73 [0.57, 0.95]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 2.38 (P = 0.02)				
Total (95% CI)			**100.0%**	**0.86 [0.83, 0.90]**
Heterogeneity: Chi² = 15.59, df = 6 (P = 0.02); I² = 62%				
Test for overall effect: Z = 7.57 (P < 0.00001)				
Test for subgroup differences: Chi² = 9.55, df = 2 (P = 0.008), I² = 79.1%				

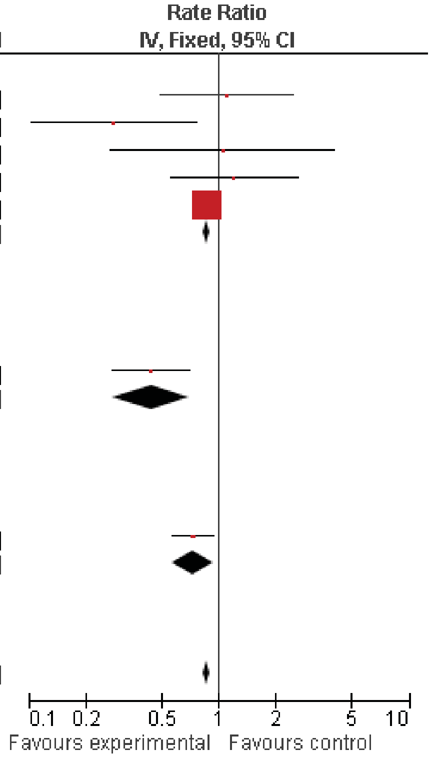


Figure 23: Hip protectors vs control: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Cameron 2001	-0.03	0.07	23.2%	0.97 [0.85, 1.11]
Harada 2001	0.23	0.14	5.8%	1.26 [0.96, 1.66]
Meyer 2008	-0.35	0.04	71.0%	0.70 [0.65, 0.76]
Total (95% CI)			**100.0%**	**0.78 [0.73, 0.84]**
Heterogeneity: Chi² = 27.83, df = 2 (P < 0.00001); I² = 93%				
Test for overall effect: Z = 7.18 (P < 0.00001)				

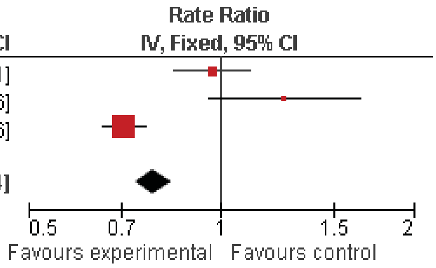


Figure 24: Clinical medication review: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Crotty 2004a	0	0		Not estimable
Crotty 2004b	0	0		Not estimable
Zermansky 2006	-0.53	0.09	100.0%	0.59 [0.49, 0.70]
Total (95% CI)			**100.0%**	**0.59 [0.49, 0.70]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 5.89 (P < 0.00001)				

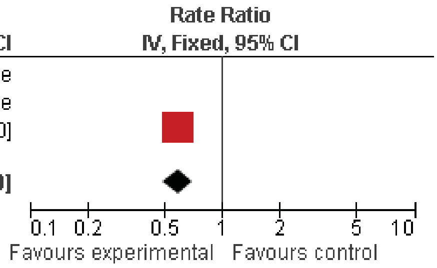


Figure 25: Multiple interventions: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Fixed, 95% CI
Becker 2003a	-0.66	0.05	96.2%	0.52 [0.47, 0.57]
Evans 1997	0	0		Not estimable
Schnelle 2003	-0.49	0.25	3.8%	0.61 [0.38, 1.00]
Total (95% CI)			**100.0%**	**0.52 [0.47, 0.57]**

Heterogeneity: Chi² = 0.44, df = 1 (P = 0.50); I² = 0%
Test for overall effect: Z = 13.33 (P < 0.00001)

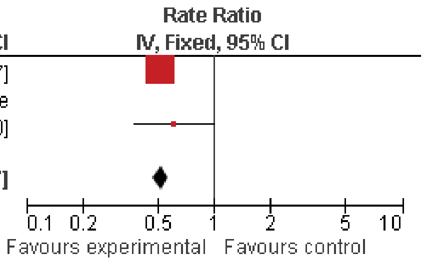
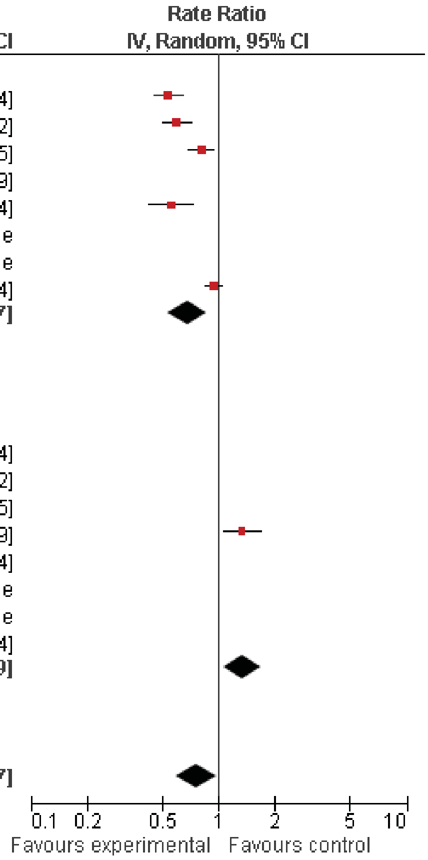


Figure 26: Multi-factorial interventions: residential aged care

Study or Subgroup	log[Rate Ratio]	SE	Weight	Rate Ratio IV, Random, 95% CI
9.2.1 Active				
Dyer 2004	-0.62	0.09	16.9%	0.54 [0.45, 0.64]
Jensen 2002	-0.51	0.09	16.9%	0.60 [0.50, 0.72]
Jensen 2003	-0.21	0.08	17.2%	0.81 [0.69, 0.95]
Kerse 2004	0.29	0.12	0.0%	1.34 [1.06, 1.69]
Rapp 2008	-0.58	0.14	15.1%	0.56 [0.43, 0.74]
Ray 1997	0	0		Not estimable
Rubenstein 1990	0	0		Not estimable
Shaw 2003	-0.06	0.05	18.0%	0.94 [0.85, 1.04]
Subtotal (95% CI)			**84.1%**	**0.68 [0.53, 0.87]**
Heterogeneity: Tau² = 0.07; Chi² = 45.31, df = 4 (P < 0.00001); I² = 91%				
Test for overall effect: Z = 3.09 (P = 0.002)				
9.2.2 Referral				
Dyer 2004	-0.62	0.09	0.0%	0.54 [0.45, 0.64]
Jensen 2002	-0.51	0.09	0.0%	0.60 [0.50, 0.72]
Jensen 2003	-0.21	0.08	0.0%	0.81 [0.69, 0.95]
Kerse 2004	0.29	0.12	15.9%	1.34 [1.06, 1.69]
Rapp 2008	-0.58	0.14	0.0%	0.56 [0.43, 0.74]
Ray 1997	0	0		Not estimable
Rubenstein 1990	0	0		Not estimable
Shaw 2003	-0.06	0.05	0.0%	0.94 [0.85, 1.04]
Subtotal (95% CI)			**15.9%**	**1.34 [1.06, 1.69]**
Heterogeneity: Not applicable				
Test for overall effect: Z = 2.42 (P = 0.02)				
Total (95% CI)			**100.0%**	**0.76 [0.59, 0.97]**

Heterogeneity: Tau² = 0.09; Chi² = 65.06, df = 5 (P < 0.00001); I² = 92%
Test for overall effect: Z = 2.19 (P = 0.03)



Appendix H

Cost estimates

Community based cost estimates

Group-based Exercise	Cost estimated from Sherrington et al (2008)[17] Based on costing each of the studies in the meta-analysis and using the weighting of each study from the meta-analysis. Estimated as $50 per class, plus 30% administration cost. The cost was doubled [as in Sherrington (2008)[17]] only in those studies with a home exercise component to account for any monitoring of prescribed home exercises. This same cost is calculated if basing the cost on a program of 26 weeks duration (which is the average length of the studies included in the meta-analysis) with 2 classes a week plus home exercises once a week (only in 50% of the studies, so multiplied by 1.5 instead of 2). Cost = [($50*2*26*1.3)/9]*1.5 Cost per participant estimated at **$563** (1st year only)
Home-based Exercise	Cost taken directly from Day et al (2009)[42] Based on a program delivered by a district-based nurse with 5 home visits starting with 1 hour visit in week 1, followed by half hour visits at week 2,4 and 8 and a booster visit at 6 months. Cost per participant estimated at $**1091** (1st year only)
Tai Chi	Costs based on estimates from Sherrington et al (2008)[17] Of the trials included in the analysis, the least amount of time was 15 weeks and the longest 48 weeks. We chose to cost out a program of 6 months and using the average of 2 times a week. Calculated as: [($115 * 2 x/weekly * 26 weeks)/12 participants] The cost of a tai chi program is estimated at **$648** (1st year only)
Home Hazard Assessment	Costs taken directly from Day et al (2009)[42] This estimate included the visit of an occupational therapist, phone and letter costs, travel costs and home modification costs. Cost per participant is estimated at **$502** (1st year only)
Cataract Surgery	Costs estimated from DRG Hospital data. The estimate is weighted by the number of separations plus one GP visit and two specialist visits. www.aihw.gov.au. Cost per participant estimated at $**2050** (1st year only) Note: both the intervention and control arm receive this cost, however the there is a delay of a year for the control arm.
Cardiac Pacing	Costs taken directly from Day et al (2009)[42] Cost estimates include the cost of screening, cardio vascular assessment, insertion of pacemaker, and post pacemaker visit. Cost per participant estimated a**t $13,526** (1st year only)
Psychotropic Medication Withdrawal	Costs taken directly from Day et al (2009)[42] Gradual reduction of medication over a 14 week period. Time calculated for 6 standard GP visits, medication reformation, practice manager/ nurse to check register. Cost per patient estimated at **$604** (1st year only)
Multiple Interventions	Costs estimated from a combination of exercise programs as well as a home hazard assessment. Relative weighting of effectiveness from the 3 studies was applied to total costs from: Campbell et al (2005)[62], using costs from the study; Swanenburg et al (2007)[137], using a combination of home hazard estimate above and exercise program of 1 hour a month for a total cost of $390; and the cost of the Stepping On program for Clemson et al (2004)[134] with a total cost of $785 as provided by NSW Health. Cost per participant estimated a**t $1,034** (1st year only)
Multi-factorial Interventions (referral only)	Costs estimated from Day et al (2009)[42] Costs based on: - an assessment of falls risk factors $427.80 (MBS code 141) - the cost of an occupational therapy home visit from the Department of Veteran Affairs $80.85- www.dva.gov.au - the cost of a nurse visit of calculated as the average of the nurse wage levels of $56.06 http://www.health.nsw.gov.au/nursing/employment/nurse_award_wage_rates_08.asp - a follow up of falls risk assessment $267.40 (MBS code 143) Cost per participant estimated a**t $832** (1st year only)
Multi-factorial Interventions (referral and active)	Costs estimated from Day et al (2009)[42] Costs based on an assessment of falls risk factors calculated above; plus a weighted cost of the combination of interventions below for each study in the meta-analysis: - an exercise program (1xweek) $534 - Sherrington et al (2008)[17] - a home hazard assessment and modification **$413** - Day et al (2009)[42] - a vision assessment $67.15 from the Department of Veteran Affairs - a medication review $143.40 (MBS Code 903 and RMMR by an accredited pharmacist) - occupational therapy $80.85 from the Department of Veteran Affairs Cost per participant estimated a**t $1,380** (1st year only)

Residential based cost estimates

Vitamin D and Calcium	Costs estimated from www.pharmacyonline.com Cost calculated based on a daily dose of 1000IU if Vitamin D plus 600mg of Calcium. Assumption made that no extra administration cost would be included as this supplement would be added to the usual daily medication/supplement regime. Cost per participant estimated at **$138**/year
Hip Protectors	Costs estimated from www.hipsaver.com.au Costs include 3 pants and 1 set of interchangeable hip protecting pads. Assumption made that no additional administration cost would be added as the wages of the attendants would remain unchanged. Cost per participant estimated at **$166** (each year)
Medication Review	Costs estimated from the Medicare Benefits Schedule (MBS) and Pharmacy Guild Cost calculated from MBS Code 903 - Residential Medication Management Review (RMMR)- $98.20 per year and RMMR by accredited pharmacist - $130.00 per bed year. Cost per participant estimated at **$228**/year
Multiple Interventions	Costs estimates based on intervention in Becker et al (2003)[21] and include: - the cost of a physiotherapist for an initial and subsequent visit estimated at $122 to train the residential aged care staff, sourced from the Department of Veteran Affairs www.dva.gov.au - a 1 hour consultation with a residential aged care nurse of $22.32 from http://www.health.nsw.gov.au/nursing/employment/nurse_award_wage_rates_08.asp - printing costs of falls prevention booklets of $6 per participant estimated from www.kainosprint.com.au/products/Booklets/A4 - a cost of $80.85 per participant for an occupational therapist from the Department of Veteran Affairs www.dva.gov.au - a group exercise program of $516, as estimated in Sherrington et al (2008)[17] - hip protectors per participant as estimated above. Cost per participant estimated at **$775**/year
Multi-factorial Interventions	Cost based on: - an assessment of falls risk factors $427.80 (MBS code 141) - a follow up of falls risk assessment $267.40 (MBS code 143) - hip protectors $166, as estimated above - hazard modification, calculated as 2 hrs for an occupational therapist to visit $161.70 from the Department of Veteran Affairs, www.dva.gov.au Cost per participant estimated at **$1,023**/year

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