Exercise programmes to prevent falls among older adults: modelling health gain, cost-utility and equity impacts

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ABSTRACT

Background Some falls prevention interventions for the older population appear cost-effective, but there is uncertainty about others. Therefore, we aimed to model three types of exercise programme each running for 25 years among 65+ year olds: (i) a peer-led group-based one; (ii) a home-based one and (iii) a commercial one.

Methods An established Markov model for studying falls prevention in New Zealand (NZ) was adapted to estimate incremental cost-effectiveness ratios (ICERs) in cost per quality-adjusted life-years (QALYs) gained. Detailed NZ experimental, epidemiological and cost data were used for the base year 2011. A health system perspective was taken and a discount rate of 3% applied. Intervention effectiveness estimates came from a Cochrane Review.

Results The intervention generating the greatest health gain and costing the least was the home-based exercise programme intervention. Lifetime health gains were estimated at 47 100 QALYs (95%uncertainty interval (UI) 22 300 to 74 400). Cost-effectiveness was high (ICER: US$4640 per QALY gained; (95% UI US$996 to 10 500)), and probably more so than a home safety assessment and modification intervention using the same basic model (ICER: US$6060). The peer-led group-based exercise programme was estimated to generate 42 000 QALYs with an ICER of US$9490. The commercially provided group programme was more expensive and less cost-effective (ICER: US$34 500). Further analyses by sex, age group and ethnicity (Indigenous Māori and non-Māori) for the peer-led group-intervention showed similar health gains and cost-effectiveness.

Conclusions Implementing any of these three types of exercise programme for falls prevention in older people could produce considerable health gain, but with the home-based version being likely to be the most cost-effective.

INTRODUCTION

Falls among people aged ≥65 years are common, with the WHO estimating 28%–35% having falls each year.[1] A majority of reported falls cause injury, for example, 68% in one study.[2] Fortunately there is a growing research base around falls prevention as demonstrated with a Cochrane Review of the effectiveness of falls prevention programmes.[3] This review included evidence for reductions in the rate and risk of falls for group-based and home-based exercise programmes (group-based rate ratio (RR)=0.71, 95% CI 0.63 to 0.82, 16 trials, 3622 participants; home-based RR=0.68, 95% CI 0.58 to 0.80, 7 trials, 951 participants). Overall, exercise interventions resulted in a statistically significant reduction in risk of fracture (RR=0.34, 95% CI 0.18 to 0.63, six trials). A subsequent meta-analysis also considered injurious falls, finding that exercise programmes for falls prevention reduced injurious falls and falls requiring medical attention (RR=0.63, 95% CI 0.51 to 0.77, 10 trials; and RR=0.70, 95% CI 0.54 to 0.92, 8 trials, respectively).[4] Although 14 out of the 17 studies in this meta-analysis were group-based, the results were not separated by home or group delivery. More specifically, two meta-analyses have reported that the traditional Chinese exercise of Tai Chi reduces the risk of falls.[5,6] The most recent of these included 18 trials and reported a dose–response effect with exercise frequency with an overall risk ratio of 0.80 (95% CI 0.72 to 0.88) and an incidence rate ratio of 0.69 (95% CI 0.60 to 0.80).[6] There are also systematic reviews indicating that exercise programmes reduce falls in community-dwelling older people with cognitive impairment[7] and in 'frail' older adults.[8] Improvements in balance seem to be a critical component of these exercise interventions, with some interventions not achieving these: as per a recent trial of social dancing which did not prevent falls.[9]

There has also been some research on the health economic aspects of exercise programmes to prevent falls, but this has often used cost per averted fall or fracture[10–12] rather than cost per quality-adjusted life-year (QALY) gained. Another limitation with such economic studies on exercise programmes has been their focus on highly specific groups such as those with Parkinson's disease[13,14] and older people posthospitalisation.[15] But where costs per QALY gained have been calculated, these have been estimated to be relatively high, for example, in an Australian modelling study for the exercise 'Tai Chi' (A$44 205), group-based exercise (A$70 834) and home exercise (A$93 432).[16] Similarly, a study in the UK reported that group-based exercise was only cost-effective among women (at GBP£22 986 per QALY).[17] In contrast, the literature on the cost-effectiveness of preventing falls via home safety assessment and modification (HSAM) seems more favourable (eg, one review that included seven health economic studies[18]), with subsequent work also suggesting relative cost-effectiveness[19] (ICER: US$6000, 95% uncertainty interval (UI):

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cost saving to US$13 000), and HSAM actually being cost-saving when social benefits are monetised (cost-benefit ratio for older people: ≥12).[20]

Given this background our study aim was to model the impact of different exercise programmes for falls prevention among community-dwelling older adults in a country with detailed epidemiological and costing data: New Zealand (NZ). We also aimed to compare the results with the cost-effectiveness of another falls prevention intervention that we have previously estimated using the same falls prevention model for the same population: that of a HSAM intervention.[19]

In the study country, NZ, falls are the seventh most important cause of health loss among those aged 75+ years (3.1% of all disability-adjusted life-years).[21] Also, an evaluation for NZ's Injury Prevention Strategy in 2010 estimated the annual cost of falls (in adults living in the community as well as residential care) for treatment and rehabilitation was 18% of the total cost of injuries in the country.[22] In response to such issues, the NZ Government has recently scaled up its investment in falls prevention (in mid-2016),[23] and there has been focused work on reducing falls in hospitals.[24]

METHODS

Interventions, perspective and modelling approach

This study built on our previously published model for home modification to prevent falls in NZ.[19] The model was revised to permit studying three types of exercise interventions: (i) a home-based exercise programme (centrally funded by government, tailored by a nurse specialist with five home visits); (ii) a peer-led group-based exercise programme (also funded by central government, weekly classes) and (iii) commercially provided group exercise classes (funded by participants themselves, but assuming that the Ministry of Health would only endorse such programmes if the key falls prevention elements such as balance improvements were included). The three exercise interventions were compared with no intervention, with the 2011 NZ population assumed as having no intervention because while a small percentage of older New Zealanders may already be participating in programme-delivered exercise activities in some specific localities (eg, in the City of Dunedin and run by the voluntary sector) there are no national programmes or mass media interventions to promote such interventions.

The analysis undertaken in this study follows the Burden of Disease Epidemiology, Equity and Cost-Effectiveness Programme (BODE[3]) Protocol.[25] This protocol specifies a health system perspective given that the main focus for NZ health sector decision-makers is for comparisons between interventions *within* the health sector. There are also limited data to allow for adopting a societal perspective in NZ studies (eg, one that included productivity costs for older people in the formal economy or who participate in the informal economy via voluntary sector activities). QALYs were used as the outcome measure with disability weights for relevant fractures extracted from the Global Burden of Disease Study data (see the online supplementary appendix for extra methods details).[26] The target population for exercise to prevent falls was all community-dwelling older adults aged 65+ years in 2011.

The time horizon was the remaining lifetime of the entire simulated population, but with the intervention horizon being for up to 25 years (depending on starting age, that is, ending at age 90 for a 65 year old in the year 2011). We assessed the effect of exercise programmes on injurious falls leading to any health service use, but not on outcomes with less measurable impact on QALYs, such as fear and anxiety from injurious falls (given the lack of robust data on these effects). The standard discount rate of 3% was applied[27] to both QALYs gained and costs, although with variation in sensitivity analyses.

Core model structure

The model structure is shown in the online supplementary figure A1 with annual cycles between states. The interventions all acted to reduce the risk of injurious falls and hence resulted in QALYs gained and changes to health costs. As with the previous model for the HSAM interventions,[19] the updated model used Accident Compensation Corporation (ACC) data on injurious falls sustained at home (the ACC is NZ's national agency compensating for injury claims). Data on falls that did not lead to injury were not available for inclusion in the model.

Heterogeneity was modelled in the incidence rates of injurious falls by age (65–69, 70–74, 75–79, 80–84 and 85+ years), sex (men and women), ethnicity (Māori and non-Māori) and whether or not they had had an injurious fall event in the past 5 years. At each point, a person could move into a residential aged care facility, at which point they were assumed to have moved beyond the reach of community-based exercise programmes.

Effectiveness of interventions

A Cochrane Review meta-analysis was the preferred source for parameters for inclusion in NZ-focused epidemiological and health economic modelling, given its large size and also its separation of group-based and home-based effect sizes.[3] It also had the advantage of a focus on community-dwelling older adults in good health (as opposed to being selected for high-risk conditions such as Parkinson's disease or frailty, as detailed in the *Introduction*). Furthermore, the trials included in the Cochrane Review for group and home-based interventions were considered relevant to the NZ setting since the settings for these 23 trials were NZ itself (n=3), Australia (5), North America (6) and other developed countries (7) (the two other trials were in Taiwan and Chile). Nevertheless, we note that the Cochrane Review covered trials of varying intensity and varying types of exercise, though the review authors judged these similar enough to include in the same meta-analyses. Further details are in the online supplementary appendix.

Intervention costs

Cost inputs were sourced from programmes that have been used in a NZ setting. For the peer-led group-based exercise programme, the 'Steady As You Go' (SAYGO) Programme, which is based on the Otago Exercise Programme (OEP), was used.[28] For the home-based programme, the cost of the OEP was used.[10–12] The commercial programme used out-of-pocket costs based on the average cost of enrolment in a commercial gym (based on two nationally available gym chains in NZ).

Uncertainty and sensitivity analyses

Monte Carlo simulation techniques were used to assess uncertainty around results. The Markov model was run 2000 times with different values of parameters sampled from their corresponding uncertainty distributions. For each simulation run, QALY gains, net costs (health system costs and intervention costs) and the ICER of the specific exercise intervention were calculated. Tornado plots were used to rank parameters according to their contribution in total uncertainty around results (one-way sensitivity analyses). These tornado plots were for incremental costs and QALYs gained and they included all key input

Table 1 Main results for the three exercise interventions for preventing falls (showing health gain (QALYs), costs and ICERs for the lifetime of the modelled cohort, 95% UI within brackets)

Baseline	QALYs gained/experienced	Net cost in NZ$ m	ICER in NZ$
No intervention (comparator) with results reflecting the background costs and health status as the cohort ages	4 090 000 QALYs experienced (3 860 000 to 4 290 000)	42 200 (41 800 to 43 100)	Not applicable
Intervention	**Incremental QALYs**	**Incremental costs**	
Home-exercise programme for adults aged 65+ years	47 100 (22 300 to 74 400)	282 (139 to 380)	6900 (2200 to 15 600) (US$4640)
Peer-led group-based exercise programme for adults aged 65+ years	42 000 (21 800 to 65 600)	535 (311 to 730)	14 100 (5900 to 30 700) (US$9490)
Commercially provided group-based exercise programme for adults aged 65+ years	42 300 (21 800 to 65 700)	1950 (1370 to 2560)	51 200 (25 400 to 1 07 000) (US$34 500)

All results rounded to three meaningful digits.
ICER, incremental cost-effectiveness ratio; NZ, New Zealand; QALY, quality-adjusted life-years; UI, uncertainty interval.

parameters or corresponding scalers. Sensitivity analysis for the discount rates of QALYs and costs were conducted using 0% and 6%. All analyses were conducted using Microsoft Excel 2010 and TreeAge Pro 2012 computer software.

Scenario analyses included additional targeting by age group (ie, for the peer-led group intervention). We focused particularly on the peer-led group intervention for the scenario analyses as we considered that this intervention might potentially be of more interest to policy-makers than the home-based one (since it also provides social contact benefits to participants—although these were not quantified in our modelling).

Further methods details

For further detail on health gain measures, transition probabilities and rates, health system costs, programme effectiveness (and participation and withdrawal parameters), cost input parameters and scenario analyses, see the online supplementary tables A1 and table A2.

RESULTS

The intervention generating the greatest health gain and costing the least was the home-based exercise programme. Health gains over the remaining life course were estimated at 47 100 QALYs (95% UI 22 300 to 74 400). The intervention cost nationally was estimated at NZ$289 million (m) for the whole 25-year intervention period and net incremental lifetime costs to the health system were NZ$282 m (all values in NZ$ for 2011 and discounted at 3% unless stated otherwise, table 1). The incremental cost-effectiveness ratio (ICER) was estimated at NZ$6900 per QALY gained (US$4640). The cost-effectiveness acceptability curves suggested that the home-based exercise programme was always likely to the best investment (ahead of the other exercise programmes) from a government's willingness-to-pay perspective (online supplementary figure A2).

The group-based exercise programme was estimated to cost a total of NZ$547 m to implement nationally for a 25-year period and net incremental costs were $535 m (table 1). Health gains were estimated at 42 000 QALYs, which equates to 75 QALYs per 1000 population aged 65+ years (95% UI 39 to 116), as shown in table 2. At the individual level, this equated to 0.075 QALYs gained per person which is equivalent to an extra 27 days of healthy life (discounted; average over all aged 65+ years). The ICER was $14 100 (US$9490) per QALY gained. The online supplementary appendix figures A3–A5 also provides tornado plots showing the major drivers of uncertainty for the results from this particular intervention. For example, for the QALY gain this included the effectiveness of the intervention in reducing falls.

The commercially provided group-exercise intervention was over three times the cost of the peer-led group intervention (at $1950 m over the 25-year period). The ICER was accordingly less favourable at $51 200.

Heterogeneity

For the peer-led group intervention, the health gain and cost-effectiveness were comparable for men and women, and for Māori and non-Māori (table 2). The ICERs suggest that this intervention was cost-effective among both of the studied ethnic groups and for both sexes (see the online supplementary table A3).

Targeting the peer-led group intervention at just the 65–74 year age group, generated nearly three times the health gain of a programme targeted at the 75–84 year age group (table 3). It was also slightly more cost-effective than the base-case intervention (for all the 65+ age group) and similarly for the older age group (ICERs: $13 800 vs $14 100 vs $15 800, respectively).

Sensitivity and scenario analyses

Setting the discount rate to 0% and 6% did not substantially alter the ICER for the peer-led group exercise ($14 300 and $14 200, respectively), reflecting the similar timing of costs and QALYs gained (table 3). But discount rates of 0% and 6% resulted in large changes in incremental costs ($817 m and

Table 2 Per capita health gains for the peer-led group exercise programme (QALYs gained per 1000 population aged 65+ by ethnic group and sex)

Population group (all aged 65+ years)	QALY gain per 1000 population (95% UI)
All participants	75 (39 to 116)
All participants but DR=0%	111 (58 to 170)
All participants but DR=6%	54 (27 to 84)
Non-Māori	76 (39 to 118)
Māori (Indigenous population)	49 (22 to 78)
Māori (equity analysis)*	79 (37 to 125)
Women	77 (41 to 120)
Men	71 (35 to 112)
Men (equity analysis)†	90 (44 to 140)

*As Māori have higher background mortality rates and higher morbidity, this essentially 'penalises' health gain for Māori in the base-case analyses. So we present an 'equity analysis' with non-Māori morbidity and mortality rates applied to Māori (ie, expanding the envelope of potential health gain for Māori).[33]
†As men have higher background mortality rates, this also essentially penalises health gain for men in the base-case analyses. So we present an equity analysis with women's morbidity and mortality rates applied to men.
DR, discount rate; QALY, quality-adjusted life-year; UI, uncertainty interval.

Table 3 Sensitivity and scenario analyses for the peer-led group exercise programme (showing health gain (QALYs), costs and ICERs for population-level results for the lifetime of the modelled cohort, 95% UI within brackets)

Intervention	QALYs gained	Net cost (NZ$ m)	ICER (NZ$)
Peer-led group-based exercise programme for adults aged 65+ years (as per table 1)	42 000 (21 800 to 65 600)	535 (311 to 730)	14 100 (5900 to 30 700)
Sensitivity analysis: discount rate=0%	62 500 (32 800 to 96 000)	817 (554 to 1046)	14 300 (7230 to 28 600)
Sensitivity analysis: discount rate=6%	30 300 (15 500 to 47 500)	378 (180 to 553)	14 200 (4700 to 33 000)
Scenario A: targeted to adults aged 65–74 years	29 400 (13 700 to 45 800)	354 (188 to 488)	13 800 (5000 to 32 900)
Scenario B: targeted to adults aged 75–84 years	11 000 (5300 to 17 100)	154 (95 to 207)	15 800 (6800 to 35 300)

All results rounded to three meaningful digits.
ICER, incremental cost-effectiveness ratio; NZ, New Zealand; QALY, quality-adjusted life-years; UI, uncertainty interval.

$378 m, respectively) and health gains (62 500 QALYs and 30 300 QALYs, respectively).

DISCUSSION

Main findings and interpretation

This study provides modelling-level evidence that implementing any of these three types of exercise programme for falls prevention in older people would produce considerable health gain in this high-income country setting. The home-based intervention was the most cost-effective (reflecting its lower running costs) but the UI for the ICER of this intervention overlapped with that of the peer-led group intervention. Nevertheless, the home-based intervention was vastly more cost-effective than the commercially provided group programme.

From an equity perspective, there was estimated to be similar health gain per capita when comparing both sexes and the two ethnic groups (for the peer-led group intervention, table 2). This finding was similar to our previous study of the cost-effectiveness of a HSAM intervention for reducing injurious falls.[19] Targeting the peer-led group-exercise intervention at just the 65–74 year age group slightly improved cost-effectiveness (since this group had a larger envelope of potential life span than the 75–84 year age group).

Prior cost-utility studies of exercise interventions in other high-income countries indicated considerably less cost-effectiveness (ie, higher cost per QALY), compared with the interventions modelled in this study. Comparisons to previous research are complicated by variations in the output metric and other methods differences as detailed in the *Introduction*. Nevertheless, one reason for the differences is that the intervention costs for NZ were under half those used in the Australian study.[16] The study in the UK also had differences that could account for its findings of lower cost-effectiveness: the focus on an older age group (70+), the proportion of fractures following a fall in this trial was relatively low compared with other literature, the smaller utility weights for some of the fracture types, and the small time horizon of just 18 months).[17]

The model used in our study was modified from one used by us previously to model a HSAM intervention in NZ.[19] This HSAM intervention had lower implementation costs than the exercise interventions but appeared to be slightly less cost-effective than the home-based exercise intervention (though UIs overlapped: see online supplementary tables A4 and A5). This may reflect the larger effect size of the exercise intervention compared with HSAM (at least for those without a history of falls), which may relate to the former preventing falls in both the home and non-home environments. Nevertheless, comparisons between these interventions are complicated by benefits not incorporated into the modelling. For example, the benefits of the HSAM intervention do not capture fall injuries prevented in younger age groups (below age 65 years), and the exercise interventions do not capture additional benefits of exercise (chronic disease prevention) and the social benefits from group exercise (as discussed below).

Study strengths and limitations

A particular strength of this study was that the methodology used was consistent with prior epidemiological and health economic modelling studies in the NZ setting. High quality and relevant data sets were also used for modelling, allowing consideration of impacts on Māori and men, for equity analyses. Locally available programmes (OEP and SAYGO) were used for model parameterisation, particularly around acceptability and costs. Furthermore, we were able to model a range of different exercise interventions (ie, group, home, and commercial), – which does not appear to have been previously done in any setting, and especially not for national-level interventions.

Nevertheless, as with all modelling studies, there are limitations as summarised below (with additional details in the online supplementary appendix):

- An inability to capture other potential health gains arising from exercise and group membership (eg, as per the association between traditional Chinese exercise in older people and reduced mortality rates[29]; and also benefits to mental health from social contact with group exercise). Similarly, we did not consider the benefits of exercise programmes in terms of reduced anxiety around falling (given data limitations with measuring this impact).
- An inability to considering targeting by fall history and frailty as this would have required a much more sophisticated model structure (to capture the dynamic nature of the changing population and to address differential background morbidity and mortality).
- The injury impact was not modelled at a fine-grained level (eg, we just consider a typical fracture without distinguishing wrist fractures vs hip fractures and so on). We also did not consider long-term morbidity from fall injuries, even though this may be large in some cases (eg, disability weight of 0.194 for a fractured pelvis[26]).
- Also given data limitations, we were required to assume the impact of the group-exercise and home-exercise interventions on reducing *falling* from the Cochrane Review meta-analysis was the same as its impact on reducing *injurious* falls. Indeed, this might have resulted in an under-estimate of benefit as the Cochrane Review effect estimate for exercise preventing fractures shows a greater effect size (although based on only six trials – see the *Introduction*). Also, we had to assume that the intervention effect sizes remained constant into the future.
- There remain various uncertainties around health costs in NZ,[30] and further improvements are part of ongoing work in our modelling work programme. In particular, background

(non-fall-related) health costs could be improved on since it is plausible that these costs are relatively higher in people who have injurious falls (ie, certain co-morbid conditions that increase the risk of falls).

- We assumed that there would be adequate capacity in community venues for providing scaled up exercise programmes (given the widespread availability of school halls, church halls and community halls), but we cannot be absolutely sure about this availability throughout NZ.

Generalisability

The results of this study might be fairly generalisable to other high-income country settings with predominantly publicly funded healthcare systems and with an ageing population. Nevertheless, labour costs in NZ are relatively low, compared with some OECD countries, and so programmes requiring professional delivery (such as elements of the home-exercise configuration) may become less cost-effective in countries with high labour costs. However, the potential for low-cost programme delivery through a peer-led group-based programme means that it is potentially also applicable to lower resourced settings. Finally, some countries may wish to use a wider perspective and take into account the costs associated with the increased use of residential care after injurious falls. This would probably make falls prevention substantially more cost-effective, given one NZ study estimating that this component was 41% of the costs from falls.[31]

Potential research and policy implications

Additional epidemiological and economic modelling could assist with describing the best combination of packages that may include both exercise interventions and HSAM. It is also ideal if future models build in the benefits of chronic disease reduction from exercise, the impact on reducing the fear of falls, potentially the social contact benefits from group exercise, and how the benefit of exercise might vary by age group and risk group.

Based on this modelling study, a government-funded falls-reduction policy might first prioritise home-based exercise programmes for the 65+ age group (given the likely probability of highest cost-effectiveness). But if policy-makers put reasonable weight on the non-quantified social contact benefits of the peer-led group intervention, then that might be the first choice of intervention.

If a government put emphasis on total societal benefit it might first favour a HSAM intervention—as this would also deliver fall injury reduction benefits to younger age groups.[32] Similarly, a government concerned with economic productivity might favour targeting exercise programmes to just the 65–74 year age group (since at least a fifth of this group are still in paid employment in NZ).

In a situation in which limited financial resources for such interventions are available from central or local government (and cost-effectiveness was not prioritised), the lower running costs would favour the HSAM intervention followed by the home-based intervention. If no government funds were available for such interventions, then non-governmental organisations could still produce guidelines for healthcare workers to encourage home-based exercise or use of commercial gym programmes. The latter would ideally involve advice as to which types of commercial programmes are most effective and cost-effective for citizens to use (eg, focusing on such design elements as improving balance, but also which minimise injury risk).

Conclusions

Meta-analyses involving thousands of participants have suggested that exercise programmes are effective at reducing the rate of injurious falls in older adults in both home-based and group-based settings. This study used epidemiological and health economic modelling to estimate that both home-based and group-based exercise programmes on a national level would be likely to generate substantial health gain and be cost-effective. In addition, there would likely be many additional social and health benefits, including the chronic disease prevention benefits and social contact benefits (from the group-based interventions). It is likely that these results will be reasonably generalisable to other high-income countries with publicly funded healthcare systems and with an ageing population. However, there is still scope for further research, especially regarding combining exercise interventions with HSAM interventions, and population-wide physical activity interventions for older people.

What is already known on this subject

- There is evidence from large meta-analyses that group-based and home-based exercise programmes effectively prevent falls in older people.
- But economic analyses of exercise interventions for falls prevention have been based on short trials, and there has not been modelling of impacts on a national level that consider a range of targeting options.

What this study adds

- Using epidemiological and health economic modelling, this study provides modelling-level evidence that home-based and group-based exercise programmes generate substantive health gain and are cost-effective in this high-income country setting, for adults aged 65+ years.
- A home-based exercise programme is probably more cost-effective than group-based ones (peer-led and commercial) and probably also more cost-effective than a home safety assessment and modification intervention studied using the same model.
- For the peer-led group-based intervention, equity analyses by ethnicity (Indigenous Māori and non-Māori) and sex (men and women) suggested no differential cost-effectiveness.

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