Economic modelling of a public health programme for fall prevention

INEZ FARAG1, KIRSTEN HOWARD2, MANUELA L. FERREIRA3, CATHERINE SHERRINGTON4

1Musculoskeletal Division, The George Institute, Level 7, 341 George Street, Sydney, New South Wales, Australia
2Sydney School of Public Health, The University of Sydney, Sydney, New South Wales, Australia
3The George Institute for Global Health, University of Sydney, Sydney, New South Wales, Australia
4Musculoskeletal Division, The George Institute for Global Health, Sydney, New South Wales, Australia

Address correspondence to: I. Farag. Tel: (+61) 296309011; Fax: (+61) 296309012. Email: ifarag@georgeinstitute.org.au

Abstract

Background: despite evidence on what works in falls prevention, falls in older people remain an important public health problem. Aims: the purpose of this study was to model the impact and cost-effectiveness of a public health falls prevention programme, from the perspective of the health funder. Methods: a decision analytic Markov model compared the health benefits in quality-adjusted life years (QALYs) and costs of treatment and residential aged care with and without a population health falls prevention programme. Different intervention costs, uptake levels and programme effectiveness were modelled in sensitivity analyses. Uncertainty was explored using univariate and probabilistic sensitivity analysis. Results: widespread rollout of a public health fall prevention programme could result in an incremental cost-effectiveness ratio (ICER) of $A28,931 per QALY gained, assuming a programme cost of $700 per person and at a fall prevention risk ratio of 0.75. This ICER would be considered cost-effective at a threshold value of $A50,000 per QALY gained. Sensitivity analyses for programme cost and effectiveness indicated that the public health programme produced greater health outcomes and was less costly than no programme when programme costs were $A500 or lower and risk ratio for falls was 0.70 or lower. At a cost of $A2,500, the public health falls prevention programme ceases to be a cost-effective option. Conclusion: serious consideration should be given to implementation of a public health programme of falls prevention as a cost-effective option that enables population-wide access to the intervention strategies.

Keywords: Markov model, falls prevention, ageing, older people

Introduction

Falls are a major cause of harm to older people [1]. With ageing of the population and increasing cost of health services, fall-related injuries are imposing a substantial burden on the health care system [2]. Falls impact on quality of life of individuals, their family and on society [3, 4]. Several intervention strategies have been found to prevent falls [5, 6]. These include single intervention strategies, which comprise individual and group exercise, as well as programmes targeting individuals with particular risk factors, such as visual difficulties, medication use and cardiac pacing. In addition, multi-factorial intervention has been shown to reduce fall rates by 25% [6].

尽管证据表明预防跌倒的益处，但与跌倒相关的医院化率仍然很高 [7]。目前的挑战似乎是实施和确保策略在群体层面的采纳 [6, 8]。通过建模可以测试试验结果，了解哪些元素在促进项目层面的采纳方面是有效的 [9]。通过改变参数，例如年龄或人口模型的居住地，可以更好地反映现实生活情况。
The purpose of this study was to (i) model the impact and cost-effectiveness of implementation of a public health programme of falls prevention, from the perspective of the health funder and (ii) explore the impact of programme effectiveness, cost and uptake on cost-effectiveness.

Methods

A Markov model was designed to simulate the natural transition between health states of the target population. The model constituted five health states that an individual may traverse within the course of the lifespan. The target population was individuals aged 65 with no prior history of falls and living independently in the community. The model was used to estimate the impact of a falls prevention programme on fall rates, health service use, hospitalisation and residential care admission. To explore the impact of programme effectiveness, cost and uptake on cost-effectiveness, sensitivity analyses were conducted using a range of values for each of these parameters.

Structure of the model

The five health states determined in the Markov model included community dweller with no prior history of falls, community dweller with a prior history of falling, community dweller with a history of prior hospitalisation, resident in an aged care facility and the death state. Transition probabilities were assigned to the likelihood of movement between health states. A schematic model of the path traversed in a health state is depicted in Supplementary data, Appendix, Figure S1 available in *Age and Ageing* online. The model terminates when all potential programme participants are deceased.

| Table 1. Model inputs base case, community dweller aged 65 and older |
|-----------------|-----------------|-----------------|-----------------|
| Probabilities   | Value           | Range           | Distribution    | Reference     |
| Fall in the community | 0.270           | 0.170–0.290     | Beta            | [7]           |
| Fall with history of falls | 0.390           | 0.250–0.600     | Beta            | [12]          |
| Injury requiring treatment | 0.203           | 0.150–0.410     | Beta            | [7]           |
| Emergency department presentation | 0.140           | 0.110–0.160     | Beta            | [7]           |
| Hospital admission following a fall | 0.110           | 0.030–0.350     | Beta            | [7]           |
| Discharge from hospital to a RAC following a fall | 0.010           | 0.010–0.200     | Beta            | [7]           |
| Admission to a RAC facility—community dweller (not age specific) | 0.060           | 0.030–0.090     | Beta            | [13]          |
| Fall-related death | 0.008           | 0.000–0.020     | Beta            | [13]          |
| Mortality rates in the general population | 0.009           | 0.010–0.020     | Beta            | [13]          |

Costs

- Emergency department consultation: $2,074, $477–$3,496, Gamma [7]
- Annual cost of RAC: $51,830, $26,645–$60,000, Gamma [7, 14]
- Other treatment: $318, $248–$388, Gamma [7]

Utilities

- Age 65 community dweller: 0.806, 1.000–0.676, Beta [15]
- Emergency department decrement: 0.040, 0.014–0.150, Beta [16]
- Hospitalisation decrement: 0.239, 0.144–0.250, Beta [16]
- Injury decrement: 0.018, 0.013–0.070, Beta [15]
- RAC decrement: 0.100, 0.030–0.940, Beta [16]
- Prior hospitalisation: 0.126, 0.050–0.200, Beta [16]

RAC, residential aged care.

The cost-effectiveness decision analysis model was constructed with two arms to compare the health benefits in quality-adjusted life years (QALYs) gained and the costs of treatment and residential aged care admission with the programme intervention, with the health benefits and costs if the programme was not offered. All analyses were conducted using TreeAge Pro Suite 2012.

Data and assumptions

It was assumed that the public health falls-prevention programme was offered only to community dwellers and as such residents of aged care facilities did not have access to the programme.

Input parameter estimates for the model

Probabilities

Age-specific probabilities for the following variables were sourced from a report to NSW Health [7]: a fall, a fall requiring treatment, hospital admission, emergency department consultation, non-hospital treatment and transfer to a high-care residential aged care facility (nursing home). The probability of a fall, where there was a history of previous falls was calculated using data from a recently completed randomized controlled trial involving 340 participants [12]. Data from the Australian Bureau of Statistics were used to determine age-specific mortality rates and fall-related deaths (Table 1).

Utilities

Utility estimates were derived from the literature. A decrement in the utility value was incurred once an individual
Programme costs ($500–$2,500) were also used in the analysis. A range of fall prevention strategies, which incorporate a process of assessment and referral to appropriate intervention strategies, are offered compared with the no programme condition. Risk ratios, for the proportion of fallers in intervention compared with control groups, of 0.4–0.9 were used, based on a systematic review conducted by the Cochrane Collaboration [6].

The impact of intervention is highly dependent on uptake and access [9, 19]. Modelling of uptake rates therefore was considered as providing valuable information that may improve cost-effectiveness.

Sensitivity analysis

Using sensitivity analyses, assumptions were tested over a range of plausible values to assess the robustness of the uncertainty in the model's parameter estimates including variation in utility values, cost of health services and probability of occurrence of events. In addition, we also specifically assessed in deterministic one-way and two-way sensitivity analyses, the impact of varying (i) the effectiveness of the intervention, (ii) the cost of the intervention programme and (iii) uptake level on the cost-effectiveness of the programme.

Probabilistic modelling

Variation in cost and effect data was modelled by creating a distribution of values, based on confidence intervals or standard errors around the variables. These estimates were obtained from the literature (Table 1) and were used in a Monte Carlo stimulation with 10,000 draws to reflect the joint parameter uncertainty.

Results

Base case scenario

The base case scenario model yielded a cost-expenditure estimate of $A28,931 per QALY gained compared with not offering a programme (programme cost assumed to be $700 per participant, programme effectiveness was 25% (relative risk = 0.75) and the programme uptake was 50% of the population). In this model, the public health falls prevention programme was more expensive ($A379), but it was also more effective (0.0139 QALY) than the alternate option of not offering a programme. Health outcome gains were predominantly driven by the avoidance of decrements in the quality of life associated with hospital admission and emergency department consultations. The calculated ICER of the base case is considered cost-effective at a threshold value of $A50,000 per QALY gained [20].

Sensitivity analysis: utilities, probabilities and costs of care

One-way sensitivity analysis for the range of parameters indicated that there was no major impact on cost-effectiveness (at a threshold value of $A50,000 per QALY gained) with alteration in the utility values corresponding to hospitalisation, presentation at the emergency department or even residential aged care admission. The probability of hospital admission following a fall with a range extending from 0.03 to 0.35 also did not significantly impact on cost-effectiveness with the ratio remaining favourable to the public health programme option. The probability of discharge to a residential aged care facility from hospital resulted in only minimal impact on the ICER with a variation of no more than $A500 per QALY across the range of probabilities tested. The baseline probability of a fall in the general population however did impact on cost-effectiveness with the public health fall prevention programme being dominant (i.e. both less costly and more effective than no programme) at a probability of falling of 0.5 and a calculated ICER of $A40,987 per QALY at a probability of falling of 0.32.

The cost of residential aged care impacted on cost-effectiveness with the ICER ranging from $A61,008 per QALY gained at an annual cost of $A26,645 to $A17,224 per QALY gained with an annual cost of $A53,290. The cost
of hospital treatment did not impact significantly on cost-effectiveness, over the range of tested values from $A1,300 to $A12,898 per admission, but there was a trend for improved cost-effectiveness with a rise in the cost of hospital admission, predominantly because of the impact of the programme on the number of hospital admissions.

Sensitivity analysis: programme characteristics

It was found that cost-effectiveness improved as the risk ratio decreased (i.e. the effectiveness improved) (Table 2). The public health programme dominated the ‘no programme option’, for risk ratio values of 0.70 and lower. A risk ratio of 0.77 was determined to be the threshold value at which the options could be considered as having the same cost and providing the same health gains.

It was found that at a programme cost of $500 the public health option was clearly dominant. At higher levels of programme costs, the public health programme became less efficient. The calculated ICER at different programme cost levels is detailed in Table 2.

It was found that with uptake ranging from 10 to 70%, there was not a significant difference in the value of the calculated ICER calculated using a programme cost of $A700 per person.

As would be expected, two-way sensitivity analysis for programme effectiveness and cost indicated that with increasing cost of the public health programme, a lower risk ratio is required to maintain cost-effectiveness. Table 2 outlines the risk ratio levels at which the calculated ICER is less than $A50,000 per QALY gained.

Probabilistic sensitivity analysis—Figure 1—indicates that at a cost-effectiveness threshold of $A50,000 per QALY gained, there is 57% probability that the public health falls prevention programme will be cost-effective.

Discussion

This modelled study indicates that a public health programme of falls prevention may be a cost-effective strategy for reducing falls in the older population. In our base case scenario, at a programme cost of $A700 per participant and risk ratio of 0.75, the value of the calculated ICER is $A28,931 per QALY gained [20]. This compares favourably to other public health programmes supported in Australia [21] and provides useful information for policymakers in their decision to invest in a falls prevention strategy. Factors that impacted on cost-effectiveness included the cost of residential aged care and the probability of falls in the older population. Other factors including cost and probability of hospital admission did not impact cost-effectiveness.

As anticipated we found there to be two major drivers of the cost-effectiveness of a public health falls prevention programme, namely the effectiveness of the intervention strategy offered in terms of the proportion of fallers and secondly the cost of the intervention programme.

The one-way and two-way sensitivity analyses indicate that cost-effectiveness is markedly susceptible to the cost of

Table 2. One-way sensitivity analysis for programme effectiveness and cost of programme

<table>
<thead>
<tr>
<th>Risk ratio</th>
<th>Incremental cost</th>
<th>Incremental QALY</th>
<th>ICER per QALY gained versus No programme</th>
<th>Cost-effectiveness at $A50,000 per QALY gained</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>+$1,777</td>
<td>0.009</td>
<td>$205,016</td>
<td>No PH programme</td>
</tr>
<tr>
<td>0.85</td>
<td>+$1,309</td>
<td>0.013</td>
<td>$100,573</td>
<td>No PH programme</td>
</tr>
<tr>
<td>0.8</td>
<td>+$842</td>
<td>0.017</td>
<td>$48,437</td>
<td>Cost-effective</td>
</tr>
<tr>
<td>0.75</td>
<td>+$374</td>
<td>0.022</td>
<td>$17,224</td>
<td>Cost-effective</td>
</tr>
<tr>
<td>0.7</td>
<td>−$92</td>
<td>0.026</td>
<td>less expensive and more QALYs</td>
<td>PH programme dominates</td>
</tr>
<tr>
<td>0.65</td>
<td>−$559</td>
<td>0.031</td>
<td>less expensive and more QALYs</td>
<td>PH programme dominates</td>
</tr>
<tr>
<td>0.6</td>
<td>−$1,025</td>
<td>0.035</td>
<td>less expensive and more QALYs</td>
<td>PH programme dominates</td>
</tr>
<tr>
<td>0.55</td>
<td>−$1,491</td>
<td>0.039</td>
<td>less expensive and more QALYs</td>
<td>PH programme dominates</td>
</tr>
<tr>
<td>0.5</td>
<td>−$1,956</td>
<td>0.044</td>
<td>less expensive and more QALYs</td>
<td>PH programme dominates</td>
</tr>
<tr>
<td>0.44</td>
<td>−$2,420</td>
<td>0.048</td>
<td>PH programme dominates</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>−$2,883</td>
<td>0.053</td>
<td>PH programme dominates</td>
<td></td>
</tr>
</tbody>
</table>

Cost ($A) of the intervention programme

- $500: −$404, 0.022, less expensive and more QALYs, PH programme dominates
- $1,000: +$1,542, 0.022, $70,917, No PH programme
- $1,500: +$3,490, 0.022, $160,404, No PH programme
- $2,000: +$5,436, 0.022, $249,893, No PH programme
- $2,500: +$7,383, 0.022, $339,381, No PH programme

Two-way sensitivity analysis of cost ($A) of programme and risk ratio

<table>
<thead>
<tr>
<th>Cost</th>
<th>Risk ratio at which ICER is &lt;$A50,000 per QALY gained</th>
</tr>
</thead>
<tbody>
<tr>
<td>$500</td>
<td>0.85</td>
</tr>
<tr>
<td>$1,000</td>
<td>0.73</td>
</tr>
<tr>
<td>$1,500</td>
<td>0.57</td>
</tr>
<tr>
<td>$2,000</td>
<td>0.43</td>
</tr>
<tr>
<td>$2,500</td>
<td>Nil</td>
</tr>
</tbody>
</table>
the programme. Exploring methods of cost reduction of the intervention, providing programme effectiveness is not compromised, should maximise cost-effectiveness. Programmes offered currently differ over a wide range of costs, with an estimated cost of $A563 for group exercise to $A1,244 for multifactorial intervention [18]. While there is interplay between the costs and effectiveness of the programme that ultimately determines cost-effectiveness, with less costly programmes for example able to be less effective, it should be highlighted that at a programme cost of $A2,500 there is no level of programme effectiveness that can make the public health falls prevention programme a cost-effective option.

There have been several cost-effectiveness studies of falls prevention strategies. Some have used trial data in the estimation of cost-effectiveness [22, 23] while others have used a combination of trial data and modelling [9, 24]. The results of this evaluation are consistent with the findings of several of the studies and indicate cost-effectiveness of several programmes that have population-wide application [9, 25]. They do however differ from the results of Church et al. [18], which suggests that without consideration of the fear of falling no intervention may be considered as cost-effective. The differences are largely due to model structure.

The results of our modelled study indicate that a public health programme of fall prevention is economically viable and should be implemented. Such implementation should involve the availability of choice of intervention strategies that are known to be effective in falls prevention. The provision of appropriate exercise programmes could be enabled by training exercise leaders and health professionals to ensure there is a workforce to deliver the intervention. Promotion of uptake of these programmes by older people through the provision of information disseminated through community groups and general medical practitioners is also necessary. Options for subsidising participation can be canvassed and modelled.

The strengths of our modelled evaluation include the use of the QALY as a multi-attribute health outcome measure, allowing for comparison between health programmes and enabling policymakers to make decisions about the most cost-effective expenditure of the healthcare dollar. Our use of age-specific parameters and distributions, rather than point estimates, allows for better modelling of the target population and narrows the confidence interval around the parameters. The model structure also allows for consideration of ongoing intervention costs.

There are several limitations in our modelled evaluation. Most of the model inputs rely on Australian data, except utility values, which are derived from the UK population. This impacts generalisability of the results to other contexts. The model also assumes that participants will derive the same level of benefit from the programme each year but there may be a threshold above which no further gains can be made. To counter that, the model does not take into consideration all of the potential benefits associated with the intervention and any gains lasting longer than 1 year have not been considered in the analysis.

**Conclusion**

With the increasing cost of health services and the rising prevalence of age-related disease, including injuries arising from falls, a full exploration of a population-based approach to falls prevention has become necessary. Ultimately, if a funder is willing to spend up to $A50,000 for each additional QALY gained, then the public health falls prevention programme should be seriously considered as good value for money for improving health outcomes.

**Key points**

- Public Health programme for the prevention of falls.
- Cost-effectiveness of implementing a public health programme.
- Health economic modelling of a falls prevention programme.

**Conflicts of interest**

None declared.

**Funding**

Prof Sherrington receives salary support from the National Health Medical Research Council (NHMRC). The financial sponsors played no role in the design, execution, analysis and interpretation of data or writing of this study.
**Supplementary data**

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

**References**


Received 14 May 2014; accepted in revised form 12 November 2014.