An economic evaluation of falls prevention strategies for older adults living in the community in Australia

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Abstract

Objective:

To evaluate the cost-effectiveness of strategies designed to prevent falls amongst people aged 65 and over living in the community in Australia.

Methods:

A decision analytic Markov model of interventions designed to prevent falls was developed. Effectiveness of the interventions was derived from a Cochrane review of randomised controlled trials for falls prevention. Incremental cost-effectiveness ratios (ICERs) using quality adjusted life year (QALYs) as the outcome measure, were calculated for those interventions aimed at the general population (home exercise, group exercise, Tai Chi, multiple and multi-factorial interventions); high risk populations (group exercise, home hazard assessment/ modification and multi-factorial interventions); and those interventions aimed at specific populations (cardiac pacing, expedited cataract surgery and psychotropic medication withdrawal). Uncertainty was explored using univariate and probabilistic sensitivity analysis.

Conclusion:

In the general population, compared with no intervention the resulting ICERs were Tai Chi ($44,205), group-based exercise ($70,834), multiple interventions ($72,306), home exercise ($93,432), multifactorial interventions with only referral ($125,868) and multifactorial interventions with an active component ($165,841). The interventions were ranked by cost, in order to exclude dominated interventions (more costly, less effective) and extendedly dominated interventions (where an intervention is more costly and less effective than a combination of two other interventions). Tai Chi remained the only cost-effective intervention for the general population. In the high risk group, home hazard assessment dominates both group-based exercise and multi-factorial interventions. For specific populations, expedited cataract surgery, cardiac pacing and psychotropic medication withdrawal all appear to be cost-effective under conventionally assumed cost per QALY thresholds.

Implications:

This study demonstrates that interventions designed to prevent falls in older adults living in the community can be a cost-effective. However, there is uncertainty around some of the model parameters which require further investigation.

Background on falls prevention

Falls are common among older people with up to one in four people aged over 65 years falling at least once a year, with many falling multiple times.[1] Fall related injuries are a major cause of morbidity and mortality. For example, each year in New South Wales, Australia, falls result in approximately 30,000 hospitalisations and at least 300 deaths in people aged 65 years and over.[2]

Projections indicate that without preventive action, the costs to the health care system from injurious falls are likely to escalate given that the Australian population is ageing. In 2006/07 the estimated treatment costs associated with falls in New South Wales was $558.5 million.[3, 4] This cost is likely to rise, since it is projected that by 2056, 23% to 25% of the Australian population will be aged over 65 years.

Several community-based strategies have demonstrated effectiveness in preventing falls, including group-based exercise, home-based exercise, tai chi, home hazard assessment and modification, clinical medication review, expedited cataract surgery, cardiac pacing, psychotropic medication withdrawal and various multiple and multi-factorial interventions.[5]

A number of economic evaluations have been published exploring the cost-effectiveness of various falls prevention strategies.[6- 14] Most report the outcome as a cost per fall avoided. This approach is useful when the objective is to choose between interventions with the same outcome measure; however it does not convey whether the intervention represents value for money relative to other disparate health care programs. To overcome this limitation, a generic outcome measure is necessary. Several studies have used a cost-utility approach to evaluate single interventions.[15- 17] Only one study has evaluated a selection of falls prevention strategies in a single model. However, this study does not allow for variations in populations or differences in falls risk factors that should be modelled separately.[18] Of the studies employing a cost-utility approach, the most cost-effective interventions were expedited cataract surgery, psychotropic medication withdrawal and Tai Chi.[17, 18]

A loss of quality of life is not restricted to injuries following a fall (e.g. hip fracture). Studies have demonstrated that fear of falling can lead to depression and restricted mobility and reduced activities of daily living leading to reductions in quality of life.[19, 20] Iglesias et al. suggest that the main impact of falling in terms of an individual's quality of life is due to a fear of falling rather than falls or fractures due to falls.[21] To date, fear of falling has not been considering in economic modelling of falls prevention.

This study adds to the literature in a number ways. First, all effective falls prevention strategies are included in a single model for both a general population and those at a higher risk of falling. Secondly, the outcome measure used is the Quality Adjusted Life Year (QALY), which includes a loss of QALYs due to fall related injuries and a fear of falling. Finally, the model accounts for the fact that individuals have different rates of falling based on baseline risk profile. Therefore individuals in the model are classified as being at low, medium or high risk of falling depending on age and prior history of falls.

Methods

Economic evaluation:

A decision analytic Markov model was developed to assess the cost-effectiveness of falls prevention strategies. The rationale of the model is that falls prevention strategies reduce the number of individuals who fall and consequently reduces the risk of falling in the future, which in turn reduces the number of injuries or hospitalisations due to falling. Injurious falls can have serious morbidity and mortality impacts and therefore a reduction in the number of fall related injuries will result in measureable QALY improvements. An incremental cost-effectiveness ratio (ICER) was calculated for interventions in the general population and high risk population and ranked according to effectiveness. For interventions in specific populations (expedited cataract surgery, psychotropic medication withdrawal and cardiac pacing) separate analyses were conducted and an ICER calculated compared to 'no intervention'.

Model

A Markov model was designed to capture the transition between various health states. Five Markov states were assigned: 1) *low risk* (individuals who have never fallen); 2) *medium risk* (individuals who have previously fallen but incurred no injury); 3) *high risk* (previously fallen and incurred an injury); 4) *residential aged care*; and 5) *death*. Individuals move between each state by following a multiple event decision tree.

The Markov model and embedded decision tree are represented in Figures 1 and 2. Transition probabilities were based on published evidence where available, supplemented with expert advice where higher level evidence was unavailable. The sensitivity of the conclusions to these assumptions was subsequently tested in a sensitivity analysis (described in detail below). Costs and outcomes were incorporated into the model as a mean value per state per cycle. The cycle length was one year and all costs and outcomes were discounted at a rate of 5% per annum, the most commonly applied approach to discounting in Australia.[22] All analysis was conducted using TreeAge Pro Suite 2009.

Insert figure 1 here

Insert figure 2 here

Model Inputs

The data used in the model were obtained from different sources including published literature on falls prevention, expert opinion, the Australian Bureau of Statistics, Australian Institute of Health and Welfare and NSW Government reports, including a report from the Injury Risk Management Research Centre, UNSW.[4] In the absence of suitable data, assumptions were made and tested in the model.

Effectiveness

The effectiveness of each intervention was based on a systematic review conducted by the Cochrane Collaboration.[5] Only interventions with a statistically significant reduction in the risk of falling were included in the model. The estimated rate ratio was used to adjust the probability of falling for each intervention compared to no intervention.

Costs

The cost of each intervention is outlined in Table I. The majority of intervention costs were taken from Day et al.[23] All other intervention costs were calculated using the mean frequency, duration or dose etc. from the studies included in the meta-analysis. All health care related costs were taken from Watson et al.[4] All costs were applied on a per fall basis in the cycle in which they occurred. The only exception was that the cost of a fall for individuals admitted to residential aged care due to a fall was assumed to be only incurred once and was calculated as the total lifetime cost of a fall-related residential aged care admission.

Insert table I here

Transition probabilities

The initial population distribution between the low, medium and high risk states was derived from Lord et al. and the probability of falling was calculated using expert opinion (Professor Stephen Lord, personal communication), and divided into age groups.[24] The transition probabilities to emergency department (ED), other medical services, hospital, residential aged care facility, respite care or death due to a fall were obtained from Watson et al. (Table II).[4] The probability of having an emergency attendance was estimated from the number of falls requiring an ED attendance dividend by the number of falls in each age group. The same calculation was used to estimate the number of falls requiring other medical services. The probability of being admitted to hospital due to a fall, contingent on ED attendance, was calculated as the number of hospital admissions divided by the total number of ED attendances. All cause mortality was obtained from the Australian Bureau of Statistics life tables and the probability of entering residential aged care facility from 'all causes' was estimated from Wang et al.[25, 26]

Insert table II here

Utility

The baseline utility estimates used in the model were based on UK Population Norms for the EQ-5D.[27] A utility decrement was incurred once an individual attended ED (-0.014), was admitted to hospital (-0.144) or had a previous fracture in the year following a fall (-0.072). These utility measures were estimated from published literature based on the proportion of hip to vertebral fractures and the corresponding utility loss from the first year and subsequent years following the fracture.[28, 29] The utility loss due to a wrist fracture was used for a non-hospitalised injury that presented at ED.[27] No quality of life decrement was assumed in subsequent years after the decrement for a wrist fracture in the first year.[30] A utility loss was also incurred once admitted to residential aged care (-0.06).[31] Using Iglesias et al., a utility decrement due to the fear of falling (-0.045) was included in the model regardless of any injury or hospitalisation.[21]

Results

Base-case analysis

In the base case, each of the interventions was analysed for a cohort of individuals aged 65 years or older based on the current age distribution in Australia.[32] The model was run until death or 100 years of age. Exercise, Tai Chi, home hazard assessment, psychotropic medication withdrawal, multiple and multi-factorial interventions were all assumed to incur the costs and benefits of the intervention in the first year only. Given that the average length of follow-up in the studies included in the meta-analysis is close to one year and no evidence is available to the contrary, the rate of falling was only adjusted in the first year and any benefits flowing through to subsequent years are due to a reduction in falls in the year of the intervention. This is a conservative assumption, and may understate the benefit of these interventions. Expedited cataract surgery and cardiac pacing were assumed to incur costs in the first year only, but the benefits of the intervention would be experienced for as long as the individual was alive.

Outcomes from the model were measured in terms of falls avoided, hospitalisations avoided and QALYs gained. The results include the actual cost of providing the intervention plus any costs for medical treatment incurred due to a fall. In this respect, 'no intervention' against which all interventions are compared is not in fact costless because this option incurs the highest fall-related treatment costs of all the considered options. Table III summarises the results from those interventions provided to the general population. The interventions are ranked according to their relative cost-effectiveness. Dominated and extendedly dominated interventions were removed, and an ICER was calculated.[33] Table IV summarises those interventions targeting high risk fallers. Table V summarises the cost-effectiveness results of interventions in specific populations and presents the ICERs calculated for each intervention compared to the 'no intervention'. Combining these interventions into one analysis is not appropriate given the different populations at baseline.

Insert table III here

Insert table IV here

Insert table V here

Univariate sensitivity analysis

A sensitivity analysis was conducted on each parameter, using confidence intervals (where available), the best estimate of possible ranges, or by adjusting the parameter by 25%. The tornado plot is presented in Figure 3, which represents the possible cost-effectiveness range given the variability around each parameter. The sensitivity analysis demonstrated that when fear of falling was excluded from the model, none of the interventions were cost-effective. Consequently 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. While the fear of falling is the main driver in the model, the effectiveness, cost of the intervention and the starting age of the cohort are also drivers in the model.

Probabilistic sensitivity analysis

A probabilistic sensitivity analysis (PSA) was also undertaken. A distribution was estimated for each of the parameters in the model, based either on confidence intervals, standard errors or an appropriate range of estimates around the mean. By assigning distributions to the model parameters, a Monte Carlo simulation with 10,000 draws was performed to reflect the joint parameter uncertainty. Tables I and II show the distributions for all the transition probabilities, costs and utility values included in the model.

Insert figure 4 here

The cost-effectiveness acceptability curves in figure 4 demonstrate the probability of each intervention being cost-effective across a range of willingness to pay thresholds. At low willingness to pay thresholds, ‘no intervention’ dominates the other interventions. Tai Chi becomes most likely to be the cost-effective option at the $60,000 threshold.

Discussion

Most economic evaluations of falls prevention strategies have reported the cost per fall avoided. This endpoint is useful when the decision maker has decided to invest in a falls prevention strategy, because the lowest incremental cost per fall avoided can be identified. However, there are limitations to such approaches, since it difficult to judge whether an intervention represents value for money in terms of the total health care budget. Unless the value society is willing-to-pay to avoid a fall is known an alternative approach is required. The approach taken in this paper was to use the generic outcome measure of QALYs gained. The advantage of using QALYs is that interventions for different health conditions (not just falls prevention) can be compared.

Another advantage of using QALYs is that other factors considered important, such as fear of falling, can be added to the model. Fear of falling may result in depression, mobility restrictions and reduced activities of daily living, leading to reductions in quality of life.[34,35] The quality of life decrement relating to fear of falling was taken from a well constructed analysis using EQ-5D data that was derived from three large studies.[21] The study concludes that the main burden to morbidity, measured as impact on health-related quality of life, is due to fear of falling rather than falls or their sequelae. However, a limitation of this study is the generalisability, given that the data is derived from a UK female population. In the model fear of falling was a significant driver of the cost-effectiveness results. 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. Clearly further research is warranted.

For the general population, the model assumes that the benefit of the intervention only occurs in the first year. This is a conservative assumption which is based on the follow-up period in clinical trials reporting effectiveness results. One of the interesting findings of the study is that interventions targeting specific patient populations, such as expedited cataract surgery, psychotropic medication withdrawal and cardiac pacing appear to be the most cost-effective. The main reason for this is that the benefits associated with both are generally large and occur for a number of years. In fact the model does not capture all the benefits associated with these interventions. For example, patients undergoing expedited cataract surgery receive other benefits in terms of the quality of life derived from improvements in vision.

The results generally concur with the findings of Frick et al,[18] in that tai chi and psychotropic medication withdrawal were considered cost-effective interventions. The results differ with respect to the inclusion of cataract surgery and the exclusion of Vitamin D. However, this study improves on Frick et al in a number of ways. These include the following: a decision analytical Markov model is used which allows for low, medium and high risk groups; specific populations are modelled separately; and fear of falling has been explicitly incorporated.

The point estimates used in the economic model are based on a Cochrane review of falls prevention interventions.[5] Therefore they do not take account of the heterogeneity of similar interventions. For example, the pooled cost and pooled effectiveness estimates may mask the fact that high cost interventions (e.g. exercise three times a week compared to once a week) are more effective relative to the cheaper equivalent. Also, while using a random effects model may widen the confidence intervals around a particular parameter, it does not explain the heterogeneity that exists between the studies. The pooling of study results may not be the most appropriate means of deriving an estimate of effectiveness. Furthermore, the costs of the interventions are estimated based on mean duration and intensity, hence a higher cost intervention could indicate a more effective intervention.

Currently there is debate in Australia regarding whether a cost-effectiveness threshold exists. An analysis of Pharmaceutical Benefits Advisory Committee decisions, suggests an implicit threshold of between $50,000 and $60,000 per QALY gained.[36] If this threshold does represent society's willingness-to-pay for a QALY gained, the following community based interventions would be considered cost-effective: Tai Chi, group-based exercise for high risk populations and psychotropic medication withdrawal. Group-based exercise, home hazard assessment/modification and multiple interventions would be approaching cost-effectiveness.

Conclusion

In the general population Tai Chi dominated all interventions other than group-based exercise, meaning it costs less and has a greater benefit. However, group-based exercise is extendedly dominated, (i.e. a combination of Tai Chi and no intervention is less costly and more effective than group-based exercise alone). In the high risk population, home hazard assessment/ modification and group-based exercise appeared to be the most cost-effective interventions. For specific populations, expedited cataract surgery is cheaper and more effective than delaying surgery. Psychotropic medication withdrawal and cardiac pacing are also cost-effective, however this result is based on limited effectiveness data and should be interpreted with caution. Of the options available for decision makers, the results presented here suggest that Tai Chi is the most cost-effective intervention for preventing falls in the general community and group exercise for those identified as high risk fallers.

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References

1. NSW Department of Health, *Report on Adult Health from the New South Wales Population Health Survey*. 2007, Sydney: NSW Health Department.
2. NSW Department of Health 2010, *Available from: http://www.gsahs.nsw.gov.au/page.asp?t=mr&p=1497 (Cited 1 June 2010)*. 2010.
3. Watson, W., A. Clapperton, and R. Mitchell, *The burden of fall-related injury among older persons in New South Wales.* Australian and New Zealand Journal of Public Health, 2011. **in press**.
4. Watson, W., A. Clapperton, and R. Mitchell, *The cost of fall injuries among older people in NSW, 2006-07.* NSW Injury Risk Management Research Centre, University of New South Wales, 2009.
5. Gillespie, L.D., et al., *Interventions for preventing falls in older people living in the community.* Cochrane Database of Systematic Reviews (Online), 2009(2): p. CD007146.
6. Medical Advisory Secretariat, *The Falls/Fractures Economic Model in Ontario Residents Aged 65 Years and Over (FEMOR).* Ontario Health Technology Assessment Series, 2008. **8(6)**.
7. Salkeld, G., et al., *The cost effectiveness of a home hazard reduction program to reduce falls among older persons.* Australian and New Zealand journal of public health, 2000. **24**(3): p. 265-71.
8. Robertson, M.C., et al., *Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 1: Randomised controlled trial.* BMJ, 2001. **322**(7288): p. 697-701.
9. Robertson, M.C., et al., *Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 2: Controlled trial in multiple centres.* BMJ 2001. **322**(7288): p. 701-4.
10. Campbell, A.J., et al., *Randomised controlled trial of prevention of falls in people aged > or =75 with severe visual impairment: the VIP trial.* BMJ 2005. **331**(7520): p. 817.
11. Smith, R.D. and D. Widiatmoko, *The cost-effectiveness of home assessment and modification to reduce falls in the elderly.* Australian and New Zealand journal of public health, 1998. **22**(4): p. 436-40.
12. Wilson, C.J. and S.K. Datta, *Tai Chi for the Prevention of Fractures in a Nursing Home Population: An Economic Analysis.* Journal of Clinical Outcomes Management, 2001. **8**(3): p. 19-27.
13. Rizzo, J.A., et al., *The cost-effectiveness of a multifactorial targeted prevention program for falls among community elderly persons.* Medical care, 1996. **34**(9): p. 954-69.
14. Elley, R., et al., *Cost-effectiveness of physical activity counselling in general practice.* New Zealand medical journal, 2004. **117**(1207): p. U1216.
15. Hendriks, M.R.C., et al., *Cost-effectiveness of a multidisciplinary fall prevention program in community-dwelling elderly people: A randomized controlled trial (ISRCTN 64716113).* International Journal of Technology Assessment in Health Care, 2008. **24**(02): p. 193-202.
16. Sach, T.H., et al., *Falls and health status in elderly women following first eye cataract surgery: an economic evaluation conducted alongside a randomised controlled trial.* British Journal of Ophthalmology, 2007. **91**(12): p. 1675-9.

17. Busbee, B.G., et al., *Cost-utility analysis of cataract surgery in the second eye.* Ophthalmology, 2003. **110**(12): p. 2310-2317.
18. Frick, K.D., et al., *Evaluating the cost-effectiveness of fall prevention programs that reduce fall-related hip fractures in older adults.* Journal of the American Geriatrics Society, 2010. **58**(1): p. 136-41.
19. Boyd, R. and J.A. Stevens, *Falls and fear of falling: burden, beliefs and behaviours.* Age and ageing, 2009. **38**(4): p. 423-8.
20. Masud, T. and R.O. Morris, *Epidemiology of falls.* Age and ageing, 2001. **30 Suppl 4**: p. 3-7.
21. Iglesias, C.P., A. Manca, and D.J. Torgerson, *The health-related quality of life and cost implications of falls in elderly women.* Osteoporosis international, 2009. **20**(6): p. 869-78.
22. Department of Health and Ageing, *Guidelines for preparing submissions to the pharmaceutical benefits advisory committee (version 4.2) http://www.health.gov.au/internet/main/publishing.Nsf/content/pbacguidelines-index*. 2007: Canberra.
23. Day, L., et al., *Modelling the impact, costs and benefits of falls prevention measures to support policy-makers and program planners. Monash University Accident Research Centre*. 2009.
24. Lord, S.R., et al., *An epidemiological study of falls in older community-dwelling women: the Randwick falls and fractures study.* Australian journal of public health, 1993. **17**(3): p. 240-5.
25. Australian Bureau of Statistics, *Life Tables Australia 2005-2007, Catalogue No. 3302055001DO001_20052007*. 2008, Canberra: Commonwealth of Australia.
26. Wang, J.J., et al., *Incidence of nursing home placement in a defined community.* Medical journal of Australia, 2001. **174**(6): p. 271-5.
27. Brazier, J.E., C. Green, and J.A. Kanis, *A Systematic Review of Health State Utility Values for Osteoporosis Related Conditions.* Osteoporosis International, 2002. **13**: p. 768-776.
28. Peel, N., M. Steinberg, and G. Williams, *Home safety assessment in the prevention of falls among older people.* Australian and New Zealand journal of public health, 2000. **24**(5): p. 536-9.
29. Strom, O., et al., *Cost-effectiveness of alendronate in the treatment of postmenopausal women in 9 European countries--an economic evaluation based on the fracture intervention trial.* Osteoporosis international, 2007. **18**(8): p. 1047-61.
30. Zethraeus, N., et al., *Cost-effectiveness of the treatment and prevention of osteoporosis--a review of the literature and a reference model.* Osteoporosis international, 2007. **18**(1): p. 9-23.
31. Honkanen, L.A., et al., *Can hip protector use cost-effectively prevent fractures in community-dwelling geriatric populations?* Journal of the American Geriatrics Society, 2006. **54**(11): p. 1658-65.
32. Australian Bureau of Statistics, *Population by Age and Sex, Australian States and Territories, June 2009*. 2009, Canberra: Commonwealth of Australia.
33. Johannesson, M. and M.C. Weinstein, *On the decision rules of cost-effectiveness analysis.* Journal of Health Economics, 1993. **12**(4): p. 459-67.
34. Boyd R and Stevens JA, *Falls and fear of falling: burden, beliefs and behaviours*. Age Ageing 2009;38(4):423-8.
35. Masud T and Morris RO, *Epidemiology of falls*. Age Ageing 2001;30 Suppl 4:3-7.

36. Henry, D.A., S.R. Hill, and A. Harris, *Drug prices and value for money: the Australian Pharmaceutical Benefits Scheme.* JAMA, 2005. **294**(20): p. 2630-2.
37. Sherrington, C., S. Lord, and J. Close, *Best practice recommendations for physical activity to prevent falls in older adults (unpublished report to the NSW Department of Health).* 2008.
38. Clemson, L., et al., *The effectiveness of a community-based program for reducing the incidence of falls in the elderly: a randomized trial.* Journal of the American Geriatrics Society, 2004. **52**(9): p. 1487-94.