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The Cost-Effectiveness of Home Assessment and Modification to Reduce Falls in the Elderly: A Decision-Analytic Modelling Approach

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ABSTRACT

A modelling exercise was conducted to assess the cost effectiveness of home assessment and modification to reduce falls in the elderly. The model was designed to simulate the costs and consequences of a fall to the elderly over a one year period. The model was developed using the results of published studies related to falls and injuries in the elderly. The intervention was assumed to reduce the fall incidence in the intervention group.

The cost effectiveness of the proposed intervention was measured in terms of incremental cost per fall prevented and injury prevented. The model predicted that the home assessment and modification to reduce fall in the elderly would incur an incremental cost $17,210 for a fall-injury prevented.

The Cost-Effectiveness of Home Assessment and Modification to Reduce Falls in the Elderly: A Decision-Analytic Modelling Approach

1 INTRODUCTION

Elderly people are a significant part of our society. In 1995, 11.7 percent of the Australian population (2,065,916) were aged 65 years or over, with 4.7% aged over 75 (Australian Bureau of Statistics, 1996). In recent years, the number and the proportion of the elderly in the population has increased, and it is estimated that over the next forty years the proportion of elderly people in Australian society will double (Davis, 1994).

This growing elderly population creates the potential for various problems associated with their special characteristics and needs (Rice, 1989). One such problem is that ageing is associated with a progressive increase in the risk of falling (Perry, 1982). Between one third and one half of elderly people fall in their home in any one year (Perry, 1982). In Australia, it is estimated that the average annual rate of death for people aged 75 and over as a direct result of falls is around 89 per 100,000 of the population (National Injury Surveillance Unit, 1996). The burden of falls and subsequent injury to the elderly themselves, their relatives and carers, and the health care provider is potentially significant. In the United States for example, it is estimated that the lifetime cost associated with fall injuries for those aged 65 years and over is around $12.6 billion (Tinetti, 1994). In Australia it has been estimated that the total direct healthcare costs resulting from accidental falls for those aged 60 years and over in 1989 was $468 million, with $180 million incurred by the hospital sector alone (for those aged 70 years and over the respective data are $396 million and $148 million)[1].

There are a growing number of epidemiological studies exploring risk factors for falls, the most recognised of which are nutritional status, environmental hazards, polypharmacy, lack of exercise, mental and/or physical changes associated with ageing, and medical conditions (NHSCRD, 1996). It is estimated that between one third and one half of falls among elderly people living in the community are due to environmental hazards, such as loose carpeting, baths without handles, poor lighting and unsafe stairways (NHSCRD, 1996).

The purpose of this study was to model, from the perspective of the health service purchaser, the cost-effectiveness of introducing a home hazard assessment and modification intervention for those aged over 75 years. It was hypothesised that the intervention would reduce the incidence of falls in the independent elderly living at home. Since there is no comprehensive evidence concerning such an intervention, this evaluation was conducted using available published literature, focusing on Australian data where possible.

Following this introduction, section 2 provides a literature review concerning the demographic profile of the elderly in Australia, and the evidence regarding risk factors, and interventions to reduce falls in the elderly. Section 3 provides the methodological background to the study, section 4 the results, and section 5 the sensitivity analyses. Section 6 provides a discussion of the issues raised in conducting the study.

[1] Data from "Disease Costs and Impact Study (DCIS)", a collaborative project of the Australian Institute for Health and Welfare and the Health Economics Unit of the Centre for Health Program Evaluation.

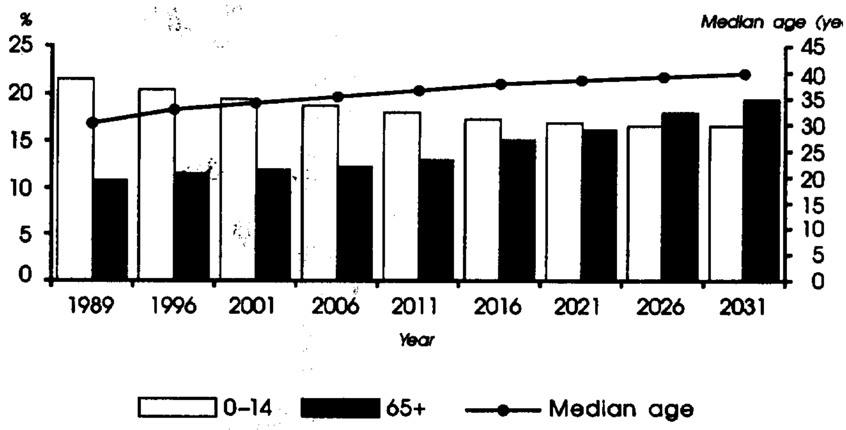
2 LITERATURE REVIEW

2.1 Demographic Profile of the Elderly

People in most parts of the world are living longer. Improvements in living conditions and lifestyles, advancements in science, medical technology, and pharmaceutical therapies, have meant great reductions in mortality from formerly fatal infectious diseases, increasing life expectancy and, consequently, the proportion of the elderly[2] in society (Rice, 1989).

In 1995, 11.7 percent of the Australian population (2,065,916) were aged 65 years or over, and 4.7% aged over 75 (Australian Bureau of Statistic, 1996). It is predicted that, due to reasons such as those mentioned above, that this population will continue to grow, both in absolute terms and as a proportion of the total population; as illustrated in figure 1.

Figure 1:
Predicted Demographic Change in the Australian Population.



Source: Davis, 1994

One can see from this that by the year 2031 the proportion of the elderly in the population in Australia is predicted to reach nearly 20 percent. The relative proportion of people aged 65 years and over in Australia is predicted almost to double over this 40 year period, while the proportion of children in the population will decrease. This trend will present the health care sector with changing needs, problems and issues concerning the health of a population which is becoming generally older.

2.2 Falls in the Elderly

Ageing is associated with a progressive increase in the risk of falling (Liversley 1989). Both the risk of falling and of suffering physical injury from such a fall appear to increase substantially from 65 years (Gloag 1987). A common theme in studies of this area is that poor health status and mobility problems seem to be most strongly associated with an increase in the frequency of falling by the elderly (Perry, 1982). However, while research into falls among the elderly has increased in recent years, neither their causes nor the most effective method of preventing them are well understood. One major barrier to this research has been the lack of a clear definition of falling.

The term falling has been used to cover many different events. A number of researchers have defined a fall as ‘an involuntary displacement of the body resulting in the subject

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2 In defining an ‘elderly’ population, most geriatric literature accepts the age of 65 as the beginning of old age, although there seems no precise reason to do so and it is likely that this is due to historical reasons, such as pensionable age, rather than any physiological necessity. For instance, in 1982, the World Health Organisation selected age 65 as the beginning of old age, recognising this as an arbitrary threshold for statistical purposes which corresponded with the generally agreed upon age of retirement and completion of professional activity in most countries (Rice, 1989).

finding himself on the ground' (Baker, 1985). This covers the two essential elements in injurious fall: (1) an involuntary motion by the individual; and (2) the consequences of hitting the floor, or other object, unintentionally as a result. While in some circumstances it might be important to know about falls that do not result in contact (ie. when assessing floor or shoe slipperiness), they are generally non-injurious events and therefore of less interest to research.

From the results of a community survey in Nottinghamshire, UK, falls occur in 35 percent of elderly persons (age ≥ 65 years) over the year before interview (Blake, 1988). A smaller study conducted in the USA (Tinetti, 1988) estimated that falls occur in 32 percent of very old persons (age ≥ 75 years), falling at least once during a 12 month observation period. Perry (1982) in a review of fall literature, concluded that between one third and one half of the elderly fall at their home in any one year.

Falls are an important public health problem among the elderly in terms of morbidity and mortality. In the USA for example, unintentional injury is the sixth leading cause of death in those over the age of 65; the majority of these deaths are attributed to falls and their complications (Sattin, 1992). In Australia, it is estimated that the average annual rate of death for people aged 75 and over as a result of falls is around 89 per 100,000 population (National Injury Surveillance Unit, 1996). The elderly also have a greater susceptibility to fatal complications following injury (Baker, 1992). Baker explains further that the high falls death rate for the elderly is reflected in the fact that in the United States 59 percent of all fall deaths involve people 75 years and over, and yet these people comprise only about 5 percent of the total population. The elderly are not only at an increased risk of death from a fall, but are also likely to suffer more severe non-fatal injuries from falling, such as hip fractures, other fractures, joint dislocations, head injuries, severe lacerations and other soft tissue injuries (DeVito, 1988). It has been estimated that such injuries occur in around 10 percent of falls (Sattin, 1992).

Hip fracture is the most significant event in terms of morbidity and mortality subsequent to a fall and has received much attention in research on fall related injuries. By age 90 approximately one third of women and one-sixth of men will have sustained a hip fracture (Kelsey, 1987). Mortality associated with hip fracture is significant. Based on a review of studies from 1983 to 1993, Harris et al (Harris, 1996) found that compared "to the expected mortality among people of similar age and sex ... mortality one year after hip fracture was three to four times higher than expected" (P16). In addition, there are often serious consequences for those who survive after sustaining a hip fracture. Approximately one half of elderly people sustaining a fractured hip will never regain their pre-fall level of functioning (Brummel-Smith, 1990). Thus, the elderly person's ability to live safely in their home may be compromised, leading to long term institutionalisation. In Australia, about 22 percent of patients with hip fractures are discharged directly to nursing homes (Australian Institute of Health and Welfare, 1995).

However, although hip fracture may have the most serious consequences, other types of injury occur more frequently. Fractures of the upper limb, neck and trunk are common although precise estimates are not available. Nevitt (1990) suggested that there are several times as many fractures of other bones in persons aged 65 years and over as there are hip and wrist fractures.

The burden of falls, and subsequent injury, to the elderly themselves, their relatives and carers, and the health care provider is potentially significant (Lord & Sinnett 1986). In the United States for example, the estimated lifetime cost associated with fall injuries for persons age 65 years and over is around $12.6 billion (Tinetti, 1994). In Australia it has been estimated that the total direct healthcare costs resulting from accidental falls for those aged 60 years and over in 1989 was $468 million, with $180 million incurred by the hospital sector alone (for those aged 70 years and over the respective data are $396 million and $148 million)[3].

[3] Data from "Disease Costs and Impact Study (DCIS)", a collaborative project of the Australian Institute for Health and Welfare and the Health Economics Unit of the Centre for Health Program Evaluation.

2.3 Risk Factors for Falls

There are a growing number of epidemiological studies exploring risk factors for falls, the most recognised of which are nutritional status, environmental hazards, polypharmacy, lack of exercise, mental and/or physical changes associated with ageing, and medical conditions (NHSCRD, 1996). Issacs (1987), grouping individuals into different categories for predicting falls, found that the highest risk group displayed one or more of the following characteristics: low gait speed, high sway, low mobility, age 75 years and over, acute illness, previous history of a fall, multiple medication use and multiple chronic illness.

From a community based surveillance system, DeVito (1988) observed that more than one half (54%) of all fall-injuries occurred in and around the home, mostly in the bedroom and bathroom (42% and 39% respectively). Other studies (such as Graham & Firth, 1992, and Lord et al, 1993) have reported that accidents most commonly occurred in areas of high activity such as the kitchen during meal preparation (22% of all accidents). Wild (1981) obtained detailed accounts of falls, and factors related to the fall, from patients presenting to their doctors and concluded that falls are attributed to extrinsic factors (environmental hazards), intrinsic factors (visual impairments, muscle weakness etc.), or to an interaction between these two factors.

Despite a number of intrinsic and extrinsic factors that have been found to be associated with risk of falling, it is generally acknowledged that the aetiology of falls and consequent injuries is complex. Many falls in the elderly are probably multifactoral, resulting from the convergence of several intrinsic, pharmacological, environmental, behavioural and activity-related factors (Nevitt, 1990).

Although environmental hazards have been recognised as an evident potential risk to falls and injuries, there is little consistent or systematic evidence to indicate the extent of the problem. Home hazards have been reported as being primarily responsible for one-third of falls (Melton, 1983) regardless of living arrangements (hospital, nursing home or private home). Wild (1981) estimated that about 25 percent of falls involved an environmental component, while Waller (1978) estimated than an environmental component contributed to 75 percent of falls treated in any one year. These differences reflect both the difficulty in defining and measuring environmental hazards, the diversities in study populations, and that multiple factors may contribute to a fall. A recent review conducted in the UK (NHSCRD, 1996) found that between one third and one half of falls among older people living in the community were due to environmental hazards, such as loose carpeting, baths without handles, poor lighting, and unsafe stairways.

Perry (1982) reported that stairs and obstacles on the floor were important causes of falls in the younger, healthier elderly, while intrinsic, host-related factors were more important in the older, more frail subjects. Sheldon (1990) noted that loss of balance on slippery floors or icy surfaces, trips on loose rugs or carpet, and trips over unexpected objects were prominent environmental factors for falls. Poor illumination has also been observed as a risk factor for falling (Nevitt, 1990). It is logical, and physiologically plausible, that the deterioration of vision in the elderly may combine with inadequate lighting to increase the risk of falling.

2.4 Interventions to Reduce Falls

With respect to interventions to reduce falls in the elderly, several randomised controlled trials have been performed. Some of these studies have focused on altering different risk factors to falls. Exercise, home assessment and surveillance, and institutional setting interventions are some general classifications of risk factor modification that have been observed (NHSCRD, 1996).

Tinetti et al. (1994) conducted a randomised controlled trial to assess the effectiveness of a multifactoral targeted risk-abatement strategy in reducing the risk of falls in older people (aged over 70 years). The interventions included home assessment and modification, behavioural recommendations, medication reviews, gait training, and balance exercise. The result was that 35 percent of the intervention group had fallen at one year follow up compared with 47 percent of the control group. The cost effectiveness of the interventions was calculated to be US$1,947 per fall prevented, and US$12,392 per fall injury prevented.

A study to assess the benefits of regular surveillance of older people at home was conducted by Carpenter (1990). The intervention consisted of volunteers who visited the elderly (aged over 75 years) in their homes. The number of falls reported in the control group doubled while in the intervention group remain unchanged. Another study by Vetted (1992) suggested that health visitors who give suggestions, home assessment and modification, reduced the incidence of fractures in the intervention group relative to the control group, although the difference was not statistically significant.

Hornbrook (1994) in the USA conducted a randomised controlled trial to evaluate the impact of a moderate intensity falls prevention program on those aged 65 years and over. The interventions given included home hazard assessment, didactic approach for fall prevention (that is, a clear and concise description of how to avoid falls), and a group exercise component. After two years follow up, there were 1730 falls in the intervention group and 2084 falls in the control group. The effect was strongest for men aged 75 years and over. However, there was no statistically significant difference in the probability of fall injuries between the intervention and control groups.

In another study conducted in the USA, Fabacher (1994) reported that the intervention group experienced fewer falls during the follow up than the control group (14% versus 23%). The intervention included a home visit by a physician’s assistant or nurse to screen for medical, functional and psycho-social problems and follow up visits every four months for one year.

In Australia, a team from the Monash University Accident Research Centre have just started research on a fall prevention program in the elderly. Another team lead by Dr. Flavia Ciccuttini from the Department of Epidemiology and Preventative Medicine at Monash University, has also begun similar research with emphasis on increasing the quality of life of disabled elderly and reducing the risk of injury. However, as both of these studies have just begun, there is little evidence to date that can be cited in this study.

In conclusion, the incidence and consequences of falls amongst the elderly are a significant burden. As the population ages, such a burden to society, and the health care sector in particular, will continue to increase in magnitude. However, evidence to date concerning the best means to prevent such falls, or reduce their injurious impact, has been inconclusive. Interventions to reduce falls are still in an experimental stage, with a variety of different methods used. Furthermore, such trials as described above are usually only concerned with the effectiveness of the intervention, and not cost-effectiveness. In particular, in Australia even studies concerning the effectiveness of falls prevention *per se* are few.

3 METHODOLOGY

In order to assess the cost effectiveness of this intervention, a decision analytic model was developed to simulate the potential costs and outcomes of the intervention versus no intervention over a one year period, from the viewpoint of the health service purchaser. The model was developed using the results of published studies related to injury in the elderly. Wherever possible, Australian studies and data were used in the model.

The analysis modelled the expected cost per elderly person which would be associated with no intervention (a control or baseline group), which predominantly comprise costs of treating fall-related injuries, compared with the costs associated with undertaking the intervention group (such treatment costs plus intervention costs).

3.1 Subjects

This study is concerned with elderly people (defined as aged 75 years or over) living independently in the community. The categorisation of the elderly as aged over 75 years was required to enable the model to draw on data from other studies.

3.2 Intervention

The intervention comprises two-stages:

1. assessment of home hazards increasing the risk of falls;
2. provision of fall-prevention devices for those identified to have such home hazards.

Assessments and provision of aids are considered to be conducted by occupational therapists or registered nurses. The assessments are considered to be conducted in areas thought to be important to fall. Sufficient lighting, non-slippery floor, safety in stairs, kitchen, bathroom, yard and entrances are the environmental areas or factors to be focused upon in the assessment, with appropriate suggestions made to remove or modify the potential hazards. For example, how inconspicuous steps could be made more obvious with white edges and reflective strips.

The provision stage is assumed to be carried out if it is determined that the elderly person could not modify those potential hazards or provide the necessary aids to minimise the risk by themselves. The typical aids given to the elderly include: non slip mat for the bathroom, grab bars in the bathroom and toilet, shower stool/bath seat, 'soap on a rope' for easy access to soap, raised toilet seat, overtoilet frame, non-skid backing for rugs, non-skid wax on floors, handrails on stairs, marking for obstacles in pathways, teapot tipper, tap turner, lightweight double handled saucepan, jar opener, a long handled shoe horn, long handle dustpan, long handled stick to pick up objects.

3.3 Effectiveness

It is assumed in the primary analysis that this intervention would reduce the fall rate over a one-year period by 25 percent, as suggested by a similar study conducted by Tinetti (1994) in the USA.

3.4 Model Development

The baseline model (ie. without the intervention) constructed concerns the elderly who live independently in their homes. It is hypothesised that home assessment and intervention given to these elderly will reduce the probability of their falling and subsequent injury.

Over a one year period, the elderly will have a specified risk of falling. Since the distribution of the timing of such falls is unknown, it was assumed that the fall would occur half way through the year of analysis: that is, at six months. Some of these falls could be injurious. It was assumed that all the injured would be taken by ambulance to hospital where they would receive medical attention in the Accident and Emergency Department. For those injured severely, it was assumed that they would be subsequently admitted to hospital. For those not injured severely, it was assumed that they would be treated in the Casualty Department and thus not require hospitalisation. Those who are only slightly injured were assumed not to receive medical care in the hospital.

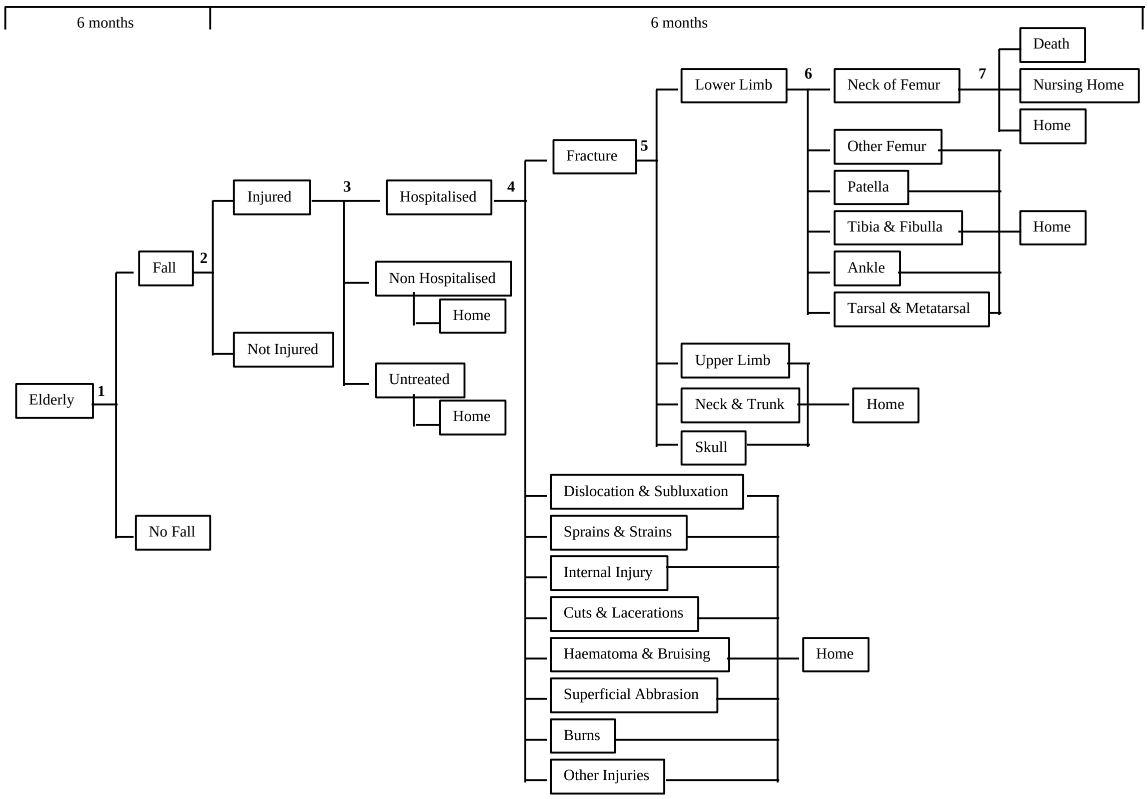
Among those who are hospitalised, some will be treated for fractures, dislocations, sprains and strains, internal injuries, cuts and lacerations, haematoma and bruising, superficial abrasion, and other injuries. For the “fractured elderly”, there are different types of fracture; neck of femur, other femur, upper limb, neck and trunk, and other lower limb fracture. Those injured elderly who are not hospitalised were assumed to have minor injuries that can be treated in a casualty room.

For each type of injury, there are several different end points in the analysis. Those who recover fully are hypothesised to be discharged to their homes. Those who become frail and too weak to live by themselves are discharged to nursing homes. To complete the analysis, the possibility of death was also accounted for.

In addition to a cost analysis, the cost-effectiveness of introducing the program was estimated as the incremental cost per incremental outcome of the intervention relative to the control: that is, cost per fall prevented and cost per injury prevented. Sensitivity analyses were conducted for several key variables, such as the probability of injuries, effectiveness of intervention and extension of the time period of the model from one-year to five and ten years in order to model the difference in the impact over the longer term. The analysis was conducted using Microsoft Excel version 5.

Figure 2 presents a graphical illustration of the model. Note that the same decison-tree was used for both baseline (or control) and intervention groups - the difference relating to the probabilities of each event represented in the tree occuring.

Figure 2:
Decision-tree Used in the Model



The diagram illustrates the progress of an 'average' elderly person through a 12 month period. It begins with the likelihood that an elderly person may fall during the year (chance node 1). If they do fall, the person might be injured (chance node 2). If injured, it is assumed that they will be taken to a hospital A&E department to receive treatment. Depending on the seriousness of the injury, they might receive different treatments represented by chance node 3. Some of the injured will only receive simple treatment in the emergency room, some will be admitted into the hospital, while others simply will not receive any treatment in the hospital (although they will incur some minor cost of assessment). Those treated but not hospitalised are assumed to have minor injuries, and discharged home directly after receiving treatment.

Those injured who are admitted into hospital may have different types of injury (chance node 4). Fracture, dislocation and subluxation, sprains and strains, internal injury, cuts and lacerations, haematoma and bruising, superficial abrasion, burns, and other injuries are recognised injuries resulting from a fall. Those experiencing other than fractures are discharged home after treatment.

At chance node 5, those elderly experiencing a fracture may suffer upper limb fracture, lower limb, neck and trunk, or skull fracture. Those not sustaining lower limb fracture are discharged home after treatment.

There are different types of lower limb fracture (chance node 6). They are neck of femur fracture, other femur, patella, tibia and fibula, ankle, and tarsal & metatarsal fracture. Those not suffering neck of femur fracture are discharged home after treatment. Those who experience neck of femur fracture (chance node 7) may die soon afterward as a result of the injury, go to a nursing home, undergo rehabilitation, or return home.

For all those hospitalised, it is assumed that after undergoing the hospitalisation they are all discharged home, where some of them would require temporary home-help, and possibly other follow-up assessment and/or treatment.

3.5 Cost

All cost data quoted in this analysis are in 1996 Australian dollars. Since the analysis covers only one year of assessment, discounting was not an issue.

3.5.1 Cost of Intervention

The cost of the intervention varies between subjects. Since the prevalence of those who need each item of the intervention aids is unknown, it is assumed that all those in the intervention group will need some kind of aid. Based on an interview with Dr. Brian Fildes who is conducting a similar study[4], each subject in the intervention group would need approximately $50 worth of equipment (not including labour).

The remaining data and assumptions in this section are based on an interview conducted with Mrs Valerie Mead, an Occupational Therapist at the Alfred Hospital in Melbourne, who is involved in the research led by Dr Flavia Ciccuttini (Department of Epidemiology and Preventative Medicine at Monash University) mentioned earlier.

It was estimated that for home hazard assessment each elderly person would require a one hour visit by an occupational therapist or nurse. This visit is intended to assess potential hazards, and give fall-prevention suggestions to the elderly person. It is assumed that the nurse has to travel an average of 36 km for each visit to the subject’s home. Assuming that the nurse is using his/her own car, then estimated travel time (for the Melbourne metropolitan area) is one hour. Hence, for each subject, the time spent for assessment is two hours (one hour assessment plus one hour travel).

For the second stage of the intervention, a nurse is estimated to require one hour to install, and give recommendations on how to use, the aid(s). Hence, the total time including the travel time for this intervention stage is also two hours.

The average cost of employing an occupational therapist or a nurse in Victoria is $26 an hour (including overhead costs). The costs of travel (assuming the nurse uses his/her own car) is 50 cents per km.

[4] An on-going research program run by the Monash University Accident Research Centre entitled ”No Falls. Falls prevention program for city of Whitehorse”

3.5.2 Other Costs

The cost of nursing home care was based on the average reimbursement by the Commonwealth for an intermediate level of dependency. The cost per day of long term nursing home care was estimated as $70.71(Harris, 1996). Cost for hip-fracture rehabilitation and cost for home help for the elderly were obtained from the same study. It was estimated that 25% of patients discharged home will require an average 14.5 hours of additional domestic assistance (that is, additional to whatever services, such as meal-on-wheels, that they may already be receiving) in the two weeks following discharge (thus 75% were assumed to require no such additional assistance). The average cost of domestic assistance is $19.30 per hour (Harris, 1996), so the estimated average cost is $279.85 per patient. Hence, the expected average cost of home-help for each patient discharged home is $279.85 ÷ 4 = $69.96. These cost data are summarised in table 1.

Table 1:
Resource Use and Cost Data/Assumptions

	Resource use	Unit cost ($)	Total Cost ($)	Data Source
*Assessment**				
• Nurse/Occupational therapist Cost	2 hour	26 /hour	52	V. Mead, 1996 (interview)
• Travel cost	36 km	0.5 /km	18	
Providing aids				
• Nurse/Occupational therapist cost	2 hour	26 /hour	52	
• Travel cost	36 km	0.5 /km	18	
• Aids/tools cost			50	B. Fildes, 1996 (interview)
Other cost				
• Nursing home		70.71 / day	2121.3/month	Harris, 1996
• Rehabilitation cost*		7454		
• Home help		69.96		
• Ambulance service**		247/service		

**For hip-fractured patient*
***Average cost of ambulance transport in 1993/94 financial year*

3.5.3 Cost of Subsequent Hospitalisation

The costs for subsequent hospitalisation of those injured were derived from a dataset obtained from the 1995 Cost Weights Study conducted by Health Solutions Pty. Ltd. and the Centre for Health Program Evaluation.

The dataset covers the costs for all treatment events in these hospitals. It also records the disease type, patient characteristics, hospital department costs, length of stay, Australian National Diagnostic Related Disease (AN-DRG3) code and several other variables. For the purpose of this study, data with relevant AN-DRG3 codes for all types of injury in the model were selected and extracted. Ideally only patients aged 75 years or over would have been included in this analysis (to avoid bias in the cost data toward younger people), but data concerning this group was felt to be insufficient. Thus, in order to maintain a dataset considered to be of reasonable size, the age group consisted of those aged 50 years or over. With the help of Dr. Terri Jackson from the Centre for Health Program Evaluation, this extracted dataset was then transferred to another file to be explored further. This new dataset consisted of 6149 cases from 14 hospitals.

To obtain cost data, each type of injury was traced to get its specific ICD-9-CM (International Code of Disease version 9 Clinical Modification) code. A range of codes which were thought to sufficiently represent the condition of each type of injury was obtained. Using these codes the average cost of treatments were extracted from the dataset. The cost for each treatment is displayed in table 2.

Table 2:
Treatment Costs, Based on DRG Data for Victoria

Type of Injury	ICD-9-CM code range	ICD-9-CM Description	Cost ($)
Fracture			
• Neck of femur	820.00 - 820.9	Fracture of neck of femur	7568.63
• Other femur	821.00 - 821.39	Fracture of other & unspecified parts of femur	9622.47
• Patella	822.0 - 822.1	Fracture of patella	3564.29
• Tibia & Fibula	823.00 - 823.92	Fracture of tibia & fibula	6502.26
• Ankle	824.0 - 824.9	Fracture of ankle	4457.36
• Tarsal & Metatarsal	825.00 - 825.39	Fracture of one or more tarsal & metatarsal bones	3086.86
• Upper Limb (eg. radius & ulna)	813.00 - 813.93	Fracture of radius and ulna	1529.37
• Neck & Trunk (eg. ribs)	807.00 - 807.6	Fracture of rib(s), sternum, larynx, & trachea	18900.54*
• Skull	800.00 - 804.90	Fracture of skull	2231.09
Non-fracture			
• Dislocations & subluxation (eg. of shoulder, elbow, or wrist)	831.00 - 833.19	Dislocation of wrist	811.56
• Sprain & strains (eg. of shoulder, elbow, wrist or hand)	840.00 - 842.19	Sprains & strains of shoulder, elbow, wrist or hand	1776.05
• Internal injuries	862.0 - 862.9	Injury to other and unspecified intrathoracid organ	2269.07
• Cuts & lacerations (eg. of shoulder, elbow, upper & forearm, or wrist)	880.00 - 881.22	Open wound of shoulder, elbow, upper & forearm, or wrist	1966.01
• Haematoma & bruising (eg. of upper limb)	922.00 - 924.9	Contusion of upper limb	478.64
• Superficial abrasion	910.0 - 916.9	Superficial injury of face, neck, and scalp except eye	353.92
• Burns	944.00 - 944.5	Burn of wrist(s) and hand(s)	528.34

** This maybe over estimated because of the lack of cases in that category.*

3.6 Probabilities

The probability of fall and injury were determined using published literature. All the data applied in the model are displayed below.

Table 3:
Probabilities Used in the Model

Event	*Probability*	*Source*
Fall rate	0.4	Perry, 1982
Injury rate after a fall	0.1	Sattin, 1992
Treatment for injured elderly		Fildes, 1989
Hospitalised (admitted)	0.17	
Non-hospitalised	0.77	
Untreated	0.06	
*Type of Injury**		Fildes, 1994
Fracture	0.675	
Lower Limb	[0.64]	
Neck of femur	(0.83)	
Other femur	(0.08)	
Patella	(0.02)	
Tibia & Fibula	(0.03)	
Ankle	(0.03)	
Tarsal & Metatarsal	(0.01)	
Upper Limb	[0.175]	
Neck & Trunk	[0.16]	
Skull	[0.025]	
Dislocation & subluxation	0.015	
Sprain & strains	0.025	
Internal injuries	0.05	
Cuts & lacerations	0.14	
Haematoma & bruising	0.05	
Superficial abrasion	0.01	
Burns	0.01	
Other injuries	0.03	
After neck of femur injury		Harris, 1996
Death	0.17	
Rehabilitation	0.23	
Nursing home	0.22	
Back home	0.38	

** Note that figures in ( ) and [ ] are subprobabilities, although they do not necessarily sum to one due to rounding.*

4 RESULTS

The model predicted that on average $71.56 would be spent on fall-related treatment per elderly person in the baseline group in one year. This was based on the assumption that there was a probability of 0.40 of falling during that year. In the intervention group, assuming that the intervention reduced the fall incidence by 25 percent, the average cost would fall to $53.67. Hence, if the intervention was ***costless***, it would generate $17.89 cost saving per person to the health care provider over that one year period.

The average cost of the intervention per person was estimated to be $190. Assuming that all those in the intervention group require the assessment and home modification, the expected total cost per person would be $243.67. Hence, the incremental cost of introducing the intervention would be $172.11 per person. Assuming that the intervention program would be applicable to fifty percent of all elderly people in Australia (roughly one million), this program would cost $172,109,370.

The expected costs both to the intervention and the baseline groups can be broken up into their cost components. This is summarised in figure 3 (overleaf) as expected cost per person. One can see from the figure that the most expensive expected cost from fall injury is the cost of neck of femur fracture. This is because of the high probability of having a neck of femur fracture combined with the high cost associated with its treatment. The other significant expected cost is from the injured who were only treated in an emergency department. This is caused by the high proportion of the injured not being injured severely.

For the intervention group, the expected cost for the no-fall and the fall-but-not-injured groups are large. This can be explained as most people in the intervention group are given the intervention even though they would not have fallen in its absence.

Figure 3:

Expected Cost per Patient for Intervention Versus No Intervention

						Expected Cost: Base-line	Expected Cost: Inter-vention
Elderly	Fall	Injured	Hospitalised	Fracture	Lower Limb: Neck of femur	29.04	22.12
					Lower Limb: Other femur	2.34	1.79
					Lower Limb: Patella	0.23	0.18
					Lower Limb: Tibia & Fibula	0.60	0.46
					Lower Limb: Ankle	0.42	0.33
					Lower Limb: Tarsal & Metatarsal	0.10	0.08
					Upper Limb	1.48	1.23
					Neck & Trunk	14.11	10.69
					Skull	0.29	0.24
				Dislocation & Subluxatn		0.11	0.10
				Sprains & Strains		0.34	0.28
				Internal Injury		0.86	0.69
				Cuts & Lacerations		2.11	1.72
				Haematoma & Bruising		0.25	0.23
				Superficial Abrasion		0.04	0.04
				Burns		0.05	0.05
				Other Injuries		0.12	0.12
			Non Hospitalised			18.51	18.27
			Untreated			0.59	0.79
		Not Injured				0	51.30
	No Fall					0	133.00
					Total Cost	71.56	243.67

The incremental cost of preventing a fall is $1,721. And since injury occurred in 10 percent of the falls, the incremental cost of preventing an injury from falling is $17,210.

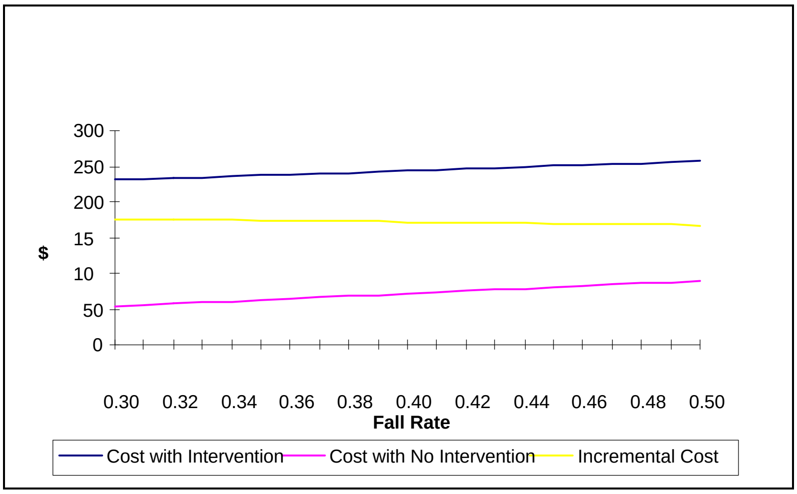
5 SENSITIVITY ANALYSES

One-way (univariate) sensitivity analyses were performed to assess the robustness of the results to changes in key variables thought to be important.

5.1 Fall Probability

In the original model, it was assumed that forty percent of the elderly would fall in one year. The data in figure 4 show the cost in the intervention and baseline groups, and the incremental cost of employing the intervention if we alter the baseline fall rate between 30 percent and 50 percent.

Figure 4:
Sensitivity Analysis for Varying the Fall Rate

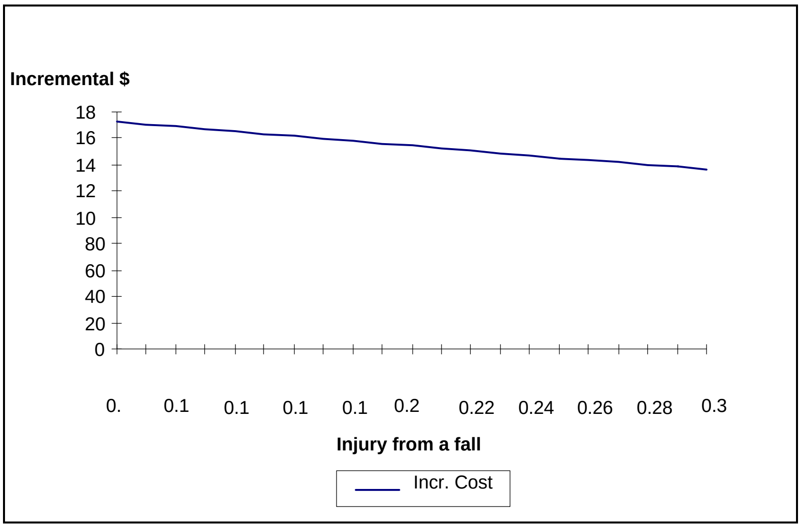


We can see that the change in fall rate did not greatly affect the expected cost per person in the intervention and control groups.

5.2 Injury Rate from a Fall

With the original model, the injury rate following a fall was assumed to be 10 percent. Figure 6 presents the change in incremental cost of introducing the intervention if the injury rate was varied between 10 percent and 30 percent (0.1 - 0.3).

Figure 6:
Sensitivity Analysis for Varying the Injury Rate

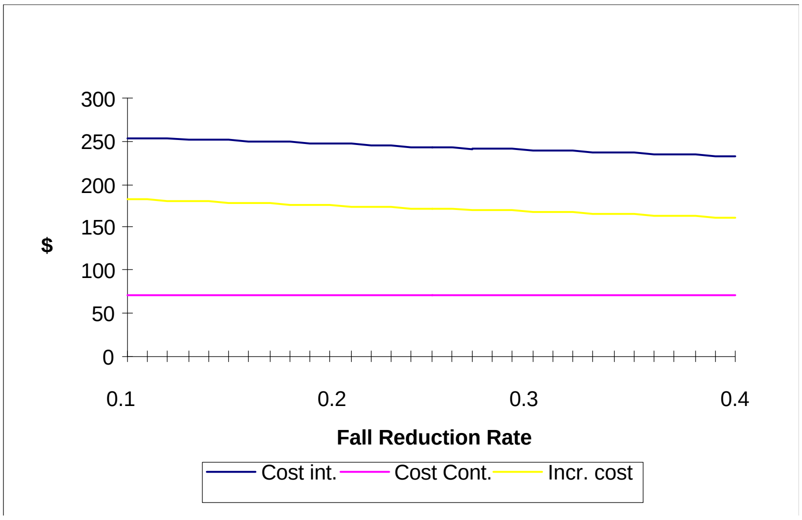


The incremental cost decreased as the injury rate was increased. However, this change was only slight.

5.3 Effectiveness of the Intervention

In the original model, the effectiveness rate was 25 percent; that is the intervention reduced the fall rate by 25%. In figure 8, we can see how changing the effectiveness between 10 percent and 40 percent (0.1 - 0.4) altered the result.

Figure 8:
Sensitivity Analysis for Varying the Effectiveness

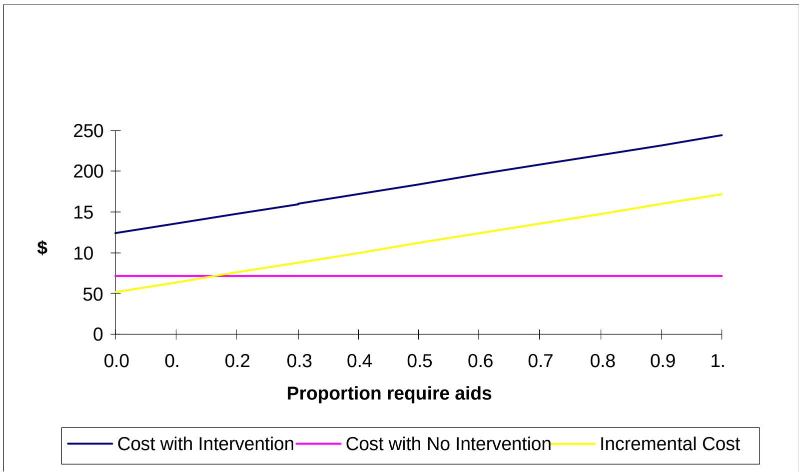


As the intervention becomes more effective, the expected cost per person in the intervention group becomes smaller. And since the expected cost for the control group is not changed, the incremental expected cost of introducing the intervention is also smaller.

5.4 Proportion of Elderly Requiring Aids

In the current model, it was assumed that each elderly person assessed would require the aids to be installed. This sensitivity analysis varies the proportion of elderly who require aids from zero to 100 percent (0.0 - 1.0).

Figure 10:
Sensitivity Analysis for Varying the Proportion Requiring Aids

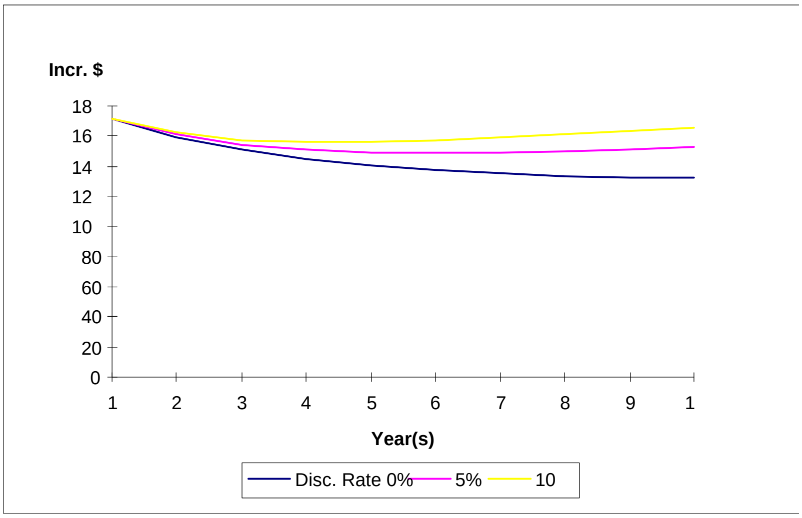


If only fifty percent of those in the intervention group requires the aids, assuming that the effectiveness was not altered, the expected cost per person in the intervention group would be $183.67. However, since all elderly in the intervention group will still require the assessment, the expected cost is everywhere positive; ie. even when nobody in the intervention group requires the aids, there is still positive incremental cost of $52.11. The expected cost would increase proportionately as the proportion requiring aids in the intervention group increased.

5.5 Time Horizon

The original model used a one year time frame. Clearly this provides a limited analysis of the costs and consequences which might be expected to accrue from such a "lifestyle" intervention. A preliminary analysis was conducted to illustrate how the result may change if the time frame is extended to 10 years. For this, the basic model, including all relevant data and assumptions, was repeated to replicate the same analysis from the first year for the second and subsequent years. The analysis was done using three different discount rates, 0%, 5% and 10%. In figure 13 the change in incremental cost as the time frame was extended is displayed.

Figure 13:
Sensitivity Analysis for Changing the Time Frame



Although the time frame did not change the incremental cost considerably, there is one point of interest worth noting. With a discount rate greater than zero, the incremental cost is initially lowered but then gradually increases. Obviously such an assessment of the impact of time on the results of the study need to be interpreted cautiously, as the analysis is simplistic and designed merely to give an impression of the possible effect. As conducted, we have taken no account of whether the probability of a fall increases with age (it is assumed to be constant each year), and that the likelihood of death is also likely to increase in each subsequent year (again assumed constant here at the rate for someone aged 75). On the cost side, there may also be the requirement for follow-up or repeat assessments and perhaps maintenance of the equipment provided. However, these caveats aside, it is reasonable to believe that the marginal cost effectiveness will improve over time, subject to the discount rate used.

5.6 Quality of Life

There is no published literature on the quality of life relating to elderly people who suffer an injury. This study, as it is a model, lends itself to a tentative assessment of the impact that incorporation of quality of life would have on the overall cost-effectiveness of interventions. To do this, a description of all possible health states in the model resulting from the possible different injuries was assessed using a visual analogue scale (where 0 is equivalent to being dead and 100 to being in the best possible health).

An occupational therapist who was familiar with elderly patients was asked to answer a set of questions covering these different health states from the perspective of the elderly person[5]. The value of each health state was then multiplied by its duration (in months) to obtain the value of the Quality Adjusted Life Year (QALY) over a one year period (see table below). These were then used to estimate the cost per QALY over a five and ten year time frame[6].

Table 4:
Quality of life weighting

Health state	*Quality of Life weight*	*Duration**	*QALY***
Living normally	1	12	1
Before injury	1	6	0.5
After non-serious injury	1	6	0.5
After serious injury	1	5	0.4166
<u>Injured Elderly</u>			
• Neck of femur (Hip) fracture	0.43	1	0.0358
• Other femur fracture	0.56	1	0.0466
• Upper Limb (eg. Wrist) fracture	0.66	1	0.055
• Patella, Tibia, Fibula, Ankle, Tarsal & Metatarsal (eg. Ankle) fracture	0.65	1	0.05416
• Neck & Trunk (eg. Rib) fracture	0.62	1	0.0516
<u>Following a hip fracture</u>			
• living independently after a hip fracture	0.69	5	0.2875
• living in nursing home	0.19	5	0.07916
• death	0		0

** in months*
*** based on one year period*

It is also assumed that the quality of life for those who end up in the nursing home is the same whether they were having the intervention or not.

Without discounting, a five and ten year analysis would yield an incremental cost per QALY gained of $132,272 and $56,114 respectively. By discounting costs and QALYs by five percent and ten percent, the five year time frame yields an incremental cost per QALY of $159,056 and $189,911, and the ten year time frame yields $92,567 and $140,966 respectively.

For the non-injured, it was initially assumed that the intervention would not alter their quality of life. If the person is injured, it was assumed that the intervention did not affect the severity of the injury; it only affected the probability of having injuries. Consequently, the quality of life of a person having the same injury in both intervention and baseline group was identical. However, the cost effectiveness of the intervention is considerably improved (ie. lower incremental cost per QALY) if the intervention is assume to differentially affect the quality of life. In reality, it is most likely that the intervention would affect the quality of life of its recipients. The elderly having had the aids installed in their homes, for example, would at least feel safer moving around their homes, hence increasing their quality of life; independent of whether the intervention was effective in

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5 As the study was preliminary, thus restricting the time and scope of the study, it was felt appropriate that this quality of life valuation be performed by an occupational therapist who was familiar with elderly patients. Although this might not give an accurate estimate of quality of life weights to each health state, since it only reflected the judgement of a single non-elderly person, it was thought that such professional judgement would be sufficient for this modelling exercise. Similarly, the technique used to value the health states was a very simple visual analogue scale instrument, which again may cause some bias, but it was felt that it was simple to understand and to complete and for such a preliminary analysis would suffice.

6 Note that in multiplying out for five and ten years the same model and the same probabilities for the second and subsequent years were used. It might be argued that if someone had fallen in the first year, then in the next year they would have a higher probability of falling, and possibly even dying, than someone who had not. It could also be argued that the risk of bone fracture increases as the person gets older. Furthermore, whether the intervention would still have the same effect on the elderly after several years is also questionable.

reducing falls. In this case, the incremental cost per QALY is highly sensitive to the change in the quality of life. For example, a one percent difference in the quality of life (one percent reduction in quality of life in the control group relative to the intervention group) would reduce the incremental cost per QALY (undiscounted over five years) from $132,272 to around $2,883 (a five percent difference would alter the incremental cost per QALY to $586 and a ten percent difference to $293). This is because when the quality of life in the control group is changed, the incremental cost remains constant (no change) while the incremental QALY gained by introducing the intervention is increased. The result is that the incremental cost per QALY is greatly reduced if the intervention did affect the quality of life of its user.

However, measuring quality of life accurately is very difficult. In this study, the quality of life instrument did not measure the quality of life among the uninjured elderly in both groups. As the intervention had not actually been taken place, it was thought that such an attempt to measure the quality of life would be difficult and inaccurate. Had the intervention been conducted, measurement of the quality of life of such intervention would still be difficult. The major requirement was that the instrument should be sensitive enough to detect the changes in the quality of life. Nevertheless, the cost effectiveness of the intervention would become more favourable if we believed that the intervention affected the quality of life on non-injured elderly.

6 DISCUSSION

Falls in the elderly population are potentially a significant cause of morbidity and cost to the health service and beyond. However, there have been few studies concerning interventions which may be used to help prevent such falls, and in particular there have been very few concerned with cost effectiveness. Given such scarcity of information upon which to build policy concerning how falls in the elderly should be tackled, this study attempted to provide some tentative indications concerning cost and cost effectiveness of a program of advice for the elderly about how to reduce risk in their homes, and if necessary provide a few simple devices to further reduce risk. As data concerning this program was minimal (for instance, there was no direct data from a randomised controlled trials of interventions, and published studies varied considerably in methodology), a modelling approach was used and the results subjected to extensive sensitivity analysis.

As a number of assumptions had to be made in order to construct the model, and several of these could be questionable. First, one could argue that some of interventions would actually reduce the severity of injury sustained. For example, non-slip bath mat not only could prevent the risk of falling but also could reduce the speed of fall movement, thus reducing the severity of impact, in turn reducing the severity of injury.

Second, the assumption that all injured elderly people were taken to hospital is also arguable. However, given that there is no available data on the proportion of the elderly who were taken and treated in other places, it was thought that the assumption was justified.

Third, the analysis was restricted to one year, ignoring possible longer term effects of the intervention. In the sensitivity analysis, this time frame was extended by considering the long run quality of life implications over a five and ten year period. However, for this it was assumed that none of the probabilities were changed. For example, an elderly person who had been treated for a hip fracture in the first year would have an identical probability of having an injury in the next year as an elderly person who had not been injured in the first year. Clearly this may not be accurate.

Fourth, the possible injuries resulting from a fall was attained from a descriptive study where data was gathered from fall related injury treatments from Victoria-wide hospitals (Fildes, 1994). It was well recognised that such a study would not truly represent the actual probabilities since it only recorded patients that were brought into hospitals and ignored those who were treated in general or private practices. However, in the absence of more ideal data, it was felt that the utilisation of this data was sufficient.

Fifth, the intervention was assumed to effectively reduce the probability of falls by 25 percent. This was based on a study conducted in the USA (Tinetti 1994). The result of this study could however be viewed as optimistic compared to others reported. For example, Hornbrook (1994) estimated that such an intervention effectively reduced the fall incidence in the intervention group by 17%. Furthermore, Tinetti's study incorporated a multifactoral intervention to reduce fall incidence while this study was only intended to evaluate the home assessment and modification. For that reason, sensitivity analysis varied the effectiveness of the intervention.

Given the possible reservations in the assumptions used to construct the model, it was found that such an intervention could potentially result in a cost saving of $17.89 per person (provided the intervention did not involve any cost). Alternatively, one could view this as the maximum cost the intervention could be to ensure it was never more than cost-neutral (holding the effectiveness of the intervention constant). The incremental cost to prevent a fall injury was $17,210. This result is similar to that conducted by Tinetti (1994) in which the cost was US $12,392 (approximately Australian $15,834). This suggests that the modelling exercise gives a quite reliable result. However, this comparison is not strictly a justified one as the intervention in Tinetti's study involved a multifactoral interventions. Furthermore, the assessment of costs was only conducted on the intervention cost, without assessing the cost of subsequent treatment to the elderly. However, there are some factors which could improve the situation.

First, neck of femur fracture was the most cost-important injury resulting from a fall. This was because of the high probability of having a neck of femur fracture combined with the high cost associated with its treatment. One implication of this is that a fall prevention program might be specifically targeted at minimising the incidence of neck of femur fracture. One possible measure was proposed by Wallace et al. (1993) who conducted an experiment by giving hip protective padding for the elderly.

Second, if the intervention was concentrated on the elderly with a high risk of falling, the result would probably be more promising. The intervention could be directed to the elderly whose general practice doctor recognises them to be in a high risk category so that the effectiveness of the intervention could be increased. For example, the intervention could be focused on the elderly having the factors that have been identified as predictors to fall, such as lack of exercise, medication, vision deterioration, and nutritional status (NHSCRD, 1996). A counter to this argument is that such predictors of falls are 'intrinsic' factors, hence the intervention (which is largely environmental) would not affect the fall incidence more than the general population.

Nonetheless, implementation of such an intervention would involve considerable resources which have the potential to yield benefits in other health care programs. As mentioned, $172,109,370 would be needed to implement the intervention in Australia. However, our analysis shows that there is the potential for considerable benefit to be gained from this in the long term, both on a clinical basis of less morbidity, cost basis of less hospitalisations, and on a quality of life basis, particularly the potential for quality of life enhancements to those who use the aids and those whom it is no longer necessary to admit to a nursing home. However, it is the healthcare decision maker who will ultimately have to decide whether implementing this intervention is a wise use of a limited healthcare budget.

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