Appendix K: Full Health Economic Report

1 Introduction

This appendix sets out de novo health economic evaluation undertaken as part of the 2013 extension of this guideline to encompass the assessment and prevention of falls in older people in the inpatient setting. It was developed by the Internal Clinical Guidelines Programme in the Centre for Clinical Practice at NICE.

1.1 Contents

2 Decision Problem

The health economic analysis addressed one question from the guideline scope, based on GDG prioritisation:

- What is the cost effectiveness of multi-factorial interventions to reduce the risk and/or severity of inpatient falls?

In the economic plan, it was proposed that the first question from the scope (what assessment tools or processes to identify risk factors for falling in hospital?) would also be addressed. However, based on the clinical effectiveness evidence, the GDG recommended not using any tools or processes; therefore, no health economic modelling was undertaken for this question.

Also, the GDG recommended that single interventions should not be used to reduce the risk and/or severity of inpatient falls. Therefore, only multi-factorial interventions were considered for health economic modelling.

2.1 Population

For this analysis, the population is all patients in hospital aged 65 or over. The guideline also covers patients in hospital aged 50–64 who are identified as being at higher risk of falling. No specific modelling was undertaken to reflect this additional group, as the GDG believed that conclusions from the 65-and-over age-group could also be applied to people who are younger, but at increased risk of falling.

2.2 Intervention

The modelled intervention is a generic multifactorial falls intervention. A number of papers exist detailing the constituent parts of multifactorial interventions (see section 4.4.2 of main guideline) and the most relevant RCTs were meta-analysed to give overall fall rates per 1000 bed days and injury rates per fall (see main guideline table 4a and forest plots in Appendix E).

2.3 Comparator

The comparator is “usual care”, which is assumed to be no specific actions to prevent falls.

2.4 Outcomes

To explore the health economic consequences of interventions to prevent falls, a cost–utility analysis was undertaken that assessed the costs and benefits (in terms of quality adjusted life years [QALYs]) for each intervention.

2.5 Systematic Review of Existing Literature

A search of published health economic analyses addressing the question of interest yielded a total of 1432 unique citations. Only one study (Haines et al., 2009) analysed both the costs and outcomes of measures to prevent inpatient falls but this study was based in Australia and did not report outcomes in terms of QALYs, and was therefore judged to be of limited value, with regard to the NICE reference case. A recent article giving guidelines on conducting and reporting economic evaluations of fall prevention strategies noted that there are no published economic evaluations of fall prevention strategies in hospitals (Davis et al., 2011). Therefore, in the absence of relevant published literature, an original health economic model was constructed.

3 De Novo Model: Methods

The model was implemented in Microsoft Visual Basic for Applications, using Microsoft Excel 2010 as a ‘front-end’ in which parameters were specified and results collected and analysed. Costs and benefits were discounted at 3.5% per annum each and all costs were based on 2010–11 financial year.

3.1 Model Structure

The model used a discrete event (or individual patient) structure, capturing the costs and benefits associated with a series of events and discrete health states.

A discrete event model structure was chosen for a number of reasons (Stevenson, 2005). Firstly, the GDG identified that previous falls increase the risk of future falls, so the model needed to ‘remember’ the falls history of each patient. This would have been difficult to implement in a Markov-type structure without a cumbersome proliferation of health-states. Secondly, the model adopted a lifetime horizon (see below), meaning it needed to track simulated patients over a number of years; however, the event of primary interest is falls in hospital and hospital stays are measured in much shorter time-periods (no longer than days; ideally shorter still). This would have been very difficult to account for in a discrete-time model without accounting for huge numbers of cycles. Thirdly, the model needed to track the living status and associated cost for each patient. Discrete event models can handle complex systems and continuous or changing time periods better than cohort models (Karnon et al., 2012).

Figure A presents a simplified representation of the model structure. A patient could be in one of five states in the model (acute hospital, non-acute hospital, home [i.e. living in the community], care [i.e. living in a residential home], dead). ‘Dead’ was the only absorbing state in the model. Falls could occur in any state in the model (apart from ‘dead’), although the probability of fall events varies according to underlying state (as well as patient-specific characteristics). As this was a discrete event simulation, the model did not have a time cycle as in a Markov model. Time is parameterised in days (although it is treated continuously), and the model generated a time to each next possible event (see table 1) and chose the next predicted event to happen.

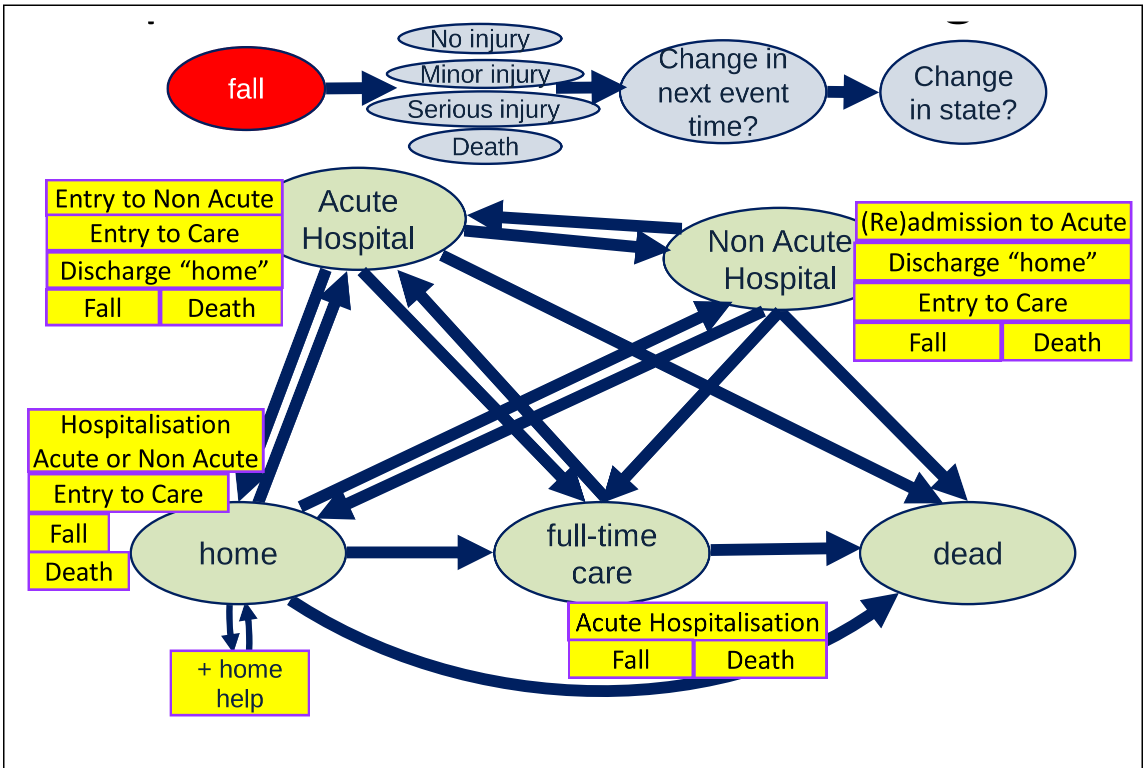

Figure A: Inpatient Falls Prevention Model Structure

The GDG requested that the hospital state was split into acute and non-acute settings for a number of reasons. Firstly, the GDG requested that the clinical evidence for question 2 be split in this manner (see main guideline section 3.4.2). Secondly, the GDG felt that unit costs and resource use (especially as regards length of stay) would differ between the two settings and the model should be able to reflect these differences (see below). Thirdly, having two separate model states allowed different scenarios to be modelled. Patients could be set to either all start in one of the settings or in a mixture of the two settings and then the intervention could be applied in one or both settings. The GDG felt this would be useful, for example to model a community/cottage hospital setting (non-acute). Whilst this gives rise to nine possible settings and intervention combinations, only the two highlighted in figure B were modelled in detail and reported here:

Acute: All patients start in the acute hospital setting but can be transferred to or admitted to acute or non-acute settings later in the model. Intervention is only ever applied in acute settings

Non-acute: All patients start in the non-acute hospital setting but can be transferred to or admitted to acute or non-acute settings later in the model. Intervention is only ever applied in non-acute settings

It seemed reasonable to assume that, if the intervention were to be cost effective (compared to doing nothing) in both the acute and non-acute settings, then it would be cost effective in the mixture setting.

Intervention / Setting	Acute	Non-acute	Mixture
Acute	X	X	X
Non-acute	X	X	X
Mixture	X	X	X

Figure B: Possible Combinations of Starting Hospital Setting and Intervention Application (Modelled Combinations Highlighted)

The care state was a generic state that represented any residential care facility (nursing or otherwise). Due to a lack of evidence and an attempt to keep the model less complicated, the GDG agreed that this state did not need to be further split between types of care facilities (e.g. nursing or residential homes). The implications of this are discussed later.

The GDG discussed the modelling of the social care process and the complex array of arrangements covered. However, no evidence was found to support any further divisions of the care process, apart from the addition of home help to those who fell in the home state or who fell in hospital and then returned to the home state.

Note that patients could not return home from the care state. This simplifying assumption was agreed by the GDG. In the NICE health economic model for hip fractures, this assumption was not made, but no patients were found to return home from care (CG124, National Clinical Guideline Centre, 2011).

Table 1: Possible next events in each state

Next Events \ Current State	Acute Hospital	Non-acute Hospital	Home	Care	Dead
Fall	X	X	X	X	
Hospitalisation to acute		X	X	X	
Hospitalisation to non-acute	X		X		
Discharge to usual residence	X	X			
Discharge to care	X	X			
Entry to care	X	X	X		
Death	X	X	X	X	

Also, there is no direct entry to the non-acute hospitalisation state from the care state. This was a reflection of the data found for direct entry to non-acute hospital settings, where less than 0.25% admissions to non-acute hospital settings were from care (see table 21).

3.2 Model Transitions

All patients began the model in the hospital state (acute or non-acute), with their age, sex, underlying residence (home or care) and falls history (falls within last 12 months) generated probabilistically.

A number of events could occur next (see table 1) – a fall whilst in hospital, transfer to a different hospital setting, discharge to usual residence, discharge to care (if previously living at home) or death. Times for each event were generated based on the patient characteristics and the next soonest event to occur is chosen. Some patients may only have their initial hospitalisation and no falls, whilst others may have repeated falls in different settings and many hospitalisations (with or without falls).

A patient's fall history was reset at one year following their last fall. This is because the majority of the evidence on the increased risk of falling for those who have previously fallen asks whether a fall has occurred within the previous 12 months. Therefore the effect cannot be assumed to have a longer impact. When the patient's fall history was reset, their next fall, entry to care and hospitalisation times were reset to reflect their decreased risk.

Patients had a risk of death whilst in all states of the model. Falls could occur in any setting and patients can move between states, subject to transition probabilities (see below). If patients were simulated to experience a fall (or multiple falls) whilst in hospital, their chances of injury were assessed.

Following the initial hospitalisation, patients were modelled for the remainder of their lives. In discussion with the GDG, it became clear that a lifetime horizon was important in order to fully capture the benefits arising from preventing inpatient falls for a number of reasons:

- The risk of falling whilst in hospital varies by sex, age, underlying residence and falls history (falls in the last 12 months). Future hospitalisations and potential falls need to be modelled, in order to track the changing risk status of each patient throughout their lifetime
- Patients may experience falls in other states that either increase their risk of falling if hospitalised again or lead directly to hospitalisation (where falls may occur)
- An inpatient fall may increase the risk of a patient spending time in the care state which will impact on costs and QALYs
- A fall resulting in serious injury may increase the risk of premature death

3.2.1 Hospital Admission Transitions

The probability of hospital admission from home or care was taken from the Health Survey for England 2000 (Department of Health, 2002). Probabilities were split by age, sex and underlying residence (see table 2).

Table 2: Probability of Hospital Admission in Any Year (Department of Health, 2002)

Sex	Age Group	Home	Care
Men	65-79	0.158	0.274
	80+	0.252	0.275
Women	65-79	0.130	0.211
	80+	0.161	0.221

The type of hospitalisation was determined once a hospitalisation occurred. No direct data source could be found to parameterise this input, so an approximation was calculated as follows. An underlying probability of hospital activity being in a non-acute setting of 2.7% was calculated from NHS reference costs (Department of Health, 2011), by taking inpatient activity in the rehabilitation currencies (TREHAB) as a proportion of all inpatient HRG activity. Relative risks by age and sex were calculated based on the HESonline data for the rehabilitation specialty (specialty code 314, NHS Information Centre for Health and Social Care, 2012) to produce probabilities by age and sex (see table 3).

Table 3: Probability That a Hospitalisation Is Directly To Non-acute Hospital Setting (Department of Health 2011, NHS Information Centre for Health and Social Care 2012)

Age Group	Men	Women
60-74	2.8%	2.6%
75+	5.8%	5.4%

There are a number of issues with the above calculations. Firstly, the model required a probability that a hospital admission episode, rather than any episode, would be in a non-acute setting. Neither of the sources used are based on admissions rather than episodes. Secondly, the NHS reference cost data contains a range of hospital activity, not just episodes. Thirdly, the rehabilitation specialty data is likely to refer to a much more specific hospital service than the required non-acute hospital setting. These limitations were acknowledged by the GDG, who agreed to use the resulting data points as an approximation.

In the above calculation, rehabilitation speciality data could be split by admission source (home or care). However, less than 0.25% of episodes were from a care state. The GDG discussed whether the likelihood of a hospitalisation being directly to the non-acute setting would vary by state (home or care) and felt it could be a reasonable assumption that anyone being admitted to hospital from a care state would not go directly to a non-acute setting. It was noted that this would vary by local health economy arrangements.

3.2.2 Hospital Discharge and Transfer Transitions

Hospital discharge time was determined by the length of stay, which was calculated on admission (see section 3.6.2).

A patient whose underlying residence was home could be discharged to care. In the acute setting, the probability of discharge to care reflected the age and gender of the simulated patient (NHS Information Centre for Health and Social Care, 2011); in addition, the likelihood of discharge to care was increased by the incidence of inpatient falls (Vass et al., 2013; relative risk for patients experiencing non-injurious falls 1.336; relative risk for patients experiencing injurious falls 1.843). In the non-acute setting, this transition was dependent on the same age and gender rates, but a different odds ratio was applied to account for inpatient falls (Aditya et al., 2003; odds ratio 3.0).

The probability of transfer from acute to non-acute hospital settings was modelled separately for patients whose original admission was from home and care states. Different underlying rates were taken from HES data (NHS Information Centre for Health and Social Care, 2011), with patients admitted from care states having higher rates of transfer from acute to non-acute hospital settings (perhaps reflecting greater underlying morbidity in this group).

For those admitted from care, HES data indicated that sex but not age influenced rates of transfer from acute to non-acute settings, whereas for those admitted from home both age and sex were important. Rates for admissions from both settings were adjusted to take account of the increased risk associated with inpatient falls (Vass et al., in print).

The only time when patients could transfer from non-acute to acute settings in the model was as a result of a serious injury fall in the non-acute setting.

3.2.3 Care Home Admission Transitions

The likelihood of entering care from home was calculated from a variety of sources. An overall rate of entry to care per year of 685 admissions per 100,000 population was taken from statutory return data (NHS Information Centre for Health and Social Care, 2011). Relative risks by age and sex were applied (Darton et al., personal correspondence, only source found) and a relative risk of 2.5 was applied to patients with a falls history (falls within last 12 months, Wang et al., 2001). As risk is linked to age, the risk of entering care is recalculated on every fifth birthday.

3.2.4 Mortality

Patient mortality was calculated as predicted time of death, based on standard Office for National Statistics life tables for 2008-2010 (Office for National Statistics, 2011). Hazard ratios are applied for the increased risk of death when entering the care state and for experiencing a serious fall (in any setting).

The increased mortality risk associated with being in a care home was estimated from a 5-year prospective cohort study of all 9,000 care home residents in Northern Ireland in 2001 (McCann et al., 2009). McCann et al.'s hazard ratio estimates for residential (1.7), nursing (2.9) and dual homes (2.6) were combined to give an overall weighted hazard ratio of 2.5.

The increased mortality risk and the duration of any risk associated with sustaining a hip fracture is documented but debated (Abrahamsen et al. 2009, Bliuc et al. 2009, Kannis et al. 2003, Parker et al. 1991), for similar causality reasons to the consequences of inpatient falls. Goldacre et al. (2002, a large UK based study) suggest a standardised mortality ratio of 187 (hazard ratio of 1.87) at 12 months following a hip fracture. The increased risk was assumed to last 1 year only, at which point the patient's death time was recalculated without the increased risk. The causal multiplier (see below) was applied to this hazard ratio for inpatients that were simulated to have a serious fall averted.

3.3 Inpatient Fall Consequences: The Causal Multiplier

A major challenge in the simulation of falls is accounting for the causal relationship between a fall and subsequent events. Evidence comparing inpatients who do and do not experience falls demonstrates that falls are associated with longer hospitalisation (Brand et al., 2010, Vass et al., 2013), lower utility (Vass et al., 2013) and a higher probability of admission to full-time care (Aditya et al., 2003, Vass et al., 2013). However, the GDG noted it would be misleading to assume that this relationship is directly causative. Instead, it must be assumed that the relationship is, to one degree or another, confounded by a wide range of known and unknown patient characteristics. For example, patients who fall are likely to have one or more comorbidities that could contribute to an extended length of stay and it is not clear whether the extended length of stay would have been incurred irrespective of a fall occurring.

From a health economic modelling perspective, the crucial consequence of this is that it is fallacious to assume that preventing an individual from falling will make the patient entirely immune from all subsequent events that are known to be associated with falls. On the other hand, it is clearly the case that preventing falls can be expected to result in some benefits in these areas. The unknown factor is the extent of these benefits.

An ideal source of model parameters would be a series of multivariate regressions associating a range of patient characteristics including empirical fall status with the outcomes of interest (a time-to-event model – e.g. Cox proportional hazards – for length of stay; a linear regression for utility; a logistic regression for probability of admission to full-time care). In this way, the impact of falls could be estimated while controlling for other covariates of the outcomes.

In the absence of such evidence, the following approach was adopted to enable the exploration of the causal relationship between falls and post-fall events:

1. For each patient, potential inpatient falls were randomly simulated in both the control and intervention arms using the fall rates appropriate to each arm (modified according to underlying age-, sex- and fall-history-specific fall-rates).

2. For simulated patients in the control arm, all falls were assumed to occur (that is, all potential falls became actual falls).

3. For simulated patients in the intervention arm, some potential falls were randomly selected to be averted, with the proportion averted equal to the incidence rate ratio observed between the two arms. This process is mathematically equivalent to simulating falls according to two arm-specific rates, but has the advantage of identifying the simulated individuals who would have fallen were it not for the intervention.

4. If the incidence rate ratio in the intervention arm is greater than 1 (a scenario used in sensitivity analysis) the model simulates additional falls in the intervention arm.

5. All actual falls were assumed to incur the full additional length of stay, health related quality of life decrement, increased mortality risk and increase in probability of admission to full-time care associated with fallers.

6. All averted (or additional) falls were assumed to incur a proportion of the length of stay, health related quality of life decrement, increased mortality risk and increase in probability of admission to full-time care associated with fallers.

This proportion became known as the ‘causal multiplier’. Setting the causal multiplier equal to 0 would be equivalent to assuming that all post-fall negative events are directly ascribable to the fall; setting it equal to 1 would be equivalent to assuming that averting falls has no benefit in attenuating subsequent disadvantages. In the base case, this multiplier was assumed to be 0.5, and the impact of varying this assumption was tested in sensitivity analysis.

The causal multiplier was applied to the following consequences of having an inpatient fall:

- Increase in length of hospital stay observed in fallers
- Utility decrement seen in fallers
- Increase in mortality seen in those experiencing a hip fracture
- Days of home help received on discharge following a fall
- Increase in probability of discharge from acute to non-acute hospital
- Increase in probability of discharge from hospital to full-time care

The direct costs associated with treating the fall were not subject to the causal multiplier, as these were not assumed to be incurred when the fall had been averted.

3.4 Patient Characteristics

The model generated each patient with a sex, age, falls history (falls within last 12 months) and underlying residence. There was no difference in the parameters used between the acute and non-acute hospital settings.

Sex and age are based on hospital episode statistics (HES) data, which contains records for all patients in English hospitals (NHS Information Centre for Health and Social Care, 2012). Age was sampled from a reflected log-normal distribution fitted to HES data. Underlying residence was also sampled from HES data, split by age and sex. Falls history in the 12 months prior to admission was based on Vass et al. (2013, see table 21).

3.5 Fall Rates and Severities

3.5.1 Hospital Fall Rates

The underlying rate of falls in hospital settings is taken from Healey et al. (2008). This paper was based on a retrospective analysis of 12 months' data from the National Patient Safety Agency (NPSA) national reporting system. All hospitals in England and Wales are required to report patient safety incidents to the national agency – the data cover 98% of hospitals in England and Wales and contain information on over 206,000 falls and nearly 25 million bed-days. The fall rates (and fall severity proportions) from the comprehensive UK data compare well to other non UK studies of inpatient fall rates (Halfon et al. 2001, Morse et al. 1987).

An average rate of 6.7 falls per 1000 bed days was calculated for patients aged 65 and over. The GDG stated that age, sex and falls history were the strongest predictors of inpatient falls, so this underlying inpatient fall rate was varied by age, sex and falls history (falls within last 12 months). Due to a lack of available data splitting fall rates by age and sex combined, incidence ratio ratios for age and sex were applied separately (Healey et al., 2008). As fall risk is related to age, the model recalculated falls risk every on fifth birthday (e.g. 75, 80, 85, etc.). The influence of falls history was applied from Vass et al. (2013), which suggests that inpatients who have experienced a fall in the past twelve months are 1.442 times more likely to fall during their hospitalisation.

When combined, the age- sex- and falls-history-specific rate of falls used in the model were as shown in table 4.

Table 4: Inpatient fall-rates (falls per 1000 bed-days), based on Healey et al., 2008 and Vass et al., 2013

Age	No falls in last 12 months		Fall(s) in last 12 months	
	Men	Women	Men	Women
65–69	2.831	2.288	4.083	3.300
70–74	3.735	3.019	5.387	4.355
75–79	4.873	3.939	7.028	5.680
80–84	5.437	4.394	7.841	6.338
85–89	7.586	6.132	10.942	8.844
90+	8.286	6.697	11.951	9.659

3.5.2 Severity of Hospital Falls

The same Healey et al. (2008) paper also reported on the severity of hospital falls, categorising falls into five categories (see table 5). It should be noted that the fall severity data covers all ages, not just patients aged 65 or older; however, those 65 or older account for over 82% of the falls reported. Also, the NPSA system does not differentiate between single and repeat falls by the same patient.

The NPSA published updated figures in 2010, but in less detail than the original Healey (2008) paper (NPSA, 2010). That paper showed similar fall rates and severities to the original paper, so the original detailed paper was used.

Table 5: Inpatient Fall Severities (Healey et al., 2008)

Fall Severity	Percent of Inpatient Falls
No harm	65%
Low	31%
Moderate	4%
Severe	1%
Fatal	0.01%

The rate and severity of falls was assumed to be the same in both acute and non-acute hospital settings. Healey et al. (2008) does give different fall rates for different hospital settings, but only gives rates for all ages (not 65+). As hospital setting and patient age are likely to be confounded, these data could not be used to generate different fall rates by hospital setting.

3.5.3 Intervention Effectiveness

The effectiveness of the modelled intervention was based on the meta-analysed RCT evidence of multifactorial falls interventions (see main guideline table 4a and forest plots in Appendix E). In the acute setting, an incidence rate ratio of 0.75 was applied; implying multifactorial interventions have the capacity to reduce fall rates by 25%. A similar rate (0.77) was used for the non-acute setting. These rates were the pooled means from the meta-analyses of RCTs only (2 studies in the acute setting, 2 studies in the non-acute setting); rates from meta-analyses with alternative study groupings (for example, all study designs together) were covered in the sensitivity analyses. Whilst these rates were very slightly different to the all-trial rates, sensitivity analysis demonstrated that model results were trivially different if those rates were used instead. Similarly, relative risks of injury following a fall were calculated by setting (1.18 for the acute setting, 1.02 for the non-acute setting) from studies reporting the necessary data (1 study for the acute setting, 1 study for the non-acute setting)

3.5.4 Home State Fall Rates

The fall rate for patients living at home was taken from the Health Survey for England (HSE) 2005 (NHS Information Centre for Health and Social Care, 2007). This national survey is based purely on home residents and asked whether respondents had fallen in the last 12 months and, if they had, how many times they had fallen. The HSE gives a fall rate of 0.46 per person per year and this figure was split by age and sex. Note this rate is higher than the per-person falls prevalence (26%) because multiple falls are taken into account. The model recalculates fall risk on every fifth birthday.

Table 6: Comparison of Home State Fall Rate Sources

Source	% of people falling	Fall rate
Blake et al. (1988)	35%	Not given
Campbell et al. (1981)	34%	Not given
Downton et al. (1991)	42% (75+ ages)	Not given
O'Loughlin et al. (1993)	29%	0.41
Prudham et al. (1981)	28%	0.54

The fall rate in the Health Survey for England compares well to other sources (see table 6) but is more recent and more comprehensive.

An incidence rate ratio of 2.643 for people with a history of falling (within last 12 months) was calculated from O'Loughlin et al. (1993), with no other suitable sources found.

3.5.5 Severity of Falls at Home

Fall severities by age, sex and underlying residence were taken from Watson et al. (2009). Whilst based in Australia, this study is one of the few to report non-injurious falls as well as injurious falls. Data from hospital records and a robust population-based falls survey in New South Wales (5,000 respondents aged 65+) are combined to generate falls by severity (see table 7) for people aged 65+ by sex and residence. Data for care home residents are generated from injurious falls (hospital) data and applied to non-injurious falls data.

Table 7: Home and Care Injury Severities and Likely Treatments (Watson et al., 2009)

Injury Severity	Likely Treatment
No injury	Self-care
Minor injury	GP/community nurse
Major injury	A&E attendance
Severe injury	Hospitalisation

In Watson et al. (2009), falls incidence is estimated at 27% per year, of which 28% suffer injury – both figures compare well to English data from the Health Survey for England 2005 (falls incidence 26%, of which 30% suffer injury) (NHS Information Centre for Health and Social Care, 2007).

England has a slightly older population than New South Wales (in 2009, 13.9% of those aged 65+ in England were aged 85+ [Office for National Statistics, 2010]; in New South Wales, the same proportion is 10.5%). This means that the model is likely to slightly underestimate injury rates. However, in New South Wales, 5.6% of residents aged 65+ live in care homes (Watson et al., 2009). This compares with 4.5% in England (Census 2001), meaning the model is likely to slightly overestimate injury rates. Therefore, these minor inconsistencies are likely to balance each other.

Watson et al. (2009) only consider death from falls that result in an A&E attendance or hospitalisation (i.e. moderate or severe injuries that lead to death). In order to treat mortality from a fall as a separate category, the probability of mortality from a fall leading to an A&E attendance or hospitalisation from Scuffham et al. (2003) was applied to moderate and serious injury rates from Watson et al. (2009). Severity of Injury rates by age and sex are shown in table 8.

Table 8: Severity of Injury from Falls at Home (Watson et al., 2009; Scuffham et al. 2003)

Age	Men					Women				
	No Inj.	Minor	Mod.	Serious	Fatal	No Inj.	Minor	Mod.	Serious	Fatal
65–69	82.9%	13.5%	1.9%	1.7%	0.0%	78.9%	15.4%	3.2%	2.5%	0.0%
70–74	85.6%	10.8%	1.7%	1.9%	0.0%	75.8%	17.7%	2.9%	3.6%	0.0%
75–79	80.5%	14.2%	2.2%	3.1%	0.0%	74.9%	17.1%	3.0%	5.0%	0.1%
80–84	74.6%	17.2%	2.8%	5.4%	0.1%	73.0%	14.8%	3.4%	8.8%	0.1%
85–89	72.0%	20.3%	2.4%	5.2%	0.1%	58.6%	27.7%	3.1%	10.4%	0.1%
90–94	51.8%	29.2%	5.8%	13.0%	0.2%	69.6%	15.1%	3.7%	11.4%	0.1%
95+	52.1%	37.4%	3.9%	6.6%	0.1%	48.0%	37.4%	4.2%	10.3%	0.1%

3.5.6 Care State Fall Rates

An ideal source of UK-based fall rates in care homes could not be located. The oft-quoted figure of rates in nursing home being three times those living in the community is based on a crude analysis of US research (Rubenstein, 1994) from an era when the use of bed restraints was common and is therefore not directly applicable to the current UK setting.

A large and comprehensive UK study covering both nursing and residential homes in Belfast reported only fracture rates, not overall fall rates (O'Halloran et al. 2004, 1.4 million bed days in the control arm). Two smaller UK studies (Dyer et al. 2004 (24,000 bed days in the control arm) and McMurdo et al. 2000 (6,000 bed days in the control arm)) reported both fall and fracture rates. At the direction of the GDG, these three studies were selected and combined to give an overall fall rate of 3.9 falls per resident per year.

An odds ratio of 2.1 was calculated from Delbaere et al. (2008) to reflect the increased risk of falling in those care home residents who had fallen within the past year. Whilst Delbaere is an Australian study, no other source was found. Delbaere's regression model found that age and sex were not significant predictors of falling, so the care home fall rates were not adjusted for age or sex.

3.5.7 Severity of Falls in Care

As for home state falls, fall severities by age, sex and underlying residence were taken from Watson et al. (2009) and Scuffham et al. (2003) (see table 9).

Table 9: Severity of injury from falls in care (Watson et al., 2009; Scuffham et al. 2003)

Age	Men					Women				
	No Inj.	Minor	Mod.	Serious	Fatal	No Inj.	Minor	Mod.	Serious	Fatal
65–69	51.3%	45.4%	1.1%	2.2%	0.0%	51.4%	43.5%	2.5%	2.6%	0.0%
70–74	51.3%	44.6%	1.9%	2.1%	0.0%	51.3%	41.5%	4.0%	3.1%	0.0%
75–79	52.1%	39.4%	4.2%	4.1%	0.1%	52.3%	36.7%	5.9%	5.0%	0.1%
80–84	52.0%	36.1%	6.2%	5.6%	0.1%	52.2%	33.9%	7.7%	6.0%	0.1%
85–89	52.5%	33.1%	7.1%	7.1%	0.1%	52.8%	29.5%	9.6%	7.9%	0.2%
90–94	52.6%	29.0%	10.0%	8.2%	0.2%	52.8%	28.7%	10.2%	8.2%	0.2%
95+	40.7%	36.3%	10.9%	11.9%	0.2%	40.7%	32.9%	15.8%	10.4%	0.2%

3.6 Resource Use and Unit Costs

Estimates of resource use were taken from a variety of sources, including GDG consensus; unit costs were mainly derived from NHS reference costs (Department of Health, 2011) and PSSRU health and social care costs (PSSRU, 2011). Resource use and unit costs can be categorised as state costs, fall costs or intervention costs.

3.6.1 Home State Resource Use and Costs

The underlying cost to the NHS and PSS of a day at home (without fall-related complications; see below) was assumed to be zero.

3.6.2 Hospital State Resource Use and Costs

Unit costs were derived from NHS reference costs (Department of Health, 2011). The cost of a day in an acute hospital setting was based on the weighted average of all elective and non-elective activity, including excess bed days. The unit cost of a day in a non-acute hospital setting was based on all inpatient rehabilitation categories[1].

Resource use whilst in an acute hospital setting was measured in days in hospital (length of stay). This was calculated based on unpublished trial data from Vass et al. (2013), because it was the only available UK study that provided details of length of stay relative to incidence and severity of falls. In this study, patients who did not experience a fall (n=1695) had an average length of stay of 11.6 days (95%CI: 11.36, 11.84); for people who had a non-injurious fall (n=93), the same figure was 21.0 days (95%CI: 19.70, 22.30) and, for people who fell and were injured (n=34), the figure was 24.4 (95%CI: 21.88, 26.92). It should be noted that relying on these data meant resource use was not differentiated by age or sex, in this area.

Resource use whilst in non-acute hospital settings was based on HES length of stay data for those transferred to ’other NHS settings’ (NHS Information Centre for Health and Social Care, 2012). Length of stay in non-acute hospital settings was split by age only, as an inspection of the data showed length of stay did not vary by gender.

The length of each hospital stay was probabilistically sampled from an exponential distribution with the relevant mean. When a fall occurred during the simulated patient’s admission, the length of stay was adjusted by sampling an additional period from a second distribution reflecting the difference between a stay without falls and one in which a fall (non-injurious or injurious, as appropriate) occurred. This difference, calculated from Vass et al.’s data, was assumed to be the same for both acute and non-acute settings, in the absence of any source of data specific to the latter.

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1 TREHAB_CSRS_LEVEL_1_ATT_APC, TREHAB_SRS_LEVEL_2_ATT_ APC, TREHAB_NSRS_ATT_APC, TREHAB_CSRS_LEVEL_1_BEDDAY_ APC, TREHAB_SRS_LEVEL_2_BEDDAY_APC and TREHAB_NSRS_ BEDDAY_APC

Extended length of stay was calculated in exactly the same way for all averted falls, but was subject to the causal multiplier (see above). The change in length of stay was only applied to the first fall experienced in any given stay, as Vass et al. did not differentiate between single and repeat fallers. The change in length of stay was assumed to be the same in acute and non-acute settings.

The cost of a day in hospital was based on NHS reference costs (Department of Health, 2011) and was the weighted average of all HRG related inpatient activity currencies – elective and non-elective activity with associated excess bed day costs and day-case costs[2]. All currencies were used as the model covers all hospital inpatient activity. This gave an average cost per bed day of £524.02.

The cost of a day in a non-acute hospital setting was based on NHS reference costs (Department of Health, 2011) and was the weighted average of all inpatient rehabilitation service currencies (starting TREHAB[3]). This gives an average cost per bed day of £588.01. Some members of the GDG expressed surprise that the cost of a day non-acute settings was greater than that in the acute/general hospital setting, but other GDG members suggested a number of reasons this could be the case:

- Non-acute settings will have less independent patients and more frail patients with multiple pathologies
- Non-acute settings may have higher levels of nursing and therapy than general settings
- Non-acute settings can be smaller and may lack the economies of scale experienced by larger general hospital settings
- The cost given of a general hospital setting will reflect a wide range of expensive and cheap treatments/hospital stays

[2] Currencies TEI, TEI_XS, TNEI_L, TNEI_L_XS, TNEI_S and TDC

[3] TREHAB_CSRS_LEVEL_1_ATT_APC, TREHAB_SRS_LEVEL_2_ATT_ APC, TREHAB_NSRS_ATT_APC, TREHAB_CSRS_LEVEL_1_BEDDAY_ APC, TREHAB_SRS_LEVEL_2_BEDDAY_APC and TREHAB_NSRS_ BEDDAY_APC

It is noted that basing these costs on NHS reference costs means they are not specific to the 65+ age group and therefore may underestimate the true cost of being in hospital for that age group.

3.6.3 Care State Resource Use and Costs

Resource use for the care state was measured in days. Once a patient enters care, they cannot leave (see assumptions, section 3.8) so the number of days in care is from entry until their next hospitalisation (calculated probabilistically, see below) or death.

The cost of a day in care was calculated from standard sources (PSSRU, 2011). Following the approach taken in previous NICE guidelines on delirium (CG103, National Clinical Guidelines Centre, 2010) and hip fracture (CG124, National Clinical Guidelines Centre, 2011) unit costs for different care home settings were weighted according to Netten et al. (1998). These combine to give a daily cost of being in care of £103.78 (see table 10).

Table 10: Values Used to Calculate Daily Cost of Being in a Care Setting

Care Setting	Weighting (Netten et al., 1998)	2010–11 weekly fees (inc. living expenses, PSSRU 2011)
Private nursing home	33%	£719
Private residential care	16%	£497
Voluntary residential care	21%	£497[4]
LA residential care	31%	£1004.80
Average Weekly Fees		£726.47
Average Daily Fees		£103.78

Not all care is NHS/PSS funded. As in previous delirium (CG103, National Clinical Guidelines Centre, 2010) and hip fracture (CG124, National Clinical Guidelines Centre, 2011) guidelines and the Department of Health (DH) Fracture Plan (Department of Health, 2009) an assumption that 60% of care is NHS/PSS funded was used. Also, a survey by Forder et al. (2009) suggested

[4] PSSRU no longer give a cost for voluntary residential care. However, the prices used in the Hip Fracture guideline (CG124, NICE, 2011) for private and voluntary residential care were very similar, so the same price was assumed here

that between 63% and 67% of residents are NHS/PSS funded at death, depending on home provider, adding weight to the assumption used.

Resource use for patients receiving home help was assumed by fall severity and agreed by the GDG . These values were varied within the sensitivity analysis. A fall leading to minor injury received 7 days' help, moderate injury 21 days' help and severe injury 42 days' help. A similar 6-week assumption was made in the DH Fracture Plan (Department of Health, 2009) for severe injuries.

The cost per day of receiving home help following a fall is calculated from the standard sources (PSSRU, 2011). Based on an average of £22/hour for 12.4 hours per week, the cost per day is estimated at £38.97. Like the cost of a day in care, the cost of a day of home help is subject to an assumption of 60% NHS/PSS funding. Home help costs were subject to the causal multiplier for people whose inpatient falls were simulated as averted.

3.6.4 Hospital Fall Resource Use and Costs

Inpatient fall resource use and costs are based on costs previously calculated by the NPSA (NPSA, 2007), uplifted from 2005–06 prices to 2010–11 prices (PSSRU, 2011). No evidence was found to assign different resource or costs by hospital setting, so the GDG agreed to assume that inpatient falls incurred the same cost, regardless of hospital setting.

Assumed resource use is shown in table 3 of the NPSA report. X-ray costs were apportioned across no harm and low severity falls. The cost of severe falls were based on a weighted average of the NPSA costs for severe falls excluding fractures, fractures excluding hip fractures and hip fractures. The NPSA fracture costs were based on the full cost of treating such injuries (treatment cost and bed day cost), but the health economic model counts bed day costs as the state occupancy costs. Therefore, in order to avoid double-counting, it was necessary to separate the treatment and bed day costs. Note that the NPSA costs for severe injuries excluding fracture were based on resource use in A&E without hospital admission, so the cost did not need splitting in the same manner.

Table 11: Calculation of treatment cost of hip fractures and other fractures

	Wrist Fractures	Hip Fractures
Average cost per procedure	£2443.89	£7022.66
Average number of bed days per procedure	2.4	14.2
Average cost of excess bed day (all specialties)	£255.64	£255.64
Bed day portion of procedure	£614.32	£3628.02
Treatment portion of procedure	£1829.57	£3394.65

Using non elective short stay (TNEI_S), long stay (TNEI_L) and excess bed day currencies (TNEI_L_XS) from NHS reference costs (Department of Health, 2011), the weighted average cost of trauma hip (currency HA1*) and trauma wrist (currency HA7*, a proxy for fractures excluding hip fractures) procedures was calculated. The average number of bed days per hip and wrist procedure and a generic cost of a hospital bed day were calculated (see section 3.6.2 on hospital state costs). These enabled the overall cost per procedure to be broken down into treatment and bed day costs (see table 11). An average weighted cost of the treatment cost portion was then calculated (see table 12).

Table 12: Calculation of weighted average treatment cost of severe injuries following an inpatient fall

Severe Inpatient Injury Type	Number	Cost
Excluding fracture	258	£371.20
Fractures (excluding hips)	442	£1829.57
Hip fractures	530	£3394.65
Weighted average (includes cost of one follow up outpatient appointment)	1230	£2290.94

Finally, as the NPSA considered only inpatient costs but the model considers all NHS costs, the cost of one follow up outpatient appointment was added to severe injury falls (£92.89, weighted average of Trauma and Orthopaedics Consultant Led: Follow up Attendance Multi-professional Face to Face (Department of Health, 2011)).

The GDG agreed to assume that fatal inpatient falls incurred no cost. Whilst this may not be true, the number of fatal inpatient falls that occurred in the model was so few that the costs will be negligible.

Table 13: Inpatient Fall Treatment Costs by Severity (based on NPSA, 2007)

Inpatient Fall Severity	Cost (2010–11)
No harm	£47.41
Low	£76.63
Moderate	£371.21
Severe	£2290.94

3.6.5 Home and Care Fall Resource Use and Costs

Resource use associated with home and care falls were based on Watson et al. (2009) and assumptions arrived at in consultation with the GDG.

Table 14: Home and Care Fall Treatment Costs (PSSRU, 2011)

Fall Severity	Resource Use (unit cost)[5]		Total Cost per Fall	
	Home	Care	Home	Care
No harm	No NHS/PSS resource use	No NHS/PSS resource use	£0	£0
Low	GP clinic attendance (£36)	GP home visit (£121)	£36	£121
Moderate	A&E attendance (£106) GP clinic follow up (£36)	A&E attendance (£106) via ambulance (£253) GP home visit follow up (£121)	£142	£480
Severe	A&E attendance(£147) via ambulance (£253), hospitalisation, outpatient follow up (T&O, £93)	A&E attendance(£147) via ambulance (£253), hospitalisation, outpatient follow up (T&O, £93)	£492.89	£492.89

Watson et al. (2009) assumed levels of health service use following each fall severity; these were combined with assumptions about further likely follow up and transport resource use (see table 14). The assumptions of one A&E attendance and/or one hospitalisation seem logical. Whilst the use of one GP

[5] GP costs include staff costs (PSSRU table 10.8b)

appointment following a fall is an assumption, research by Iglesias et al. (2009) lends some weight to this assumption.

The unit cost of home and care falls were based on standard sources (PSSRU, 2011) for each activity. The cost of hospitalisation following a severe fall was calculated separately by the model. Hospitalisations incur a cost per day in hospital and therefore the cost will depend on the length of stay.

3.6.6 Intervention Resource Use and Costs

As no economic evaluations of inpatient falls prevention programmes currently exist (Davis, 2011), there were no examples of costed fall prevention interventions.

The effectiveness evidence in the model was based on a meta-analysis of a number of studies. One GDG member agreed to provide unpublished resource use estimates from a published trial that was included in the meta-analysis and therefore the intervention costs are based on Healey et al. (2004). All the percentages and staff time requirements are assumptions and were varied in the sensitivity analysis.

Table 15: Proportion of Medication Reviews Conducted by Different Grade Doctors by Hospital Setting

Setting	Grade	Proportion
Acute	Consultant	50%
	Registrar	50%
Non-acute	GP[6]	90%
	Registrar	10%

The intervention first conducts a multi-factorial assessment of a patient's risk factors. The assessment is assumed to be undertaken by a nurse and to require 20 minutes of his or her time. It is assumed the proportion of patients receiving the assessment will vary by setting (30% in acute; 80% in non-acute). Depending on the outcome of the assessment, patients then receive the necessary components of the multi-factorial intervention. Assumed

[6] The GDG member on whose paper the costings are based advised that the majority of medical input in the non-acute setting was given by GPs

proportions of patients receiving each intervention component and associated resource use (staff time and consumables) are shown in table 16. One resource use difference was assumed between acute and non-acute settings – the proportion of medication reviews done by different grade doctors (see table 15).

The intervention cost is calculated as the cost per admitted patient. Given the different proportion of patients assessed, the acute cost per admitted patient is £7.83 and the non-acute cost per admitted patient is £21.81.

Table 16: Components Used to Cost Multifactorial Intervention

Staff Member	Intervention Component	% of those assessed receiving component	Staff Time Required (mins)	Notes
Nurse	Eyesight - ophthalmology referral	3% (1/30)	30	More complex referral, hence staff time needed
	Medication - extra BP checks if CVD drugs changed	12% (20% of those having medication review (Dr))	35	Extra daily checks for 1 week
	Bed height alteration and bedrail removal	100%	5	Assess and remove if necessary
	Blood pressure check - referral to medical staff if high/low	Unknown	0	Referrals sticky label based, so no burden. No extra staff resource, just prioritisation
	Mobility - physiotherapy referral	80%	0	Referrals sticky label based, so no burden
Healthcare Assistant	Urine test - send sample for analysis	25%	10	Also laboratory costs (estimated £1 per test, 2010-11 costs)
	Footwear check and advise relatives on replacements	10%	5	Phone call to relatives. Also 100 pairs slippers purchased (£4 each at 0102 costs, £5.35 at 1011 costs)
	Patient position in ward - move close to nurses	10%	10	2x HCA 5min each
	Call bell and hazard education (assumed grade)	100%	0	No additional cost, ought to happen as part of routine practice
Doctor	Medication review	60%	7	Review 2mn, explan 5mn
Optician	Optician referral for glasses	Unknown	Unknown	Referral sticky label based, so no burden

Staff costs were taken from standard sources (PSSRU, 2011 – see table 17). No hourly rate is given for opticians, but their annual salary is almost the same as nurses, so the same hourly rate is assumed.

Table 17: Staff Costs per Hour (PSSRU, 2011)

Staff Group	Cost per Hour
Healthcare Assistant	£20
Nurse	£34
Optician	£34
Doctor – Registrar	£59
Doctor – GP	£121
Doctor – Consultant	£137

3.7 Utilities

In order to complete a cost–utility analysis, values reflecting societal preference for health states and events are required. In this instance, utility values for the home, hospital and care states and for falls by severity in each setting were required.

3.7.1 State Utilities

No literature was found that detailed the utility decrement suffered as a result of being in hospital. Unpublished data, based on EQ-5D assessments from a falls prevention trial, were used (Vass et al., 2013) to estimate utility decrements of 0.720 for men and 0.714 for women. The GDG agreed that utility decrements were unlikely to differ between acute and non-acute hospital settings.

Utility values for people in the home state were taken from the standard source for UK population norms (Kind et al., 1999). As UK population norms data have 75+ as their highest age category and a high proportion of patients in this model lived to be older than 75, polynomial (quadratic) regression was used to allow extrapolated estimates of utility values in older age groups. All subsequent changes to utility were applied as decrements to this baseline. As utility decreases over time, baseline utility was recalculated on every fifth birthday.

No literature was found that detailed the utility decrement suffered as a result of being in the care state. The GDG agreed to use an assumption of 0.8, which was a decrement compared to being at home, but less than that for being in hospital. One small American study noted the limitations of using SF-36 in nursing home residents, but can be shown to produce a decrement similar to the assumption of 0.8 (Andresen, 1999).

3.7.2 Fall Utilities

Falls in any setting are assumed to have a detrimental impact on utility. A search for published studies containing utility values related to inpatient falls yielded a total of 3460 unique citations. 91 papers were retrieved at title and abstract search, of which 3 were retained at full text review. However, none were found to meet the NICE reference case.

Utility decrements for no, minor and moderate injury inpatient falls were taken from unpublished data (Vass et al., 2013). Data used were the relative decrements for fallers compared with non-fallers, rather than absolute utility values (see table 18). As Vass et al.'s data did not allow differentiation between types of injurious falls, the relative decrements for home/care injurious falls were applied to Vass et al. Due to the small number of severe injuries sustained in Vass et al., utility decrements for inpatient falls resulting in severe injuries were assumed to be the same as those associated with a hip fracture (in any setting; see below).

Table 18: Utility decrement associated with inpatient falls by fall severity

Fall Severity	Inpatient Decrement
No injury	0.942
Minor injury	0.753
Moderate injury	0.736
Severe injury	0.700 (year 1)
	0.800 (year 2 onwards)

Vass et al. did not differentiate between single and repeat fallers, so fall utility decrements could not be applied repeatedly. If more than one fall occurred whilst in hospital, the decrement associated with the most serious fall was applied. Once a patient was discharged, they reverted to the utility decrement associated with the same severity of fall in the home or care state. For example, a man aged 65.5 who is admitted to hospital and suffers a minor fall whilst an inpatient is calculated to have a utility of 0.434 following the fall. The patient leaves hospital on the 5th day and the fall utility decrement is changed to the minor fall utility decrement associated with being at home, so his utility becomes 0.782 for another 360 days (the rest of the year following his fall).

Utility decrements for falls in the home and care states were assumed to be equal – as multiplicative decrements for state and fall were applied, the actual utility following a fall in care will be lower than that at home.

In the absence of any fall-specific literature, utility decrements for falls in the home and care states were derived from the updated systematic review of utility decrements associated with osteoporotic fractures (Peasgood et al., 2009). Falls resulting in serious injury (in any setting) were assumed to be similar in utility loss and duration to hip fractures; falls resulting in moderate injury were assumed to be similar in utility loss and duration to wrist fractures. In line with Iglesias et al. (2009); falls resulting in minor injury were assumed to have half the impact on utility of moderate falls. Outside the inpatient setting, falls resulting in no injury were assumed to have no impact on utility (see table 19); this assumption was tested in sensitivity analysis.

All fall utility decrements were assumed to last 1 year, with the exception of falls resulting in severe injury which were spread over 5 years, in accordance with Peasgood et al. (2009).

Fall utility decrements from multiple falls are applied multiplicatively in the home and care states. Finally, the causal multiplier was applied to utility decrements associated with averted falls in the inpatient setting.

Table 19: Utility decrement associated with home or care states falls by fall severity

Fall Severity	Home/Care Decrement	Duration
No injury	1	1 year

Minor injury	0.978	1 year
Moderate injury	0.956	1 year
Severe injury	0.7	1 year
	0.8	Year 2 onwards

3.8 Model Assumptions

The health economic model of interventions to prevent inpatient falls relies on a number of assumptions. These assumptions tend to arise for two reasons – either to reduce the model complexity or because no data point could be found in the evidence base. The assumptions were discussed with and agreed by the GDG and are listed in table 20 – the most important assumptions will be considered in the discussion section. Where possible, a range of values for assumed inputs were tested in the sensitivity analyses.

Table 20: Assumptions made in the preventing inpatient falls health economic model

Area	Assumption	Comment
Inpatient falls	Inpatient fall rates are assumed to be the same in both acute and non-acute hospital settings	Considered in discussion section
	Inpatient fall severity rates are based on data for all ages, not for those aged 65+	Could underestimate (older patients more likely to suffer injury) or overestimate (older patients more likely to fall) fall severities
	Changing risk of fall over duration of hospital stay is not modelled	Considered in discussion section
Costs	Resource use and costs of inpatient falls assumed, true cost unknown	Varied in sensitivity analysis
	Fatal falls in any setting incur no cost to the NHS/PSS	Likely to underestimate true cost, but numbers tiny (see NPSA 2007). Varied in sensitivity analysis
	Cost of a day in hospital settings is not specific to 65+ age group	Could underestimate or overestimate true cost. Varied in sensitivity analysis
	Cost of a day in non-acute hospital settings assumed from a variety of data sources not necessarily specific to non-acute settings	Considered in discussion section. Varied in sensitivity analysis
	The cost of social care borne by the NHS/PSS is assumed to be 60% of the full cost	True proportion unknown. Varied in sensitivity analysis
	Days of home help received following a fall were assumed	True resource use unknown. Varied in sensitivity analysis
	Intervention cost calculated on assumptions from one GDG member based on one study (Healey et al., 2004)	Generic intervention costed. Cost varied in deterministic sensitivity analysis
Utilities	Utility decrement associated with severe injury inpatient falls based on that for a hip fracture in any setting	Considered in discussion section. Varied in sensitivity analysis
	There is no difference in utility decrements or duration associated with falls in acute and non-acute hospital settings	Considered in discussion section
	Length of utility decrement following IP fall assumed; assumed that decrement reverts to home/care decrement on discharge	Considered in discussion section. Varied in sensitivity analysis
	There is no difference in the utility decrement associated with falls in the	Considered in discussion section

	home or in care	
	No utility decrement from non-injurious falls in the home or care states	Could underestimate utility decrement. Varied in sensitivity analysis
	There is no difference in utility decrements associated with being in acute and non-acute hospital settings	Considered in discussion section
	Utility decrement associated with being in care is 0.8	Considered in discussion section. Varied in sensitivity analysis
State transitions	Probability of admission directly to non-acute hospital settings are not based on robust or directly relevant evidence	Considered in discussion section. Varied in sensitivity analysis
	Patients can only be transferred from the non-acute to the acute hospital setting following a serious injury fall	Could underestimate transfers to acute setting, but impact on cost and utility unknown
	Patients cannot be admitted directly to non-acute hospital settings from the care state	Considered in discussion section
	The full time care state is modelled as a single state rather than split into residential, nursing and other settings	Considered in discussion section
	Patients cannot leave full time care once they have entered it	Considered in discussion section
Mortality	Falls with less than severe injury have no impact on mortality	Could underestimate impact on mortality
	Preventing serious falls reduces the premature mortality associated with falling	Varied in sensitivity analysis
Causal Multiplier	It is not possible to ascertain how much of the consequences of an inpatient fall are directly attributable to the fall	Considered in discussion section. Varied in sensitivity analysis

3.9 Sensitivity Analysis

Sensitivity analysis was conducted to explore the various areas of uncertainty and their impact on the model including one way, two way and threshold analyses (using point estimates of parameters only). Note that the use of a discrete event simulation model accounts for first order (patient level) uncertainty (O'Hagan et al., 2007).

3.9.1 Sensitivity Analysis

One-way sensitivity analyses were conducted to establish which model parameters have the greatest impact on the cost–utility results. Two-way sensitivity analysis was also conducted to explore the relationship between fall rates and intervention costs.

3.9.2 Threshold Analysis

Following the one way sensitivity analysis, parameters to which the model appeared most sensitive were further analysed. The value of each parameter chosen was varied across a plausible range to determine the parameter level at which the cost-effectiveness conclusions change – the threshold at which a different decision should be considered.

3.9.3 Probabilistic Sensitivity Analysis

Given the large number of inputs, it would be of benefit to perform probabilistic sensitivity analysis (PSA) to explore the effects of parameter uncertainty of model outputs. However, at the time of reporting, this has not been feasible because of the additional computational burden introduced by the discrete event simulation approach.

4 Parameter tables

Table 21: Parameter Input Table for Input Falls Model

Area	Parameter	Estimate	Parameters for PSA (not performed)			Source
			Distribution	Parameters		
Model Parameters	Discount rate – costs	3.5% per annum	NA	NA		NICE reference case
	Discount rate – benefits	3.5% per annum	NA	NA		NICE reference case
	Causal Multiplier	0.5	NA	NA		Assumption
Intervention parameters	Inpatient falls – acute settings (IRR)	0.753	Log normal	SE=0.331		RCT meta-analysis
	Inpatient falls – non-acute settings (IRR)	0.775	Log normal	SE=0.136		RCT meta-analysis
	Injury rates – acute settings (relative risk)	1.178	Log normal	SE=0.454		RCT meta-analysis
	Injury rates – non-acute settings (relative risk)	1.020	Log normal	SE=0.242		RCT meta-analysis
Patient Characteristics	Age at start of model	Probabilistically sampled from reflected log normal distribution (mean=4.669; SD=0.121; max=177.437)	Reflected log normal	Mean=4.669 SD=0.121 Max=177.437		NHS Information Centre for Health and Social Care, 2012
	Sex (% male of all admissions)	65-69=0.525 70-74=0.526 75-79=0.509 80-84=0.472 85-89=0.413 90+ =0.317	Beta	α=553,991 α=570,538 α=540,665 α=425,522 α=261,698 α=106,304	β=501,042 β=514,467 β=520,687 β=476,475 β=371,777 β=228,922	NHS Information Centre for Health and Social Care, 2012

Area	Parameter	Estimate	Parameters for PSA (not performed)			Source
			Distribution	Parameters		
	Underlying residence is a care home: Males (% of admissions)	65-69=0.001 70-74=0.001 75-79=0.002 80-84=0.003 85-89=0.006 90-94=0.008 95-99=0.013 100+ =0.019	Beta	α=563 α=742 α=1,053 α=1,379 α=1,503 α=724 α=221 α=35	β=553,428 β=569,796 β=539,612 β=424,143 β=260,195 β=86,253 β=17,228 β=1,843	NHS Information Centre for Health and Social Care, 2012
	Underlying residence is a care home: Females (% of admissions)	65-69=0.001 70-74=0.001 75-79=0.002 80-84=0.005 85-89=0.008 90-94=0.012 95-99=0.018 100+ =0.018	Beta	α=332 α=672 α=1,209 α=2.287 α=2,948 α=2,088 α=906 α=153	β=500,710 β=513,795 β=519,478 β=474,188 β=368,829 β=167,521 β=49,996 β=8,258	NHS Information Centre for Health and Social Care, 2012
	Falls history (in last 12 months) prior to admission (%): No previous fall Previous non-injurious fall Previous injurious fall	0.192 0.504 0.304	Dirichlet	α= 353 α= 927 α= 559		Vass et al. (2013)
Fall Rates – Inpatients	Fall rate for ages 65+ (falls per bed day)	0.007	Log normal	SE=0.00002		Healey et al. (2008)
	Incidence Rate Ratio (age)	65-69=1.000 70-74=1.278 75-79=1.640 80-84=1.837 85-89=2.546 90+ =2.689	Log normal	SE by age: 70-74=0.016 75-79=0.015 80-84=0.014 85-89=0.015 90+ =0.015		Healey et al. (2008)

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Incidence Rate Ratio (sex)	Male =1.000 Female=0.808	Log normal	 SE=0.006	Healey et al. (2008)
	Proportion of bed days (by falls history in last 12 months)	No falls=0.192 Falls =0.171	Dirichlet	α= 15,080 α= 3,107	Vass et al. (2013)
	Incidence Rate Ratio (by falls history in last 12 months)	No falls=1.000 Falls =1.442	Log normal	 SE=0.23	Vass et al. (2013)
Fall Consequences – Inpatient Falls	Fall consequence – probability of any injury	No injury=0.647 Injury =0.353	Beta	 α=72,096, β=133,417	Healey et al. (2008)
	Severity of injury, given a fall has occurred (probability)	Minor =0.880 Moderate=0.103 Severe =0.017 Death =0.0004	Dirichlet	α=64,144 α=7,506 α=1,230 α=26	Healey et al. (2008)
	Length of inpatient stay in acute setting (days)	No fall =11.6 No injury fall=21.0 Injurious fall=24.4	Log normal	SE=0.238 SE=1.2966 SE=2.521	Vass et al. (2013)
	Length of inpatient stay in non-acute setting (days)	Baseline=18.3	Log normal	SE=0.013	NHS Information Centre for Health and Social Care, 2012
	Length of inpatient stay in non-acute setting (days, difference from baseline)	65-69=-3.9 70-74=-1.8 75-79=-0.3 80-84=1.1 85-89=2.0 90-94=1.8 95-99=1.1 100+ =-1.5	Normal	SE=0.017 SE=0.033 SE=0.031 SE=0.030 SE=0.032 SE=0.046 SE=0.085 SE=0.242	NHS Information Centre for Health and Social Care, 2012

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Rate of entry to care from hospital (acute or non-acute hospital setting, by age, males)	65-69=0.002 70-74=0.002 75-79=0.004 80-84=0.007 85-89=0.013 90-94=0.022 95-99=0.031 100+ =0.044	-	-	NHS Information Centre for Health and Social Care, 2012
	Rate of entry to care from hospital (acute or non-acute hospital setting, by age, females)	65-69=0.001 70-74=0.003 75-79=0.006 80-84=0.013 85-89=0.024 90-94=0.037 95-99=0.052 100+ =0.036	-	-	NHS Information Centre for Health and Social Care, 2012
	Probability of entry to care	No fall =0.374 No injury fall=0.500 Injurious fall =0.690	-	-	Vass et al. (2013)
	Proportion of fallers in source cohort	No fall = 0.939 No injury fall= 0.040 Injurious fall =0.020	Dirichlet	α= 1,595 α= 74 α= 29	Vass et al. (2013)
	Relative risk of entry to care (by inpatient fall category)	No fall = 1.000 No injury fall=1.336Injurious fall =1.843	Log normal	 SE=0.121 SE=0.129	Vass et al. (2013)
	Relative risk of entry to care (by sex)	Male =1.000 Female=1.949	Log normal	 SE=0.012	NHS Information Centre for Health and Social Care, 2012

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Relative risk of entry to care (by age - Males)	65-69=1.000 70-74=1.619 75-79=2.605 80-84=4.775 85-89=8.430 90-94=14.554 95-99=20.375 100+ =28.658	Log normal	SE by age: 70-74=0.048 75-79=0.045 80-84=0.043 85-89=0.043 90-94=0.047 95-99=0.069 100+ =0.157	NHS Information Centre for Health and Social Care, 2012
	Relative risk of entry to care (by age - Females)	65-69=1.000 70-74=1.939 75-79=3.918 80-84=8.672 85-89=15.951 90-94=24.963 95-99=34.922 100+ =24.205	Log normal	SE by age: 70-74=0.056 75-79=0.047 80-84=0.043 85-89=0.040 90-94=0.040 95-99=0.041 100+ =0.046	NHS Information Centre for Health and Social Care, 2012
	Discharge from acute to non-acute setting (rate per discharge, by sex, when initial admission was from care)	Males =0.090 Females=0.053	Beta	α=386 β=4,119 α=370 β=6,734	NHS Information Centre for Health and Social Care, 2012
	Discharge from acute to non-acute setting (rate per discharge, when initial admission was from home)	0.017	Beta	α=68,016 β= 3,856,441	NHS Information Centre for Health and Social Care, 2012
	Discharge from acute to non-acute setting (relative risk, by sex, from home)	Male =1.000 Female=1.282	Log normal	SE=0.008	NHS Information Centre for Health and Social Care, 2012

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Discharge from acute to non-acute setting (relative risk, by age, from home - males)	65-69=1.000 70-74=1.082 75-79=1.352 80-84=1.855 85-89=2.470 90-94=3.307 95-99=3.913 100+ =4.929	Log normal	SE by age: 70-74=0.020 75-79=0.019 80-84=0.019 85-89=0.020 90-94=0.027 95-99=0.052 100+ =0.140	NHS Information Centre for Health and Social Care, 2012
	Discharge from acute to non-acute setting (relative risk, by age, from home - females)	65-69=1.000 70-74=1.279 75-79=1.824 80-84=2.869 85-89=4.228 90-94=5.699 95-99=6.515 100+ =3.554	Log normal	SE by age: 70-74=0.022 75-79=0.020 80-84=0.019 85-89=0.019 90-94=0.022 95-99=0.030 100+ =0.078	NHS Information Centre for Health and Social Care, 2012
	Care placement from non-acute setting following an inpatient fall (Odds ratio)	No fall=1.000 Fall =3.040	Log normal	SE=0.429	Aditya et al. (2003)
	Probability of being a faller	No fall=0.740 Fall =0.260	Beta	α=39 β=111	Aditya et al. (2003)
Fall Rates – Home State	Falls per 100 people in last 12 months	Persons=0.455 Males =0.392 Females=0.505	Log normal	SE=0.010	NHS Information Centre for Health and Social Care (2007)
	Falls per 100 people in last 12 months (incidence rate ratio by sex)	Male =1.000 Female=1.289	Log normal	SE = 0.047	NHS Information Centre for Health and Social Care (2007)

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Falls per 100 people in last 12 months (incidence rate ratio by age, males)	65-69=1.000 70-74=1.271 75-79=1.136 80-84=1.644 85+ =2.814	Log normal	SE by age: 70-74=0.105 75-79=0.116 80-84=0.120 85+ =0.117	NHS Information Centre for Health and Social Care (2007)
	Falls per 100 people in last 12 months (incidence rate ratio by age, females)	65-69=1.000 70-74=1.036 75-79=1.096 80-84=1.518 85+ =1.855	Log normal	SE by age: 70-74=0.088 75-79=0.091 80-84=0.088 85+ =0.091	NHS Information Centre for Health and Social Care (2007)
	Proportion of patient days in people with history of falling in last 12 months	0.057	Beta	α=8,218 β=136,752	O'Loughlin et al. (1993)
	Falls history in last 12 months (incidence rate ratio)	No falls history=1.000 Falls history =2.643	Log normal	SE=0.207	O'Loughlin et al. (1993)
Fall Consequences – Home State	See table 22	See table 22	See table 22	See table 22	Watson et al. (2009)
	Probability of death from a fall that led to A&E attendance or hospital admission (by age)	65-69=0.004 70-74=0.006 75+ =0.009	Beta	α=322 β=74,635 α=563 β=86,107 α=3,722 β=405,299	Scuffham et al. (2003)
Fall Rates – Care State	Fall Rate (per day, control arms only)	Dyer =0.011 McMurdo =0.011 O'Halloran=0.007[7]	-	SE=0.001 SE=0.001 SE=0.002[8]	Dyer et al. (2004) McMurdo et al. (2000) O'Halloran et al. (2009)

[7] O'Halloran fall rate estimated as O'Halloran only gives fracture rates. Estimated using fracture rates from Dyer and McMurdo

[8] SE estimated based on micro simulation (5000 replications) in which underlying parameters were probabilistically varied

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Proportion of care home falls resulting in fractures (both arms)	Dyer =0.015 McMurdo=0.030	-	-	Dyer et al. (2004) McMurdo et al. (2000)
	Fracture rate per day	O'Halloran=0.0001	-	-	O'Halloran et al. (2009)
	Fall rate (per day, weighted average)	Average=0.011	Log normal	SE=0.001	
	Odds ratio for fall history in last 12 months as a risk factor for falls (multivariate model)	Could stand unaided? Yes =1.740 No =1.840 Pooled=1.791	Log normal	SE=0.112 SE=0.243 SE=0.102	Delbaere et al. (2008)
	Proportion of people with falls in the last year	0.516	Beta	α=1,004 β=942	Delbaere et al. (2008)
Fall Consequences – Care State	See table 23	See table 23	See table 23	See table 23	Watson et al. (2009)
State Transitions – Home to Care	Rate of entry to care (per year, ages 65+)	0.007	Log normal	SE=0.001 (assumed)	NHS Information Centre (2011)
	Probability of entering care (per year, ages 65+)	Males =0.0005 Females=0.0010	Beta	α=228 β=437,152 α=581 β=592,285	Darton et al. (2006)
	Probability of entering care (per year, by age, males)	65-69=0.0001 70-74=0.0002 75-79=0.0004 80-84=0.0009 85-89=0.0020 90+ =0.0057	-	-	Darton et al. (2006)

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Probability of entering care (per year, by age, males)	65-69=0.00005 70-74=0.0002 75-79=0.0005 80-84=0.0016 85-89=0.0030 90+ =0.0077	-	-	Darton et al. (2006)
	Relative risk of entering care (per year, by age, males)	65-69=1.000 70-74=2.212 75-79=4.216 80-84=8.324 85-89=18.951 90+ =52.968	Log normal	SE by age: 70-74=0.320 75-79=0.302 80-84=0.296 85-89=0.294 90+ =0.297	Darton et al. (2006)
	Relative risk of entering care (per year, by age, males)	65-69=1.000 70-74=4.268 75-79=11.101 80-84=34.176 85-89=66.082 90+ =168.650	Log normal	SE by age: 70-74=0.423 75-79=0.398 80-84=0.387 85-89=0.386 90+ =0.385	Darton et al. (2006)
	Proportion of people with history of falling in last 12 months	0.258	Beta	α=770 β=2213	Wang et al. (2001)
	Relative risk of entering care for prior fallers v no falls	2.478	Log normal	SE=0.152	Wang et al. (2001)
State Transitions – Home to Hospital	Probability of Hospital Admission (per year)	0.154	Beta	α=258 β=1419	Department of Health (2002)
	Relative risk of hospital admission (per year, by age and sex)	Male 65-79 =1.026 Male 80+ =1.637 Female 65-79=0.842 Female 80+ =1.045	Lognormal	SE=0.110 SE=0.159 SE=0.113 SE=0.163	Department of Health (2002)

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
State Transitions – Care to Hospital	Probability of Hospital Admission (per year)	0.233	Beta	α=576 β=1901	Department of Health (2002)
	Relative risk of hospital admission (per year, by age and sex)	Male 65-79 =1.178 Male 80+ =1.181 Female 65-79=0.909 Female 80+ =0.949	Lognormal	SE=0.118 SE=0.090 SE=0.108 SE=0.061	Department of Health (2002)
State Transition – Type of Hospitalisation	Probability hospital episode is directly to non-acute setting (per year)	0.027	Beta	α=1,575,505 β=57,608,054	Department of Health (2011)
	Relative risk hospital episode is directly to non-acute setting (by sex)	Males =1.074 Females=1.000	Log normal	SE=0.011	NHS Information Centre (2012)
	Relative risk hospital episode is directly to non-acute setting (by age)	0-14 =0.002 15-59=0.301 60-74=0.484 75+ =1.000	Log normal	SE=0.218 SE=0.013 SE=0.014	NHS Information Centre (2012)
Mortality	Period life expectancy by age and sex	See online tables	-	-	Office for National Statistics (2011)
	Excess mortality in year following hip fracture (hazard ratio)	1.87	Lognormal	SE=0.111	Goldacre et al. (2002)
	Proportion of dataset by type of care home	Residential=0.273 Dual =0.303 Nursing =0.424	Dirichlet	α=577 α=640 α=895	McCann et al. (2009)
	Excess mortality for residing in care home (hazard ratio, by type of care home)	Residential=1.740 Dual =2.570 Nursing =2.900 Average =2.483	Log normal	SE=0.064 SE=0.066 SE=0.050	McCann et al. (2009)
Costs – state costs	State cost (per day, by hospital setting)	Acute =£524.02 Non-acute=£588.01	Gamma	SE=£52.40 (assumed) SE=£58.80 (assumed)	Department of Health (2011)

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	State cost (per day, by state)	Home=£0 Dead =£0	-	-	Assumed
	State cost per day (care)	Care=£103.78	-	-	Calculated from below
	Proportion of people in each care setting	Nursing =0.325 Residential=0.158 Voluntary =0.207 LA =0.310	Dirichlet	α=5,746 α=2,791 α=3,664 α=5,476	Netten et al. (1998)
	Cost care in each care setting (per week)	Nursing =£719 Residential=£497 Voluntary =£497 LA =£1,005	Gamma	SE=£143.80 (assumed) SE=£99.40 (assumed) SE=£99.40 (assumed) SE=£200.96 (assumed)	PSSRU (2011)
	Proportion of care cost met by NHS & PSS	0.60	Triangular	Min =0.4 Max =0.8	Assumed
Costs – inpatient falls (acute and non-acute)	Number of severe falls by type	No fracture =258 Other fract =442 Hip fracture=530	-	-	NPSA (2007)
	Treatment costs for severe falls (excluding bed days, per fall, by fall type)	No fracture =£371.21 Other fract =£1,829.57 Hip fracture=£3,394.65	Gamma	SE=£74.24 (assumed) SE=£365.91 (assumed) SE=£678.93 (assumed)	Department of Health (2011)
	Treatment costs for inpatient falls (excluding bed days, per fall, by severity)	No injury =£47.41 Minor =£76.63 Moderate=£371.21 Serious =£2,198.05* Fatal =£0**	Gamma	SE=£9.48 (assumed) SE=£15.33 (assumed) SE=£74.24 (assumed) See above	NPSA (2007) *weighted average of all serious fall types, see above **assumed

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
Costs – Home falls	Treatment costs (per fall)	No injury =£0 Minor =£36.00 Moderate=£142.00 Serious =£492.89 Fatal =£0	Gamma	SE=£7.20 (assumed) SE=£28.40 (assumed) SE=£98.58 (assumed)	PSSRU (2011) Hospitalisation costs of serious falls counted elsewhere
Costs – Care Falls	Treatment costs (per fall)	No injury =£0 Minor =£121.00 Moderate=£480.00 Serious =£492.89 Fatal =£0	Gamma	SE=£24.20 (assumed) SE=£96.00 (assumed) SE=£98.58 (assumed)	PSSRU (2011) Hospitalisation costs of serious falls counted elsewhere
Costs – home help	Cost of home help (per day)	£38.97	Gamma	SE=£7.79 (assumed)	PSSRU (2011)
	Help required following a fall (days, by fall severity)	No injury =0 Minor =7 Moderate=21 Serious =42 Fatal =0	Triangular	Min=0 Max=7 Min=0 Max=14 Min=7 Max=35 Min=21 Max=63	Assumption
Costs – Intervention	Cost per admitted patient (by hospital setting)	Acute =£7.83 Non-acute=£21.81	-	-	See detailed explanation in text
Utility - by state	Home (polynomial regression, males)	Constant=0.991 Age =-0.003 Age^2 =-0.000005	-	-	Kind et al. (1999)
	Home (polynomial regression, females)	Constant=0.959 Age =-0.004 Age^2 =-0.00003	-	-	Kind et al. (1999)
	Care (decrement to home)	0.8	Triangular	Min=0.6 Max=1.0	Assumption

Area	Parameter	Estimate	Parameters for PSA (not performed)		Source
			Distribution	Parameters	
	Hospital (decrement to home, by sex)[9]	Males = 0.721 Females=0.714	Log normal	SD= 0.025SD= 0.022	Vass et al. (2013)
Utility loss – following a fall	Hospital falls - utility values (absolute)	Non fallers = 0.52 Non-injured faller= 0.49Injurious faller = 0.38	Beta	SD= 0.26SD= xxxx**Error! Bookmark not defined.**0.31SD= 0.19	Vass et al. (2013)
	Hospital falls - utility loss following a fall (decrements)	No injury = 94.2% Minor = 75.3% Moderate = 73.6%Serious (yr1) = 70.0%	-	-	Vass et al. (2013)
	Home or Care (decrement)	No injury =100% Minor =97.8% Moderate =95.6% Serious (yr1) = 70.0% Serious (yr2+) = 80.0%	Triangular Beta Beta Beta	Min=97.8% Max=100% (50% of moderate) SE=0.036 SE=0.033 SE=0.071	Assumption Iglesias et al. (2009) Peasgood et al. (2009) Peasgood et al. (2009) Peasgood et al. (2009)
	Home or Care (length of decrement, years)	No injury =1 Minor =1 Moderate=1 Serious (yr1)=1 Serious (yr2+)=forever	Triangular Triangular Triangular Triangular	Min=0.5 Max=2.0 Min=0.5 Max=2.0 Min=0.5 Max=2.0 Min=2.0 Max=10.0	Assumption Iglesias et al. (2009) Peasgood et al. (2009) Peasgood et al. (2009) Peasgood et al. (2009)

[9] Based on micro simulation (10000 replications) in which underlying parameters were probabilistically varied

Table 22: Fall Consequences – Home State

Home state fall consequence data taken from Watson et al. (2009). All data were subject to Dirichlet distributions, within each age group and sex. Note that deaths from falls were further split using data from Scuffham et al. (2003).

Age Group	Parameter	Males	Females
	No injury (no medical treatment)	0.829	0.789
	Minor injury (GP)	0.135	0.154
	Moderate injury (A&E, inc deaths)	0.019	0.032
	Serious injury (hospitalisation, inc deaths)	0.017	0.025
70-74	No injury (no medical treatment)	0.856	0.758
	Minor injury (GP)	0.108	0.177
	Moderate injury (A&E, inc deaths)	0.017	0.029
	Serious injury (hospitalisation, inc deaths)	0.019	0.036
75-79	No injury (no medical treatment)	0.805	0.749
	Minor injury (GP)	0.142	0.171
	Moderate injury (A&E, inc deaths)	0.022	0.030
	Serious injury (hospitalisation, inc deaths)	0.032	0.051
80-84	No injury (no medical treatment)	0.746	0.730
	Minor injury (GP)	0.172	0.148
	Moderate injury (A&E, inc deaths)	0.028	0.034
	Serious injury (hospitalisation, inc deaths)	0.054	0.088
85-89	No injury (no medical treatment)	0.720	0.586
	Minor injury (GP)	0.203	0.277
	Moderate injury (A&E, inc deaths)	0.024	0.032
	Serious injury (hospitalisation, inc deaths)	0.053	0.105

90-94	No injury (no medical treatment)	0.518	0.696
	Minor injury (GP)	0.292	0.151
	Moderate injury (A&E, inc deaths)	0.059	0.037
	Serious injury (hospitalisation, inc deaths)	0.131	0.115
95+	No injury (no medical treatment)	0.521	0.480
	Minor injury (GP)	0.374	0.374
	Moderate injury (A&E, inc deaths)	0.039	0.043
	Serious injury (hospitalisation, inc deaths)	0.066	0.104

Table 23: Fall Consequences –Care State

Care state fall consequence data taken from Watson et al. (2009). All data were subject to Dirichlet distributions, within each age group and sex. Note that deaths from falls were further split using data from Scuffham et al. (2003).

Age Group	Parameter	Males	Females
65-69	No injury (no medical treatment)	0.513	0.514
	Minor injury (GP)	0.454	0.435
	Moderate injury (A&E, inc deaths)	0.011	0.025
	Serious injury (hospitalisation, inc deaths)	0.022	0.026
70-74	No injury (no medical treatment)	0.513	0.513
	Minor injury (GP)	0.446	0.415
	Moderate injury (A&E, inc deaths)	0.019	0.041
	Serious injury (hospitalisation, inc deaths)	0.021	0.031
75-79	No injury (no medical treatment)	0.521	0.523
	Minor injury (GP)	0.394	0.367
	Moderate injury (A&E, inc deaths)	0.043	0.060
	Serious injury (hospitalisation, inc deaths)	0.042	0.050
80-84	No injury (no medical treatment)	0.520	0.522
	Minor injury (GP)	0.361	0.339
	Moderate injury (A&E, inc deaths)	0.062	0.078
	Serious injury (hospitalisation, inc deaths)	0.057	0.061
85-89	No injury (no medical treatment)	0.525	0.528
	Minor injury (GP)	0.331	0.295
	Moderate injury (A&E, inc deaths)	0.072	0.097
	Serious injury (hospitalisation, inc deaths)	0.071	0.079

90-94	No injury (no medical treatment)	0.526	0.528
	Minor injury (GP)	0.290	0.287
	Moderate injury (A&E, inc deaths)	0.101	0.103
	Serious injury (hospitalisation, inc deaths)	0.083	0.083
95+	No injury (no medical treatment)	0.407	0.407
	Minor injury (GP)	0.363	0.329
	Moderate injury (A&E, inc deaths)	0.110	0.159
	Serious injury (hospitalisation, inc deaths)	0.120	0.105

5 Model Outputs

5.1 *Results*

In order to verify the face validity of the health economic model of multifactorial interventions to prevent inpatient falls, various model outputs were checked. All results are taken from a model run of 200,000 patients through an acute setting.

It should be noted that, as this is a cohort model, model outputs are not expected to exactly match inputs (which are generally based on cross-sectional data samples). Patients are generated and then continue through the model for the rest of their lifetime and as many fall-related inputs are age related, model outputs are likely to be higher or more severe than the equivalent input data.

5.1.1 Patient Characteristics

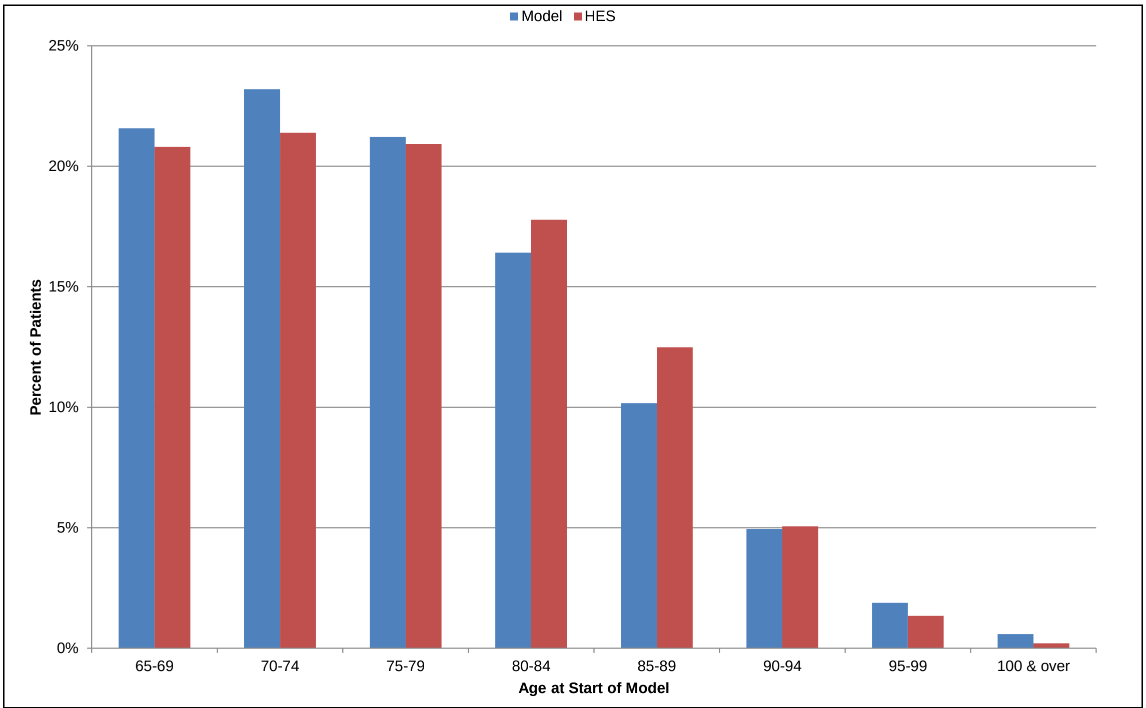

Figure C: Age Distribution of Patients at the Start of the Model and in Data Source

Patients were slightly more likely to be female (51.1%) than male, which was in line with the source data (HES, females 51.5%). The mean starting age of patients in the model was 77.2 years (range 65.0 to 109.3 years), with an age distribution as shown in figure C. The model generates slightly younger patients than the underlying data – this is a desirable characteristic, given this is a cohort model.

5.1.2 Event Counts and State Occupancy

Patients spent an average of 10.1 years in the model (range 0 to 43.5 years) and the average age at death was 87.3 years (range 65.2 to 111.0 years).

0.3% of patients started the model in care (source data HES 0.2%) and another 23.1% of patients entered care at some point. Patients who started in or entered full time care spent an average of 2.6 years in full time care (see figure D).

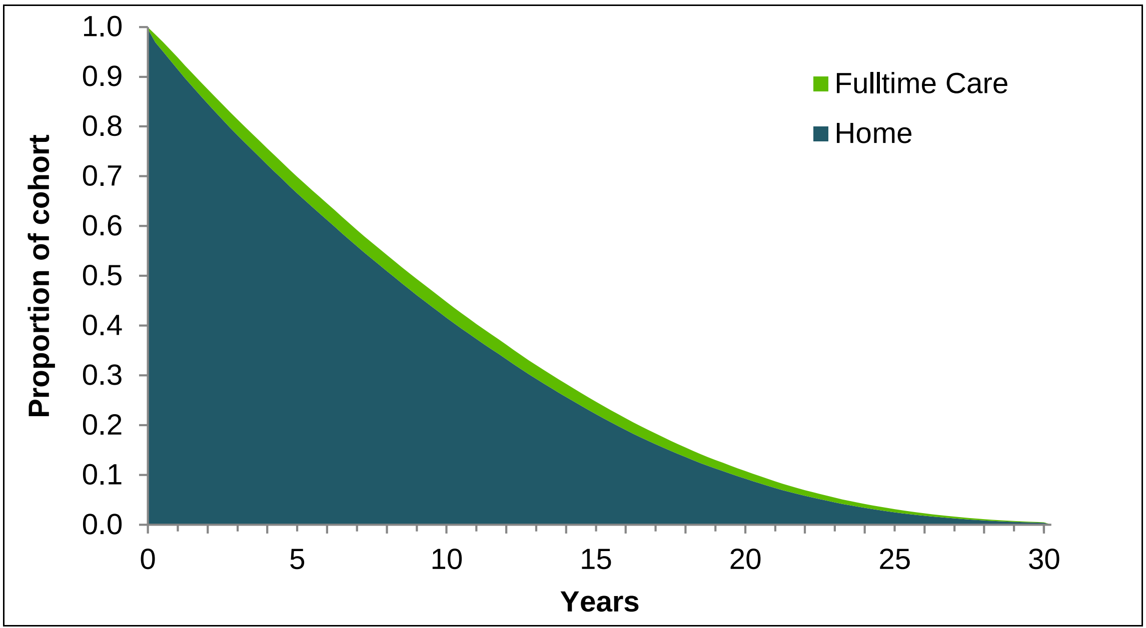

Figure D: Proportion of patients in full time care, by time in model

Throughout their model lifetime, patients had an average of 3.9 hospitalisations (including the first, which everyone incurs). 20.1% had no more hospitalisations whilst 10.5% of patients had 8 or more hospitalisations (see table 24). Given this was an acute run, no initial hospitalisations were to the non-acute setting, but 7.0% of subsequent hospitalisations were directly to non-acute hospital settings or transfers from acute to non-acute.

Table 24: Number of Hospitalisations

Number of hospitalisations	Percent of Patients
1 (initial episode only)	20.1%
2	18.7%
3	15.7%
4	12.6%
5	9.8%
6	7.3%
7	5.3%
8 or more	10.5%

The initial acute hospitalisation had a mean length of stay of 12.3 days (range 0.0 to 157.0 days). Subsequent non-acute hospitalisations had a mean length of stay of 20.4 days. Length of stay was higher for fallers and recurrent fallers than non-fallers.

5.1.3 Fall Rates

The model produced an inpatient fall rate of 7.2 falls per 1,000 bed days over the lifetimes of all simulated patients. As previously stated, this is higher than the input rate (6.6 falls per 1,000 bed days, Healey et al. 2008) as the model is a cohort model in which simulated people become older and subject to greater risks of falling. The fall rate varied by age in a similar manner to the source data (Healey et al., 2008, see figure E). The majority (93.1%) of patients had no falls and very few (1.0% of patients) fell more than once during their hospital stay (see table 25). 6 patients fell 6 times and 2 patients fell 7 times during a single hospital episode.

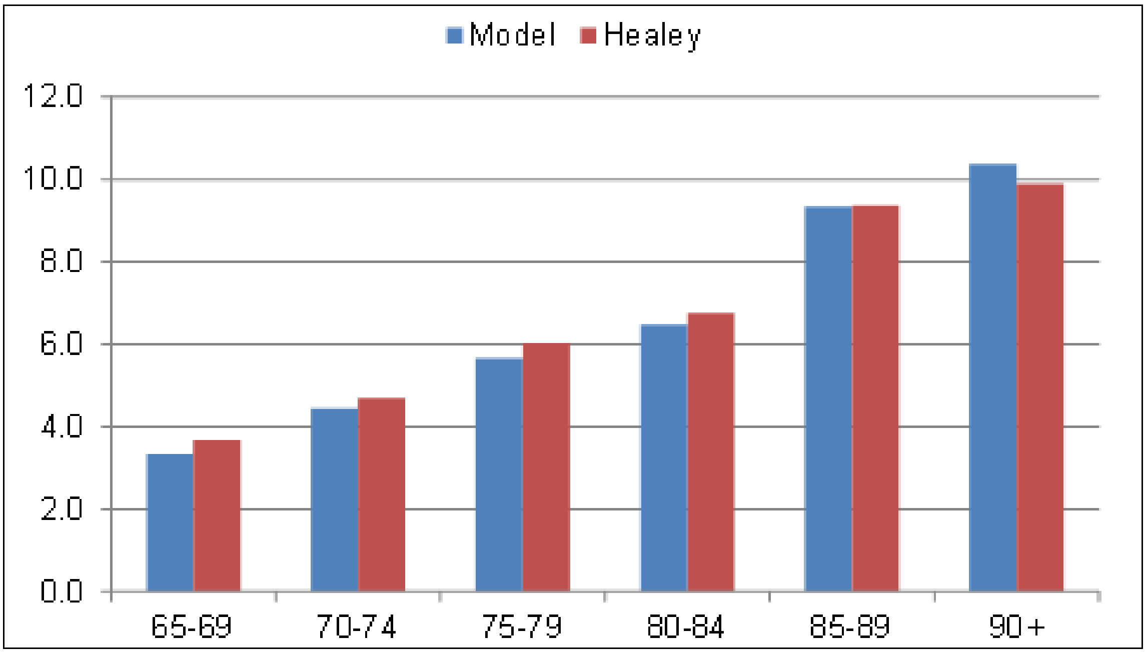

Figure E: Inpatient fall rates per 1,000 bed days

Table 25: Number of falls per hospital episode

Number of falls during a single hospitalisations	Percent of Patients
0	93.1%
1	5.9%
2	0.9%
3 or more	0.1%

The severity of inpatient falls compared well with the source data (Healey et al. 2008, see table 26). The inpatient fall severity data was not differentiated by age; hence, this output does not differ from the input value in the same way the inpatient fall rate does.

Table 26: Inpatient Fall Severities

Inpatient Fall Severity	Model	Healey et al. (2008)
No harm	64.6%	64.7%
Low	31.0%	31.1%
Moderate	3.7%	3.6%
Severe	0.6%	0.6%
Fatal	0.01%	0.01%

Patients had a mean of 1.0 falls per year at home and 4.8 falls per year in care. Injuries were more likely to occur in care. Again, as this is a cohort model, the injury severities are higher than the source data – more so in the home state, as the effect of increasing age on injury rates is more pronounced in the home state than the care state (see table 27).

Table 27: Fall severities for home and care states (Source: Watson et al. (2009)

Fall Severity by Setting	Home		Care	
	Model	Source	Model	Source
No harm	70.3%	76.0%	51.5%	51.7%
Low	19.5%	16.5%	32.2%	33.9%
Moderate	3.1%	2.7%	8.9%	7.9%
Severe & Fatal	7.1%	4.7%	7.4%	6.5%

Table 28: Lifetime falls across all states

Number of Falls	All Falls	Injurious Falls
0	6.5%	20.6%
1	5.8%	15.8%
2	5.7%	12.2%
3	5.6%	9.7%
4	5.3%	7.6%
5	5.1%	6.1%
6-10	20.5%	17.7%
11-20	25.8%	8.6%
21-50	18.7%	1.6%
50+	1.1%	0.0%

In terms of lifetime falls across all states, very few patients have no falls. However it should be remembered that the model simulates all falls, including non-injurious falls. It may be more informative to consider lifetime injurious falls – here, 20.9% of patients have no injurious falls and 49.0% of patients have 2 or fewer injurious falls (see table 28). The median number of lifetime falls is 9 and the median number of lifetime injurious falls is 3. The most extreme patient had 69 injurious falls over 23 years, virtually all of which was spent in full time care (67% of these were minor injuries, with 6 serious injuries).

5.2 Cost–Utility Results – Deterministic Base Case Analysis

The health economic model to assess the cost effectiveness of a multifactorial inpatient fall prevention intervention (compared with no action) was run with 500,000 patients per arm. Results are shown in table 29 and figure F.

Table 29: Base-case cost and QALY results (all costs and QALYs discounted at 3.5% per annum, run with 500,000 patients per arm)

Outcome	Arm	Acute	Non-acute
Lifetime Costs	Control	£32,440	£36,853
	Intervention	£32,202	£36,725
	Difference	−£238	−£128
Lifetime QALYs	Control	5.446	5.419
	Intervention	5.448	5.422
	Difference	0.002	0.003
Cost per QALY (ICER)		Dominant	Dominant
Incremental net monetary benefit (£20k threshold)		£268	£189

5.2.1 Acute Setting

In the acute setting, the multifactorial inpatient falls prevention intervention reduced costs and increased QALYs so is said to be dominant over the control arm, producing a net monetary benefit (NMB) of £268 at the £20,000/QALY threshold.

The QALY difference (0.002 extra QALYs) generated was small – equivalent to less than 1 extra quality-adjusted day over the average 10-year lifetime of a patient in the model. The QALY gain arose from a small increase in time spent at home and a decrease in time spent in care.

In the acute setting, the cost difference was less than 1% of lifetime (discounted) costs. The difference in costs was largely generated by a saving in the hospital state (see table 30). As no cost was associated with being in the home state, the increase in home state costs must be due to a slight increase in injurious falls following the intervention to reduce inpatient falls, which presumably occurred as a result of living slightly longer at home. In hospital, the savings result from a slight reduction in length of stay (average

0.06 days shorter following the intervention) and reduced costs of treating falls. These savings are more than enough to offset the cost of implementing the intervention. The care savings also come from a marginal reduction in time spent in care.

Table 30: Breakdown of cost and QALY differences of acute model by setting (negative cost values indicate a saving in the intervention arm)

State	Costs	QALYs
Home	£15.92	0.003
Care	−£86.41	−0.001
Hospital	−£167.10	−0.00027
Total	−£237.59	0.0015

5.2.2 Non-acute Setting

In the non-acute setting, the multifactorial inpatient falls prevention intervention reduced costs and increased QALYs so is said to be dominant over the control arm, producing a NMB of £189 at the £20,000/QALY threshold.

Table 31: Breakdown of cost and QALY differences of non-acute model by setting (negative cost values indicate a saving in the intervention arm)

State	Costs	QALYs
Home	£22.00	0.003
Care	−£28.92	−0.0002
Hospital	−£121.51	−0.0002
Total	−£128.43	0.0030

The QALY difference (0.003 extra QALYs) was similar to the acute setting and was again driven by a slight increase in time spent at home.

In the non-acute setting, the cost difference was less than 0.5% of lifetime (discounted) costs. The difference in costs was due to a slight decrease in the average length of hospital stay (see table 31).

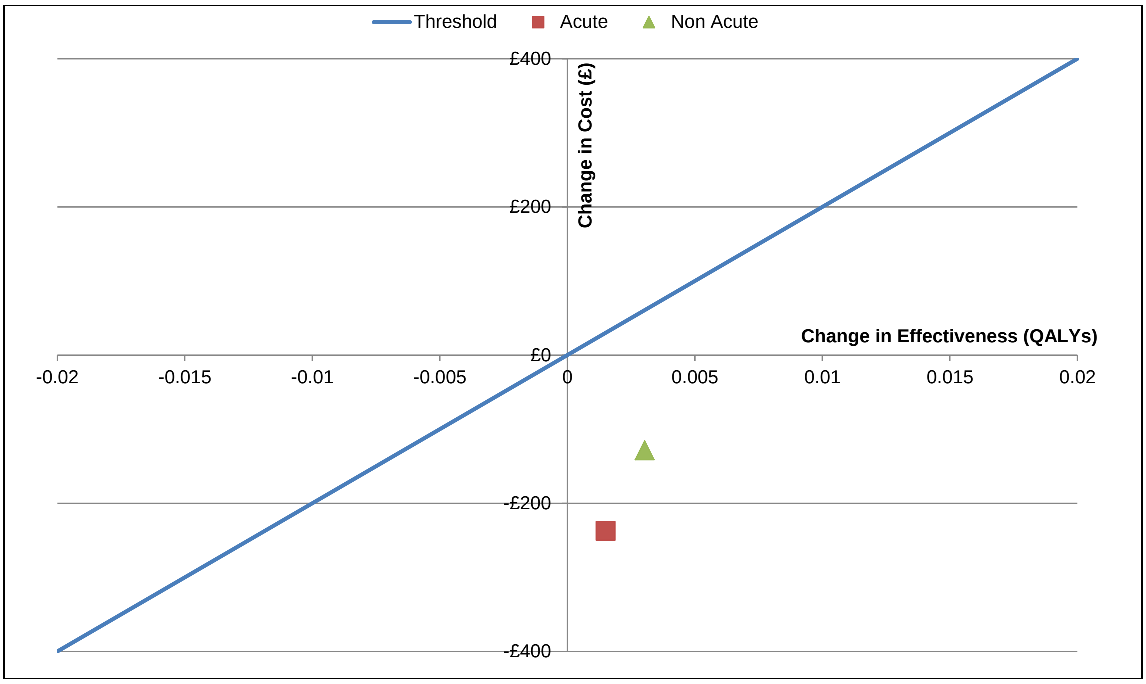

Figure F: Cost Effectiveness Plane Showing Different Hospital Settings

6 Sensitivity Analysis

Given the large number of inputs to this model, it is important to assess whether any inputs have a large influence on the outcomes generated. All deterministic sensitivity analyses were run in the acute setting only with 500,000 patients and with a fixed (rather than random) seed. Deterministic sensitivity analyses were not run in the non-acute setting due to lack of computational time. Regression lines were fitted to the threshold analyses to minimise remaining sampling variation.

6.1 One-Way Sensitivity Analysis

A number of input parameters had an impact on the cost effectiveness of the intervention (see figure G).

The only parameter that impacted the cost effectiveness of the intervention to such an extent as to make the intervention not cost effective was the intervention effect (IRR for falls with intervention compared with control). If the intervention effect was 2 (i.e. the intervention caused twice as many falls as the control), then the intervention was no longer cost effective. This is explored further in the threshold analysis.

The cost of the intervention per patient was explored between £0 and £100 (base case £7.83 per patient) and the intervention remained cost-effective; however it can be seen from figure G that it is inevitable that an even higher intervention cost would make the intervention not cost effective.

Varying individual parameters reflecting the costs and utilities associated with falls within plausible ranges did not affect the apparent cost effectiveness of the intervention.

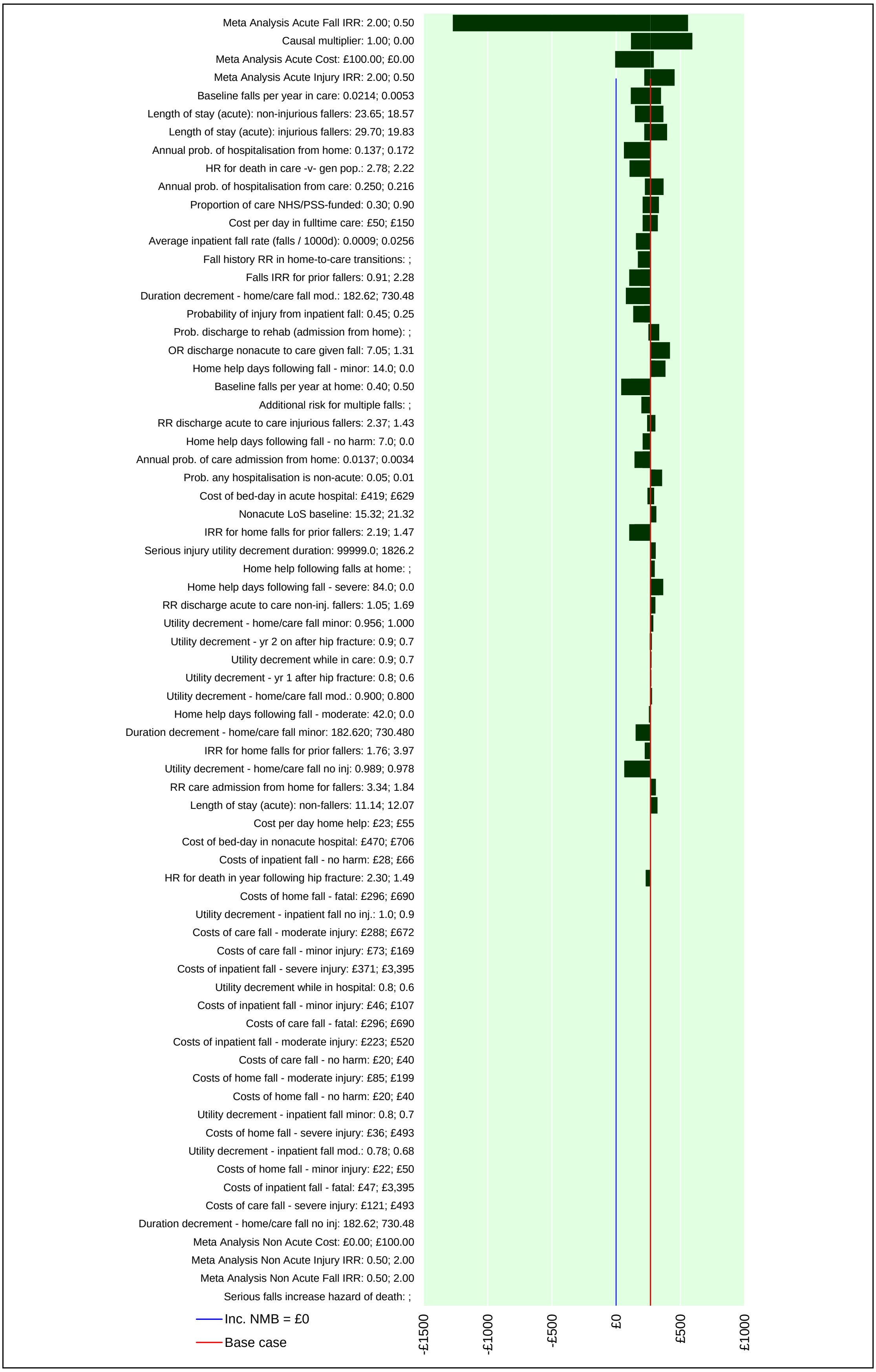

Figure G: Tornado Plot of One Way Sensitivity Analysis in Acute Setting

6.2 Threshold Analysis

A number of input parameters could take a range of values, rather than extreme values as tested in the one way sensitivity analysis. These were investigated via threshold analyses. Due to issues of computational time, all threshold analyses were run in the acute setting and regression lines were fitted to the threshold analyses to minimise any remaining sampling variation.

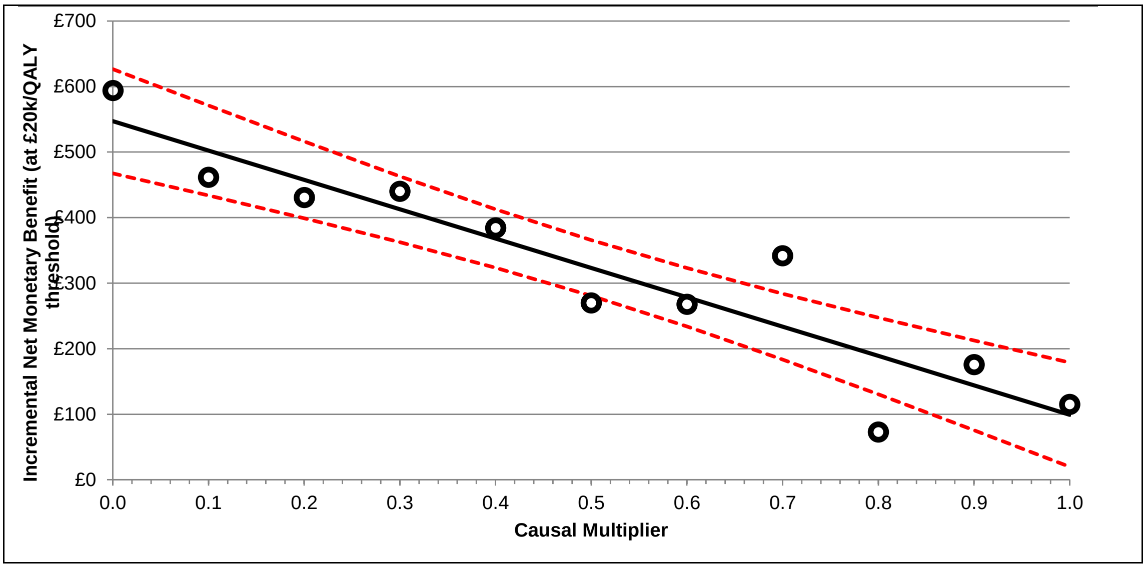

Figure H: Threshold analysis of the causal multiplier

The causal multiplier is a key structural assumption and could take any value between 0 and 1. Assessing values at intervals of 0.1, the threshold analysis shows that the intervention remains cost effective as long as the causal multiplier is less than 1 (see figure H). This means that the intervention is cost effective as long as some of post fall negative events or consequences are due to the fall (rather than being related to underlying morbidity or other factors). Note that the causal multiplier was set to 0.5 in all base-case analyses.

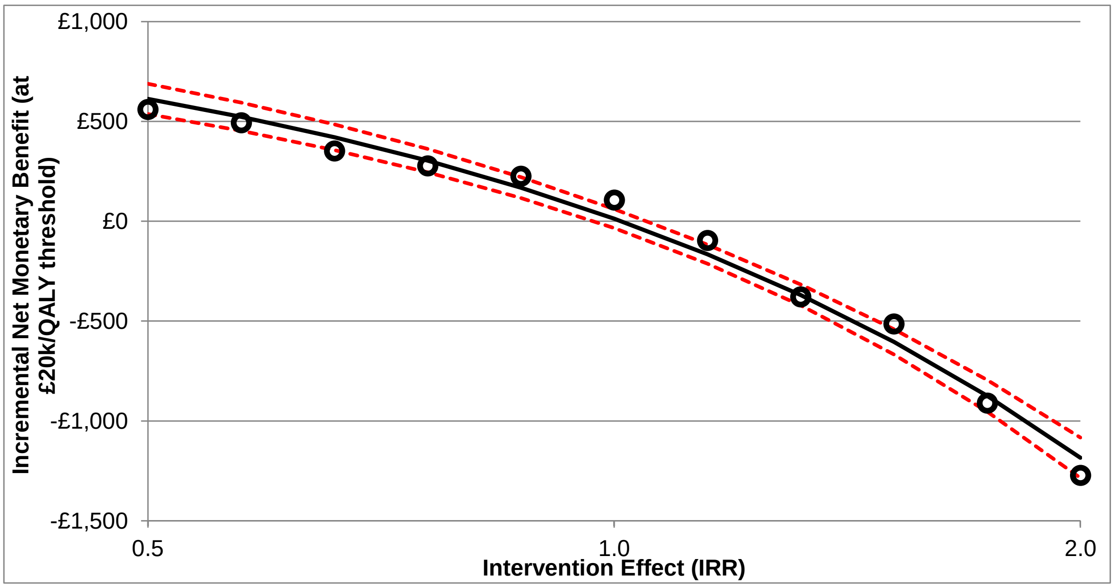

Figure I: Threshold analysis of the incidence rate ratio for the multifactorial falls preventions intervention

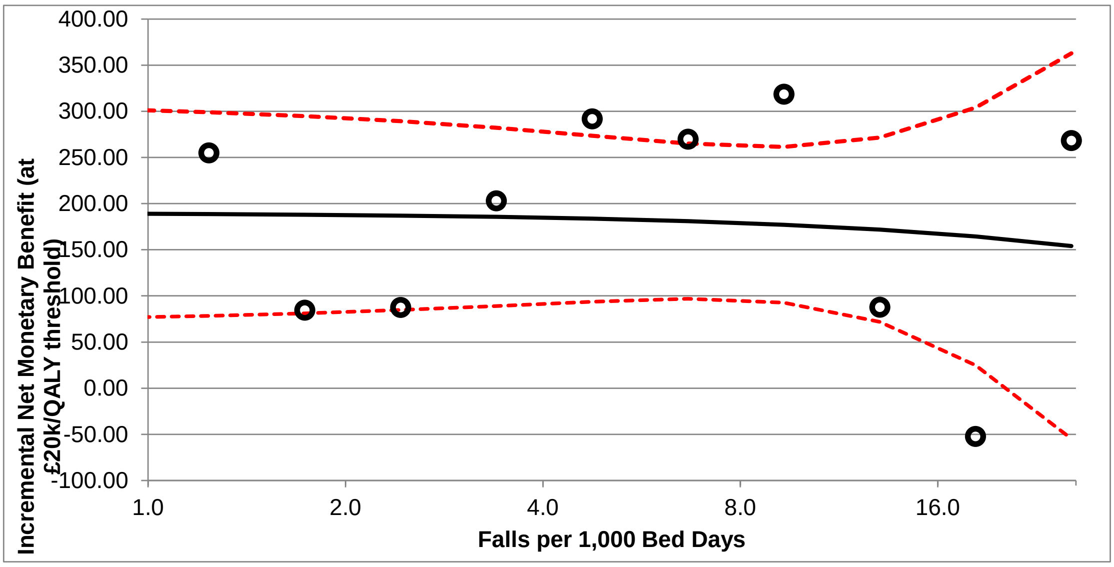

Figure J: Threshold analysis of the average fall rate

The IRR associated with multifactorial inpatient falls prevention intervention was set to 0.76 in the base case, but it would be useful to know what level of reduction in falls is necessary to for the intervention to be cost-effective. The threshold analysis (figure I) suggested that, as long as some falls are prevented (IRR<1), the intervention is likely to be cost effective.

It is conceivable the average fall rate could need to reach a certain level for the intervention to be cost effective – i.e. there needs to be enough falls to prevent. The threshold analysis (see figure J) produced extremely variable results; it is difficult to infer any direct relationship between the underlying fall rate and the cost effectiveness of the intervention.

6.3 Two-Way Sensitivity Analysis

The GDG indicated it would be useful to consider the relationship between intervention effectiveness and cost. This two-way sensitivity analysis may be helpful for decision-makers by estimating either the cost worth paying for a known effectiveness, or the effectiveness required for a known cost.

The two way sensitivity analysis shows that if the intervention effectiveness IRR is less than 0.85, the intervention remains cost effective even when the intervention cost is £100 per admitted patient or more. The meta-analysis gave an IRR of 0.75, for which the two-way sensitivity analysis implies the intervention is cost effective even when the intervention costs £100 per admitted patient. Similarly, if the intervention is known to cost £7.83, then it remains cost effective as long as the IRR is less than 1.

6.4 Probabilistic Sensitivity Analysis

Given the large number of inputs and the small and variable changes in costs and QALYs generated by the inpatient falls health economic model, it would be of benefit to run a probabilistic sensitivity analysis (PSA). However, the ability to conduct such an analysis is limited by computational time – running the model with 100,000 patients takes over 15 minutes on a standard computer. Running more patients to reduce variability and running separate PSAs for two settings would impose a serious computational burden.

7 Discussion

7.1 Principal Findings

It would appear that, if inpatient falls can be prevented, this is very likely to be a cost-effective course of action.

However, in both settings, the difference in QALYs is small, as can be seen in figure F. The changes represent less than 0.06% of lifetime QALYs in the model. The cost differences are slightly bigger, but still less than 0.7% of total lifetime costs. Such small differences pose two questions – are they consistently replicable and are they clinically meaningful?

Table 32: Outcomes for inpatient falls model when running 500,000 patient cohorts through the model 10 times

Outcome	Metric	Acute	Non-acute
Average cost difference	Minimum	-£170	-£43
	Average	-£247	-£88
	Maximum	-£298	-£162
Average QALY difference	Minimum	0.0004	0.0011
	Average	0.0019	0.0033
	Maximum	0.0045	0.0059

With such small differences, it is important to ensure the model has converged and the results are replicable across model runs. When the model was run ten times with 500,000 patients, both the acute and non-acute settings were cost saving and saw a small increase in QALYs (see table 32 and figure K). Taking the average cost and QALY differences across ten model runs, the intervention remained dominant in the acute and non-acute settings.

A difference of 0.003 QALYs or less (1 quality-adjusted day or less) may be viewed as clinically not relevant over an average lifetime of ten years. However, the average experience of the simulated cohort contains a great heterogeneity of experience, and some simulated patients will have derived very appreciable benefit from having falls averted during their hospitalisation(s). Certainly, the 25% reduction in fall rates (taken from the meta-analysis) was thought to be clinically significant by the GDG. Cost differences were small but generally indicated savings in both settings.

Therefore, although predicted QALY gains are very small for the average patient, they appear robust to modelling uncertainty and are consistently estimated to outweigh the costs incurred in achieving them.

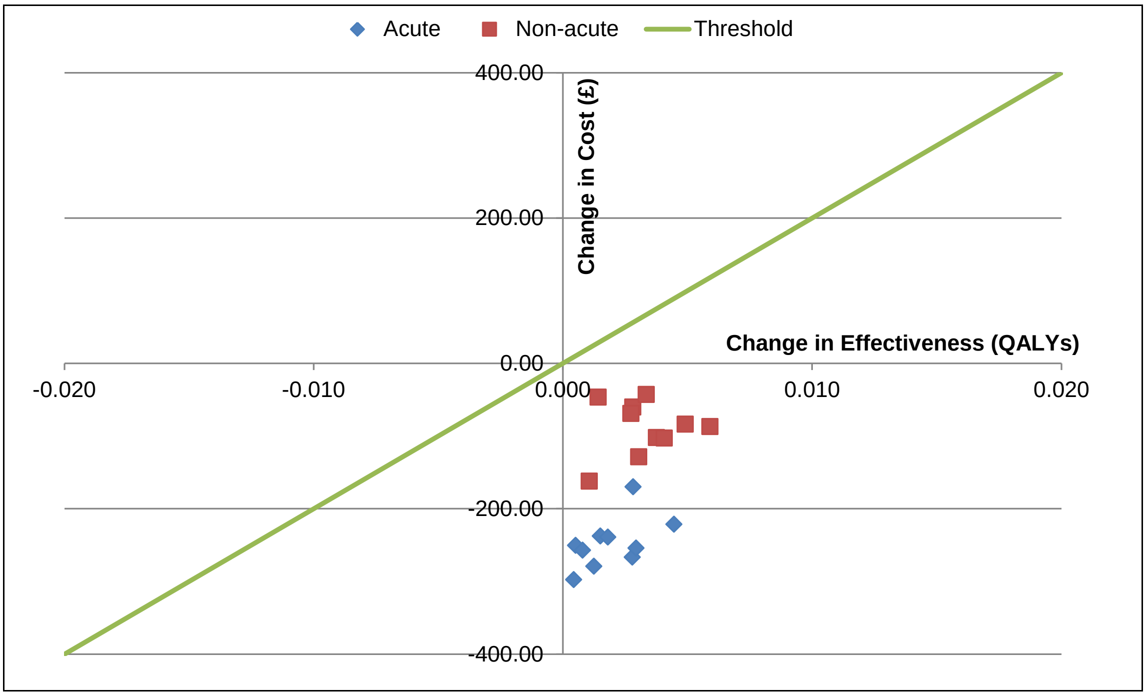

Figure K: Multiple runs of base case scenarios

The split of settings was reflective of the clinical effectiveness evidence presented to the GDG. In reality, how well local clinical arrangements reflect each model may determine whether the intervention is cost effective. However, it should be noted that the both the cost savings and QALY gains are small – over an average of 10 years, the intervention adds less than 1 day and saves no more than £250. Whilst these results are stable in the sensitivity analysis, the gains remain modest.

This de novo health economic model to assess the cost effectiveness of intervention to prevent inpatient falls and/or reduce their severity has a number of strengths and limitations.

7.2 Model Strengths

This is one of the first health economic analyses that have attempted to capture both the costs and benefits of interventions to prevent inpatient fall rates and is, to the best of our knowledge, the first to consider outcomes in terms of QALYs. Davis et al. (2011) noted that only ten economic evaluations of community fall prevention programmes exist and none exist for the hospital setting, although a number are underway. As such, there are no benchmarks to compare the cost and QALY changes against.

Similarly, there are few discrete event simulation models in the literature (O'Hagan et al., 2007). For reasons already highlighted, a traditional Markov model would not have been suited to a problem where individual patient history not only predicts future event risk, but changes throughout the model timespan. The discrete event approach enables a realistic simulation of a heterogeneous population, and allows the detailed exploration of the history of simulated patients and their likelihood of experiencing subsequent events.

The lifetime horizon of the model allows all potential costs and benefits associated with preventing inpatient falls to be captured. The importance of this horizon was proved by the benefits of inpatient fall prevention being found to mainly occur after the patient was discharged from hospital.

The model was developed with a high degree of expert input from the GDG members. Feedback from the expert panel resulted in significant changes to both the model structure and the parameter values used.

The model relies on a number of parameter assumptions some of which are in potentially key model areas. However, the sensitivity analysis has shown the results of model to be stable to changing the values of most of these assumptions.

7.3 Model Limitations

Despite having a number of strengths, the model is subject to several acknowledged limitations.

The model relies heavily on estimates of the cost of the intervention, the cost of treating inpatient falls and the ability of the multifactorial interventions to reduce fall rates – the true values of each remain unknown. The multifactorial intervention is deliberately generic but is costed based on informed estimates from one RCT and the estimated costs of treating inpatient falls are based on a number of assumptions about treatment received by each patient. Despite being based on a meta-analysis of reasonably powered RCTs, the intervention effect has relatively wide confidence intervals and, as discussed in section4.4.5 of the full Guideline, using different groupings of evidence in meta-analyses produced different intervention effect sizes. However, the analysis suggests that the intervention as modelled is likely to be cost effective as long as (a) some reduction in falls is achieved and (b) the costs of the intervention do not outweigh this benefit.

The splitting of hospital states into acute and non-acute is unlikely to reflect the complex array of arrangements that exist in the NHS. It was based on a simplifying decision by the GDG and is likely to be a source of structural uncertainty in the model. In some instances, the non-acute setting inputs were based on approximations to the true rates and, whilst they were shown not to impact the results, the parameters were not ideal. It is debatable whether splitting the hospital state into acute and non-acute settings increased the value of the health economic model or just increased the uncertainty within the model.

The modelling of the social care process is a gross simplification of reality. The focus of the model was preventing falls during a patient's stay in hospital and, for this reason, the structure of the model was focused primarily on the hospital episode. However, the care state has a nontrivial influence on cost savings and QALY gains and therefore perhaps more modelling time should have been given to refining this state. This is set against the low quality of the evidence base and parameters on which to base the existing parameters – any further refinement of the care state would have probably introduced more uncertainty into the model.

It is also worth noting that, from a practical point of view, the costs and benefits of interventions to prevent inpatient falls are likely to be borne by different parts of the NHS/PSS system. Unless joint commissioning arrangements are well developed, patients have personalised budgets or appropriate system incentives are developed, this may represent an obstacle to implement for commissioners.

There was an intention to run a “mixture” hospital setting of the model, where patients could start in either the acute or non-acute hospital setting. However, given that less than 3% of admissions were to the non-acute setting, it was not possible to run enough patients through the model to reduce the sampling variability to acceptable levels.

No attempt has been made to model the changing risk of falling during a patient’s hospital stay. Some members of the GDG suggested that an ‘adaption factor’ may exist, whereby patients become less likely to fall as they adapt to their surroundings. This could also impact on the numbers of repeat fallers. Whilst some potential data sources were found (Vassallo et al., 2003, Burleigh et al., 2007), these were not included in the model. A similar argument could be applied to fall rates in the care state.

The model used multifactorial fall prevention intervention rates from the clinical review meta-analysis. Given the timescales of the included studies, it is unlikely that many patients were admitted and subject to the interventions more than once. However, the model generates around four hospitalisations in each patient’s lifetime and applies the intervention to each hospitalisation. It is entirely possible that the falls prevention intervention may be more or less effective on subsequent applications and, accordingly, the model may under- or overestimate the value for money it provides.

An incremental cost effectiveness analysis of various falls prevention intervention was not conducted. Due to a lack of evidence, the GDG did not recommend one multifactorial falls prevention intervention over another. Hence, the health economic model only assessed the costs and effectiveness of a generic intervention compared with doing nothing. If the appropriate costs and benefits of a variety of interventions had been available, an incremental analysis could have been performed. This may also have allowed some assessment to be made of which components of multifactorial interventions are cost effective compared to others.

A variety of literature has highlighted the influence of many risk factors on inpatient falls (including Bates et al. 1995, Brand et al. 2010, Halfon et al.

2001, Hill et al. 2007, Morse et al. 1987, Vassallo et al. 2005). On the advice of the GDG, only age, sex and falls history (falls within the last 12 months) were included within the model but others could have been chosen for inclusion. Even with this limited set of risk factors, the model relies on a linear combination of data on inpatient fall risk factors and is not able to account for the interactions that are likely to exist between these risk factors.

The causal multiplier was a necessary but limiting assumption. No evidence exists to quantify the causal relationship between an inpatient fall and subsequent events. However, sensitivity analysis shows that the model is relatively robust to this uncertainty: as long as it can be assumed that some of the negative experiences associated with falls are avoided by averting the falls themselves, some value can be anticipated from the intervention.

It should be remembered that whilst this model covers a patient lifetime and models falls occurring in all states (acute hospital, non-acute hospital, home, care), the intervention only applies to the hospital setting. No costs or utilities associated with community falls prevention (section 3 of the main guideline) are included within this model. The cross over between the community falls prevention recommendations and the inpatient falls prevention may be an area for potential future health economic research.

There remains a lack of direct evidence on the utility experienced by patients in hospital and the utility decrement and duration suffered following an inpatient fall. Similarly, the utility of people in care homes and the impact of falls therein were based on assumed values. The non-acute hospital setting model avoids this issue because all patients start in the non-acute setting, so there are enough non-acute hospitalisations to adequately reflect the parameter variability.

It is a significant weakness of this analysis that it has not proved computationally feasible to undertake full probabilistic sensitivity analysis, to explore the implications of parameter uncertainty for decision-making. A wide range of one-way sensitivity analyses was undertaken; this enables a fair degree of inference on the impact of such ‘second-order’ uncertainty and, in the light of these analyses, it is possible to state with some confidence that the intervention would be associated with a greater than 50% probability of cost effectiveness in a fully probabilistic analysis. However, it is not possible to quantify this probability accurately, or to explore the potential value of further research, in the absence of such an analysis.

Finally, it is acknowledged that the model is extremely complex. As well as increasing the potential for calculation and coding errors, a bigger model carries more inherent uncertainty. The one-way sensitivity analysis tested over 75 input parameters. Even when 500,000 patients are run through the model, more sampling error than would be desired remains in the model. In turn, this impacts on the computational time required to run the model. Sampling error also remains because inpatients are still rare events.

7.3.1 Suggested priorities for health economic research

In order to improve the modelling of inpatient fall prevention, future health economic research could usefully focus on:

- What is the relationship between inpatient falls and their apparent consequences (i.e. the true value of the causal multiplier)?
- The actual cost of treating inpatient falls
- The underlying utility of patients in hospital and people in care
- Utility decrements and duration following inpatient falls
- Whether different multifactorial interventions are incrementally cost effective when compared with each other

8 Conclusions

An innovative discrete event health economic model has been built that showed that, if it is possible to reduce inpatient fall rates, then this appears likely to be a cost effective course of action in the acute and non-acute hospital settings. However, the gains in both costs and QALYs were, for an average patient, small.