Modelling the cost-effectiveness of impact-absorbing flooring in Swedish residential care facilities

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Objective: Fall-related injuries among the elderly, specifically hip fractures, cause significant morbidity and mortality as well as imposing a substantial financial cost on the health care system. Impact-absorbing flooring has been advocated as an effective method for preventing hip fractures resulting from falls. This study identifies the cost-effectiveness of impact-absorbing flooring compared to standard flooring in residential care facilities for the elderly in a Swedish setting. Method: An incremental cost-effectiveness analysis was performed comparing impact-absorbing flooring to standard flooring using a Markov decision model. A societal perspective was adopted and incremental costs were compared to incremental gains in quality-adjusted life years (QALYs). Data on costs, probability transitions and health-related quality of life measures were retrieved from the published literature and from Swedish register data. Probabilistic sensitivity analysis was performed through a Monte Carlo simulation. Results: The base-case analysis indicates that the impact-absorbing flooring reduces costs and increases QALYs. When allowing for uncertainty we find that 60% of the simulations indicate that impact-absorbing flooring is cost-saving compared to standard flooring and an additional 20% that it has a cost per QALY below a commonly used threshold value. Conclusions: Using a modelling approach, we find that impact-absorbing flooring is a dominant strategy at the societal level considering that it can save resources and improve health in a vulnerable population.

Introduction

Fall-related injuries, specifically hip fractures, cause significant morbidity and mortality in the population as well as imposing a substantial economic cost on society. Studies have shown that fall-related costs make up around 0.85–1.5% of total health expenditure.¹ The risk of fall injuries increases with age and ill-health and the most fragile and elderly, living in residential care facilities and nursing homes, are especially vulnerable.

It has been suggested that a majority of fractures in elderly are not explained by osteoporosis, but by the energy released in a fall in combination with elderly people lacking the capacity to counter a fall.²,³ Recently, impact-absorbing flooring with a hard top surface has been invented and promoted as a promising strategy for reducing the injury risk from falls. In this article, we identify the cost-effectiveness in preventing hip fractures, of impact-absorbing flooring compared to standard flooring in the setting of Swedish residential care facilities for the elderly.

The aim is to explore the conditions under which installing impact-absorbing flooring is cost-effective from a societal perspective. We construct a Markov decision model utilizing input data on effectiveness and costs from published literature and Swedish registers, and we evaluate the flooring in terms of the incremental cost per gained quality-adjusted life year (QALY).

Impact-absorbing flooring

One of the main arguments for impact-absorbing flooring is that there is no need for active compliance, which is the case for preventive measures such as, e.g., hip protectors. The intervention analysed in this study is the installment of Kradal™ flooring, but there are other similar types of absorbent flooring on or about to enter the market. In the event of a fall, the load is spread on a hard top surface through a foam base layer underneath. According to laboratory tests, this reduces the peak force by 65–80% compared to bare wood or concrete and by 30–40% compared to wood or concrete with carpet overlay.⁴ It is not straightforward to translate this reduction into a decrease in the hip fracture risk, but laboratory results for hip protectors show force reductions of a similar size to those seen with impact-absorbing flooring,⁴,⁵ and the odds ratio for sustaining a hip fracture while wearing a hip protector compared to not wearing one is reported to be between 0.31 and 0.77.⁶,⁷ Assuming an average odds ratio of 0.50 corresponds to a hip fracture risk reduction of about 60%. This is in line with preliminary evidence from the supplier of the flooring, who is reporting a preliminary injury risk reduction (for all injuries) of two thirds.⁸

The cost-effectiveness of impact-absorbing flooring has hardly been studied at all. An exception is Latimer, Dixon, Drahota and Severs⁹ who evaluated the cost-effectiveness of installing one type of impact-absorbing flooring (Tarkett Omnisports Excel, which is a type of sports flooring.) in hospital wards for older people. In this case, absorbent flooring was cost-saving in the base-case but generated QALY losses due to an increased rate of falls. The latter may have been due to the fact that it was not hard-surface flooring, and therefore negatively affected balance.

Zacker and Shea⁴⁰ found an early version of impact-absorbing flooring (The Penn State Safety Floor.) to be cost-saving in terms of life years saved, and in an unpublished manuscript Njogu and Brown⁴ report impact-absorbing flooring to be cost-saving compared to the use of hip protectors in residential care facilities.

Methods

The cost-effectiveness model

We construct a cohort Markov simulation model (one group entering a care facility with standard flooring and one group...
entering a care facility with impact-absorbing flooring), so as to compare the costs and effects of installing impact-absorbing flooring compared to standard flooring in a Swedish residential care setting. Markov modelling is effective in situations where the risk of ill-health is ongoing, as in our case where elderly persons may incur anything from zero to several repeated hip fractures. We include three different states and an individual is assumed to always be in one of these states: ‘healthy’, ‘hip fracture’ or ‘dead’, as illustrated in Figure 1. In each of the three states, for each one-year cycle, we assign estimates for health-related quality of life (0–1) and economic cost, as well as probabilities for the transition between states (differing according to type of flooring). We use a societal perspective, i.e. considering costs and effects regardless of who is affected, with a time horizon of 10 years, and use a social discount rate of 3%. The time horizon is set at a maximum of 10 years given the small probability of someone living in residential care for more than 10 years when entering at the average age of 85 years.

Considering the societal perspective, we also include consumption and production costs, and due to the age of the target population for this intervention this implies taking the cost of added life years into account, i.e. consumption net of production during the extra years an individual lives due to a life-saving intervention or drug. Whether or not to include the cost of added life years is not straightforward, and when comparing the incremental cost effect ratios (ICERs) of different interventions, it is important to acknowledge if it is included or not.

We present the outcomes of the models by calculating the present value of costs and QALYs reporting the result in terms of the incremental cost/effect ratio (ICER), which measures the difference in cost divided by the difference in QALYs of installing the impact-absorbing flooring compared to standard flooring: $ICER = \frac{Cost_{IMPACT-ABSORBING} - Cost_{STANDARD}}{QALY_{IMPACT-ABSORBING} - QALY_{STANDARD}} = \frac{\Delta Cost}{\Delta QALY}$.

**Model assumptions on probabilities, costs and effects**

Input data on the costs, effects and probabilities used in the base-case model are summarized in Table 1 and discussed briefly below. Table 1 also presents the ranges and distribution assumptions used in the sensitivity analysis, which is presented in Sensitivity analysis section. Probabilities for mortality rate and hip fracture risks are assumed to have a Beta distribution, which takes into account that they are bounded between 0 and 1 and in line with recommendations.22 The risk reduction of impact-absorbing flooring compared to standard flooring is assumed to have a uniform distribution. A log-normal distribution may have been preferred, but is not chosen due to very limited data for this parameter. The distribution for the cost parameters in our analysis is the Gamma distribution, which takes into consideration both the fact that the cost is constrained to be positive and is in accordance with recommendations for modelling the distribution of costs.22 The data on health-related quality of life used to calculate the QALYs is also assumed to have a Beta distribution, considering that they are bounded between 0 and 1.

**Transition probabilities**

Data from the National Board on Health and Welfare12 indicates that, on average, 27% of the residential care population dies each year. In general, more and more elderly persons are receiving care and support in their homes, and moving to residential care facilities later and in a worse state of health than was previously the case.23 The mortality rate is adjusted, in this article, to exclude hip-fracture-related mortality, since the transition probability from the ‘healthy’ to the ‘dead’ state should account for all causes but hip fractures; this leads to an annual mortality rate of 0.25. Furthermore, in each cycle (1 year) the mortality rate is increased by 0.025 to acknowledge the aging of the cohorts.

For those suffering a hip fracture, there is an increased probability of mortality. Age- and sex-standardized mortality has been shown to increase threefold for those suffering a hip fracture25 and one study showed that in the first year following a hip fracture about 50% of those in residential care when injured die.16 As a conservative assumption, we here assume an increase in mortality by 30% in the year following the fracture (implying a total mortality of $1.3 \times$ base mortality for those in the hip fracture state).

The hip fracture risk is based on data from the National Hip Fracture Database,13 in which Swedish hospitals register all hip fractures. According to data on age and residential status, the annual hip fracture incidence in residential care is 5.7%.

Due to the similarity of force reductions observed in laboratory studies mentioned earlier, results on the effectiveness of hip protectors are used to estimate the effectiveness of impact-absorbing flooring in reducing the hip fracture incidence. The average of the reported odds ratios for hip fractures using hip protectors corresponds to a risk reduction of 60%, and this figure is used as the base-case assumption in the model.

![Figure 1 Markov state diagram with first stage transition probabilities](https://academic.oup.com/eurpub/article-abstract/26/3/407/2467160/1)

**Figure 1** Markov state diagram with first stage transition probabilities
**Table 1 Summary of model assumptions**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base case (sensitivity range)</th>
<th>Distribution</th>
<th>Reference/comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probabilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality rate</td>
<td>25.3% + annual increase 2.5%. (20.3–30.3%)</td>
<td>Beta</td>
<td>12–14</td>
</tr>
<tr>
<td>Hip fracture risk—standard flooring</td>
<td>5.7% (1.7–9.7%).</td>
<td>Beta</td>
<td>13,14</td>
</tr>
<tr>
<td>Increase in mortality due to hip fracture</td>
<td>30% (20–40%).</td>
<td>Beta</td>
<td>13,15,16</td>
</tr>
<tr>
<td>Risk reduction due to impact-absorbing flooring</td>
<td>60% (40–80%)</td>
<td>Uniform</td>
<td>6,7,17,18</td>
</tr>
<tr>
<td>Cost data (SEK)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip fracture cost</td>
<td>131 893 SEK (±25%) (€14,300)</td>
<td>Gamma</td>
<td>19</td>
</tr>
<tr>
<td>Incremental cost of impact-absorbing flooring</td>
<td>3226 (±25%) (7350)</td>
<td>Gamma</td>
<td></td>
</tr>
<tr>
<td>Cost in added life years</td>
<td>97 960 SEK (±25%) (€10,600)</td>
<td>Gamma</td>
<td>20</td>
</tr>
<tr>
<td>Health-related quality of life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health-related quality of life in 'healthy' state</td>
<td>0.35 (0.30–0.40)</td>
<td>Beta</td>
<td>21</td>
</tr>
<tr>
<td>Health-related quality of life in 'hip fracture' state</td>
<td>0.21 (0.15–0.27)</td>
<td>Beta</td>
<td>21</td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Costs**

The additional cost of installing the absorbent flooring rather than standard flooring is 1600 SEK/m² (€174/m²) based on information from the Swedish retailer of Kradal™. Each person living in a residential care facility is assumed to have 30 m² of living space. The cost is recalculated as an annuity based on the assumption that absorbent flooring has the same life-span as standard flooring, i.e. 20 years, and a 3% social discount rate is used.

Hip fracture costs have been studied a number of times, but usually including the costs due to transferal to a residential care facility, which is irrelevant here given that the cohort already is living in a residential care facility. Hektoen, Aas and Luras studied costs due to fall-related injuries in elderly community-dwelling women in Norway, specifying costs in a way that makes it possible for the costs relevant to the residential care population to be identified. Costs included in our model are in- and outpatient costs, costs of rehabilitation, general practitioner visits, physical therapy, ambulances and other forms of patient transport, while costs due to occupational therapy, home equipment, community nursing, home care, staff transport and nursing homes are excluded. Costs are also adjusted to recognize that not all patients survive hip fractures. Finally, the costs are adjusted by the GDP ratio to reflect price-level differences between Norway and Sweden.

The cost of added life years is based on the recommendations previously given by the Swedish Dental and Pharmaceutical Benefits Agency; a net cost of 97 960 SEK (€10 600) is used in the model. For example, this includes health care consumption (pharmaceuticals, dental, primary and hospital care but excluding elderly care) and other consumption (private and public; Public consumption is about 20% of the cost of added life years used here and is originally estimated from the Swedish national accounts and other government sources.) for those above the age of 80.

**Health-related quality of life**

Assigning QALY values to severely ill or injured elderly persons is difficult; see, e.g., the discussion in Jaldell. There are studies indicating that health states such as 'confined to bed, slight pain' and 'unconscious, but not aware or in pain' are considered the same as or worse than death by respondents 75 years and older.

Only the most fragile elderly persons obtain places in residential care, indicating a poorer than average health state. Gandjour and Weyler use data for states with and without hip fractures for elderly individuals with a previous need for daily care, and we use the same indices in this model. The QALY weights applied are 0.35 for the healthy state and 0.21 for the hip fracture state.

**Results**

**Base-case results**

The results indicate that the impact-absorbing flooring reduces costs and increases QALYs. For the base-case assumptions, installing impact-absorbing flooring leads to average incremental savings of 2786 SEK for an average gain of 0.02 QALYs per individual. If we exclude the cost of added life years, the cost-saving properties are enhanced.

**Sensitivity analysis**

In modelling the cost-effectiveness, the assumptions made on the prevention effect of the flooring, as well as on other variables, are crucial for the conclusion. In order to assess the robustness of the results, probabilistic sensitivity analysis (PSA) by means of Monte Carlo simulation is performed in accordance with the sensitivity ranges presented in Table 1. PSA allows for joint uncertainty of all parameters of the model and is generally the recommended approach for sensitivity analysis in cost-effectiveness analysis.

In 60% of the 10 000 iterations made, installing impact-absorbing flooring will produce cost savings. In another 20% of the iterations, installing impact-absorbing flooring is cost-effective compared to a threshold value of QALY commonly used in Sweden of 500 000 SEK (€54 350). In 15% of the iterations, the ICER is above 500 000 SEK, and in the remaining 5% installing impact-absorbing flooring is the inferior strategy. In Figure 2, we present the cost-effectiveness acceptability curve, showing the probability of each of the two strategies being the most cost-effective at a given level of willingness to pay for a QALY.

**Discussion**

The base-case results in this article indicate that installing impact-absorbing flooring rather than standard flooring in residential care facilities is cost-saving under the assumptions of the cost-effectiveness model. Considering that the model used is based on the Swedish residential care setting and contextual differences in, e.g., residential care organization, hip fracture incidence and costs, the transferability of the results to other countries will vary. In a one-way sensitivity analysis (available as Supplementary Appendix), we see that the effectiveness of the impact-absorbing flooring must be below 25% for the ICER to be over 500 000 SEK (€54 350), which is the cost-effectiveness threshold commonly referred to in Sweden. Doubling the cost of the flooring, which could be the case due to a higher cost per square meter or due to residential homes providing more space per person, yields an ICER of 256 000 SEK (€27 800). Installment costs and effectiveness will differ between different types
of impact-absorbing flooring. Hence, the above indicates the limits within which the results can be transferred to other types of flooring. It has been suggested that a majority of fractures in elderly are explained by the energy released in a fall in combination with a lack of capacity to counter the fall.\(^1\) Even small reductions in the energy transferred to the bone when falling have been shown to reduce the number of fractures resulting from falls.\(^2\) This means, though not included here, that flooring might have a potential to reduce not only hip fractures but also other fall-related injuries such as vertebral fractures and wrist fractures that commonly occur as a result of falls, which would make the floor more cost-effective.

An additional issue discussed in relation to the model is whether to include the cost of added life years. Most authors tend to argue that future costs related to the intervention should be included, whereas there have been more controversy regarding the inclusion of future unrelated health-care costs (e.g. future increase in dementia cost given the reduction in fall-related injuries and deaths) and even more debate about future unrelated non-health care costs (e.g. future increase in social services costs due to an intervention that add life years).\(^1\)\(^,\)\(^3\)\(^,\)\(^6\)

Including costs of added life years will tend to favour interventions that affect quality of life over those that extend life. Also, interventions directed towards the younger, productive population will be favoured over interventions directed towards the older population. In Sweden, its inclusion has previously been recommended by the Dental and Pharmaceutical Benefits Agency, in opposite to e.g. recommendations by NICE, arguing that when applying a true societal perspective all costs and benefits should be included and ethical viewpoints should considered separately.\(^1\) However, this recommendation is now under revision. It appears that also the Swedish authorities will recommend an exclusion of the costs of added life years, most likely more due to ethical and value judgments rather than based on economic decision theory.\(^11\) The results from the model in this article indicate that the flooring is cost-saving and a dominant strategy both including and excluding costs of added life years.

Finally, an issue of relevance in the decision making context is the perspective of the analysis. In the Swedish setting, residential care facilities are generally operated at the local level (by municipalities) and health care at the regional (by county councils). Thus, impact-absorbing flooring could be cost-effective at the societal level but one actor would bear the cost of instalment (municipalities) while another would benefit from the effects of reduced hip fracture costs (county councils). This could be a dilemma even in a cost-saving scenario, counteracting the implementation of a cost-saving intervention given that from a pure municipal-level perspective the intervention is not cost-saving. This highlights the importance both for economic evaluations and decision-makers to have a broader societal perspective in order to achieve rational and welfare-improving outcomes.

### Conclusion

The results in this paper indicate that installing impact-absorbing flooring in residential care facilities will prevent hip fractures while saving costs compared to standard flooring. If the costs of added life years are excluded, the cost-saving properties are enhanced. The result is robust even when allowing for a large span of uncertainty in the model assumptions according to probabilistic sensitivity analysis.

### Funding

We are grateful for financial support from the Swedish Civil Contingencies Agency (MSB) and from the Swedish Research Council for Health, Working Life and Welfare (Forte).

### Conflicts of interest
None declared.

### Supplementary data

Supplementary data are available at EURPUB online.

### Key points

- Installing impact-absorbing flooring in residential care facilities, instead of standard flooring, will prevent hip fractures, lead to a gain in quality adjusted life years and to economic savings at the societal level.
- Based on a parametric sensitivity analysis the results indicate that there is a large likelihood that the instalment of impact-absorbing flooring is a cost-effective intervention (60% of the iterations showed a cost per QALY < 0 and an additional 20% showed a cost per QALY below a commonly used threshold value).
- The economic cost-savings mainly occur in the health care sector, while the investment costs occur in the long-term care sector. This may reduce the likelihood of the intervention to be implemented if the involved actors do not consider the societal effects of the intervention.

### References

5. Laing AC, Robinovitch SN. The force attenuation provided by hip protectors depends on impact velocity, pelvic size, and soft tissue stiffness. J Biomech Eng 2008;130:061005