The impact of absorbent floor in reducing hip fractures

A cost-utility analysis among institutionalized elderly in Sweden

Economics

Master`s Thesis

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Abstract

This paper analysis the cost-utility, measured in cost per QALY gained, of impact absorbent flooring that reduce hip fractures among institutionalized elderly in comparison to standard flooring. The study is based on experimental data from an elderly institution, where the absorbing floor was installed in 2010. Using a decision tree, the costs and benefits related to the new flooring are calculated on a one year basis, resulting in an incremental cost per QALY of 71337 SEK for the base case. Although the experimental data shows that there is an impact of the new flooring in reducing hip fractures a conclusion whether the policy is cost-effective or not can hardly be drawn. Sensitivity analysis based on a simulation of 5000 cases suggests that the result is robust.

Keywords: cost-utility analysis, QALY, absorbent floor, hip fracture
Contents

1. Introduction ........................................................................................................................................ 1
   1.1. Problem discussion .................................................................................................................. 3
   1.2. Purpose ....................................................................................................................................... 3
   1.3. Method ....................................................................................................................................... 4
   1.4. Limitations ................................................................................................................................. 4
   1.5. Disposition .................................................................................................................................. 4
2. Theoretical Framework ..................................................................................................................... 5
3. Analysis ........................................................................................................................................... 10
   3.1. Decision analysis model .......................................................................................................... 10
   3.2. Data .......................................................................................................................................... 12
      3.2.1. Probabilities ....................................................................................................................... 12
      3.2.2. Costs .................................................................................................................................. 13
      3.2.3. Quality-adjusted life-time weights ...................................................................................... 14
   3.3. Sensitivity analysis .................................................................................................................... 15
4. Results ............................................................................................................................................ 18
5. Discussion and Conclusion ............................................................................................................ 20
References ........................................................................................................................................... 22
Appendix ............................................................................................................................................ 26
1. Introduction

The number of elderly in the society grew slightly over the last decades. In 2010 the share of people older than 65 years was about 18 percent of the total population in Sweden. Due to deteriorating functionalities among elderly, like decreased eyesight, sense of balance and reflexes, the rate of falls increases among these persons, causing affliction and high costs to society. According to previous studies more than 30 percent of elderly people fall more than once a year (Njogu & Brown, 2008). In 2010 the number of falls causing hospitalization for at least one day for people older than 65 was about 47013, representing a raise of more than 14 percent over the last 10 years (MSB, 2011). The number of people dying due to accidental falls was 798 in 2010, which is nearly twice as high as in 2000, when 402 people older than 65 years died1. According to the World Health Organization an accidental fall is defined as “an event which results in a person coming to rest inadvertently on the ground or floor or other level.”

Besides the direct consequences such as slighter injuries, fractures and in the worst case death accidental falls can also result in psychological problems. Individuals experience a decrease in their self confidence as they are more and more dependent on the help of others, which in addition to reduced mobility can result in depression and isolation (Gyllensvärd, 2009).

Injuries as a consequence of falls can take various forms, such as soft tissue and head injuries or fractures. Previous studies focusing on different types of injuries and the related costs have shown that a hip fracture is the most expansive consequence of a fall for the society (Njogu & Brown, 2008) Hence, it is clearly an important policy issue to investigate ways to reduce the number and the consequences of falls among elderly.

A reduction of injuries due to accidental falls can be achieved in two general ways. The first (1) one is to reduce the risk of falling by (a) eliminating sources of danger in the living environment of elderly, such as thresholds or cables individuals can stumble over, (b) physical exercise to increase the sense of balance and mobility again or (c) regular control of eyesight and composition of medication (SKL, 2009). The second (2) possibility is to try to reduce the

1 Statistic about cause of death according to ICD’s classification, W00-W1, from 2000 and 2010
risk of an injury if an accidental fall occurs. An example of the latter is a hip protector, which is a common prevention method against hip fractures. Hip protectors are pants containing pads on each side which in case of falling absorbs and spreads the energy affecting the hip. Although studies have shown that this treatment leads to a significant reduction in the number of hip fractures there are some disadvantages in its use. Beside the point that they just provide protection against hip fractures and not against other injuries due to fall, the effectiveness of hip protectors strongly depends on the elderly themselves, as fractures just can be avoided if the protector is worn. And the acceptance to wear hip protectors among elderly has been found to be low to moderate in most cases (Schoor, Deville & Lips, 2002). As an example, Zweifel & Telser (2002) showed that elderly were willing to pay 155 USD on average for not being obliged to wear a hip protector. Furthermore additional administration of such a program is needed, leading to increased costs to society (Njogu & Brown, 2008).

The disadvantages of this treatment generated the need of more effective strategies, which in contrast to the hip protectors are not dependent on the compliance of the individuals and are therefore referred to as passive interventions. One such passive intervention is innovations regarding floor, such that they are built to reduce the consequence of a fall. Already in the 1990’s studies have been done focusing on the effect of different floors on the risk for injuries. Significant differences have been found between e.g. fitted carpets and linoleum floor (Maki & Fernie, 1990).

Further studies and research has been done and led to the invention of a special kind of floor. The new type is made of plastic with a high share of air in it. Under normal use it is as hard as usual floor coverings, but in the case of a fall it deforms and by this absorbs and spreads the energy of a fall, reducing the risk not just of hip fractures but of any injury. Test have shown that the reduction of the peak force of falling is about 20% to 40% compared to wood or concrete floor with underlay and carpet, and almost 65% to 80% compared to bare wood or concrete floor². Although the floor has the ability to absorb this quite high share of energy by deforming it has no negative impact on the sense of balance of elderly and even provides a reduction of the sound level.

² Results from product testing summary report of Kradal, ACMA
Previous studies comparing the absorbent floor to hip protectors using cost-utility and cost-effectiveness analysis have shown that the absorbent floor is less costly and more effective. While the hip protectors reduced the number of hip fractures with just 25 percent the floor reduced them with almost 67 percent (Njogu & Brown, 2008).

1.1. Problem discussion

Hip fractures as a consequence of an accidental fall increase the morbidity and mortality of elderly, causing affliction and high costs to society. It is therefore important to examine different possibilities to decrease the number of hip fractures. As it is difficult to decrease the risk of falling it is more useful to try to reduce the probability of a fracture in the case of a fall. This study is based on data from a nursing home in Sunne, Sweden. The residents living in this institution have lost their ability to live alone, are often suffering from dementia and in the need of special care. Accidental falls occur often resulting in injuries, increasing the morbidity and mortality even more. Therefore decision makers chose to install the absorbent floor instead of the usual linoleum when a new section in this institution was built in 2010 to reduce the risk of physical consequences of falls. The new floor was installed at the corridor, the day room and all apartments, despite the bathrooms, in the new section. In total there are 59 residents living in the nursery home, with 12 of them inhabit the part with the absorbent floor. The territorial separation of the section provides the opportunity to monitor the difference between the consequences of accidental falls. The experimental time horizon is 13 months. In total there occurred 208 accidental falls under this period, with 23 occurring on the absorbent floor resulting in no fractures and 185 on standard flooring leading to 3 fractures. This study examines the effect of energy absorbing floor on falls among institutionalized elderly in Sweden compared to standard floors.

1.2. Purpose

This paper analyses the cost utility, measured in cost per quality-adjusted life year (QALY), of absorbing floor in reducing hip fractures among institutionalized elderly in comparison to standard flooring.
1.3. Method

Data was obtained from an experiment in an elderly institution in Sweden, from international literature studies and official statistic databases. Using a decision tree model, the cost utility of absorbent floor, expressed as cost per quality-adjusted life year gained, in reducing hip fractures among institutionalized elderly was examined in comparison to traditional flooring. All costs and utilities were calculated on a hypothetical one year basis. Sensitivity analysis was conducted to incorporate uncertainty in costs and probabilities. All calculations were done in Excel and the statistical program STATA.

1.4. Limitations

This paper examines the cost utility of the impact of absorbing floor in reducing hip fractures in contrast to standard flooring. It would have been preferable to also include other kinds of injuries as a consequence to an accidental fall. But hip fractures were chosen due to three reasons: (1) the accessibility of data, as under the experimental period in the elderly institution only hip fractures were monitored, (2) the time constraint of this study, and (3) hip fractures are the most costly consequence of accidental falls, causing morbidity and mortally among elderly. The data is based on an experimental study and therefore underlying uncertainty, since probabilities are calculated on a few numbers of accidental falls.

1.5. Disposition

The rest of the paper is structured as follows: the theoretical framework is discussed in chapter 2, containing a brief discussion of cost-benefit and cost-effectiveness analysis and giving a broader description of cost-utility analysis and the components of it. The analysis is described in chapter 3, while 3.1 provides a characterization of the decision analysis model and 3.2 gives explanations about the data and calculations done. Results are presented in chapter 4. In section 5 the paper is concluded with a discussion and conclusion.
2. Theoretical Framework

Due to the scarcity of resources the purpose in economics is to achieve efficiency, i.e. how to allocate the maximum amount of benefits given a certain amount of resources or costs. The equilibrium or optimal allocation is reached when the marginal cost equals the marginal benefit that is the additional cost of one more unit is exactly the same as the additional revenue of consuming one more unit. This allocation is also called pareto-optimal, which means that it is not possible to make one party better off without making it worse for another one (O´Sullivan, Sheffrin, & Perez, 2008). If the marginal benefit exceeds the marginal cost of an intervention or policy there is an incentive to higher activity and thus there are higher net benefits to generate. In contrast to this if the marginal cost exceeds the marginal benefit the resources are not allocated optimal (Rosen & Gayer, 2008).

In order to maximize social welfare decision makers are interested in whether a policy is potentially pareto improving\(^3\), i.e. the social welfare increases when the beneficiaries of an intervention theoretically could compensate the loser of it (Rosen & Gayer, 2008). This is done with the help of applied welfare economics. Cost-benefit analysis (CBA) is the most common method in this context and is e.g. adapted in governmental decision making regarding infrastructure investments. Benefits as an impact of a policy are measured in terms of the public’s willingness to pay and are compared to the costs of an intervention. After having defined all the relevant costs and benefits related to the different interventions under consideration these values need to be adjusted for differential timing. Individuals tend to prefer to get benefits in the near future or the present while they would like to postpone the costs, i.e. positive time preferences. Thus it is necessary to discount the costs and benefits related to an intervention to the point in time the valuation is done (Drummond et al., 2005). The result of CBA can be presented in two different ways: (1) as the benefit-cost ratio, showing the relation between the discounted present value of a stream of benefits to the discounted value of the stream of costs, or (2) as the net benefit, i.e. the difference between the total benefits and the total costs. The most efficient alternative is presented by the highest benefit-cost ratio or (most positive) net benefit (Drummond et al., 2005; Rosen & Gayer, 2008).

\(^3\) Also referred to as the Hicks-Kaldor-criteria or compensated pareto-criteria (Rosen & Gayer, 2008)
To measure the willingness to pay (WTP) can be difficult for several reasons: (1) differences in income can lead to a varying WTP and (2) asymmetric or imperfect information about the benefits of an intervention can result in under- or overvaluation of the impact. Furthermore it is sometimes not just complicated but impossible or impractically to determine benefits in monetary units. Hence, when the impact of a new drug is analyzed it can be more reasonable to measure outcomes in a different way. An alternative method of economic evaluation, which is often used in health care economics, is cost-effectiveness analysis (CEA). In contrast to CBA, CEA provides the possibility to compare health care interventions which are expected to result in the same kind of outcome but to a different extent. For example, two different drugs may have varying impact on blood pressure. CEA compares different programs or treatments in terms of the ratio of their costs, measured in monetary units, in relation to their benefits, expressed in some non-monetary unit. Hence the first step in using CEA is to determine all costs and benefits related to the intervention. Economic valuation in healthcare uses different types of costs: (1) direct cost, (2) indirect costs and (3) intangible costs. While intangible costs contain for example the cost of suffering of an illness or anxiety, indirect costs take forgone consumption, productivity losses and time off work into account. Both are difficult to measure as people may value time or pain different and these costs are for this reason not included in this study. Direct costs contain resources used by the health care program or intervention, such as drugs, hospital costs or material costs (Drummond et al., 2005).

The benefits of a health care intervention can be various. In CEA the outcome is measured as a single quantified impact and reported in natural units, such as lives saved, cases deducted or percentage reduction in blood pressure, which is also called the effectiveness. After having defined all inputs (costs) and outcomes (benefits) of the interventions under consideration the incremental cost-effectiveness ratio (ICER) is calculated. The ICER presents the difference in costs in relation to the difference in the outcome, expressed as effectiveness, as it can be seen in equation 1.

\[
ICER = \frac{\text{Cost (treatment 1)} - \text{Cost (treatment 2)}}{\text{Effectiveness (treatment 1)} - \text{Effectiveness (treatment 2)}}
\]  

(1)
The results of ICER presents the cost per effectiveness unit of treatment 1 in comparison to treatment 2, for example cost per life saved. The treatment with the highest efficiency, i.e. the lowest cost-effectiveness ratio, should then be chosen in a context with different treatments and a fixed budget (Elliot & Payne, 2005; Drummond et al., 2005).

A problem that can occur while using CEA is that there may be more than just one outcome as a consequence to a health care intervention. For example is it possible that the drug discussed above does not just decrease the blood pressure but also causes pain or has other side effects. Therefore, cost-utility analysis (CUA), which is considered as a special case of CEA, is a more appropriate form of economic evaluation. Again costs are measured in monetary units but in contrast to CEA benefits/outcomes are expressed in utility-based units. Utility in economics represents preferences for a certain outcome or is related to an individual’s wellbeing (Robinson, 1993).

CUA is commonly used when health care programs or treatments can result in different health related states of quality of life. Furthermore it provides the opportunity to compare not just the varying results of one program but of different interventions with health related outcomes, by comparing the utility generated. The most common measurement of utility in health economics is quality-adjusted life years (QALY). Using QALY gives the opportunity to combine the impact of an intervention on the length of life, i.e. the quantity, and the quality of the life time gained, which show the preference related to a certain health state.

Figure 1 illustrates the quality-adjusted life-years concept. The red line shows the initial situation, i.e. without intervention. Due to the disease the individual suffers from, it has an expected life-time of 2 more years at the quality-adjusted life time weight of 0.5. In contrast to this the blue line shows the effect of a health care intervention, for example a new drug, where the individual is now has a life-time expectancy of 3 years at the higher quality-adjusted life-time weight of 0.75. The area between the red and the blue curve shows the total QALY gained by the health care intervention can be divided into the two smaller areas A and B. The improvement in quality of life time is represented by area A, while the increased life time expectancy is shown by area B (Drummond et al., 2005). According to this simple example the individual would gain \((0.25 \times 2) + (0.75 \times 1) = 1.5\) QALY in total from the health care intervention.
Thus it is necessary to define quality-adjusted lifetime weights to calculate the QALY’s gained from a treatment. QALY-weights are expressed on an interval scale as a value between 1, representing perfect health and 0, showing death. The weights can be determined in different ways: (1) standard gamble, which is based on decision making under uncertainty and tries to find the probability at which an individual is indifferent between two alternatives. For this purpose are two different situations presented to the participants and they are asked which one to prefer. The first alternative is to life a certain period of time at a defined health state, mainly suffering from an illness, while the second alternative is a gamble with a probability of $p$ to live the same time period without suffering from the disease and the probability of $1-p$ for immediate death. The probabilities are changed until an individual is indifferent between the two alternatives. Another possibility is (2) time trade-off, where individuals are asked to choose whether to live a certain period of time at a defined health state or to live a shorter period of time at a better health state. The lifetime of the second alternative is again changed until the individual is indifferent between to the choice. The utility related to the health state under consideration can then be calculated as the ratio of the period of fixed lifetime from alternative one to the time living at the better health state. When using (3) visual analogue scales (VAS) participants are asked to mark their health state on a scale to find the difference.
in utility of health states. Furthermore is it possible to measure QALY-weights with the help of standardized questionnaires, for example the EQ-5D or the health utility index, where the related quality-adjusted lifetime weights depend on how individuals answer to questions (Drummond et al., 2005; Elliot & Payne, 2005).

In CUA QALY is again used to calculate ICER showing the change in costs in relation to the change in QALY gained as it can be seen in equation 2.

\[
\text{ICER} = \frac{\Delta \text{Cost} \ - \ \text{Cost (treatment 1)} - \text{Cost (treatment 2)}}{\Delta \text{QALY} \ - \ \text{QALY (treatment 1)} - \text{QALY (treatment 2)}}
\]  

(2)

The resulting ICER presents the cost per QALY gained (Drummond et al., 2005; Robinson, 1993; Elliot & Payne, 2005).

In a context with different treatments and a fixed budget the calculated ICERs can be used to identify the intervention which is most cost-effective, i.e. has the lowest ICER. However, decision makers often face the situation that only one treatment is valued and they have to decide whether to introduce the intervention or not. For this purpose the incremental cost-effectiveness ratio can be used in a threshold analysis, where it is compared to a critical value of a QALY. If the calculated ICER is lower than the threshold value the policy is cost-effective or dominant (Elliot & Payne, 2005). In CUA the critical value can be found as the maximum willingness to pay for one additional quality-adjusted life year. Johannesson (2001) found this value to be around 500000 SEK, while Persson (2003) assumed it to be 655000SEK.
3. Analysis

3.1. Decision analysis model

There are many different models in economic evaluation and which one to choose depends on the focus of the study and the data set used. One common approach is to use a decision-tree as it gives the possibility to simplify the reality and also to show the outcomes of different alternatives graphically. It is drawn as a tree-like graph from the left to the right and contains 5 components. (1) The starting point, representing the initial situation where the evaluation of a treatment begins. In health-care economics, this point is often a defined group or category of patients. It is followed by (2) a decision node which is graphically shown as box. In a decision-tree there should always just be one decision node from where the different paths split up, showing (3) the alternatives to choose and evaluate. Each path has (4) a chance nodes, indicated by a circle. These are uncertain events, occurring with a certain probability, which lead to (5) an outcome. The outcome, represented by a triangle, is the endpoint of the evaluation and is therefore also called time horizon (Elliot & Payne, 2005; Drummond et al., 2005).

Figur 2: Decision tree for the two policies
Figure 2 illustrates the decision-tree for this study. The two alternative policies are whether to install the traditional floor or the absorbent one, represented by the two arms leading away from the decision node. The first chance node for both alternatives shows the possible events. The individuals may have an accidental fall or not. It is important to notice that the probabilities attached to these events have to sum up to 1 for every chance node implemented in the diagram, i.e., the probability to fall is defined as Pr(fall) and the probability of not falling is then calculated as Pr(not fall) = 1 - Pr(fall). The probabilities are the same for both policies. If an accidental fall occurs, again there are two possible events, represented by the next chance node. This time the two events expected to happen are hip fracture, with Pr(hip), and no injury, with the probability Pr(no) = 1 - Pr(hip). In this case the probabilities for the two interventions differ from each other. The risk of suffering from a hip fracture is bigger for the traditional floor than for the absorbent one.

The last chance node shows the possible events with the respective probabilities of dying due to the hip fracture, Pr(dead), and regaining health, Pr(health) = 1 – Pr(death). For both policies the mathematical expectations are the same.

It is now possible to calculate the probabilities for a certain outcome. While the probability of not falling and by this not getting a hip fracture just is shown by Pr(not fall), the probability for the outcome death as a consequence of an accidental fall is calculated as

\[
Pr = Pr(\text{fall}) \times Pr(\text{hip}) \times Pr(\text{death}).
\]

This decision-tree shows the possible events and outcomes for one year. Using the defined probabilities the expected outcomes and expected utilities are calculated, generating the ICER for the base case study. The cost-effectiveness ratio presents the additional cost to society per QALY gained.

This study takes a societal perspective as it tries to find the allocation of resources which maximizes society´s welfare. Since health care is financed publically it is important to notice that the resources, i.e., the additional costs for the absorbent floor, could maybe be used more efficient elsewhere. Thus to provide comparability throughout the health care system the costs and benefits employed in this model are expressed on a one year base. This is due to the reason that the places in elderly institutions are limited, i.e., not every person who got a place assigned has the possibility to move to an institution immediately. Hence it is assumed in the
model that the institutions have complete capacity utilization as every time an inhabitant passes away, another individual will move in. The utilization is the same every year, making calculations on a yearly base reasonable.

3.2. Data

3.2.1. Probabilities

According to previous studies one third of the population older than 70 years falls at least once in a year. (Luukinen et al., 1994) The risk of falling among institutionalized elderly is assumed to be much higher and varying between 30 and 70 percent (Luukinen et al., 1994; Nurmi & Lüthje, 2002). The statistical results from the nursing home in Sunne, Sweden, show the high number of 208 accidental falls under a one year period among the 59 residents which is due to the fact that individuals can fall several times in a year. The probability of falling is therefore based on previous studies and is assumed to be $P(\text{fall}) = 0.7$, which is on the upper bound found in the literature.

The probability of sustaining a hip fracture after an accidental fall is again calculated with the data from the experiment. Using the number of falls as the denominator and the number of hip fractures as the numerator the probability of a hip fracture is given with $P(\text{fracture}) = 0.016$ for falling on usual floor. This is also consistent with previous studies, where the risk is assumed to be between 1 and 2 percent (Njogu & Brown, 2008). In contrast to this the data from the experiment does not provide evidence for a hip fracture when falling on the absorbent floor. This may be due to the short time horizon or mere chance. Simpson et al. (2004) found in their study a reduction up to 80 percent of the risk of a hip fracture depending of the kind of flooring. The probability for sustaining a fracture on the absorbent floor is therefore calculated as an average of their finding and the experimental data, resulting in a probability of $P(\text{fracture-absorbent floor}) = 0.0016$ for the base case.

The mortality rate within one year after a hip fracture has been found to range from 23 to 35 percent (Boereboom, Raymakers, & Duursma, 1992; Keene, Parker, & Pryor, 1993). Due to the health state of institutionalized elderly the mortality rate in this study is assumed to be $Pr(\text{death}) = 0.35$. 

12
Table 1 provides an overview of the probabilities used in the base case.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falling</td>
<td>0.7</td>
</tr>
<tr>
<td>Hip fracture standard floor</td>
<td>0.016</td>
</tr>
<tr>
<td>Hip fracture absorbent floor</td>
<td>0.0016</td>
</tr>
<tr>
<td>Death</td>
<td>0.35</td>
</tr>
</tbody>
</table>

| Tabel 1: Probabilities of the base case |

3.2.2. Costs

All cost data quoted in this study is expressed in 2011 Swedish crowns. The direct costs of the two alternative interventions were received from the firm who installed the absorbent floor in the nursing home and include material and labor costs. Traditional flooring has a price of 400 SEK per square meter and the price of the absorbent one is 1600 SEK. The floor was installed on a total area of 300 square meters with 12 persons living in this section. Hence the average area for an individual is 25 square meters at a cost of 1200 SEK each, resultant in a total additional cost of 30000 SEK per person. Since the time horizon of the model is one year the additional cost of the absorbent flooring is expressed as an annuity over the lifetime of the floor. According to Goorée et al. (2002) the life expectancy is about 20 years. The total costs are calculated as an annuity with 3 percent over this period to find the additional costs per year and person of 2016 SEK in this institution.

According to the official Diagnosis Related Group (DRG) price list is the cost for medical care of a hip fracture about 45689 SEK. These are just the direct costs for the surgery. A more appropriate calculation of costs was done by Zethraeus et al. (2002), taking also costs for nursing and physicians into account. The costs related to a hip fracture employed in the analysis are 75754 SEK. However, this is lower as in many other studies, since increasing

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4 In compliance with Läkemedelsförmånsnämnden which recommends a discount rate of 3 percent for health care economic evaluations (LFNAR 2003:2)

5 According to the DRG-price-list the direct costs related to the code 236 are about 44524 SEK in 2010 prices.

6 According to Johansson (2008) the costs to society range from 296974 SEK to 370170 SEK in 2004 prices.
costs for elderly care are disregarded from due to the reason that this study focuses on institutionalized elderly.

The direct costs related to death are assumed to be 41000 SEK. The calculation is based on a previous study done by Räddningsverket (2005). The costs contain just the medical costs related to death. Usually are also costs of production losses taken into consideration but since the individuals in this age are not assumed to have any production, so therefore production losses may be disregarded from.

Table 2 present an overview of the costs per person for one year.

<table>
<thead>
<tr>
<th>Costs items</th>
<th>Price</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>standard floor</td>
<td>672</td>
<td>Price Hagfors Målei</td>
</tr>
<tr>
<td>absorbent floor</td>
<td>2688</td>
<td>Price Hagfors Målei</td>
</tr>
<tr>
<td>hip fracture</td>
<td>75754</td>
<td>Zethraeus et al. (2002)</td>
</tr>
<tr>
<td>death</td>
<td>40812</td>
<td>Räddningsverket (2005)</td>
</tr>
<tr>
<td>health care consumption</td>
<td>32185</td>
<td>Ekman (2002)</td>
</tr>
</tbody>
</table>

Table 2: Costs identified per person and year, expressed in 2011 prices

Health care consumption costs were included in the calculations, representing the increased need of medical care of the institutionalized elderly.

3.2.3. Quality-adjusted life-time weights

Quality-adjusted life-time weights range from 1, representing perfect health, to 0, showing death. In previous studies the QALY-weight for a person aged 85 and older is given with 0.7 (Burström, Johannesson, & Diderichsen, 2001). The health state of institutionalized elderly is worse, as they often suffer from dementia and are in the need of special care, therefore their QALY-weight must be lower than the average. In this study a quality-adjusted life-time weight of 0.6 is used (Jaldell, 2012).
The loss of quality-adjusted life-time weights related to a hip fracture was the subject of many previous studies. The results of these studies give a QALY-weight loss ranging between 0.1 and 0.3 (Borgström, Zethraeus, & Johnell, 2006; Tosteson et al., 2001). Therefore in this study an average loss of 0.2 QALY-weights related to a hip fracture is assumed. As individuals fall at different points of time, for example in the beginning of a year losing the total amount of 0.2 QALY or in the end of the year losing less than the total amount, the average of 0.5 QALY-weights is related to an individual sustaining a hip fracture. The same principle was applied calculating the quality-adjusted lifetime weight related to death. Dying in the first days of a year in consequence to a hip fracture would reveal a loss of 0.6 QALY, while the same incidence in the end of the year would lead to a loss close to zero. For that reason the loss of QALY related to death is assumed to be 0.3 in the model.

The QALY-weights of the health related states for the base case are shown in table 3.

<table>
<thead>
<tr>
<th>Health related state</th>
<th>QALY-weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy</td>
<td>0.6</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>0.5</td>
</tr>
<tr>
<td>Death</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Tabel 3: QALY-weights for health related states in the base case

3.3. Sensitivity analysis

As every economic evaluation is based on some assumptions it will also contain a certain degree of uncertainty. Thus the robustness of the results of the base case study is tested with a sensibility analysis. Such an analysis contains of 3 steps: (1) identifying the uncertain parameters, (2) defining the range for these parameters and (3) calculating or simulating results within the defined ranges (Elliot & Payne, 2005) (Drummond, et al., 2005). The costs, benefits and probabilities used in this study are from literature studies and the experiment. Hence all these parameters contain uncertainty.
The data about costs related to the different health states have been determined in many previous studies and are assumed to be well-defined. Thus in the sensitivity-analysis a range of plus and minus 5 percent was selected.\footnote{Changes of 10 and 20 percent were also tested, leading to higher ranges and increased mean values, while median values were similar}

The quality-adjusted lifetime weights related to the different states of health were assumed to be (1) 0.6 for not falling or falling but not sustaining an injury, (2) 0.5 for case of falling and sustaining a hip fracture and (3) 0.3 for death as a consequence of the fracture. For all the three QALY-weights a range of plus and minus 0.1 QALY was selected in the sensitivity-analysis.

Since previous studies determined the risk of sustaining a hip fracture as a consequence of an accidental fall between 1 and 2 percent and regarding the probability calculated on the base of the experimental data, the risk for both, the absorbent and the standard floor, is assumed to vary between plus and minus 30 percent of the base case. Furthermore are the ranges for the rate of mortality and the risk of falling defined with 15 percent around the probabilities for the base case.

For the sensitivity analysis were 5000 randomly chosen parameters within the defined ranges drawn to calculate the ICER for the absorbent floor.
Table 4 provides an overview about the base case variables and the minimum and maximum ranges in the sensitivity analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Case</th>
<th>Sensitivity minimum</th>
<th>Sensitivity maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost no injury standard</td>
<td>32185</td>
<td>30576</td>
<td>33794</td>
</tr>
<tr>
<td>Cost hip fracture standard</td>
<td>107939</td>
<td>102542</td>
<td>113336</td>
</tr>
<tr>
<td>Cost death standard</td>
<td>116566</td>
<td>110738</td>
<td>122394</td>
</tr>
<tr>
<td>Cost no injury absorbent</td>
<td>34201</td>
<td>32491</td>
<td>35912</td>
</tr>
<tr>
<td>Cost hip fracture absorbent</td>
<td>109955</td>
<td>104458</td>
<td>115453</td>
</tr>
<tr>
<td>Cost death absorbent</td>
<td>118582</td>
<td>112653</td>
<td>124512</td>
</tr>
<tr>
<td>QALY-weight no injury</td>
<td>0.6</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>QALY-weight hip fracture</td>
<td>0.5</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>QALY-weight death</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Probability of falling</td>
<td>0.7</td>
<td>0.595</td>
<td>0.805</td>
</tr>
<tr>
<td>Probability of death</td>
<td>0.35</td>
<td>0.2975</td>
<td>0.4025</td>
</tr>
<tr>
<td>Probability hip fracture standard</td>
<td>0.016</td>
<td>0.0112</td>
<td>0.0208</td>
</tr>
<tr>
<td>Probability hip fracture absorbent</td>
<td>0.0016</td>
<td>0.00112</td>
<td>0.00208</td>
</tr>
</tbody>
</table>

*Table 4: Uncertain parameters for the base case and sensitivity analysis*
4. Results

For the base case the expected costs and QALY´s gained for an institutionalized elderly in Sweden were calculated using the defined probabilities and cost parameters (3.2.).

Using standard flooring the expected costs sum up to 33067 SEK and the expected QALY´s are 0.5981 for an individual in one year. In contrast to this installing the absorbent floor results in expected costs of 34290 SEK and expected QALY of 0.5998 per individual. The ICER, calculated as the difference in costs divided by the difference in QALYs, showing the cost per QALY gained, is about 713372 SEK.

\[ \text{ICER} = \frac{\text{cost (standard floor)} - \text{cost (absorbent floor)}}{\text{QALY (standard floor)} - \text{QALY (absorbent floor)}} = \frac{34290 - 33067}{0.5979 - 0.5981} = 713372 \text{ SEK} \] (3)

Figure 3 shows the cost-effectiveness plane for the ICERs resulting from the simulation, with the change in incremental QALY on the horizontal axis and the change in incremental cost on the vertical one.

Figure 3: cost-effectiveness plane for simulation of 5000 ICER
The threshold value of 500000 SEK is marked with the red line. ICERs below this red line are cost-effective, while those above are not. 1992 observations resulted in an ICER below the threshold value of 500000 SEK, which indicates that in only 39.84 percent of the simulations the absorbent floor was cost-effective in reducing hip fractures. Employing the higher maximum willingness to pay of 655000 SEK found by Persson (2003), increases the share of cost-effective outcomes to 46.98 percent.

Incremental cost-effectiveness ratios which are lying in the south east quadrant of the cost-effectiveness plane show the cases which provide cost saving, i.e. increased effectiveness at decreased costs. Totally 20 percent, which are exactly 1001 cases of the simulation, were pure cost saving. Table 5 provides an overview of the results of the simulation.

<table>
<thead>
<tr>
<th></th>
<th>cost saving</th>
<th>cost-effective</th>
<th>cost-effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of cases</td>
<td>1001</td>
<td>1992</td>
<td>2349</td>
</tr>
<tr>
<td>percentage share</td>
<td>20.02%</td>
<td>39.84%</td>
<td>46.98%</td>
</tr>
</tbody>
</table>

Table 5: Results of simulation applying different threshold values

Furthermore shows figure 4 a histogram, illustrating the distribution of the simulated results of the sensitivity analysis, excluding the 5 percent and the 95 percent quartiles. It can be seen that the probability distribution is positive skewed with a mean of 873959 SEK and a median of 719651 SEK.

![Histogram about simulation results, excluding 5 and 95 percent quartiles](image-url)
5. Discussion and Conclusion

The incremental cost for one quality-adjusted life year is 713,327 SEK in the base case. This can be compared to the maximum willingness to pay for a quality-adjusted life year. As already mentioned have different values been measured in previous studies. Nevertheless it is obvious that the ICER resulting from this study is more than 40 percent higher than the maximum willingness to pay of 500,000 SEK, which was presented by Johannesson (2001), and is suggested a threshold by the National Board of Health and Welfare (Socialstyrelsen, 2007) and still more than 8 percent higher than the threshold value of 655,000 SEK, calculated by Persson (2003). However, the results from the simulation show that almost 20 percent of the cases are pure cost savings representing increased effectiveness at decreased costs. The results can be seen as a borderline case, making it difficult to draw a conclusion about the cost-effectiveness of the absorbent flooring.

The probability of sustaining a hip fracture on the absorbent floor was assumed to be $Pr(fRACTURE-ABSORBENT FLOOR) = 0.0016$ in the calculation, based on literature studies. In contrast to this the data from the nursing home in Sunne indicate that the probability is close or even equal to zero, since under the experimental time period no fracture on the absorbent floor occurred as a consequence to accidental falls. Applying this value in the calculations the incremental cost for one quality-adjusted life year becomes 595,698 SEK\(^8\), which is between the both critical values applied in this study, which is an argument for interpreting the results as a borderline case.

Another limitation of this study is that in the cost-utility analysis only the impact on hip fractures was taken into account. This is due to the experimental data underlying the analysis, where only hip fractures were monitored. It would have been interesting to determine the impact of the absorbent floor on a broader number of injuries, such as head or soft tissue injuries. Taking these effects into consideration would provide a more significant result of the cost-utility, respectively cost-effectiveness, of the absorbent floor, which now can be undervalued. Furthermore can the short time horizon of the experiment, only 13 months, and

\(^8\) A more detailed overview of the results applying the probability of zero for sustaining a hip fracture on the absorbent floor in the calculations can be found in the Appendix.
the small sample size of the treatment group, containing just 12 individuals, represent another weakness of the study.

The use of the maximum willingness to pay as measurement, however, is strongly discussed in economic literature (Lundin, 2004). Instead of employing these values as benchmarks for cost-effectiveness it may be more reasonable to see them as an overall guide value. The calculations leading to these values are often complicated and based on strong assumption like for example the excludability of taxation effects. Furthermore are these threshold values usually not adjusted for price changes over the years, which again is an argument for using them just as “rule of thumb”.

There are not many previous studies the results can be compared to as the material for the absorbent flooring has just been invented and Sunne is among the first ones in Europe to test this kind of flooring. However, it would have been interesting to not just compare the absorbent flooring to the “status quo” but to other treatments like hip protectors or strength and agility training to decrease the risk and the consequences of accidental falls. Hence, further studies on this field are suggested.
References


Appendix

1. Results of the simulation with Pr(fracture-absorbent floor) = 0

Figur 5: cost-effectiveness plane for the simulation of 5000 ICER

<table>
<thead>
<tr>
<th>cost saving</th>
<th>cost-effective</th>
<th>cost-effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0 SEK</td>
<td>&lt; 500000 SEK</td>
<td>&lt; 655000 SEK</td>
</tr>
<tr>
<td>number of cases</td>
<td>1132</td>
<td>2335</td>
</tr>
<tr>
<td>percentage share</td>
<td>22.64%</td>
<td>46.7%</td>
</tr>
</tbody>
</table>

Tabel 6: Results of the simulation applying different threshold values