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Getting a grip on the effect of preventive public health interventions – A study of the economic benefits of subsidized ice cleats

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Abstract

Purpose: This thesis studies an ice cleat subsidy programme for seniors introduced in 2018 by Region Jönköping in Sweden. The aim of the study is to examine whether the subsidy was a cost-effective way of decreasing the number of Emergency room (ER) visits caused by snow and ice related fall injuries for seniors.

Methods: Data from Swedish Traffic Accident Data Acquisition (STRADA) is used for a Difference-in-Differences (DID) analysis to investigate whether the ice cleat subsidy reduces the number of ER visits. The cost-effectiveness of the subsidy is studied through an Incremental Cost Effectiveness Ratio (ICER) analysis.

Results: The cost-effectiveness analysis concludes that the subsidy could be cost-effective if it prevents 1,75% of the ER visits. The DID analysis reports a 20% decrease in ER visits, however the decrease is statistically insignificant.

Conclusions: The question whether a large-scale ice-cleat subsidy programme is cost-effective remains unanswered.

Keywords: QALY, ICER, ice grip, ice cleat, STRADA, pedestrian, traffic, injury, quality of life, DID, Difference-in-Difference, subsidy, Intent-to-Treat, weather, gender, negative binomial regression

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1. Introduction

If the old English proverb "An ounce of prevention is worth a pound of cure" were to be changed into the question, "is an ounce of prevention worth a pound of cure?", that would describe a dilemma facing many politicians and government officials concerned with the allocation of the often scarce funding to the government budget. The answer to that question is by no means clear-cut, and this debate has been going on for decades (Russel, 2012). One preventive measure which many governments are particularly interested in are preventive health interventions. The goal for these kinds of interventions are to increase the economic welfare for the citizens, of which health is an important component, and to decrease the costs of healthcare.

This thesis investigates the public health issue of preventive interventions through a health economic scope, with a focus on reducing the demand of health care. Falling accidents are an issue of particular interest for Swedish decision-makers to mitigate, since they are by far the most common accident to cause hospitalization in Sweden. Those most vulnerable to falling accidents are senior citizens. Sweden has an aging population where seniors make up twenty percent of the total population (Statistics Sweden 2020a). The large share of elderly inhabitants emphasizes the need of effectively preventing fall related injuries (Gyllensvärd, 2009). In 2018 alone, 69 487 people were hospitalized due to falls, of which 49 704 were over 65, according to the Swedish National Board of Health and Welfare (2019a, 2019b). Severe injuries such as bone fractures are a big spending item in regional healthcare budgets. Hip fractures alone are estimated to cost 14 billion SEK annually in both direct- and indirect costs according to The Swedish National Registry of hip fracture patient care (RIKSHÖFT, 2019). Falls that cause bone fractures are also particularly dangerous for seniors since these can have fatal outcomes. The Swedish Agency for Health Technology Assessment and Assessment of Social Services (2014b) estimated that about 8% of all elderly who had a hip fracture from falling died shortly thereafter.

Preventive actions can be taken to lessen the risk of falling, and thus, reduce the risk of suffering for seniors and costs of healthcare. Examples on an individual level are exercise and balance training. On a societal level, intervention programmes such as providing rollators, fixer services or snow clearing in the wintertime are common (Swedish National Board of Health and

Welfare, 2019b).[1] Pedestrian falls are a category of falling accidents that have been overlooked by researchers according to a literature review by Schepers, Den Brinker, Methorst & Helbich (2017). Single-pedestrian falls are much more common than pedestrian-vehicle collisions, yet pedestrian falls are not proportionately covered by the literature (Schyllander, 2014, Methorst et. al, 2015).

Sweden is a country with cold winters, making the population, seniors in particular, prone to snow and ice related falling injuries. Over time it has become increasingly common for local governments to provide free anti-slip devices, or ice cleats, to their senior citizens to reduce the number of pedestrian falls in the winter. However, it appears to be no consensus whether such intervention programmes are cost-effective. This is apparent in the case of Gothenburg, a municipality in which a large-scale ice cleat subsidy was introduced for inhabitants above the age of 65 in 2013. The Gothenburg programme has been removed, and then later reinstated due to shifts in the political landscape, where parties had different conclusions regarding the cost-effectiveness of the programme (Larsson, 2019; Ekström, 2019; Risenfors, 2019).

There are few studies on how large-scale programmes that provide ice cleats free of charge reduce injuries. We are investigating ice cleats programmes from a potential cost-effectiveness perspective and are enabling comparability between different interventions to prevent pedestrian falls. Comparability may aid decision-makers to allocate their healthcare budget as efficiently as possible. This thesis therefore aims to bridge economics with the public health literature of pedestrian injuries, public health of seniors, and preventive health programmes by applying a health economic lens.

This thesis aims to answer the related questions "*are ice cleats subsidy programmes a cost-effective preventive health intervention?*" and "*are ice cleats subsidy programmes a successful way of decreasing pedestrian falls among seniors?*". This is done by examining the ice cleats subsidy programme introduced by Region Jönköping, Sweden, in 2018. The subsidy is aimed at preventing fall accidents among senior citizens by providing free ice cleats.

[1] Fixer services are free services provided by municipalities to reduce injury risks for elders. Examples of these services are change of drapes or change of lightbulbs in ceiling lamps.

Our study provides an economic evaluation which estimates the required number of prevented ER visits for the implementation of an ice cleats programme to be cost-effective. The cost-effectiveness is investigated by using a willingness to pay estimate for quality of life gains (Olofsson, Gerdtham, Hultkrantz, & Persson, 2019), along with monetary thresholds from the National Board of Health and Welfare (2018). These are used in an Incremental Cost-Effectiveness Ratio analysis to determine potential cost-effectiveness per Quality-Adjusted Life-Year gained. Our study is the first to investigate these aspects from the perspective of Incremental Cost-Effectiveness Ratios.[2] Cost-effectiveness analysis facilitates utility maximization in preventive health programmes, that is, maximizing the gained health improvements per spent unit of taxpayer money.

We perform a quasi-experiment to study the effect on reducing Emergency Room (ER) visits by implementing an ice cleats subsidy programme. The effect is estimated by a using the Difference-in-Differences methodology. The analysis investigates a possible reduction of ER visits per 100 000 inhabitants from pedestrian falls due to ice or snow in Region Jönköping. The estimated reduction in the number of ER visits is compared to the reduction required for cost-effectiveness. Our thesis complements previous studies on the impact of this type of policies by retesting their hypothesis in a different setting. Our main contributions are to add control variables for weather conditions and by investigating gender differences in reduced injury incidence, as proposed by previous research (Bonander & Holmberg, 2019).

The study is investigating the *Intent-to-Treat effect* of being eligible for subsidy programme for free ice cleats in Region Jönköping in 2018. The advantage of this approach is that we can account for real world human behaviours, such as non-adherence to the assigned treatment (Angrist & Pischke, 2015; Detry & Lewis, 2014). This enables us to analyse the effectiveness of the subsidy programme itself rather than the effeteness of ice cleats.

The key result of the cost-effectiveness analysis shows that any reduction in the number of ER visits is in some degree cost-effective. It is however uncertain whether the ice cleat subsidy does reduce the number of ER visits. The results from the Difference-in-Differences analysis show a reduction of over 20% in the number of ER visits for seniors in the treatment group after

[2] The PubMed database was searched with the key words: (((QALY*) AND ICER) AND ice cleat*) OR ice grip*

the implementation. However, these estimates are not statistically significant, likely due to too few observations.

2.1 Background

2.1.1. Policy history

Our thesis studies the ice cleats subsidy programme in Region Jönköping which was decided by the regional council in 2017. The programme was provided a budget of 2 million SEK. A total of 41 000 ice cleats were purchased for the winter of 2018, and the distribution started at the end of October 2018. The ice cleats were available to seniors aged 65 and older for free at primary healthcare centres, and 38 500 ice cleats were claimed (Region Jönköping, 2018; Naskret, 2018; U. Stefansson, personal communication, January 24th, 2020). The population eligible for free ice cleats was 75 127, according to population data from Statistics Sweden (2020a), which indicates that roughly 50% of all seniors in Region Jönköping collected a pair of ice cleats. The total cost of a single pair of ice cleats for the programme is calculated to 48-52 SEK.[3]

2.1.2 Literature review

Many Swedish municipalities have introduced programmes to hand out free ice cleats to the elderly in the community to prevent pedestrian falls in the winter (Swedish National Pensioners' Organisation, 2018). The fall-preventing effect of ice cleats has been studied in an intervention study by Berggård & Johansson (2010). The authors concluded that those who were provided with free ice cleats had a higher tendency to use them compared to those who had to acquire ice cleats themselves. The study found that using ice cleats decreases fall accidents and increases the daily walking distances, but the results were insignificant. Another intervention study, in Wisconsin, USA, (McKiernan, 2005) did find a significant reduction of falls when studying the effects of anti-slip devices similar to the ice cleats in the Swedish study. Although it is important to note that both studies were based on small samples, the studies may suggest that a programme for free ice cleats to seniors would increase the use of ice cleats and perhaps a reduction of pedestrian falls.

[3] The cost per ice cleat depends on whether the assigned budget is allocated to all purchased ice cleats or just those that were collected.

The effect of a large-scale subsidy programme of ice cleats to seniors was studied by Bonander & Holmberg (2019). The authors suggested with a Difference-in-Differences analysis that the number of pedestrian falls among senior citizens in Gothenburg was significantly reduced by 45% in the first year when free ice cleats were introduced to all seniors above the age of 65. The authors further suggested that the policy was an economic success. These suggestions are however based on calendar years instead of winter seasons. The results were no longer statistically significant once winter seasons were considered. We expand on their study by investigating the generalizability of their findings, as well as any differing effects based on gender.

A study on pedestrian falls among senior citizens concludes that a majority of the accidents occur in the winter months, December through March (Gyllencreutz, Björnstig, Rolfsman, & Saveman, 2015). Half of the pedestrians in the study suffered fractures from the accident, with hip fractures being the most common. According to a report from the Swedish National Road and Transport Research Institute (Eriksson & Sörensen, 2015), most falling accidents occur either when it’s snowing or when the temperature fluctuates around zero. A Norwegian study also found that the risk of injury in the winter season is higher for older individuals (Elvik & Bjørnskau, 2019). These findings emphasise the importance of studying whether ice cleats subsidy programmes could reduce fall accidents among seniors in particular. The increased risk of falling for seniors during colder weather warrant us to control for weather in the econometric specification.

Severe falling accidents most commonly induce hip fractures, along with wrist-, vertebral-, and arm- and shoulder fractures (Hartholt et al., 2011; Rundgren, Bojan, Mellstrand Navarro & Enocson, 2020; Berry & Miller, 2008; Huffman, Pignolo, Keenan & Hebela, 2011). Therefore, we include the distribution of the most common injuries following a pedestrian fall in our economic evaluation. We investigate how these injuries negatively affect the utility of impacted seniors and how much the injuries cost for Region Jönköping.

Fractures further disproportionately affect women (Gyllencreutz, Björnstig, Rolfsman, & Saveman, 2015; Olofsson et al. 2016; Berry & Miller, 2008), which is explained by women being more prone to osteoporosis (Alswat, 2017). The skewed impact towards women further warrant gender separate analysis as proposed by Bonander & Holmberg (2019).

Falling accidents are not only costly for the healthcare system, they are most importantly a cause of much pain and suffering, causing a decrease in *quality of life* for those affected. The reduction in quality of life is also caused by psychological factors resulting from the fall, such as fear of going outside and a decrease of independence (Ambrose, Cruz & Paul, 2015). The loss of quality of life can be quantified, and a standardized method for estimating a value of different health outcomes is Quality-Adjusted Life-Years (QALY) (Nord, 2014; Dolan, P. 1995). Some reports have estimated the costs and the reduction in quality of life associated with different kinds of falling accidents. A report by the Swedish National Institute of Public Health (Gyllensvärd, 2009) estimated the cost in QALYs for all falling accidents for senior citizens, and The Swedish Institute for Health Economics (Olofsson et al., 2016; Persson & Olofsson, 2014) did the same for pedestrian falls in the general population. Falling accidents may also have spillover effects by affecting the quality of life of family members (Wittenberg, James & Prosser, 2019) and some health economists argue that these aspects should be included (Brouwer, 2019). Spillover effects of QALYs are however a fairly new field of health economics and are not typically not included, hence omitted in our analysis.

In studies of whether to implement preventive health intervention programmes, e.g. vaccination programmes (Public Health Agency of Sweden, 2016), it is common to estimate cost-effectiveness of the programme with the Incremental Cost-Effectiveness Ratio (ICER). This is the ratio between the total change in costs divided by the change in quality of life. This value can then be analysed by comparing it to a threshold monetary value or with ICER values of other presumptive intervention programmes to determine if the programme should be implemented (Public Health Agency of Sweden, 2019).

Summarily, pedestrian falls due to ice and snow are causing much suffering for senior citizens and has scarcely been covered by previous public health research. The study on the economic aspects have been even fewer. Bonander & Holmberg (2019) investigated a subsidy of large-scale ice cleats provision to seniors with mixed results. The approach of our thesis is to retest the hypothesis, and further attempt to develop the method of measuring the effect by adding weather control variables and by investigating genders separately. Our approach of cost-effectiveness contributes by applying the QALY approach, allowing for comparability between different interventions.

2.2 Theoretical framework

Cost-effectiveness analysis is a popular form of economic evaluation of health policies, in which Quality-Adjusted Life-Years is a central concept. This approach is used to compare or rank different health interventions based on their health outcomes (World Health Organization, 2016). The economic foundations of cost-effectiveness analysis are based on classical utility maximization theory. In this case, the utility is maximized when the most QALY have been gained, within the constraint of the healthcare budget.

The calculation of QALY is described in formula (1).

$$QALY_i = Q_i * L_i \qquad (1)$$

The health outcome for an *average* individual *i* is calculated by multiplying an estimator of the quality of life Q_i, with the amount of time in years L_i, they are expected to live with that quality of life.[4] The quality of life ranges in a continuous span between 1 and 0, i.e. between being perfectly healthy, having full quality of life, and being dead, having no quality of life.[5] The quality of life can be interpreted as a discount factor on life expectancy, e.g. living one year with perfect health is valued the same as living 2 years with quality of life reduced by half.

QALY is used when calculating the Incremental Cost-Effectiveness Ratio (ICER). This captures the difference in cost and benefit between a proposed health intervention and the status quo. ICER is described in formula (2) (World Health Organization, 2016; Drummond, Sculpher, Claxton, Stoddart & Torrance, 2015).

$$ICER = \frac{Cost_{intervention} - Cost_{status\ quo}}{QALYs_{intervention} - QALYs_{stats\ quo}} = \frac{\Delta Cost}{\Delta QALYs} \qquad (2)$$

ICER analysis is suitable if the intervention has a better QALY outcome and a higher monetary cost compared to the status quo (Swedish Agency for Health Technology Assessment and Assessment of Social Services, 2014a). If a proposed intervention would increase QALY for a lower price than status quo, or conversely, a decrease in QALY for a higher price in status quo, no ICER analysis is required since that would be a definitive yes, and a definitive no, about implementing the intervention.

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[4] The average individual has a distribution of age and gender and is presented in Appendix 2.

[5] The QALY value can be negative (Bernfort L, Gerdle B, Husberg M, Levin LÅ, 2018; Dolan, P. 1995). Negative QALYs are however not applicable in the setting of this study.

ICER is a comparative tool that allows decision-makers to compare the cost per gained QALY from an intervention, A, versus keeping the status quo, B. If there is an intervention C, which can give larger gains in QALYs but at a higher cost, then it is possible to compare intervention C and A to see which are the most cost-effective per gained QALY. In this thesis however, we only investigate a single intervention to the status quo.

3.1 Methodology

We present our ICER methodology and Difference-in-Differences approach in this section. We use ICER to estimate a hypothetical cost per additional QALY for each potentially avoided ER visit that an ice cleats subsidy could prevent. This is used to determine the potential cost-effectiveness of ice cleats programme in Region Jönköping. The costs in our analysis are evaluated on a societal perspective with Region Jönköping as payer.[6] Our Difference-in-Differences analysis is performed to investigate whether the programme was successful in reducing ER visits due to ice and snow.

3.1.1 Incremental Cost-Effectiveness Ratio Analysis

The numerator of ICER formula (2) is the cost of the ice cleat programme and the change in healthcare costs, as described by formula (3).

$$\Delta Cost = (\Delta Healthcare\ costs) + (Cost\ of\ programme) \qquad (3)$$

Healthcare costs change with the number of prevented ER visits *n*, i.e. the more accidents prevented the more healthcare costs saved. The change in healthcare costs is expected to be negative, since the implementation of the programme will plausibly be associated with a decrease in healthcare costs. The cost of the programme is equal to the budget of the ice cleat subsidy.

The denominator of the ICER formula (2) is illustrated in formula (4). The difference in QALY, is estimated by summing all the falling accidents estimated to be avoided by the programme and calculating how many QALYs are expected to be gained from it.

[6] Region Jönköping is responsible both for the cost of the ice cleats subsidy and for the costs of health care for its inhabitants. The costs per injury are estimated to include all surrounding costs of healthcare.

$$\Delta QALYs = \sum_{i=1}^{N}([Q_i * L_i] - [\sum_{\tau}^{\mathrm{T}}(Q_i - S_\tau) * L_i * \rho_\tau]) \quad (4)$$

Formula (4) calculates gained QALYs by using the initial level of quality of life, Q_i, the average life expectancy, L_i, the reduction of quality of life, S_τ, associated with an injury τ, which occurs with the probability ρ_τ. The first term with brackets on the right-hand side calculates the QALY value for individuals when N number of falling accidents are avoided, and thus keep their QALY unchanged. The second term with brackets, the status-quo scenario, calculates the expected loss of QALYs associated with a falling accident. The difference is the expected gain in QALYs that follow from preventing a falling accident.

The benefit-function only varies with respect to the number of avoided ER visits. In the model, the loss of quality of life is assumed to be constant over time since the estimates used for the loss of life quality are estimated for one year after the accident and many seniors don't ever regain the quality of life they had before the accident (Schyllander, 2014; Ambrose, Cruz & Paul, 2015). The lasting reduction in quality of life following a fracture is in line with previous studies on the long-term recovery fractures (Ström et al. ,2008; Cooper, 1997).

The model time horizon should capture the health- and cost-implications of the policy (Drummond, Sculpher, Claxton, Stoddart & Torrance, 2015). We have set the time horizon as the expected remaining life span of the seniors to capture the time spent with the consequences of a pedestrian fall. Lastly, a discount rate of 3% on QALYs is applied, in line with Swedish health economic evaluations (Dental and Pharmaceutical Benefits Agency, 2003). This accounts for time preferences, and the discounting will be applied at the end of the period.

In the setting of this study, the ICER formula becomes formula (5).

$$ICER = \frac{\Delta Cost}{\Delta \text{QALYs}} = \frac{(\Delta Care\ expenditure) + (Cost\ of\ programme)}{\sum_{i=1}^{N}[Q_i * L_i] - [\sum_{\tau}^{\mathrm{T}}(Q_i - S_\tau) * L_i * \rho_\tau]} \quad (5)$$

Summarily, the ICER will be calculated by using the costs and QALYs for the two scenarios; ice cleats programme and status quo, with the programme preventing N fall related ER visits and status quo preventing none. The ICER value will then be compared to threshold values of the willingness to pay for an increase in QALYs, to conclude whether the Region Jönköping ice cleats subsidy programme is cost-effective.

When using a model to explain reality certain simplifying assumptions are often required to make the model feasible. The underlying assumptions of our ICER are the following. The loss of QALY is permanent, life expectancy is unaffected by being injured, using ice cleats do not have any other effects than preventing a pedestrian fall, the risk of fractures is constant, only the most common injuries are included, and lastly, any spillover effects are excluded. These assumptions will lead to a conservative estimate of gained QALYs.

Finally, to emphasize the inherent uncertainty of the model, a sensitivity analysis of the model is performed by altering each variable used in the calculation, while holding all other variables constant. The examined variables are the cost of the ice cleat subsidy, costs of healthcare, risks of suffering more/less severe injuries, discount rate of QALYs, and the assumption of permanent QALY reduction.

3.1.2 Difference-in-Differences methodology

To estimate the effect of the ice cleats subsidy programme, we use the following Difference-in-Differences (DID) model specification, both for the full sample and separately for men and women:

$$Y_{mt} = \alpha + \beta Treatment + \gamma Post_t + \delta Post_t * Treatment + \mu_m + \theta_{mt} + \epsilon_{mt} \qquad (6)$$

Where Y_{mt} is the *ER visits per 100 000 inhabitants* observed in municipality *m* at time *t*. *Treatment* is a dummy variable indicating whether the age group was treated or not in 2018, when the ice cleats programme was implemented. $Post$ is a dummy variable indicating whether time *t* is post-intervention, i.e. 2018. δ is the coefficient for the difference between treatment- and control group post-treatment. The model also includes municipality fixed effects, μ_m, which intend to capture the invariant differences between the municipalities in the sample. The specification also includes control variables for weather conditions, θ_{mt}. These weather control variables are interacted with the treatment dummy to allow for weather conditions to have different effects on the treatment group and the control group, thus improving the precision of the difference-in-differences estimator.

The parameter of interest in the model is the coefficient of the interaction in the post-treatment year, δ_{2018}, labelled as "*Treatment effect in 2018*" in the result section. This coefficient will estimate the difference-in-differences effect, i.e. the effect of ice cleats on the treatment group compared to pre-treatment and the control group. The goal of the control group is to control for underlying trends in the data and stand in as a counterfactual observation of what would have happened without the programme. (Stock & Watson, 2015; Angrist & Pischke, 2008, 2014). The coefficient will be negative if the ice cleats programme is associated with a decrease in ER visits.

The treatment group consists of all senior inhabitants in Region Jönköping aged 65 and above. This age group was eligible for free ice cleats in 2018. The control group consist of inhabitants in Region Jönköping aged 55-64, which was ineligible to receive free ice cleats. This age group is likely to exhibit similar patterns in pedestrian falls as the control group according to reports by Schyllander (2014), and Eriksson & Sörensen (2015).

The main analysis is made with the specification in (6) using an ordinary linear regression, in line with Bonander & Holmberg (2019). An additional regression, using negative binomial distribution is performed to account for skewness in our data. In this version of the model the dependent variable is changed to the absolute *number of ER visits* instead of *ER visits per 100 000 inhabitants*. This is necessary because the negative binomial distribution is a count data distribution, i.e. a distribution for integers (Cameron & Trivedi, 2013). The negative binomial regression measures the prevalence instead of the incidence of ER visits, but the result is equally useful for the analysis.

The standard errors are clustered on a municipal level which results in few clusters, *N=12*. Further, there is inherent cross-correlation in the data, across years within the same municipalities. These properties will cause our standard errors to be downward biased, and therefore more likely to over-reject the null hypothesis. (Khotari & Warner, 2007; Angrist & Pischke, 2008; Cameron, Gelbach & Miller, 2008). Therefore, wild cluster bootstrapped standard errors are used as a sensitivity check in postestimation to correct the standard errors of any significant coefficients.

Parallel trends for the treatment and control group is the most important assumption for the DID methodology, i.e. the groups must share similar change of patterns in the measured outcome variable after the policy changes. This cannot be directly tested, since we cannot observe the treatment group in 2018 without any treatment. However, if the treatment- and control group have parallel trends before the treatment year, it is plausible to assume that they would have continued having parallel trends after treatment too.

In the setting of this study, the DID methodology will estimate the Intent-to-Treat (ITT) effect. This is the effect observed on those allocated to the treatment group and does not depend on the adherence to treatment in the treatment group. Instead, it is assumed that the treatment- and control group consist of three kinds of subjects: *compliers*, *always-takers* and *never-takers*. *Compliers* will comply with the treatment, which is to always be using ice cleats if given them for free, and conversely, not using any ice cleats if not assigned them for free. The *always-takers* are those who always pick the treatment, i.e. even if not assigned ice cleats for free, they use ice cleats which they have acquired themselves. The *never-takers* are those who never picks the treatment, i.e. even though getting free ice cleats, they do not use them. In a randomized, or "as if randomized" sample, it is assumed that the share of compliers, always-takers and never-takers are the same within each group (Angrist & Pischke, 2015; Detry & Lewis, 2014). In this context, we are assuming to have an "as if randomized" sample. Furthermore, since the model acknowledges the different adherence to the allocated group, it does have value for the study since it shows the effect of human behaviour in a real-world setting. It should be noted though that a sample with many never-takers or always-takers increases the risk of not being able to identify an effect of the ice cleats programme.

3.2 Data

3.2.1 Data for ICER analysis

To determine the change of healthcare costs and change in quality of life in the ICER formula, the different outcomes of a snow or ice related ER visits are categorized in three different degrees of severity: fatal-, severe- and minor injuries. A fatal injury results in the death of an individual, with quality of life equal to 0. The severe injuries decrease the quality point of life for an individual below the starting level and require surgery, thus increase healthcare spending. The severe injuries are comprised of four subcategories based on the most common injuries: hip-, vertebra-, wrist- and shoulder fractures.[7] Minor injuries are simplified to have no long run

[7] Femoral neck fractures, vertebral compression fractures, distal radius or ulna fractures, and humerus fractures.

effect on the quality of life.[8] The treatment group is divided into two age groups, 65-74 and 75+, to more accurately measure the changes in gained and lost QALYs.

The probabilities of suffering certain injuries, and the associated reduction in quality of life, are calculated by using the relative relationships of reported severe and fatal injuries by The National Board of Health and Welfare (Gyllensvärd, 2009). The number of minor injuries is estimated through an approximation by the Swedish Rescue Services Agency (2003) that 60% of injuries by elderly are deemed to be minor. This results in 1,45% probability of having a fatal injury, 38,55% probability of a severe injury and 60% probability of a minor injury.

It should be noted that probabilities for the different outcomes are not based on pedestrian falls due snow and ice but from the general risk of falling for seniors, both indoors and outdoors. Higher rates of severe accidents were estimated by Gyllencreutz, Björnstig, Rolfsman & Saveman, (2015) when studying elderly falls outside, though with a small sample. As a precaution, the lower rate of severe injuries and higher rate of minor injuries, presented by Gyllensvärd (2009), will be used as not to overestimate any reductions in healthcare costs or QALY gains. This makes our model render relatively conservative estimates for the gained QALYs.

The distribution of ER visits is estimated by using a database consisting of all registered pedestrian falls resulting in an emergency room visit between 2012-2018, acquired from STRADA, Swedish Traffic Accident Data Acquisition. The data in this database is collected from hospitals with emergency rooms in Sweden and has been gradually increasing its accident coverage between 1999 and 2015. STRADA has nationwide data coverage since 2016. The inclusion year per hospital in Region Jönköping is included in appendix 1 and shows that all hospitals in this study have had a complete registry during the time frame of the study. This data set has been cleaned to only include observations with the keyword "snow" or "ice" in the description of the road conditions.

The estimated distribution of ER visits is based on age group and gender and is presented in appendix 2. Table A2.1 presents the distribution of age group and gender for every avoided ER

[8] Examples of minor injuries are bruises, scratches and other superficial wounds. These injuries are assumed to not require additional medical attendance after the initial ER visit. This approach will lead to an underestimation of gained QALYs.

visit, derived from the STRADA data on falls up until 2018. Table A2.2 presents the weighted probabilities of injury severity for each avoided ER visit by gender and age group. The weighted probabilities are obtained by multiplying the distribution of non-weighted probability of injury severity obtained from Gyllensvärd (2009) with the distribution presented in table A2.1. The expected remaining life span has been adjusted with data from Statistics Sweden (2020a; 2020b).

The healthcare costs are based on estimates of costs per outcome. The costs for hip-, vertebra-, wrist-, and shoulder fractures, minor injuries, and death are collected from the report by The National Board of Health and Welfare (Gyllensvärd, 2009), and are presented in table 1 along with the distribution of each outcome. These cost calculations intend to capture all healthcare costs associated with the different injuries. To get a fair estimate of the costs per injury in 2018, the costs have been adjusted for inflation using Consumer Price Index data (Statistics Sweden, 2020c), and then increased with the same rate as the net cost of healthcare per capita during the same time period in Region Jönköping, which is approximately 20% (Swedish Association of Local Authorities and Regions, 2019).

Table 1: Cost estimates per fall outcome

Fall outcome	Cost estimate 2006	Cost estimate 2018	Distribution (full sample)
Hip fracture	129 886	154 593	21,16%
Vertebra fracture	131 485	156 497	6,58%
Wrist fracture	18 117	21 563	3,72%
Shoulder fracture	59 092	70 333	7,10%
Minor injury	2 813	3 348	60%
Death	36 465	43 402	1,45%

Sources: Gyllensvärd (2009), Statistics Sweden (2020c) and Swedish Association of Local Authorities and Regions (2019)

The cost of the ice cleats is set to 2 million SEK, as the ice cleats programme was allocated 2 million SEK in regional budget 2018 (Region Jönköping, 2018). Cost of keeping status quo will be set to zero, i.e. no cost for any programme and no reduction in healthcare costs.

Data for the benefit functions, quality of life, is presented in table 2. Data for the age group 65-74 is directly obtained from The National Board of Health and Welfare (Gyllensvärd, 2009) and the quality of life for the age group 75+ is a mean value of two age groups (75-84 and 85+) presented in the report by Gyllensvärd. The expected remaining life span in years is calculated with population data from Statistics Sweden (2020a, 2020b).

Table 2: Health statistics of seniors

Age group	Quality of life Q_i	Expected remaining life span in years (average) L_i, Men	Expected remaining life span in years (average) L_i, Women	Expected remaining life span in years (average) L_i, Men and Women
65–74	0,8	15,99	18,16	17,09
75+	0,74	8,46	9,25	8,91

Source: Gyllensvärd (2009) and Statistics Sweden (2020a, 2020b).

Table 3 presents statistics obtained from The National Board of Health and Welfare (Gyllensvärd, 2009) on how the different injury outcomes affect the quality of life for an individual. The change in quality of life is assumed to be the same for both age groups and genders for severe and minor injuries. A fatal outcome reduces the quality of life to zero. This makes the quality of life loss higher for the younger group since they have a higher initial quality of life.

Table 3: Changes in quality of life after suffering a fall accident

Type of injury τ	Change in quality of life S_τ	Age group
Fatal	-0,8	65-74
Fatal	-0,74	75+
Hip	-0,17	Full Sample
Vertebra	-0,26	Full Sample
Wrist	-0,06	Full Sample
Shoulder	-0,115	Full Sample

Source: Gyllensvärd (2009)

The threshold value for the analysis come from a Swedish study of the willingness to pay for QALY improvements, which concluded that the willingness to pay is approximately 300 000€ regardless of the severity of the injury (Olofsson, Gerdtham, Hultkrantz & Persson, 2019). This corresponds to 2 785 000 when converted to SEK with the 2018 average exchange rate (European Central Bank, 2020). Other threshold values for cost per additional QALY have been obtained from The National Board of Health and Welfare (2018) which value the cost of a QALY which they use in various national guideline documents for public health interventions. They will be used to classify to which degree, if any, the programme was cost-effective. These cost-effectiveness thresholds are combined and presented in table 4.

Table 4: ICER thresholds

Threshold	Cost per additional QALY
Low cost	< 100 000 SEK †
Moderate cost	100 000 – 499 999 SEK †
High cost	500 000 – 1 000 000 SEK †
Very High cost	1 000 000 SEK † – 2 785 000 SEK*

The upper threshold for the Very High cost uses the maximum willingness to pay for a QALY, estimated by Olofsson et al. (2019)

Source: The National Board of Health and Welfare (2018)† and Olofsson, Gerdtham, Hultkrantz & Persson (2019)*

3.2.2 Data for Difference-in-Differences regression

3.2.2.1 Variables

The variables for the DID regression originate from the same STRADA database described in section 3.2.1., with ER visits due to ice or snow. The groups we focus on are defined by binned gender and age, and by using population data from Statistics Sweden, we created our main dependent variable: *ER visits per 100 000 inhabitants*, which varies at municipality- and year level.

Data on daily weather observations was obtained through NOAA, National Oceanic and Atmospheric Administration (2020), for all active weather stations in Region Jönköping between 2012-2018. After matching weather stations with our sample municipalities by coordinate data, control variables were created which are meant to capture weather that will increase the risk of falling. This to account for the findings by Eriksson & Sörensen (2015), that most falling accidents occur when either when it is snowing or when the temperature fluctuates around zero. Therefore, the control variables created are the number of days per winter with snowfall and the number of days per winter with temperature fluctuations going from below freezing to just above freezing temperatures.

3.2.2.2 Sample selection

The general characteristics of the sample groups are presented in table 5. Worth noting is that women are overrepresented in the sample, this is however in line with previous research (Gyllencreutz, Björnstig, Rolfsman, & Saveman, 2015; Olofsson et al. 2016; Berry & Miller, 2008). Additionally, the ER visits per 100 000 inhabitants seem similar between the treatment group and the control group, and the share of women and men within each group are almost identical. This implies that our samples are balanced and could be considered "as if randomized" from a gender perspective.

The sample consists of 12 municipalities in Jönköping county that have been covered by the county programme for free ice cleats for senior citizens during the winter season of 2018. The municipality of Tranås has been excluded since they introduced a programme of their own two years prior to the county programme, which then was cancelled. By excluding this municipality, we create a balanced dataset where all included municipalities were treated only once, and at the same time.

The time frame for the study is set to November 2012 – March 2019, and contains a set of 7 winter seasons, where November year *t* through March year *t+1* are designated as winter season year *t*. This creates 6 winter seasons before the implementation of the programme to check for any existing pre-trends in the data. This definition of a winter season creates a balanced set of seasons, with a clear post-intervention season, since the free ice grips programme was launched in the end of October 2018. With this limitation, ER visits occurring in April and October were dropped.[9]

Table 5: Sample characteristics

	Characteristics	**All**	**Men**	**Women**
Treatment Group	Age group	65+	65+	65+
	ER visits, total	400	123	277
	Average # ER visits per year	57	18	40
	Average population per year	67 689	36 657	31 032
	Average ER visits per 100 000, per year	84,2	49,1	128,9
Control Group	Age group	55-64	55-64	55-64
	ER visits, total	255	79	176
	Average # ER visits per year	36	11	25
	Average population per year	38 716	19 025	19 691
	Average ER visits per 100 000, per year	93	57,8	127
Weather	Average # days per winter with snowing	11,2	11,2	11,2
	Average # days per winter with fluctuating temperatures	44	44	44

Source: Swedish Traffic Accident Data Acquisition and National Oceanic and Atmospheric Administration (2020)

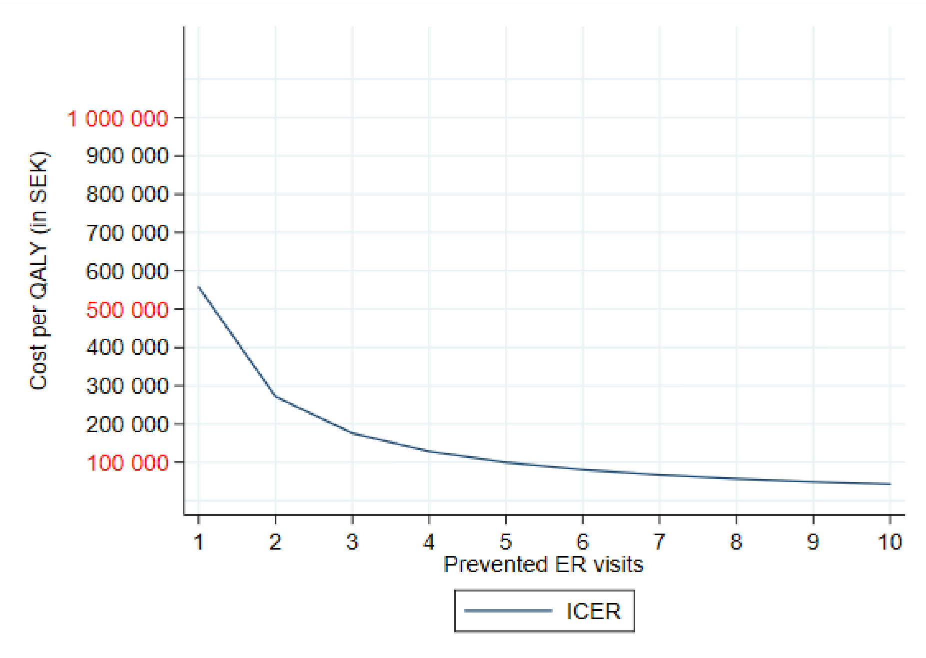
[9] 8 out of 656 ER visits were dropped. 1 in April 2013 and 7 in October 2018.

4.1 ICER results

The number of prevented ER visits that is required for the subsidy to be cost-effective is dependent on the willingness to pay per gained QALY. The underlying assumptions behind the gained QALYs in the ICER rests on the scenario in which the individual(s) do not fall compared to a scenario where the individual(s) falls and suffers a permanent reduction in their quality of life but with unchanged life expectancy. The average annual number of snow related ER visits in Region Jönköping is 57 for inhabitants aged 65 or older. Each potential prevented ER visit corresponds to a decrease of 1,75% of the annual average of 57.

Figure 1 shows the ICER results. The red values in the graph correspond to the different thresholds of cost-effectiveness used by The National Board of Health and Welfare (2018), and Olofsson et al. (2019), found in table 4.

Figure 1: Main ICER results



The ICER of the first avoided ER visit is about 550 000 SEK per additional QALY, making it cost-effective at the high cost threshold of up to 1 000 000 SEK per additional QALY. The second avoided ER visit has an ICER of 270 000 SEK and is below the moderately cost-effective threshold of 500 000 SEK per additional QALY. Five or more avoided ER visits result in an ICER below the low cost per additional QALY, i.e. below 100 000 SEK per additional QALY.

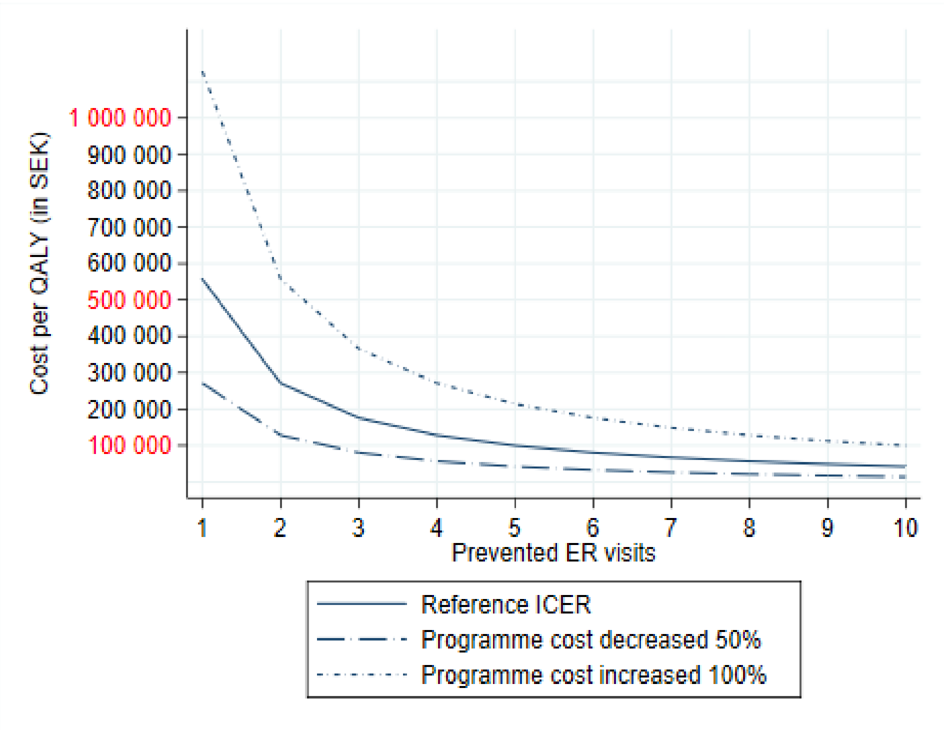
Appendix 3 presents more detailed economic results. Table A3.1 presents the cost per additional QALY per avoided ER visit. Table A3.2 presents the *expected* number of ER visits required for cost effectiveness for the main results and the sensitivity analysis results presented in the next subsection.

4.1.1 Sensitivity analysis of economic results

The sensitivity of the ICER model is investigated by changing one of the components in the economic analysis, keeping all other components constant. All graphs include the main ICER result as a reference.

Figure 2 investigates how the cost of the ice cleats and administration of the subsidy programme affect the cost-effectiveness of the policy. The dashed line assumes a cost decrease of 50%, i.e. a total cost of the subsidy programme of 1 000 000 SEK. This would create cost-effectiveness below the 500 000 SEK threshold at the first prevented ER visit. The dotted line assumes a cost increase of 100%, i.e. a total cost of 4 000 000 SEK in which the policy would still be cost-effective below the 2 785 000 SEK threshold for the first avoided ER visit.

Figure 2: ICER sensitivity of subsidy cost



The Dental and Pharmaceutical Benefits Agency (2003) recommends that health outcomes should be discounted by five percent and zero percent in a sensitivity analysis and is included in Figure 3.

The dashed line assumes no discount rate. This is the most generous approximation of gained QALYs. The number of avoided ER visits decreases from five to four for cost-effectiveness at the 100 000 SEK threshold. Moderate cost-effectiveness below 500 000 SEK per additional QALY is achieved at the second avoided ER visit.

The dotted line applies a discount factor of 5%. The policy is still cost-effective at the 1 000 000 SEK per additional QALY threshold value if one ER visit is avoided and cost-effective at the moderate level of 500 000 SEK per additional QALY if two ER visits are avoided. The number of avoided injuries needs to increase from five to seven for the policy to be cost effective at the 100 000 SEK level.

Figure 3: ICER sensitivity of discount rate

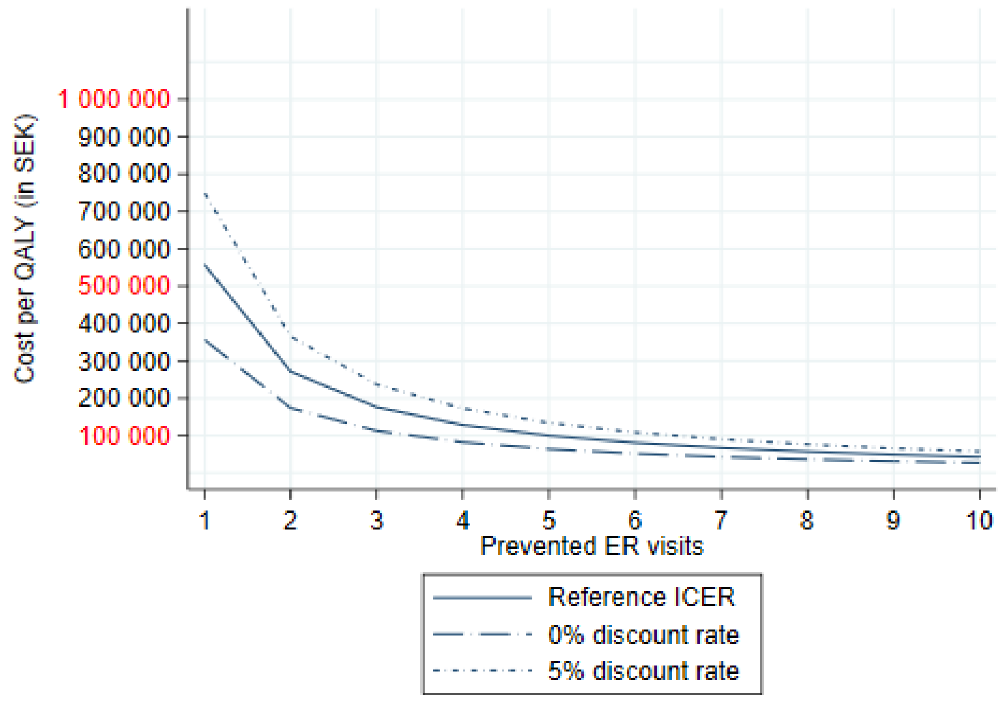
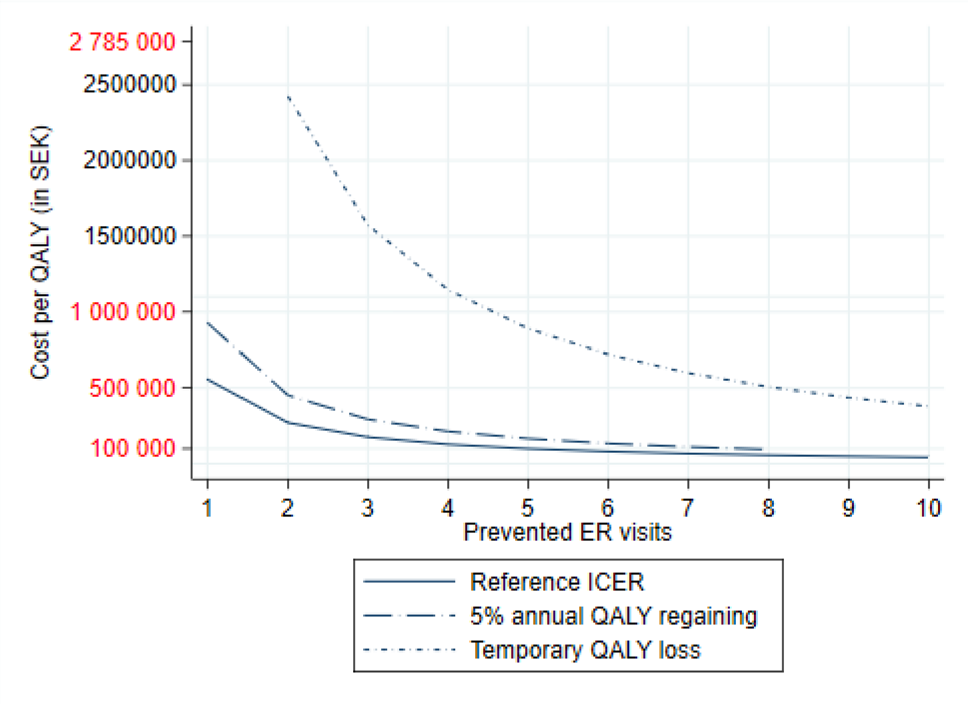


Figure 4 explores how different assumptions of QALY loss affect the cost per additional QALY. The dashed line assumes a degree of rehabilitation where injured individual(s) regains their lost quality of life over time. Instead of a permanent quality of life loss after a pedestrian fall, the lost quality of life increases by 5% annually. Thus, the scenario in which the individual(s) do not fall is compared to the scenario where the individual(s) fall but regain quality of life gradually. The policy is cost-effective at the high cost threshold up to 1 000 000 SEK per additional QALY for the first avoided ER visit. Moderate cost-effectiveness up to 500 00 SEK per additional QALY is achieved for the second avoided ER visit. Cost-effectiveness below 100 000 SEK per additional QALY is achieved by the eight avoided ER visit.

The dotted line assumes that the reduction in quality of life is limited to one year for the injured individual(s). A scenario in which the individual(s) do not fall is compared to the scenario where the individual(s) fall but only suffers a reduction in quality of life for one year. The dotted line is the most conservative approximation of gained QALYs. This is the only scenario that requires more than one avoided ER visit to be cost-effective at any level. Two ER visits need to be avoided for cost effectiveness below the very high cost threshold, 2 785 000 SEK per additional QALY. Five avoided ER visits are required for cost-effectiveness at the high cost threshold below 1 000 000 SEK and at least 9 avoided ER visits for moderate cost-effectiveness below 500 000 SEK per additional QALY. Cost-effectiveness at the 100 000 SEK per additional QALY cost threshold requires 23 avoided ER visits.

Figure 4: ICER sensitivity of health assumptions



The changes in the healthcare costs, QALY losses and the risk of suffering severe or minor injuries, only induce small changes in the economic analysis. These changes are presented in figures A4.1, A4.2 and A4.3 in appendix 4.

Summarily, between one to two ER visits are required to be prevented in order to have a cost-effective ice cleats programme at the 2 785 000 SEK per additional QALY threshold, depending on the assumptions regarding QALY loss. This equals a decrease in incidence of between 1,75% and 3,5% in Jönköping

4.2 Difference-in-Difference results

4.2.1 Investigating the parallel trend assumption

Figure 5 illustrates the annual group means of ER visits per 100 000 inhabitants of the full sample, and for the two gender-based subsamples in figure 6 and 7. The graph is used to investigate the parallel trends before the programme implementation. The group means do seem to follow similar trends, which is in line with previous literature on pedestrian fall incidence within the different age groups (Schyllander, 2014; Eriksson & Sörensen, 2015). Even though the trends might look slightly different, it should be noted that the relatively short time frame and the enlarged scale of the ER visits variable will visually emphasize any noise in the data and make the differences look bigger. We measure the correlation for the average annual number of ER visits per 100 000 inhabitants between the treatment- and control group. In the full sample the correlation is 0,96. In the male subsample the correlation is 0,86, and in the female subsample the correlation is 0,98.

Figure 5 reports a steeper decline of ER visits in the treatment group compared to the control group after the start of the ice cleats programme in 2018. Figure 6 and figure 7 present the averages for the two subsamples, and both subsamples also seem to have fairly parallel trends between their respective treatment and control group. The patterns observed in figure 6 and 7 suggest that the decline in ER visits post treatment in figure 5 is dominated by females.

It is worth noting that the full sample, and the female subsample in particular, experience a decline in ER visits in the treatment group in 2018. This is the first year in our time frame in which the treatment group has fewer ER visits per 100 000 inhabitants than the control group. This might suggest some change associated with the implementation of the ice cleats programme. This relation is tested in the next subsection.

Figure 5: Average ER visits per 100 000 inhabitants, full sample

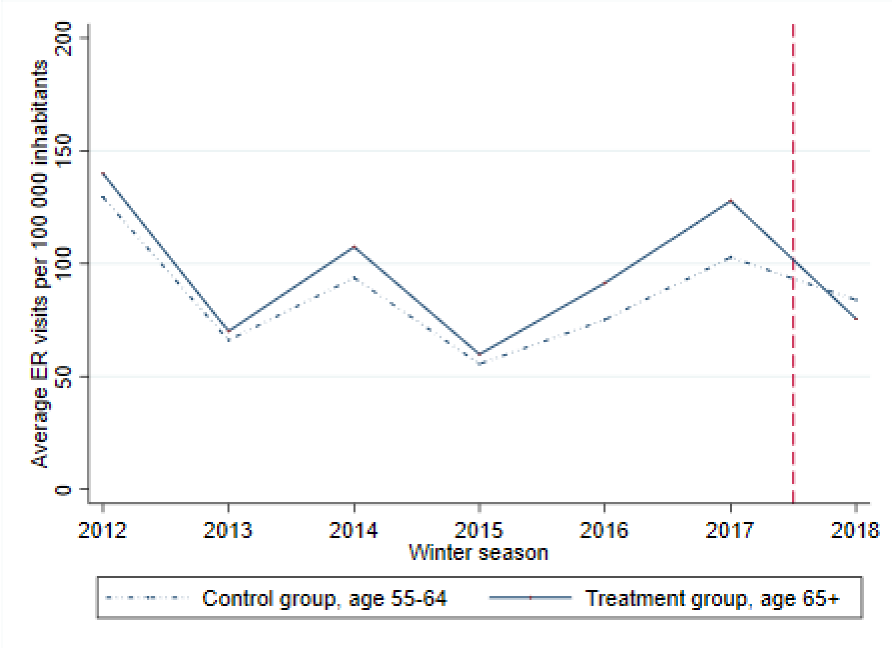


Figure 6: Average ER visits per 100 000 inhabitants, male subsample

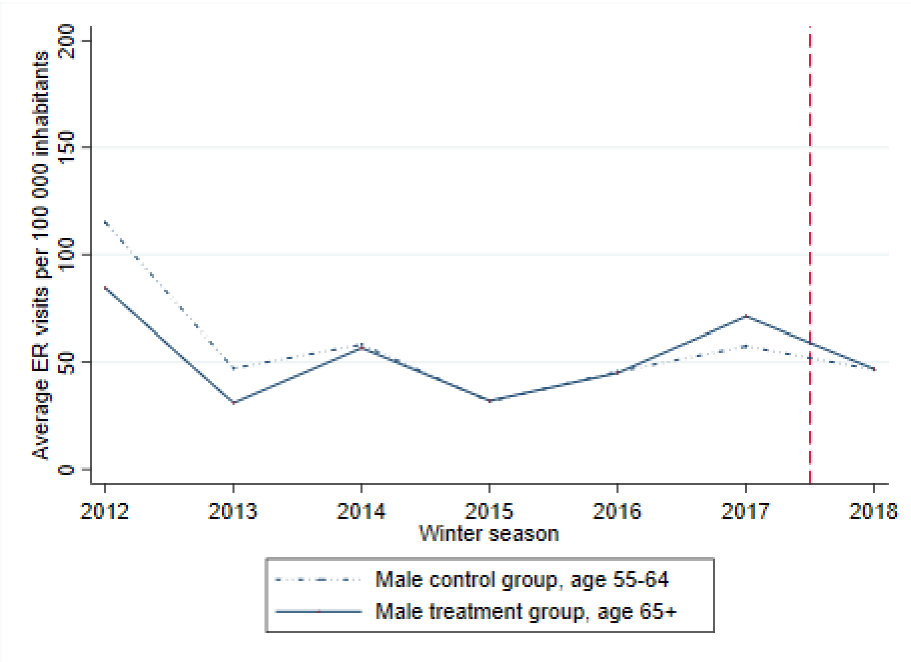
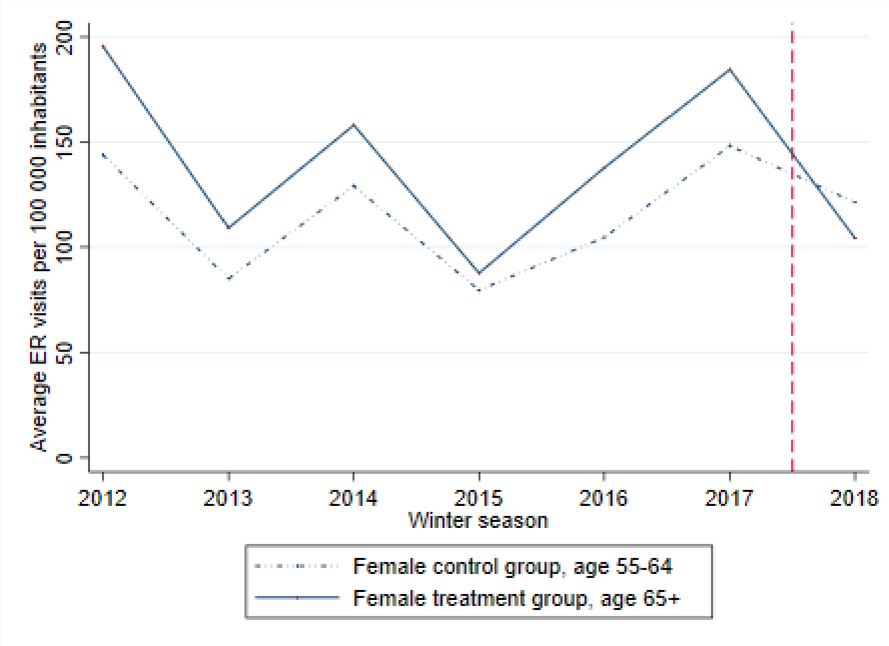


Figure 7: Average ER visits per 100 000 inhabitants, female subsample



4.2.2 Regression outputs

Our main regression results are presented in Table 6. Regressions 1-3 exclude the control variables and present the results for the full sample, male subsample, and female subsample respectively. Only the coefficients for *Treatment effect in 2018* and *Post* are reported for brevity, the full regression table can be found in appendix 5. These regressions are the most similar to the study design of Bonander & Holmberg (2019) and investigates the relationship between the group means presented in figures 5, 6 and 7. Both the full sample and the female subsample are estimated to have a decline in *ER visits per 100 000 inhabitants* in the treatment group post treatment. The treated male subsample is estimated to have an increase in ER incidence. The estimate for the full sample is 20,64 fewer *ER visits per 100 000 inhabitants* compared to the control group, which serves as the counterfactual observation. This decrease corresponds to a about 21,5% in the full sample. The male subsample has an estimated increase by 6,15 *ER visits per 100 000 inhabitants* compared to the control group. This corresponds to an increase of 11,7% for male ER visit incidence. Women are estimated to have 47,44 fewer *ER visits per 100 000 inhabitants* compared to the control group. This corresponds to a decline of 34% for female ER visit incidence. The coefficients for *treatment effect in 2018* in the respective regressions are however insignificant.

Regressions 4-6 include the control variables for weather conditions. Controlling for weather results in negative coefficients for the *treatment effect in 2018* in all samples, including the male subsample. The decrease in fall incidence in these regressions is 21,8% for the full sample, and 18,9% for men, and 22,9% for women. However, no change in significance of the coefficients is observed, and the weather control variables does not succeed in increasing the precision of the estimates. Instead the standard errors increase, most likely due to losing degrees of freedom when including additional regressors.

Since no significant coefficients were found in neither regression, there is no need for applying wild-bootstrapped standard errors to adjust for possible over-rejection of the null hypothesis.

Table 6: DID regressions, with and without weather control variables

VARIABLES	(1) All ERVcapita	(2) Men ERVcapita	(3) Women ERVcapita	(4) All ERVcapita	(5) Men ERVcapita	(6) Women ERVcapita
Treatment effect in 2018	-20.64 (29.79)	6.153 (29.73)	-47.44 (46.02)	-20.90 (34.30)	-9.863 (31.27)	-31.93 (64.62)
Post	-3.200 (24.42)	-12.63 (25.24)	6.235 (40.78)	0.347 (31.01)	12.63 (25.11)	-11.94 (59.34)
Control variables	No	No	No	Yes	Yes	Yes
Observations	504	252	252	504	252	252
R-squared	0.005	0.003	0.014	0.033	0.073	0.048
Number of Municipalities	12	12	12	12	12	12

ERVcapita is the number of ER visits per 100 000 inhabitants
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

When regressing the alternative model, which uses a negative binomial distribution to account for skewness in the data, the coefficients of interest were still insignificant. The regression output table can be found appendix 6.

4.3 Analysis

4.3.1. ICER

Our ICER results indicate that a decrease between 1 and 5 *absolute* ER visits render cost-effectiveness between the 1 000 000 SEK and 100 000 SEK thresholds. This corresponds to a decrease of 1,75% to 8,75% from the average annual of ER visits of the treatment group.

In terms of the *expected* number of ER visits, a decrease between 0,99% to 8,72% is required for cost-effectiveness between 1 000 000 SEK and 100 000 SEK thresholds. This corresponds to an incidence decrease of 0,83 to 7,34 ER visits per 100 000 inhabitants in the average annual ER visit incidence of the treatment group.

The limitations, delimitations and assumptions investigated in the sensitivity analysis do not substantially change the results of the ICER. They are however worth discussing. The ICER model is limited and does not capture *all* of the possible changes in quality of life and life expectancy which follow from a pedestrian injury. This will in turn lead to some under- and overestimations of gained and lost QALYs.

The ICER model does not account for the increased risk of bone fractures associated with increased age (Elvik & Bjørnskau, 2019). This leads to a plausible underestimation of gained QALYs. Disregarding any QALY loss associated with minor injuries could underestimate the number of gained QALYs from each avoided injury. Several health economists argue for the inclusion of spillover effects of QALYs to family members (Brouwer, 2019). Disregarding how spillover effects of senior pedestrian falls could affect family members by decreasing emotional wellbeing, or by creating dependence on next of kin, could further contribute to the underestimation of gained QALYs. If the ice cleats subsidy would increase physical activity among seniors, it could have positive outcomes such as better cardio-vascular status or better psychological well-being which are not captured by the model, leading to another underestimation of QALYs. Additionally, it could be argued that suffering a severe fracture could reduce the expected life span, this results in a potential underestimation of gained QALYs from preventing a pedestrian fall. The sensitivity analysis reports however that substantial changes in lost or gained quality of life of severe injuries would only change the cost per additional QALY marginally.

Delimiting the model to only include the most common injuries, leads to an underestimation of both the healthcare costs and the QALY losses. The sensitivity analysis in appendix 4 reports however that a doubling of healthcare costs of the most common injuries, has close to no effect on the ICER values. Even though we are fairly certain of the programme cost, we also explored the implications of changing the programme budget allocation. This allows us to compare other hypothetical fall preventing interventions.[10] Doubling of the cost for the same number of

[10] We assume that other fall preventing interventions for seniors would induce the same changes in health care costs.

distributed ice cleats would still be cost-effective at 1 prevented ER visit at the Very High cost-effectiveness threshold of 2 785 000 SEK per additional QALY.

Summarily, the analysis concludes that any measurement errors that could be present in the ICER model would plausibly not change the cost per additional QALY substantially. Further, the assumptions made about permanent loss in quality of life in the main results is in line with previous research (Ström et. al, 2008; Cooper, 1997).

4.3.2. Difference-in-differences

The Difference-in-Differences regressions are used to retest the hypothesis of whether ice cleats subsidy programmes decrease the number of ER visits. No significant decrease of ER visits is observed in any of the main regressions. The treatment effects remained insignificant in the negative binomial regressions. Since the decreases in ER visits may be due to random chance, nothing conclusive can be said about the causal effect of the subsidy programme on the ER visits due to ice or snow. Therefore, it cannot be concluded that a decrease of 1,75% to 8,75% ER visits per 100 000 inhabitants required for cost-effectiveness was achieved, even though the estimated treatment effect were equivalent to a decrease of over 20% per 100 000 inhabitants for the full sample.

The insignificant results may have several causes. It could that the parallel trends assumption is not fulfilled which leads to a biased estimator. Considering that that the weather circumstances affect the different age groups differently according to previous literature (Elvik & Bjørnskau, 2019), it was unexpected that these controls yielded lower precision for injury incidence. This loss of precision could be explained by the loss of degrees of freedom when adding additional regressors, making the standard errors larger. It is further possible that weather control data on monthly level is a too coarse of a measurement to increase the precision of the variable of interest, ER visits per 100 000 inhabitants.

The sample size and the few clusters could yield low statistical power and large standard errors, and therefore an inability to identify a significant effect. The insignificant results could also be due to compliance issues in the treatment group. This does not need to become a problem for a DID model estimating the Intent-to-treat effect. Poor compliance within the groups will however decrease the ITT effect. We do not know whether there is a gender difference in the share of always-takers and never-takers in the sample. Perhaps women in the control group are more likely to be always-takers, then this would lead to an underestimation of the ITT effect in the regressions with the female subsample. There could also be spillover effects from the treatment group since we cannot observe the ice cleat prevalence among the control group.

We suspect that data on municipal snow clearing, the usage of the ice cleats, and the geographical distribution of the ice cleats, would have increased the precision of our variable of interest. Differences in municipal snow clearing could however be captured by municipal fixed effects in the DID model if they were constant over time. Having data on the usage in the control group and treatment group would enable us to control for compliance. Data on the collection of the ice cleats could have controlled for potentially uneven density in ice cleats coverage among the seniors in the different municipalities. These are all sources of potential omitted variable bias.

It could be the case that the ice cleat programme affects movement patterns for the treatment group. Berggård & Johansson (2010) suggested that ice cleat users tend to walk roughly twice as long as non-ice cleat users, resulting in a lower "*fall per distance walked*" when wearing ice cleats. This may result in no changes in the ER visits per 100 000, since the longer distances may increase the risk of falling and crowd-out any decrease in risk induced by the ice cleats.

5. Conclusion

Is the provision of a large-scale programme of free ice cleats is a cost-effective and successful way of decreasing pedestrian injuries among the elderly? The answer remains uncertain. Our study combines an ICER analysis to estimate cost-effectiveness with a quasi-experimental econometric approach to finding the causal effect of the programme. Our study does find that fall preventing interventions, in this case an ice cleats subsidy, could be a cost-effective intervention if it prevents as few as a single ER visit. Although our analysis shows that only a small treatment effect is required for a cost-effective subsidy, our econometric analysis lacks the precision to identify this effect. This implies that this subsidy programme is at risk of being considered ineffective from an economic point-of-view, despite its potential to be cost-effective. This emphasises the importance of combining economic evaluation and econometric analysis in research.

The tools provided by our thesis should be applicable for fall preventing policies in Sweden and other countries with similar winter climates where many pedestrian injuries are caused by snow and ice. However, it is possible that Region Jönköping is a non-representative sample compared to rest of Sweden. It is likely that the effectiveness of an ice cleats subsidy programme is dependent on the climate and topography. It may also be the case that the senior population in Region Jönköping is unusually healthy or have other traits that enables them to have a lower risk of falling.

The question of whether to implement an ice cleats programme ultimately depends on assessment of the likelihood of preventing enough ER visits for a subsidy programme to be cost-effective. However, since no statistical evidence of a decrease in ER visits is associated with subsidized ice cleats, we encourage future research on the topic. We believe that including weather control variables has been a move in the right direction, but further sophistication of the model is required. Daily observations of weather could perhaps better explain the variation in the number of snow related falls, suggestively with a negative binomial regression which would account for the even larger excess of zero-values in the sample that daily observations would induce. We suggest that future research explores this option along with additional data on e.g. snow clearance, ice cleats usage, walking distances and finally, the use of a larger sample. One possible way of expanding the sample size is by using Event Study methodology.

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Appendix

Appendix 1. STRADA inclusion year per hospital in Region Jönköping

Table A1. 1 STRADA inclusion year per hospital in Region Jönköping

Hospital	Start of reporting
Höglandssjukhuset Eksjö/Nässjö	February 2007
Länssjukhuset Ryhov	October 2006
Värnamo sjukhus	February 2011

Source: Swedish Transport Agency (2018):

Appendix 2. Distribution and probability tables for the ICER

Table A2. 1: Distribution of pedestrian injuries by gender and age group.

Share of each avoided fall	Men	Women	Women and Men
Age 65–74	17,36%	43,42%	60,78%
Age 75+	13,82%	25,40%	39,22%
Both age groups	31,18%	68,82%	100,00%

Source: Swedish Traffic Accident Data Acquisition

Table A2. 2: Probability of injury severity by gender and age group for each fall

Avoided injury 65-74	Probability Men	Probability Women	Probability Women and men
Fatal	0,15%	0,15%	0,15%
Hip surgery	11,78%	13,35%	12,86%
Vertebra surgery	3,66%	4,15%	4,00%
Wrist joint surgery	2,07%	2,35%	2,26%
Shoulder surgery	3,95%	4,48%	4,32%
Minor injury	33,40%	37,86%	36,47%
Avoided injury 75+	**Probability Men**	**Probability Women**	**Probability Women and men**
Fatal	1,30%	1,30%	1,30%
Hip surgery	9,38%	7,81%	8,30%
Vertebra surgery	2,92%	2,43%	2,58%
Wrist joint surgery	1,65%	1,37%	1,46%
Shoulder surgery	3,15%	2,62%	2,78%
Minor injury	26,60%	22,14%	23,53%

Source: Swedish Traffic Accident Data Acquisition, Gyllensvärd (2009) and Statistics Sweden (2020a, 2020b).

Appendix 3. ICER per prevented ER visit

Table A3. 1 ICER per prevented ER visit for the main results

Prevented ER visit	**Percentual decrease, relative to the annual average of falls**	**Cost per additional QALY (in SEK)**
1	1,75%	556 808,11
2	3,50%	271 053,76
3	5,25%	175 802,31
4	7,00%	128 176,59
5	8,75%	99 601,15
6	10,50%	80 550,86
7	12,25%	66 943,51
8	14,00%	56 738,00
9	15,75%	51 444,84
10	17,50%	42 450,28

Table A3. 2: Break-even thresholds for when the policy is expected to be cost-effective.

Model specification	Cost effectiveness threshold	Expected number of falls required for cost effectiveness	Expected number of falls required for cost effectiveness per 100 000 inhabitants	Expected decrease of falls required relative to the annual average of falls
Main result model (figure 1), QALYs are discounted by 3%	2 785 000 SEK	0,20	0,29	0,36%
	1 000 000 SEK	0,56	0,83	0,99%
	500 000 SEK	1,11	1,64	1,94%
	100 000 SEK	4,98	7,34	8,72%
Sensitivity analysis (figure 2, dashed line), cost of programme decreased by 50%	2 785 000 SEK	0,10	0,15	0,18%
	1 000 000 SEK	0,28	0,41	0,49%
	500 000 SEK	0,56	0,83	0,97%
	100 000 SEK	2,49	3,67	4,36%
Sensitivity analysis (figure 2, dotted line), cost of programme increased by 100%	2 785 000 SEK	0,41	0,60	0,71%
	1 000 000 SEK	1,13	1,67	1,97%
	500 000 SEK	2,22	3,27	3,89%
	100 000 SEK	9,97	14,69	17,44%
Sensitivity analysis (figure 3, dashed line), QALYs are discounted by 0%	2 785 000 SEK	0,13	0,19	0,23%
	1 000 000 SEK	0,36	0,53	0,63%
	500 000 SEK	0,72	1,06	1,26%
	100 000 SEK	3,34	4,92	5,85%
Sensitivity analysis (figure 3, dotted line), QALYs are discounted by 5%	2 785 000 SEK	0,27	0,40	0,48%
	1 000 000 SEK	0,75	1,11	1,31%
	500 000 SEK	1,48	2,18	2,59%
	100 000 SEK	6,42	9,46	11,24%
Sensitivity analysis (figure 4, dashed line), 5% annual quality of life regaining	2 785 000 SEK	0,34	0,50	0,59%
	1 000 000 SEK	0,93	1,37	1,63%
	500 000 SEK	1,82	2,68	3,18%
	100 000 SEK	7,65	11,27	13,40%
Sensitivity analysis (figure 4, dotted line), temporary loss of quality of life, 1 year	2 785 000 SEK	1,75	2,58	3,06%
	1 000 000 SEK	4,52	6,66	7,91%
	500 000 SEK	8,09	11,92	14,16%
	100 000 SEK	22,08	32,54	38,64%

Appendix 4. Sensitivity analysis

Figure A4. 1: ICER sensitivity of healthcare costs

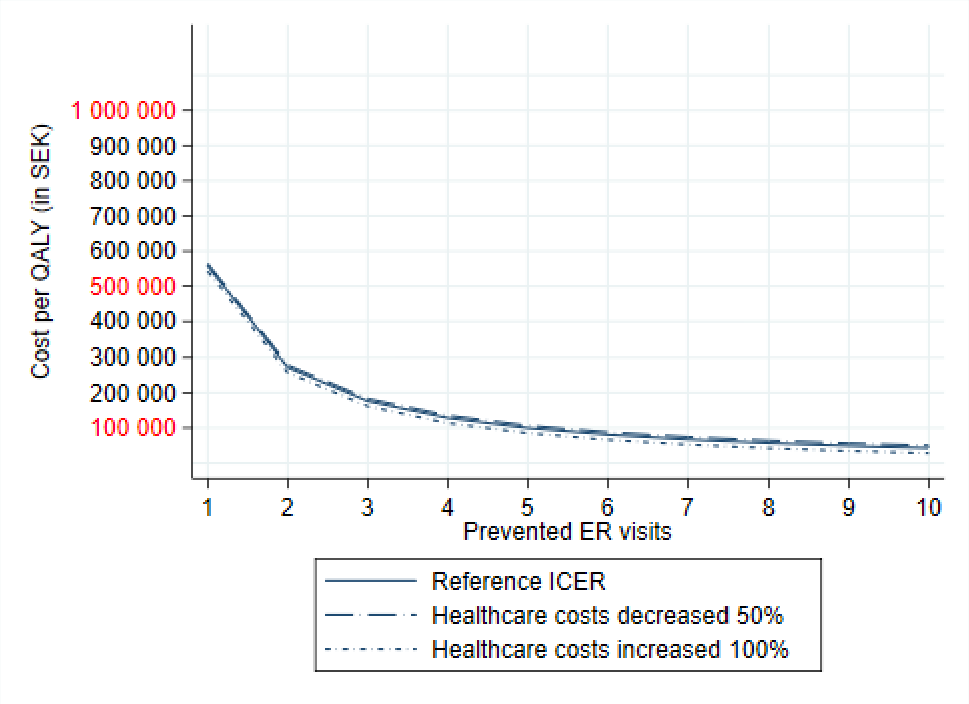


Figure A4. 2: ICER sensitivity of QALY loss per injury

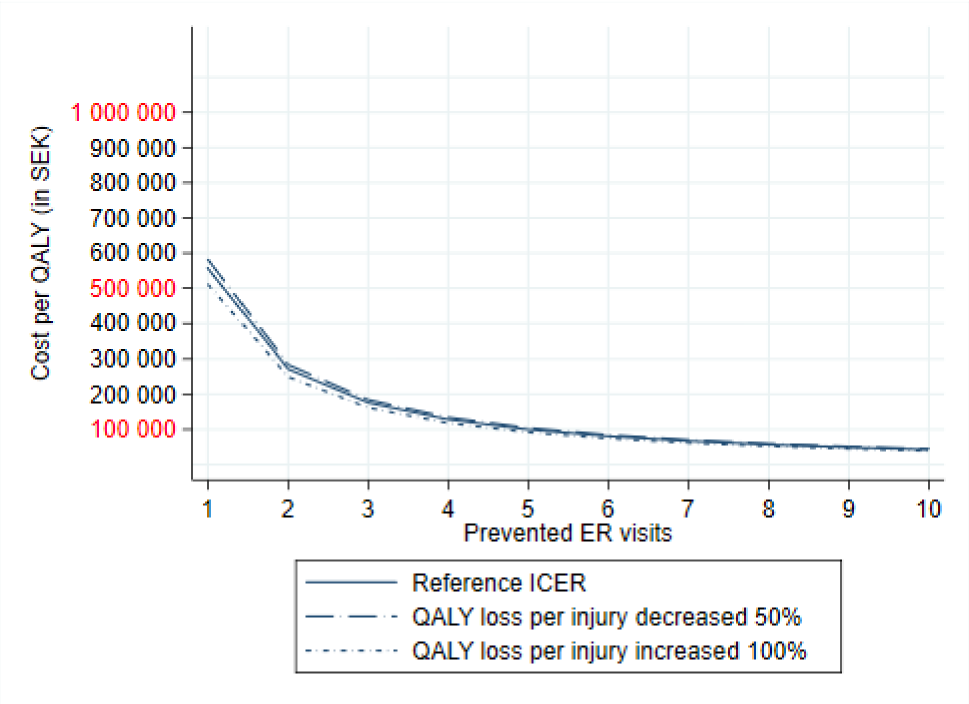
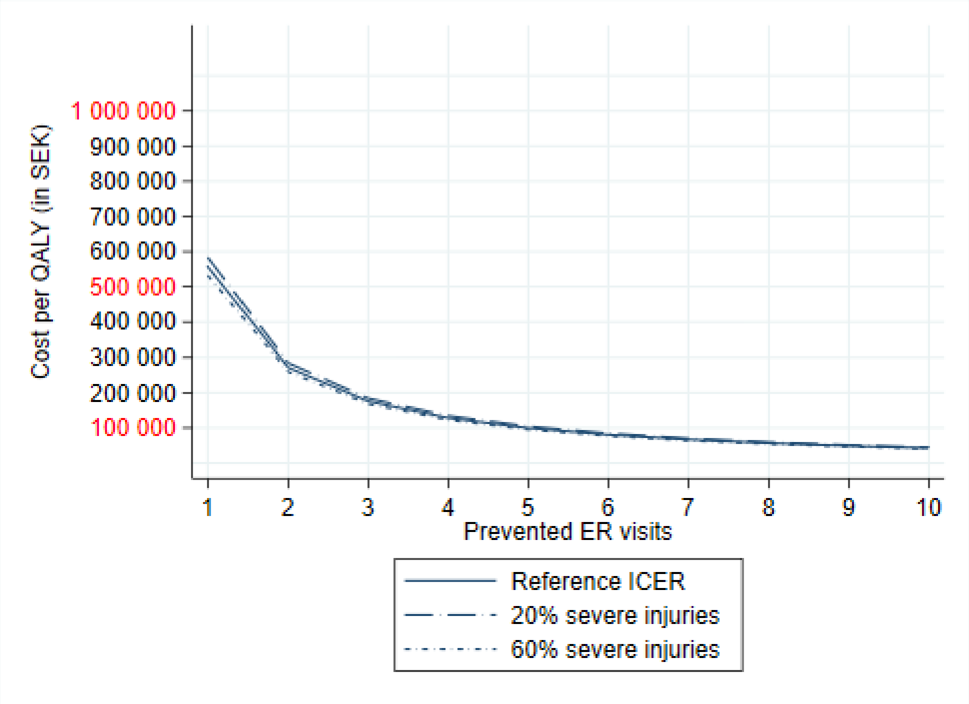


Figure A4. 3: ICER sensitivity of injury severity risk



Appendix 5. Results, Difference-in-Differences

Table A5. 1: Results, Difference-in-Differences

VARIABLES	(1) All ERVcapita	(2) Men ERVcapita	(3) Women ERVcapita	(4) All ERVcapita	(5) Men ERVcapita	(6) Women ERVcapita
Treatment	12.28	-5.826	30.39	-7.907	-20.22	4.404
	(11.44)	(8.697)	(22.50)	(23.09)	(25.32)	(46.15)
Post	-3.200	-12.63	6.235	0.347	12.63	-11.94
	(24.42)	(25.24)	(40.78)	(31.01)	(25.11)	(59.34)
Treatment effect	-20.64	6.153	-47.44	-20.90	-9.863	-31.93
in 2018	(29.79)	(29.73)	(46.02)	(34.30)	(31.27)	(64.62)
ThawDays				4.403	-0.417	9.222
				(3.623)	(3.441)	(6.565)
Snowing				8.178	18.27*	-1.915
				(5.020)	(8.772)	(14.57)
ThawDays ×				1.775	3.724	-0.174
Treatment				(2.922)	(2.511)	(5.245)
Snowing ×				2.046	-7.227	11.32
Treatment				(8.532)	(11.02)	(18.65)
Constant	87.12***	59.22***	115.0***	29.52	18.43	40.60
	(7.001)	(6.063)	(13.28)	(27.63)	(36.73)	(42.38)
Observations	504	252	252	504	252	252
R-squared	0.005	0.003	0.014	0.033	0.073	0.048
Number of Municipalities	12	12	12	12	12	12

ERVcapita is the number of ER visits per 100 000 inhabitants
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix 6. Results, Negative binomial regression

Table A6. 1: Regression output table, Negative binomial regression

VARIABLES	(1) All ERV	(2) Men ERV	(3) Women ERV	(4) All ERV	(5) Men ERV	(6) Women ERV
Treatment	-0.170	-0.237	-0.158	-0.373	-0.852*	-0.177
	(0.179)	(0.234)	(0.189)	(0.350)	(0.497)	(0.382)
Post	-0.117	-0.0533	-0.130	-0.0804	0.174	-0.200
	(0.274)	(0.387)	(0.318)	(0.319)	(0.414)	(0.426)
Treatment × Post	0.0361	0.0602	0.0352	0.00842	-0.0813	0.0896
	(0.390)	(0.538)	(0.427)	(0.439)	(0.545)	(0.557)
ThawDays				0.0708**	0.0161	0.100***
				(0.0347)	(0.0539)	(0.0366)
Snowing				0.0231	0.0754**	-0.00560
				(0.0249)	(0.0294)	(0.0280)
ThawDays × Treatment				0.0804*	0.146**	0.0355
				(0.0424)	(0.0617)	(0.0871)
Snowing × Treatment				-0.00513	-0.0265	0.0224
				(0.0637)	(0.0763)	(0.111)
Constant	-0.723***	-0.811***	-0.623***	-1.616***	-1.422***	-1.644***
	(0.111)	(0.140)	(0.118)	(0.282)	(0.484)	(0.272)
Observations	504	252	252	504	252	252

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A6. 2: Marginal effects, negative binomial regression

MARGINS	(1) All ERV	(2) Men ERV	(3) Women ERV	(4) All ERV	(5) Men ERV	(6) Women ERV
Post=0, Treatment=0	1,46597	0,93389	2,01591	1,67878	1,43736	2,0459
	(0,156)	(0,1314)	(0,222)	(0,399)	(0,524)	(0,524)
Post=0, Treatment=1	1,23651	0,73683	1,72066	1,15547	0,61339	1,71393
	(0,091)	(0,071)	(0,142)	(0,133)	(0,086)	(0,224)
Post=1, Treatment=0	1,30465	0,88539	1,76965	1,54876	1,71008	1,67439
	(0,282)	(0,285)	(0,485)	(0,472)	(0,806)	(0,567)
Post=1, Treatment=1	1,14087	0,74194	1,56459	1,07518	0,67278	1,53414
	(0,124)	(0,113)	(0,23)	(0,138)	(0,108)	(0,284)
Control variables	No	No	No	Yes	Yes	Yes

Robust standard errors in parentheses