Fall-Related Injuries Amongst Elderly in Sweden
Still an Emerging Risk?

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PREFACE

As a registered physiotherapist, fall-related injuries were a common sight and seemed almost an inevitable part of everyday life for elderly people. At the time, whilst my primary goal was to ensure that patients were rehabilitated as effectively as possible, I was fascinated by the irregularity of the process from fall to potential injury. In a sense, why don’t all falls lead to injuries and why do different injuries result from the same type of fall? After learning, teaching and researching the topic for a number of years, the underlying causes and the pathway from fall to fall-related injury is more complex, multidimensional and, sometimes, incomprehensible than I could ever have imagined. Although I still cannot claim to be able to fully answer the seemingly simple questions, I have come somewhat closer in understanding how societal and individual factors affect the risk of injury once an elderly person has fallen.

Despite moments of despair and rumination, the time has come for me to make my contribution to the academic world in the understanding of fall-related injuries amongst elderly. Hopefully, this knowledge can be used as one of the many pieces in the “fall-related injury puzzle” to enable elderly to live healthier, longer lives in the future without the risk of an injury shortening or disabling their life.

Although fortunate circumstances and hard work has had an important role in completing this thesis, it would have been impossible without the support and help from many individuals. Therefore, I would like to mention a number of people who have been especially important.

Firstly my main supervisor, Ragnar Andersson, who has done an amazing job in helping me convert my ideas into articles and finally a thesis. Your patience and belief in my ability has been invaluable, as has your knowledge within the risk management and injury prevention field. Despite troubles along the way, both professionally and privately, I have always known that you’ve backed me up and stood up for me. Thank you!

Secondly, thank you to my second supervisor, Syed Moniruzzaman, who has helped me considerably with injury epidemiology and the dos and don’ts when dealing with scientific journals.
My colleagues and co-authors, Johanna Gustavsson and Carl Bonander, who have been supportive and generous throughout this process. I am also very thankful for our teamwork and friendship that helps make our Centre for Public Safety such an enjoyable place to work at.

A special thank you to Karlstad municipality and especially Lars Sätterberg and Tommy Rosenberg. Without your work in creating a research centre for elderly safety in Karlstad, that subsequently lead to the founding of Centre for Public Safety, I would never have had this opportunity.

My colleagues at Karlstad University, especially those within Risk Management and Public Health but also colleagues within Environmental Science, Sports Science and Oral Health. A special mention to Helene Hjalmarson, Carolina Jernbro, Staffan Janson and Malin Knutz who have contributed with discussions, comments and advice in the writing of this thesis.

An extra special mention to my nearest family; Marielle, Leo and Lova, thank you for your tolerance when my mind and focus has been elsewhere. Thank you also to my father Torsten, who has shown that with drive and hard work, you can accomplish anything. Also, thank you to Towe, Bobo and Tord for keeping me grounded and for all our sibling rivalry. There is no better way to prepare for the academic world!

Finally, I would like to posthumously thank, and mention, two important people who passed away shortly before this thesis was finished.

Maj, my grandmother, who would keenly read my reports on the prevention of fall-related injuries so that she could lecture the visiting nurses and correct them when they suggested out-dated methods.

My mother Annika, who passed away after a hip fracture a year before this thesis was finished. She always believed that I would become a doctor despite the fact that my grades sometimes painted another picture. Her death is a stark reminder that behind every statistic is an individual and their family.
ABSTRACT

In Sweden, injuries due to falls are the most common cause of injury-related hospitalization and injury-related death amongst elderly. Also, during the 20th century, increasing trends in fall-related injuries, both in terms of absolute numbers and incidence, have been observed in many high-income countries. Whilst fall-related injury trends have been reported from national studies in other comparable countries, no studies from Sweden using national data have been published, despite this issue sometimes being pointed out as one of the most important emerging societal risks both in Sweden and elsewhere. With large individual and societal costs, as well as prognosticated continued increases in high-income countries, the aim of this thesis is to update the knowledge on the trends of fall-related injuries amongst elderly in Sweden. Also, this thesis aims to consider whether fall-related injuries amongst elderly are still to be seen as an emerging risk in Sweden.

Since the 1980’s, Sweden has had reliable and comprehensive national mortality and morbidity registers. This enables the possibility of national longitudinal injury morbidity and mortality studies over a longer time span as a tool to better understand long-term injury trends. By also studying the fall-related injury panorama from different viewpoints, such as medical diagnoses or external cause, a more diversified picture can be presented. Methodologically, the national fall-related mortality and morbidity trends were primarily studied using linear regression analyses and calculating percentage changes during the studied time series.

The results from the studies included in this thesis show that in similarity to some other nations, hip fractures, the most common serious fall-related injury in Sweden, are now decreasing both in terms of risk and absolute numbers simultaneously with an increasing mean age at fracture occurrence. Likewise, with regards to all hospitalized fall-related injuries, the risk has also decreased. However, although the general fall-related injury trends amongst elderly are decreasing, diverging trends are observed in terms of age- and sex-specific groups. Younger elderly (65-79 years) now have considerably lower rates of fall-related injuries compared to a decade ago, whilst older elderly (80 years and above) are still increasingly being hospitalized due to minor fall-related injuries. Also, increasing hip fracture mortality trends were observed in the group 80 years and above. Differences were also observed between men and women. Although fall-related injuries in general are more common amongst women, the
injury trends for women are generally decreasing at a quicker rate than for men. Also, contradictorily to almost all fall-related injury morbidity, the results confirm previous research that men are overrepresented with regards to hip fracture mortality.

The results highlight a number of interesting aspects. Firstly, the results seem to contradict the dramatic developments predicted at the end of the 20th century, showing instead that the risk amongst elderly of attaining a hip fracture or other fall-related injury is now generally declining. However, the differences between younger and older elderly also highlight contrasting developments with increasing rates of hospitalization in some minor injuries amongst the older elderly as well as increasing rates of hip fracture mortality. These differences indicate that from a preventative perspective, focus needs to more strongly include men as well, plus focusing on older elderly. Also, given the diverging trends between the age-specific groups, the importance of differentiating between younger elderly and older elderly, not only from a research perspective but also from a preventative perspective, cannot be understated.

In conclusion, this thesis can show a change in trend in fall-related injuries amongst elderly in Sweden since the turn of the century, apart from amongst older elderly and with regards to hip fracture mortality. The implications on future prognoses needs to be studied further as do the causes underlying this shift in trend.
SAMMANFATTNING


bekräftar resultaten tidigare forskning att män är överrepresenterade vad gäller höftfraktursdödlighet.

I stort verkar resultaten motsäga den dramatiska utveckling som förutsåddes i slutet av 1900-talet. Istället har risken för att ädra sig en höftfraktur eller annan fallskada i allmänhet minskat bland äldre sedan början av 2000-talet. Trots detta finns det aspekter som är viktiga att belysa för framtiden. Skillnaderna i skadetrender mellan de åldersstratifierade grupperna tyder på att fokus i det skadeförebyggande arbetet i högre grad bör inkludera även män och äldre äldre (80 år och äldre) i syfte att hindra en fortsattökning av sjukhusinläggningar till följd av mindre allvarliga fallskador och fortsattökad fallskaderelaterad dödlighet. Skillnaderna belyser också vikten av att differentiera mellan yngre äldre och äldre äldre, inte bara ur ett forskningsperspektiv, utan även ur ett skadeförebyggande perspektiv.

Avhandlingen påvisar sammanlagt ett trendbrott kring millennieskiftet när det gäller fallskador bland äldre utom för de allra äldsta och vad gäller dödligheten i höftfrakturer. Vad detta innebär för framtida prognoser av skadeutvecklingen behöver studeras närmare, liksom vilka bestämningsfaktorer som ligger bakom trendskiftet.
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This thesis is based on the following original publications, referred to in the text by Roman numerals (I-IV).


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**Author contributions**

All papers included in this thesis are a result of a collaborative effort between the authors. However, in all four papers the main author has carried out a clear majority of the work. This includes initiating the papers, formulating the research questions, analysis of data and writing of the papers. Ragnar Andersson has predominantly been involved in formulating the research questions and editing the papers. Syed Moniruzzaman (papers I-III) and Carl Bonander (paper IV) have predominantly been involved as methodological support in the data analysis. Johanna Gustavsson (papers I & IV) has predominantly been involved in initiating and editing the papers.
ABBREVIATIONS

BMI  Body Mass Index

CDR  Cause of Death Register

EHLASS  European Home and Leisure Accident Surveillance System

ICD  International Classification of Diseases

IDB  Injury Database

NCECI  NOMESCO (Nordic Medico-Statistical Committee) Classification of External Causes of Injuries

NPR  National Patient Register

OECD  Organisation for Economic Co-operation and Development

PIN  Personal Identification Number

STRADA  Swedish Traffic Accident Data Acquisition

WHO  World Health Organisation
INTRODUCTION

Falls and fall-related injuries have, during the 20th century, increasingly become an integrated part of old age. During the second half of the 20th century, both the number and risk of fall-related injuries, and hip fractures especially, has increased dramatically amongst elderly in a majority of high-income countries. This has largely been explained by increased numbers of elderly and increased frailty amongst elderly. If the number of elderly continues to increase, as well as the number of frail elderly, the question arises what effect this will have on the fall-related injury trends in Sweden.

From a societal risk perspective, the increasing injury trends among elderly are potentially a serious issue. Not only due to the individual suffering but also due to the change in population structure, meaning that the increased economic burden has to be covered by declining workforces. For Sweden especially, this issue has been given priority as Sweden has been identified as having amongst the highest fall-related injury rates in the world (Kanis, Oden et al. 2012). Injuries amongst elderly, and fall-related injuries especially, were labelled as one of the most important and growing societal risks in Sweden (OECD 2007) within the project “Emerging Risks in the 21st Century” (OECD 2003). The aim of this thesis, therefore, is to update the knowledge on fall-related injury trends in Sweden and to determine whether fall-related injuries are to be considered a continuously growing societal risk.
BACKGROUND

Fall-related injuries are the most common cause of injury-related hospital admission among elderly in Sweden (Sjögren, Björnstig 1989), costing the Swedish society in excess of 9.5 billion SEK (1.5 billion USD as of March 2014) per year (Ryen, Berglöf 2012). Whilst falls, defined as “an event, which results in a person coming to rest inadvertently on the ground or other lower level” (Ballinger, Payne 2002), are common amongst children and an important part of developing motor skills, serious injuries from falls are less common in this age group. Instead, serious fall-related injuries increase in middle age and upwards with an average of 42000 elderly per year visiting an accident and emergency department due to a fall-related injury in Sweden (Schyllander, Rosenberg 2008).

Merely from a societal perspective, an increase in hospitalized fall-related injuries can have dramatic consequences. This is not least due to the considerably higher costs, as a Swedish patient requiring hospitalization on average is three times as expensive after one year compared to a patient treated in primary care with the same diagnosis (Ryen, Berglöf 2012). Although societal costs are high, and thereby motivate the need for research and preventative measures, the true cost of fall-related injuries is rather on an individual level. Besides the immediate pain and suffering following a fall-related injury, a large number of elderly suffer from fear of falling, self-imposed physical inactivity as well as an increased risk of admittance to nursing homes (Rubenstein 2006, Tinetti, Williams 1997). Also, as a result of fall-related injuries, a large number of individuals never recover. This means that to a large extent fall-related injuries among elderly are either directly fatal or lead to a premature death (Stevens, Ryans et al. 2006).

Fall-related injury trends among elderly in Sweden

Although Sweden has been identified as having amongst the highest fall-related injury rates in the world (Kanis, Oden et al. 2012), relatively few Swedish fall-related injury trend studies have been published. Of the published articles over the past 30 years, all have focused on hip fractures and have used local or regional hospital data from either Malmö/Lund (Johnell, Nilsson et al. 1984, Jarnlo 1991, Rogmark, Sernbo et al. 1999, Ahlborg, Rosengren et al. 2010),
Uppsala (Nungu, Olerud et al. 1993), Gothenburg (Zetterberg, Elmerson et al. 1984), Umeå (Bergström, Jonsson et al. 2009) or Östergötland (Löfman, Berglund et al. 2002).

Perhaps due to using local data, the results from these studies vary. Generally, the studies using data from the 1970s and 1980s showed increasing trends in hip fractures (Jarnlo 1991, Johnell, Nilsson et al. 1984, Zetterberg, Elmerson et al. 1984) although rates in Uppsala during the same time period remained stable (Nungu, Olerud et al. 1993). Differing trends are also observed in the studies using data from the 1990s and early 2000s with decreasing (Bergström, Jonsson et al. 2009), stable (Rogmark, Sernbo et al. 1999, Ahlborg, Rosengren et al. 2010) or sex-specific diverging (Löfman, Berglund et al. 2002) trends.

The differing trends in the local studies from Sweden clearly show the difficulty in generalizing local results to a national level. Despite this, global hip fracture review articles have used data from Malmö to represent Sweden when discussing Swedish levels (Kanis, Oden et al. 2012, Cooper, Campion et al. 1992), even though these results may not be representative for Sweden as a whole. Whilst local studies have an important role in injury research, in order to understand national, secular trends, national datasets are preferable. For this reason, the following review of the literature on fall-related trends in an international context is limited to nationwide studies.

**International fall-related injury trends during the 20th century**

Whilst it is possible to analyze all hospitalized fall-related injuries by using ICD (International Classification of Diseases) chapter XX (external causes of morbidity and mortality), very few international studies have investigated these trends among elderly. There are a number of problems with studying all hospitalized fall-related injuries that may explain the lack of studies within this area. Firstly, not all fall-related injuries are admitted to hospital. Rather, a large majority of fall-related injuries are minor, leading only to mild contusions or bruising and are therefore not requiring hospital care, meaning that there are a considerable number of unknown cases. Secondly, in order to study national levels of fall-related hospitalizations, a national reliable injury surveillance system is required. Finally, with continuing improvements in healthcare as well as changes in healthcare organizations, the official fall-related injury data can
inadvertently be affected. Perhaps due to these aspects, national studies concerning the trends of hospitalized fall-related injuries up to the mid 1990s are sparse. However, national data from The Netherlands showed large increases in hospitalization rates from 1981 up to the 1990s (Hartholt, van der Velde et al. 2010).

Of all hospitalized fall-related injuries, hip fractures are the most common (Haleem, Lutchman et al. 2008), generating 245000 hospital days per year in Sweden alone (Schyllander, Rosenberg 2008). As well as being the most common type of serious fall-related injury, hip fractures are also commonly studied due to a number of other factors. Firstly, compared to other injury diagnoses, hip fractures are almost always caused by falls (Hayes, Myers et al. 1996) meaning that ICD chapter XIX, medical diagnoses, can be studied rather than the diagnoses’ external cause (ICD chapter XX). Secondly, hip fractures are hospitalized in all cases, meaning that the risk of missing cases is diminishable. Thirdly, no changes in diagnosis or ICD coding have occurred since reliable injury surveillance started. Therefore, hip fractures are commonly studied and also used as a proxy for all fall-related injuries amongst elderly.

On a global scale, hip fracture trends among elderly have been studied comprehensively during the second half of the 20th century and especially during the last 20-year period. Towards the end of the 20th century, increasing trends in hip fracture rates were seen in many countries worldwide (Kanis, Johnell et al. 2002). With a continued global increase, the general consensus was that hip fractures would increase exponentially with a worldwide estimate of 6.3 million hip fractures per year in 2050 (Marks 2010, Cooper, Campion et al. 1992).

Despite a considerable number of hip fracture studies being published during the 1980s and early 1990s, a large majority of these were local studies (Cooper, Campion et al. 1992). As described above, whilst these studies are important in order to understand local conditions, they are not always representative of the national levels or trends. Of the nationwide studies, published with data from the 1970s to the 1990s, all showed increases in the risk of attaining a hip fracture. In Finland, between 1970 and 1997, the risk of hip fracture for those 50 years and above increased from approximately 200 per 100 000 in 1970 to 450 per 100 000 in 1997 (Kannus, Niemi et al. 2006). In The Netherlands, among individuals 65 years and above, increases were observed from 464 per 100 000 in 1981 to 704 per 100 000 in 1996 (Hartholt, Oudshoorn et al. 2011)
and in the Czech Republic rates increased from roughly 200 per 100,000 in 1981 to 500 per 100,000 in 2004 amongst individuals 50 years and above (Stepan, Vaculik et al. 2012).

**Suggested explanations to the increasing trends**

On the basis of these increasing trends, in the early 2000’s, OECD and the Swedish Rescue Services Agency identified injuries among elderly as one of the major emerging risks in Sweden and other high-income countries (OECD 2007, Schyllander 2007). Apart from the documented increases in injuries, a number of aspects were raised as further increasing the societal impact. Most notably, the continuous increases in life expectancy, both at birth and at 65 years, have lead to an increased dependency ratio, meaning that there are fewer individuals in the working age population in relation to the elderly population. In the early 2000s, Sweden had the third largest population in the world over 65 years in proportion to the total population. Therefore, with continuous increasing trends in the absolute number of fall-related injuries, the predicted parallel increases in healthcare expenditure were extensive (OECD 2007).

This identified risk development clearly illustrates that fall-related injuries amongst elderly has grown into an important global public health issue. However, in historical terms the issue has been to a large extent ignored due to other health-related problems dominating the total morbidity and mortality panorama. Up to the 19th century, although injuries were probably more common in the general population than today, other health-related issues largely shrouded the issue. According to the “London vital statistics” of 1662, a majority of deaths during the 17th century occurred due to malaria, fever, child deaths, tuberculosis and plague. The proportion of deaths due to accidents and injuries was relatively small (Loimer, Guarnieri 1996). With the industrial revolution, however, came a change in society where an increased industrialisation and modernisation reduced the risk of infectious diseases as well as increasing both the risk of injury and the economic costs of injuries (Cooter, Luckin 1997). Therefore, not only did injuries account for a larger percentage of deaths, the incentive to understand and prevent injuries became considerably greater. Despite the general view at the time of injuries being largely caused by mistakes by the individual (Heinrich 1931), the need for knowledge on injury determinants and prevention strategies lead to injury
registration systems being developed in the mid 19th century (McKenzie, Fingerhut et al. 2012) and ground-breaking injury research at the beginning of the 20th century (De Haven 1942, Gordon 1949, Stapp 1957, Haddon, Suchman et al. 1964).

This shift in societal health problems, from diseases of poverty to disorders related to well-being has been well described in the literature concerning health transition (Omran 1971, Hjort 1994). In terms of injuries, similar transitions have previously been shown (Moniruzzaman 2006). Whilst the majority of injury categories are most prevalent in poorer countries, injuries amongst elderly seem to become a societal problem and increase, in conjunction with improved prosperity and affluence (Moniruzzaman, Andersson 2005). With economic growth and social development, two interconnected aspects seem to occur. Firstly, the risk of injuries other than fall-related decreases and secondly, the number of elderly surviving to old age increases, therefore increasing the absolute number of fall-related injuries as a consequence.

The effect of increasing elderly populations in the western world during the 20th century and the subsequent effect on absolute numbers of fall-related injuries is an aspect that has been generally accepted by researchers (Marks, Allegrante et al. 2003). However, whilst increases in absolute numbers can be directly connected to this development, the increases in risk (i.e. regardless of changes in population size) that were identified have been far less discussed in terms of the causes to this development. Suggestions have been put forward that the increases are due to declines in physical activity or increases in the prevalence of osteoporosis (Lau, Cooper 1996), although a general consensus seems to be that increased survival rates of frail elderly is the main cause (Cummings, Melton 2002, McColl, Roderick et al. 1998).

Whilst a majority of geriatricians would argue that frailty is becoming more common amongst elderly in high-income countries and that typical symptoms of frailty include weight loss, fatigue, impaired grip strength, diminished physical activity or a slow gait, agreeing on a definition has been difficult (Rockwood 2005). However, frailty is now increasingly being defined as a biologic syndrome of decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiologic systems, and causing an increased risk to adverse outcomes (Fried, Tangen et al. 2001). This definition means that not only physical but also mental frailty is included. In terms of fall-related injuries, a large number of symptoms included in frailty have been
shown to increase the risk of fall-related injuries. For example, low BMI (Body Mass Index) (Laet, Kanis et al. 2005), fatigue (Cummings, Nevitt 1989), low physical activity (Wickham, Walsh et al. 1989) and slow gait (Dargent-Molina, Favier et al. 1996) have all been shown to increase the risk of fall-related fractures.

Frailty, with this more general definition, is closely linked to advanced old age and the health status seen in this age group. Also, frailty can be viewed as a condition where minor stimuli are sufficient to cause serious disability or death (Campbell, Buchner 1997). Although frail elderly have existed also in the past, the improvements in medical treatment and societal care for the elderly has meant that parallel to increasing survival rates of all elderly following diseases, the group of frail elderly has increased. Therefore, the trend of increasing absolute numbers of fall-related injuries as well as the relative risk can, perhaps, be viewed as an indicator of successful social development based on improvements in nutritional status, healthcare and medical treatment in the population.

**International fall-related injury trends in the 21st century**

Since the turn of the century, the volume of research on fall-related injury trends has increased immensely, perhaps due to an increased availability of data and improved quality of national injury data. Despite this, only two studies have been published regarding fall-related injuries, based on national data using ICD chapter XX. Both these show large increases in fall-related incidence rates for both men and women. In The Netherlands, the observed increase in fall-related injury rates resulted in an increase of 61% between 1981 and 2008 (Hartholt, van der Velde et al. 2010). Similarly, in The United States an increase was seen of 31% between 2001 and 2008 (Hartholt, Stevens et al. 2011).

With regards to hip fractures, although exponential global increases were predicted towards the end of the 20th century, there is evidence that suggests that this has not occurred in countries with similar socio-economic standard as Sweden. Of the national hip fracture trend studies that previously showed increasing trends, all showed different trends at the turn of the century. In both The Netherlands and Finland, downturns were seen from 1996 or 1997, respectively, and decreased from 450 to roughly 370 per 100 000 in 2005.
(Finland) and from 700 to 650 per 100 000 in 2006 (Netherlands) (Kannus, Niemi et al. 2006, Hartholt, Oudshoorn et al. 2011). In the Czech Republic, a largely stable, horizontal trend was observed from 2004 to 2009 (Stepan, Vaculik et al. 2012).

As well as these studies, a number of other national hip fracture trend studies, in countries similar to Sweden, have been published during the 21st century covering shorter time periods. In Denmark, for example, a decrease in hip fracture rates of at least 20% in both sexes, 60 years and above was observed between 1997 and 2006 (Abrahamsen, Vestergaard 2010).

Two countries show slightly different secular trends with downturns occurring considerably earlier. In Canada, between 1985 and 2005, decreases were seen amongst both men (-25.0%) and women (-31.8%) with the largest decreases in the younger age groups (≤74 years). The decreasing trend was evident throughout the studied time period but increased from 1996 to 2005 (Leslie, O'Donnell et al. 2009). In New Zealand, hip fracture rates among individuals 50 years and above increased for women from 1974 to 1987 to thereafter decrease. For men, an increasing trend was observed from 1974 to 2007 (Langley, Samaranayaka et al. 2011).

Although some national hip fracture trend articles show downturns in incidence rates, some evidence suggests that a general downturn has not occurred, although decreases occurred in certain age- and sex-specific groups. Between 2000 and 2007 in Belgium, hip fracture rates among those 50 years and above, decreased amongst women and remained stable for men (Hiligsmann, Bruyere et al. 2012) and similar results were observed in Norway between 1999 and 2008 (Omsland, Holvik et al. 2012). In Switzerland between 2000 and 2007 a small decrease was seen amongst women and a small increase amongst men (Lippuner, Popp et al. 2011). In Germany, Icks, Haastert et al showed a decrease in incidence for women 74 years or younger while the incidence for women 75 years and over has continued to increase (Icks, Haastert et al. 2008). Kannus, Niemi et al, in Finland, also showed a much larger decrease for women, compared to men, although both showed a decreasing trend (Kannus, Niemi et al. 2006), in similarity to data from France and The Netherlands (Maravic, Taupin et al. 2011, Hartholt, Oudshoorn et al. 2011).

In contrast to these studies showing a change in trend in at least some age- and sex-specific groups, there is contradictory evidence from other countries. Most
noticeably, hip fracture rates amongst elderly in Austria have continued to increase between 1994 and 2006 (Mann, Icks et al. 2008). Taiwan and Ecuador also show similar results with continuing increasing trends (Shao, Hsieh et al. 2009, Orces 2011).

Whilst the national trends of hip fracture incidence in the last decade have been studied in a number of countries, very few studies have been published with focus on other, less common, fall-related injuries amongst elderly. A number of problems exist with studying other fall-related injuries and comparing trends as well as incidence rates between countries. Firstly, in contrast to hip fractures, not all are hospitalized. Patients with wrist fractures, for example, are very rarely hospitalized and are instead treated within the outpatient system. Whilst injury registration systems (for example the Injury Database (IDB) system) exist also for these patients, these are rarely nationwide registers. Secondly, whilst the treatment of hip fractures has improved considerably during the last three decades, no changes have occurred with regards to hospitalization criteria. For other, minor fall-related fractures, criteria can be different between hospitals as well as over time. However, despite this, the fact that a minor fall-related injury is hospitalized does also indicate that a minor injury has had a major impact on the individual. Any injury that has a major impact on an individual is also likely to have a major impact on society and therefore the trends of hospitalized, minor fall-related injuries are important to study as it gives indications on the status of the studied population.

In terms of national trend studies on specific fall-related injuries amongst elderly, few have been published, although generally, increases in hospitalization have been observed. In two studies from The United States and The Netherlands, fall-related intracranial head injuries were shown to be increasing considerably (Hartholt, Van Lieshout et al. 2011, Ramanathan, McWilliams et al. 2012). In Finland, the trends of distal and proximal humeral fractures as well as ankle fractures have been studied between the 1970s and late 2000s. Increases have been observed from the 1970s up to the mid 1990s followed by a stabilization or decrease in incidence rates (Kannus, Palvanen et al. 2009, Palvanen, Kannus et al. 2010, Kannus, Palvanen et al. 2008). A Dutch study, however, showed continuing increases of wrist fractures and upper-arm fractures between 1981 and 2008 (Hartholt, van der Velde et al. 2010).
Suggested explanations to the diverging trends

The decreases in hip fracture rates seen in other high-income countries has lead to a discussion as to why this has occurred. Typically, healthier elderly populations, increases in BMI among the elderly population, improved functional ability, improved treatment of osteoporosis or fall prevention programs have been suggested as potential underlying causes (Kannus, Niemi et al. 2006, Leslie, O'Donnell et al. 2009, Abrahamsen, Vestergaard 2010). These hypothetical causes are largely based on a biomechanical understanding of why certain falls lead to injuries and it has been suggested that the decisive factor as to whether a hip fracture occurs is the inability of the individual to cope with the energy within the fall (Lauritzen 1996). The suggested causes are closely connected to aspects of frailty, as described previously and therefore indirectly, the hypothetical causes as to why a change in trend has occurred would seem to suggest that the overall frailty within the elderly population is decreasing.

The observed gender differences that have been seen with regards to hip fractures in for example Germany, Finland and Switzerland (Icks, Haastert et al. 2008, Kannus, Niemi et al. 2006, Lippuner, Popp et al. 2011) have also given rise to similar suggestions as for the general decreases. For example, a difference in body mass distribution between men and women (Shimokata, Andres et al. 1989) has been suggested, as has the fact that preventative measures may have been focused on women rather than men (Wong, Wan et al. 2011). The use of hormone therapy to treat osteoporosis may also be underlying these diverging trends, although there is considerable doubt as to how important this treatment has been (Icks, Haastert et al. 2008, Kannus, Niemi et al. 2006, Lippuner, Popp et al. 2011). Finally, suggestions have been put forward that the general decreasing trends with larger reductions among women are due to an overall reduced risk of osteoporosis, with an observed 7% decrease in femoral neck osteoporosis amongst women and 3% decrease amongst men between 1988-1994 and 2005-2006 in The United States (Looker, Melton et al. 2010).

Fall-related mortality trends

Whilst a number of national studies have investigated fall-related morbidity using national patient registers, very few have been published on fall-related
mortality using a national Cause of Death Register (CDR). In Finland, The Netherlands and The United States, increasing trends of fall-related mortality have been observed during the 21st century, despite decreasing trends being observed during the 1980s and 1990s (Korhonen, Kannus et al. 2013, Hartholt, Polinder et al. 2012, Alamgir, Muazzam et al. 2012). In all of the three countries, men are at a higher relative risk of fall-related mortality and the increases are predominantly within the oldest old population.

In terms of the type of fall-related injury that has lead to death amongst elderly, although this has not been studied specifically, it is hypothesized that hip fractures account for at least fifty per cent and that a large part of the other deaths are head injuries (Korhonen, Kannus et al. 2013). This aspect creates the possibility of confounding factors when studying all fall-related injury deaths from merely an external cause perspective. Specifically, whilst the methods for diagnosing hip fractures has remained unchanged during the last 30 to 40 years, considerable developments have been made in the diagnosing of head injuries with the general application of CT scans and MRI. This development could greatly affect the trends of diagnosed serious head injuries and therefore also the general fall-related mortality trends. In other words, without the diagnostic capabilities available today, a risk is that falls were not recognized as a decisive cause of death.

In the literature review, no studies using a national cause of death register were found concerning hip fractures, although a large number of follow-up studies have been published showing an increased risk of mortality following a hip fracture (Haleem, Lutchman et al. 2008). The fact that hip fracture patients have considerably higher risks of death within a year of the injury compared to individuals who have not had a hip fracture is largely undisputed (Abrahamsen, van Staa et al. 2009). However, there is a risk that the causal effect of the hip fracture on mortality is overly interpreted in these types of studies. Frailty, physical and mental disability as well as poor general health are well-known risk factors for hip fractures (Marks, Allegrante et al. 2003) but also for general mortality (Fried, Tangen et al. 2001) and so the fact that mortality is higher amongst hip fracture patients compared to controls is unsurprising. This is also clearly illustrated by the fact that hip fracture patients have a higher risk of mortality even 15-20 years after the hip fracture (Snijder, van Schoor et al. 2006, Soderqvist, Ekstrom et al. 2009), when the direct effect of the hip fracture trauma is minimal. Therefore, comparing the risk of death several months or
years after a hip fracture between hip fracture patients and controls may be biased, as there are confounding elements.

Although no studies have been published that have investigated the secular trends of hip fracture mortality using the national cause of death registers, a review article of several hip fracture mortality studies from around the world could show no changes in risk between 1958 and 1998. It is argued that the fact that hip fracture mortality has not increased over the decades may be related to improvements in operative techniques as well as other aspects of improved medical management. Increased awareness with regards to the need for early surgery, better nursing and community care may have contributed substantially. Another possible factor could be an elderly population more medically fit and not as frail as in earlier years (Haleem, Lutchman et al. 2008). Interestingly, this explanation seems to partly contradict the main explanatory causes as to why hip fracture rates increased during the 1980s and 1990s. If hip fracture morbidity rates increased due to improved medical care and the consequent effect on the number of frail individuals, it would seem peculiar that hip fracture mortality rates are unchanged during the same time period due to fewer frail elderly and improved healthcare.

**Background summary and research question**

A number of review articles on hip fracture rates over the last 30 years have shown that Sweden has amongst the highest rates in the world (Kanis, Johnell et al. 2002, Kanis, Oden et al. 2012, Cummings, Nevitt 1989, Cheng, Levy et al. 2011). Also, both the absolute number of fall-related injuries, and hip fractures especially, as well as the relative risk, has steadily increased during the 20th century in both Sweden and other high-income nations (Marks 2010). This has largely been explained by increasing numbers of elderly and specifically frail elderly although the unaffected rates of hip fracture mortality has been explained by fewer numbers of frail elderly.

Newer research from countries similar to Sweden now indicates that hip fracture rates are decreasing although the current status in Sweden is unknown. There is also evidence to suggest that the general fall-related injury risk is increasing amongst elderly despite reductions in hip fracture incidence, that the types of fall-related injuries leading to hospitalization are changing and signs of
differentiated trends in age- and sex-specific groups. With these disparities, with regards to both morbidity and mortality fall-related injury trends, as well as the considerable societal and individual cost of these injuries, these issues are important to explore. Whilst the primary objective of this thesis is to update the knowledge concerning these issues in Sweden in order to plan and prepare future healthcare needs, the issues are relevant to investigate from a broader perspective. Through a better understanding of fall-related trends amongst elderly as well as insights into possible causes to the development, public health initiatives can be improved and modified in order to counteract this issue, not only in Sweden but probably also in other similar countries.
AIMS

The overall aim of this thesis is to update the level of knowledge on the trends of fall-related injuries amongst elderly in Sweden and thereby contributing to the understanding of why fall-related injury trends seem to diversify over time. Based on empirical data, this thesis also aims to consider whether fall-related injuries amongst elderly are still to be seen as an emerging risk in Sweden and how the future fall-related injury panorama may develop.

Specific aims


- To explore age- and sex-specific trends of hospitalized fall-related fractures amongst elderly in Sweden by type of fracture between 1998 and 2010. (Paper II)

- To explore hospitalized fall-related injury trends amongst elderly in Sweden by type of injury between 2001 and 2010. (Paper III)

- To explore age- and sex-specific trends of hip fracture mortality amongst elderly in Sweden between 1987 and 2009. (Paper IV)
MATERIALS AND METHODS

Globally, injury data is collected through a variety of means and at differing levels of severity. For the most part, the ICD coding system is used. The ICD system, originally designed to classify cause of death, has existed in different versions since the mid 19th century (McKenzie, Fingerhut et al. 2012). Although the ICD system was, and is, predominantly used to code causes of death, a development has occurred during the mid 20th century where the system also is increasingly used to code hospitalized cases as well as non-hospitalized cases.

With regards to injuries, the ICD system categorizes these in two separate chapters, chapter XIX (injury, poisoning and certain other consequences of external causes) and chapter XX (external causes of morbidity and mortality). This means that all injuries are categorized twice, once from a strictly medical injury diagnosis (chapter XIX) and once from a broader approach where the external cause, i.e. the causing accident, act of violence or self-harm, is determined (chapter XX). Due to a continued effort to improve the ICD coding, periodically, new versions replace older. This development has meant that compared to previous versions, the improvements to the ICD system when introducing ICD-9 and ICD-10 have been predominantly focused on matching the needs of mortality registration (Jette, Quan et al. 2010).

Sweden has the oldest continuous population statistics in the world with the establishment of Tabellverket (Statistics Sweden) in 1749. Registration of causes of death was included in these population statistics and although broad categories were used, deaths due to accidents have continuously been registered in Sweden since the 18th century. Up to 1951, when ICD-6 was adopted, national or Scandinavian registration systems were continuously developed (Smedby, Schiøler 2006).

With regards to injury morbidity registration, the first attempts to categorise hospitalized diseases and injuries in Sweden started in 1874. As with mortality registration, a number of different systems were used, until ICD-7 was adopted in 1964 (Smedby, Schiøler 2006). Although hospitalized injury data has been collected since 1964, it was not until 1987 with the implementation of ICD-9, that the reporting system was all-encompassing, covering all Swedish healthcare providers and considered reliable (Ludvigsson, Andersson et al. 2011). ICD-10 was endorsed by the World Health Assembly in 1990 and implemented in Sweden the first of January 1997 (Socialstyrelsen 1996). Due to the Swedish
Personal Identification Number (PIN), injury data in Sweden is considered highly reliable with 99.9% of the Swedish population having a PIN (Ludvigsson, Otterblad-Olausson et al. 2009).

The Swedish patient register is generally seen as a reliable data source and although errors have been identified in the Swedish Cause of Death Register, these are considerably less than in other comparable databases (Johansson, Westerling 2002). Globally, problems in data quality have been observed in regards to injury surveillance data, often in conjunction with changes in ICD coding versions when dramatic effects have been seen on trend development within injury mortality (Anderson, Rosenberg 2003, Jansson, Johansson et al. 1997, Pearson-Nelson, Raffalovich et al. 2004).

Whilst a reliable, national, CDR and national patient register (NPR) contribute to a considerable body of knowledge, these registers merely collect data regarding the top of the injury pyramid. The large majority of injuries do not cause death or require hospitalization and to fill this gap of knowledge, the Injury Database (IDB) exists. IDB is a pan-European initiative designed originally to identify injury-causing consumer products. Launched in the mid 1980's in its previous form, EHLASS (European Home and Leisure Accident Surveillance System), the purpose of the register was to record injuries that required healthcare but not hospitalization.

Contrary to CDR and NPR, the Swedish IDB registers injuries based on the NCECI (NOMESCO Classification of External Causes of Injuries) system (Socialstyrelsen 2014), meaning that comparisons between the systems can at time be difficult. Likewise, whilst CDR and NPR are national systems, IDB in Sweden merely covers approximately nine per cent of the population. Whilst this means that national non-hospitalized injury data is merely approximated, IDB has an important roll in local injury prevention surveillance. Also, as European data is combined, emerging dangers and products can quickly be found and controlled.

Sweden also has a number of specific injury registers that are concerned with particular arenas or fields. Most complete is the Swedish Traffic Accident Data Acquisition (STRADA), compiling data from police (and in a majority of counties also from the healthcare system) on traffic-related injuries.
All four studies in this thesis have used data from either the Swedish National Patient Register or Cause of Death Register. In the selection of cases, only primary diagnosis (papers I-III) or underlying cause (paper IV) was included. In the model below, the graphical relationship between the four papers is presented (figure 1). In terms of fall-related injury morbidity, this thesis includes two papers using both chapter XX and XIX of the ICD; all fall-related injuries and fall-related fractures, and one paper based on chapter XIX; hip fractures. As is clear from the model and as has been mentioned previously, some hip fractures are caused by other external causes than falls. In terms of fall-related mortality, one paper is included; hip fracture mortality, based on chapter XIX. Whilst it is possible to study fall-related mortality with chapter XX data, as was mentioned in the background, there are potential confounding issues when using this data.

There is also a problem when using data spanning across two or more coding versions in that the coding instructions are often adapted or changed in order to improve the data quality. In this thesis two papers include data from ICD-9 and ICD-10 (paper I and IV). Both of these are focused on chapter XIX of the ICD and the diagnosis hip fracture. Between ICD-9 and ICD-10 no changes occurred in the diagnosis or coding criteria with regards to hip fractures, whilst changes did occur in the coding of falls as external cause.

![Diagram](image.png)

**Figure 1.** Schematic model of the four papers included in the thesis.
When investigating hospitalized injury rates, common definitions are vital in order for comparisons to be possible between countries and over time. In terms of injury definitions, the ICD coding system is widely recognised as a functional data classification system. The definition of elderly, however, is more complex. Historically, no clear definition of elderly, or “old age”, has existed. Generally, during the 20th century, researchers have used 60 or 65 as defining old age in high-income countries largely due to this being the age of retirement (Roebuck 1979). Whilst the retirement age is still largely within this age-bracket, with improved medical care, social welfare and economical development, it is argued that this definition of old age is out-dated and that old age is now reached at a later stage in life and therefore should be limited to those over 75 years (Orimo 2006).

As of yet, no new or standardized definition of elderly has been adopted and other studies on fall-related injury trends have used data on individuals 50 years and above (Chevalley, Guilley et al. 2007, Jaglal, Weller et al. 2005, Kannus, Niemi et al. 2006, Rosengren, Ahlborg et al. 2010, Bergström, Jonsson et al. 2009), 55 years and above (Lönnroos, Kautiainen et al. 2006), 60 years and above (Abrahamsen, Vestergaard 2010, Lefaivre, Levy et al. 2011) and 65 years and above (Hartholt, Oudshoorn et al. 2011). In the papers included in this thesis, the definition proposed by OECD, when identifying injuries among elderly as an emerging risk in Sweden, has been used, i.e. elderly as those 65 years and above, younger elderly as those 65-79 years and older elderly as those 80 years and over (OECD 2007).

For all papers included in this thesis, the Statistical Package for the Social Sciences (SPSS) software (version 15.0) has been used for all statistical analysis. P-values <0.05 were considered statistically significant.

**Paper I**

For the first study, hip fracture data among those 65 years and older and information on gender and age, on a yearly basis, from 1987 to 2009 was studied. Hip fractures were defined as 820.x according to ICD-9 and S720-722 (ICD-10).
The statistical analysis for this study was performed in three steps. First, age- and sex-specific hip fracture rates per 100,000 were trend analysed. Secondly, annual percentage changes of incidence rates were used to compare time periods that helped quantify changes in secular trends. Finally, linear regression analysis was used to examine the trend data and observed rates. Two time periods with seemingly different trends were identified (1987-1996 and 1997-2009) and analysis was therefore computed on the total time period as well as these two time periods.

**Paper II**

For this study, data was obtained regarding fall-related injury hospitalizations among those 65 years and above and information on types of fall-related fractures, gender and age, on a yearly basis, from 1998 to 2010. Fall-related fractures were defined as fractures with external codes W00-W19 (ICD-10). The fall-related fractures were grouped into hip fractures (fracture of femur (S72)), upper extremity fractures (fractures of shoulder or upper-arm (S42), forearm (S52), wrist and hand (S62)), lower extremity fractures (fracture of lower leg and ankle (S82), foot (S92)) and central fractures (fractures of skull and facial bones (S02), neck (S12), ribs, sternum and thoracic spine (S22), lumbar spine and pelvis (S32)).

Age- and sex-specific fall-related fracture rates were calculated per 100,000 population. The statistical analysis for this study was performed in multiple steps. First, trend lines were drawn to show the secular trends of fall-related fracture rates (per 100,000) by age- and sex-specific groups. In order to explain the fall-related fracture trends over the study period, trend lines for type of fracture (i.e. hip fractures, upper extremity fractures, lower extremity fractures and central fractures) was also presented. Secondly, linear regression analyses for the entire study period were performed. The types of fracture rates (per 100,000) were used as dependent variables in the regression models. Finally, annual percentage changes of incidence rates between 1998 and 2010 were calculated to help quantify changes in secular trends.
**Paper III**

For the third study, data was obtained regarding hospitalized injuries with falls as external cause among those 65 years and above with information on injury type, gender and age, on a yearly basis, from 2001 to 2010. Fall-related injuries were defined as injuries with external cause codes W00-W19 (ICD-10). The fall-related injuries were grouped into superficial injuries (S00, S10, S20, S30, S40, S50, S60, S70, S80 and S90), open wounds (S01, S11, S21, S31, S41, S51, S61, S71, S81 and S91), fractures (S02, S12, S22, S32, S42, S52, S62, S72, S82 and S92), luxations (S03, S13, S23, S33, S43, S53, S63, S73, S83 and S93), intracranial injuries (S06) and other or unspecified injuries. Population data was obtained from Statistics Sweden.

The statistical analysis was performed in three steps. First, age- and sex-specific incidence rates were calculated (per 100 000 population) for all fall-related injuries and for each injury type. Age- and sex-specific trend lines were drawn for fall-related injury trends (per 100 000) as well as sex-specific type of fall-related injury trend (per 100 000). Secondly, linear regression analyses for the study period were performed. Type of fall-related injury incidence rates (per 100 000) was used as dependent variable in the regression models. Finally, the percentage change of incidence rates was calculated between 2001 and 2010 for types of fall-related injuries.

**Paper IV**

Data for this study was obtained from the Swedish CDR and NPR regarding hip fractures among those 65 years and older with information on gender and age, on a yearly basis, from 1987 to 2009. With regards to hip fracture data from the CDR, hip fractures registered as immediate or underlying causes of death were included. Hip fractures were defined as 820.x according to ICD-9 and S720-7229 (ICD-10). Population data was obtained from Statistics Sweden.

The statistical analysis for this study was performed in a number of steps. First, age- and sex-specific hip fracture case fatality rates (CFR) were calculated and plotted using CDR data and NPR data. From the trend analysis, two time periods with seemingly different trends were identified (1987-1996 and 1997-2009). Segmented regression analysis was used to investigate whether differing
linear trends were present and if changes in trend had occurred between the two time periods (Wagner, Soumerai et al. 2002). Lastly, percentage change was calculated on the statistically significant trends in order to quantify the changes between 1987 and 1996 as well as 1997 and 2009.

Ethical considerations

The Swedish NPR and CDR are both hosted by the National Board of Health and Welfare based on regular hospital discharge and cause of death records. The collection of this data is governed in law by the burial law (begravningslagen (1990:1144)) (CDR) and the National Board of Health and Welfare policies SOSFS 2008:26, SOSFS 2009:26 and SOSFS 2011:4 (NPR). Both registers aim to serve public health and research interests.

Due to injury data being routinely and mandatory collated in this manner no approval is needed by the individual in order for data to be collected. Whilst this clearly strengthens the data quality and thereby the connected research, from an ethical perspective, this form of health and injury surveillance requires stringent routines to ensure that no individual can be harmed.

The National Board of Health and Welfare manage and determine the availability of both the NPR and CDR for research purposes. Generally, data is available freely as long as there is no risk of identifying individual persons. If a risk of identifying individuals is determined, ethical consideration, from an ethical board, is required. With regards to the data used in this thesis, no such risks were determined from the National Board of Health and Welfare due to the data being delivered anonymized in 5-year age groups, on a yearly basis. Also, due to the large number of cases per year, the risk of identification, regardless if personal data was removed, was regarded as minimal. Therefore, no further ethical approval was needed for any of the papers included in this thesis.
RESULTS

Paper I

Between 1987 and 2009 the total number of hip fractures among elderly (65 years and above) remained fairly stable with a very slight decrease from 20448 to 20291. However, as is clear from figures 2 and 3, hip fracture incidence rates have varied with regards to trends. In the older age groups, increasing trends are seen from 1987 until the ICD coding change in 1997 to thereafter decrease and finally level off from 2001 until 2009. The younger age groups have had a stable trend from 1987 to 1996 to thereafter decrease (figures 2 and 3).

Figure 2. Age-specific hip fracture incidence rates between 1987 and 2009, women 65 years and above (vertical dashed line indicates the transition from ICD-9 to ICD-10).
Figure 3. Age-specific hip fracture incidence rates between 1987 and 2009, men 65 years and above (vertical dashed line indicates the transition from ICD-9 to ICD-10).

During the entire studied time period (1987-2009), hip fracture incidence rates for all age- and sex-specific groups decreased with the largest absolute decrease amongst women 80 years and above (from 4341 to 3364 per 100 000) and the largest percentage decreases in the younger age groups (Men 65-79: from 476 to 363 per 100 000; -23.7%, Women 65-79: from 918 to 581 per 100 000; -36.7%). In the older age group a large difference is seen between the sexes (Men 80+: from 2258 to 2242 per 100 000; -0.7%, Women 80+: from 4341 to 3364 per 100 000; -22.5%). Between 1987 and 1996 the hip fracture incidence rates increased for all age- and sex-specific groups with large increases among men (65-79: from 476 to 540 per 100 000; 13.5%, 80+: from 2258 to 2632 per 100 000; 16.6%) and only marginal increases among women (65-79: from 918 to 943 per 100 000; 2.8%, 80+: from 4341 to 4423; 1.9%). During the later time period (1997-2009), the hip fracture incidence rates decreased for all age- and sex-specific groups with the largest decreases among the younger age groups (men 65-79: from 514 to 363 per 100 000; -29.4%, women 65-79: from 882 to 581 per 100 000; -32.8%) while slightly more moderate decreases were seen in the older age groups (men 80+: from 2514 to 2242 per 100 000; -10.8%, women 80+: from 4305 to 3364 per 100 000; -21.9%) (Figures 2 and 3 & table 1).
Table 1. Percentage changes of absolute number and incidence rates (/100 000) of hip fractures by age- and sex-specific groups.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in absolute number of hip fractures, 65-79 years, males (%)</td>
<td>10.1</td>
<td>-19.8</td>
<td>-16.4</td>
</tr>
<tr>
<td>Changes in incidence rates, 65-79 years, males (%)</td>
<td>13.5</td>
<td>-29.4</td>
<td>-23.7</td>
</tr>
<tr>
<td>Changes in absolute number of hip fractures, 80 years and above, males (%)</td>
<td>46.7</td>
<td>9.1</td>
<td>55.3</td>
</tr>
<tr>
<td>Changes in incidence rates, 80 years and above, males (%)</td>
<td>16.6</td>
<td>-10.8</td>
<td>-0.7</td>
</tr>
<tr>
<td>Changes in absolute number of hip fractures, 65-79 years, females (%)</td>
<td>-0.4</td>
<td>-32.8</td>
<td>-37.9</td>
</tr>
<tr>
<td>Changes in incidence rates, 65-79 years, females (%)</td>
<td>2.8</td>
<td>-34.2</td>
<td>-36.7</td>
</tr>
<tr>
<td>Changes in absolute number of hip fractures, 80 years and above, females (%)</td>
<td>27.7</td>
<td>-12.4</td>
<td>10.6</td>
</tr>
<tr>
<td>Changes in incidence rates, 80 years and above, females (%)</td>
<td>1.9</td>
<td>-21.9</td>
<td>-22.5</td>
</tr>
</tbody>
</table>

As is seen in figure 4, between 1987 and 2009, the mean age of sustaining a hip fracture amongst those 65 years and above has steadily increased from 81.3 (women) and 79.8 (men) in 1987 to 83.8 (women) and 82.1 (men) in 2009 (figure 4).

![Mean age of sustaining a hip fracture](image)

Figure 4. Mean age of sustaining a hip fracture in the Swedish population 65 years and over.
Paper II

For the ICD-10 time period, while hip fractures rates have decreased considerably, the same is not true for other hospitalized fall-related fractures. Between 1998 and 2010, hospitalized fall-related fractures among women showed larger decreases than men in the same age-specific group, despite fall-related fractures being more common among women. The largest decreases are seen in the younger age group (65-79 years) for both men and women (Figure 5 and table 2).

Figure 5. Incidence trend lines for hospitalized fall-related fracture incidence (rates/100 000) by age- and sex- specific groups, 1998-2010.

Table 2. Incidence rates (/100 000) and percentage changes of hospitalized fall-related fractures between 1998 and 2010 by age- and sex-specific groups.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>1998</th>
<th>2010</th>
<th>1998-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incidence rate (per 100 000)</td>
<td>Incidence rate (per 100 000)</td>
<td>Percentage change (%)</td>
</tr>
<tr>
<td><strong>Men 65-79</strong></td>
<td>692.2</td>
<td>600.1</td>
<td>-13.3</td>
</tr>
<tr>
<td><strong>Men 80+</strong></td>
<td>2484.0</td>
<td>2596.7</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Men 65+</strong></td>
<td>1107.6</td>
<td>1071.5</td>
<td>-3.3</td>
</tr>
<tr>
<td><strong>Women 65-79</strong></td>
<td>1336.4</td>
<td>1122.3</td>
<td>-16.0</td>
</tr>
<tr>
<td><strong>Women 80+</strong></td>
<td>4716.4</td>
<td>4493.6</td>
<td>-4.7</td>
</tr>
<tr>
<td><strong>Women 65+</strong></td>
<td>2410.0</td>
<td>2223.8</td>
<td>-7.7</td>
</tr>
</tbody>
</table>
For both men and women, hip fractures are the most common type of hospitalized fall-related fracture. Amongst men, central fractures are the second most common while for women the equivalent is upper extremity fractures. Lower extremity fractures are the least common type of fracture for both men and women.

Despite being the most common type of hospitalized fall-related fracture, hip fractures are also the fracture type that has decreased in incidence the most between 1998 and 2010. The largest decreases can be seen in the younger group (65-79 years) for both men (-28.2%) and women (-28%). The largest increases are observed amongst upper extremity fractures in the elderly group (80 years and above) for both men (21.5%) and women (10.7%). A similar result is seen in central fractures with statistically significant increases for both sexes. The largest increases are seen in the older (80 years and above) age groups (men: 17.0%, women: 8.6%). Lower extremity fractures increased in the older age groups and decreased in the younger (table 3).
Table 3. Linear regression analysis and percentage change for type of fractures in age- and sex-specific groups between 1998-2010.

<table>
<thead>
<tr>
<th>Type of fracture</th>
<th>Age and Sex</th>
<th>B*</th>
<th>p-value</th>
<th>95% confidence intervals for B</th>
<th>R²</th>
<th>Percentage changes between 1998 and 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central fractures</strong></td>
<td>Male</td>
<td>65-79</td>
<td>0.58</td>
<td>0.198</td>
<td>-0.35, 1.51</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>7.88</td>
<td>0.006</td>
<td>2.75, 13.01</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>2.51</td>
<td>0.001</td>
<td>1.36, 3.65</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>65-79</td>
<td>-2.08</td>
<td>0.006</td>
<td>-3.45, -0.71</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>7.41</td>
<td>0.021</td>
<td>1.32, 13.50</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>1.67</td>
<td>0.074</td>
<td>-0.19, 3.53</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>Hip fractures</strong></td>
<td>Male</td>
<td>65-79</td>
<td>-8.65</td>
<td>&lt;0.001</td>
<td>-9.42, -7.87</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>0.65</td>
<td>0.798</td>
<td>-4.81, 6.10</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>-5.78</td>
<td>&lt;0.001</td>
<td>-8.33, -3.23</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>65-79</td>
<td>-16.17</td>
<td>&lt;0.001</td>
<td>-18.11, -14.23</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>-28.33</td>
<td>&lt;0.001</td>
<td>-36.43, -20.24</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>-17.95</td>
<td>&lt;0.001</td>
<td>-22.28, -13.62</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>Lower extremity fractures</strong></td>
<td>Male</td>
<td>65-79</td>
<td>-0.89</td>
<td>0.022</td>
<td>-1.64, -0.15</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>0.58</td>
<td>0.384</td>
<td>-0.83, 1.99</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>-0.53</td>
<td>0.143</td>
<td>-1.28, 0.21</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>65-79</td>
<td>-0.89</td>
<td>0.140</td>
<td>-2.12, 0.34</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>0.50</td>
<td>0.474</td>
<td>-0.99, 2.00</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>-0.35</td>
<td>0.480</td>
<td>-1.42, 0.71</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Upper extremity fractures</strong></td>
<td>Male</td>
<td>65-79</td>
<td>0.42</td>
<td>0.233</td>
<td>-0.31, 1.16</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>3.06</td>
<td>0.017</td>
<td>0.67, 5.45</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>1.12</td>
<td>0.033</td>
<td>0.10, 2.13</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>65-79</td>
<td>-1.12</td>
<td>0.094</td>
<td>-2.46, 0.22</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80+</td>
<td>7.96</td>
<td>&lt;0.001</td>
<td>4.41, 11.52</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65+</td>
<td>2.23</td>
<td>0.014</td>
<td>0.54, 3.92</td>
<td>0.43</td>
</tr>
</tbody>
</table>

*Unstandardized regression coefficient
Paper III

Between 2001 and 2010 the total number of hospitalized fall-related injuries in Sweden increased from 37772 to 40731, an increase of 7.8%. As is seen in figure 6, the incidence rates of fall-related injuries were considerably higher amongst women than men in both age groups (figure 6).

![Incidence rates of fall-related injuries (per 100 000) in age- and sex-specific groups.](image)

Figure 6. Incidence rates of fall-related injuries (per 100 000) in age- and sex-specific groups.

Between 2001 and 2010, the incidence rates of hospitalized fall-related injuries decreased in both younger elderly (65-79 years) groups, with a slightly larger decrease amongst women. In the older age group (80 years and above) no statistically significant increases or decreases were observed amongst women whilst an increasing trend was observed amongst men. With regards to the total elderly population, a statistically significant decrease was observed amongst women (table 4).
Table 4. Linear regression analysis and percentage change for fall-related hospitalization in age- and sex-specific groups.

<table>
<thead>
<tr>
<th></th>
<th>B*</th>
<th>p-value</th>
<th>95% confidence intervals for B</th>
<th>R(^2)</th>
<th>Incidence rate (per 100 000) 2001</th>
<th>Incidence rate (per 100 000) 2010</th>
<th>Percentage change 2001-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men 65-79 years</strong></td>
<td>-13.64</td>
<td>0.001</td>
<td>-19.31, -7.98</td>
<td>0.79</td>
<td>1059.8</td>
<td>948.1</td>
<td>-10.5</td>
</tr>
<tr>
<td><strong>Men 80+ years</strong></td>
<td>42.40</td>
<td>&lt;0.001</td>
<td>30.26, 54.55</td>
<td>0.89</td>
<td>3502.9</td>
<td>3902.7</td>
<td>11.4</td>
</tr>
<tr>
<td><strong>Men 65+ years</strong></td>
<td>-4.80</td>
<td>0.255</td>
<td>-13.83, 4.23</td>
<td>0.16</td>
<td>1676.5</td>
<td>1645.6</td>
<td>-1.8</td>
</tr>
<tr>
<td><strong>Women 65-79 years</strong></td>
<td>-27.23</td>
<td>&lt;0.001</td>
<td>-32.24, -22.22</td>
<td>0.95</td>
<td>1637.5</td>
<td>1399.2</td>
<td>-14.6</td>
</tr>
<tr>
<td><strong>Women 80+ years</strong></td>
<td>15.73</td>
<td>0.087</td>
<td>-2.88, 34.34</td>
<td>0.32</td>
<td>5787.1</td>
<td>6035.0</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Women 65+ years</strong></td>
<td>-19.23</td>
<td>0.005</td>
<td>-30.89, -7.57</td>
<td>0.64</td>
<td>3050.4</td>
<td>2913.8</td>
<td>-4.5</td>
</tr>
</tbody>
</table>

*Unstandardized regression coefficient

As is seen in figures 7 and 8, between 2001 and 2010, fractures were by far the most common type of fall-related injury in both sex-specific groups. However, whilst superficial injuries are the second most common fall-related injury amongst women, intracranial injuries are the second most common amongst men (figures 7 and 8).
In terms of age- and sex-specific type of fall-related injury trend, a number of statistically significant trends were observed. With regards to superficial injuries, decreasing trends were observed amongst both men and women in the younger age group and increasing trends in the older age group. Hospitalization due to open wounds also increased in the older age group though a linear trend was
only observed amongst older men. Decreasing trends were observed in both younger age groups with regards to fractures, whilst an increase was observed amongst older men. Statistically significant decreasing trends were observed in all age- and sex-specific groups apart from older men in intracranial injuries. Luxations decreased in all age- and sex-specific groups whilst increases were observed in all age- and sex-specific groups with regards to other or unspecified injuries (table 5).
Table 5. Linear regression analysis and percentage change for types of hospitalized fall-related injuries in age- and sex-specific groups.

<table>
<thead>
<tr>
<th>Type</th>
<th>Group</th>
<th>B*</th>
<th>p-value</th>
<th>95% confidence intervals for B</th>
<th>R²</th>
<th>Percentage change 2001-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superficial injuries</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men 65-79 years</td>
<td>-1.82</td>
<td>0.003</td>
<td>-2.82, -0.82</td>
<td>0.69</td>
<td>-13.81</td>
</tr>
<tr>
<td></td>
<td>Men 80+ years</td>
<td>11.15</td>
<td>&lt;0.001</td>
<td>8.06, 14.24</td>
<td>0.90</td>
<td>19.50</td>
</tr>
<tr>
<td></td>
<td>Women 65-79 years</td>
<td>-2.65</td>
<td>0.003</td>
<td>-4.14, -1.17</td>
<td>0.68</td>
<td>-15.93</td>
</tr>
<tr>
<td></td>
<td>Women 80+ years</td>
<td>11.45</td>
<td>&lt;0.001</td>
<td>6.82, 16.09</td>
<td>0.80</td>
<td>16.95</td>
</tr>
<tr>
<td><strong>Open wounds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men 65-79 years</td>
<td>-0.05</td>
<td>0.903</td>
<td>-0.86, 0.77</td>
<td>0.00</td>
<td>10.22</td>
</tr>
<tr>
<td></td>
<td>Men 80+ years</td>
<td>3.59</td>
<td>0.001</td>
<td>1.95, 5.23</td>
<td>0.76</td>
<td>33.61</td>
</tr>
<tr>
<td></td>
<td>Women 65-79 years</td>
<td>-0.16</td>
<td>0.415</td>
<td>-0.60, 0.27</td>
<td>0.09</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Women 80+ years</td>
<td>2.78</td>
<td>0.059</td>
<td>-0.14, 5.70</td>
<td>0.38</td>
<td>37.34</td>
</tr>
<tr>
<td><strong>Fractures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men 65-79 years</td>
<td>-8.05</td>
<td>0.001</td>
<td>-11.45, -4.64</td>
<td>0.79</td>
<td>-10.26</td>
</tr>
<tr>
<td></td>
<td>Men 80+ years</td>
<td>23.53</td>
<td>&lt;0.001</td>
<td>15.95, 31.10</td>
<td>0.87</td>
<td>8.87</td>
</tr>
<tr>
<td></td>
<td>Women 65-79 years</td>
<td>-20.30</td>
<td>&lt;0.001</td>
<td>-24.60, -15.99</td>
<td>0.94</td>
<td>-13.62</td>
</tr>
<tr>
<td></td>
<td>Women 80+ years</td>
<td>6.11</td>
<td>0.349</td>
<td>-8.04, 20.27</td>
<td>0.11</td>
<td>2.55</td>
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<tr>
<td><strong>Luxations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men 65-79 years</td>
<td>-1.10</td>
<td>0.003</td>
<td>-1.69, -0.51</td>
<td>0.70</td>
<td>-13.94</td>
</tr>
<tr>
<td></td>
<td>Men 80+ years</td>
<td>-1.95</td>
<td>0.032</td>
<td>-3.69, -0.21</td>
<td>0.46</td>
<td>-22.89</td>
</tr>
<tr>
<td></td>
<td>Women 65-79 years</td>
<td>-0.87</td>
<td>0.004</td>
<td>-1.37, -0.37</td>
<td>0.66</td>
<td>-15.22</td>
</tr>
<tr>
<td></td>
<td>Women 80+ years</td>
<td>-1.05</td>
<td>0.124</td>
<td>-2.45, 0.36</td>
<td>0.27</td>
<td>-12.76</td>
</tr>
<tr>
<td><strong>Intracranial injuries</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men 65-79 years</td>
<td>-4.26</td>
<td>0.001</td>
<td>-6.28, -2.23</td>
<td>0.75</td>
<td>-21.40</td>
</tr>
<tr>
<td></td>
<td>Men 80+ years</td>
<td>2.57</td>
<td>0.186</td>
<td>-1.52, 6.67</td>
<td>0.21</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Women 65-79 years</td>
<td>-3.68</td>
<td>&lt;0.001</td>
<td>-4.74, -2.62</td>
<td>0.89</td>
<td>-27.92</td>
</tr>
<tr>
<td></td>
<td>Women 80+ years</td>
<td>-6.47</td>
<td>0.002</td>
<td>-9.74, -3.19</td>
<td>0.72</td>
<td>-9.32</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Men 65-79 years</td>
<td>1.62</td>
<td>&lt;0.001</td>
<td>1.05, 2.19</td>
<td>0.84</td>
<td>33.02</td>
</tr>
<tr>
<td></td>
<td>Men 80+ years</td>
<td>3.52</td>
<td>0.002</td>
<td>1.79, 5.25</td>
<td>0.73</td>
<td>65.86</td>
</tr>
<tr>
<td></td>
<td>Women 65-79 years</td>
<td>0.43</td>
<td>0.033</td>
<td>0.05, 0.81</td>
<td>0.45</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>Women 80+ years</td>
<td>2.89</td>
<td>&lt;0.001</td>
<td>1.88, 3.91</td>
<td>0.84</td>
<td>40.96</td>
</tr>
</tbody>
</table>

*Unstandardized regression coefficient
Paper IV

Between 1987 and 2009, an average of 679 elderly individuals died as a direct result of a hip fracture in Sweden, with the highest number in 2008 (805 individuals) and the lowest in 1994 (562 individuals). As is seen in figure 9, hip fracture mortality was, in absolute numbers, most common amongst elderly women (80 years and above) throughout the studied time period. Whilst a downward trend can be seen in all groups between 1988 and 1994, after this, the trend for the elderly group (80 years or above) changed to an increasing trend, whilst for the younger group the decreasing trend continued (figure 9).

Figure 9. Hip fracture mortality (absolute numbers) between 1987 and 2009 in age- and sex-specific groups.

In order to truly see the risk of death following a hip fracture, case fatality rates are presented (figure 10). As is clear, in similarity to the results in paper I, a change in trend seem to occur in all age- and sex-specific groups between 1996 and 1997, simultaneously with the ICD coding change. For this reason the time series was divided into two time periods (1987-1996 and 1997-2009).

In terms of case fatality rates, the risk of mortality is higher in the oldest group compared to the younger group and higher amongst men in both age-specific groups. In both sex-specific groups in the younger age category, decreasing
trends are observed between 1987 and 1996, to be followed by a stable, horizontal trend. In the older age group, downward trends are observed between 1987 and 1996. Contrary to the younger age group, between 1997 and 2009, statistically significant increasing trends are observed in the older age group (figure 10).

Figure 10. Hip fracture case fatality rates in Sweden between 1987 and 2009 in age- and sex-specific groups (vertical dashed line indicates the transition from ICD-9 to ICD-10).
As is seen in table 6, apart from men and women 65-79 years between 1997 and 2009, all age- and sex-specific groups significantly fit a linear trend. Also, all groups showed a significant trend change between the two time series. In terms of percentage change the largest decrease between 1987 and 1996 was observed amongst men 80 years and above, whereas the largest increase between 1997 and 2009 was observed amongst women 80 years and above (table 6).


<table>
<thead>
<tr>
<th></th>
<th>B*</th>
<th>p-value</th>
<th>95% confidence intervals for B</th>
<th>Percentage change (based on significant linear trend lines)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men aged 80+ years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987-1996</td>
<td>-0.364</td>
<td>&lt;0.001</td>
<td>-0.496, -0.231</td>
<td>-40.63</td>
</tr>
<tr>
<td>1997-2009</td>
<td>0.139</td>
<td><strong>0.004</strong></td>
<td>0.051, 0.228</td>
<td>28.11</td>
</tr>
<tr>
<td>Trend change</td>
<td>0.503</td>
<td>&lt;0.001</td>
<td>0.344, 0.662</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Women aged 80+ years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987-1996</td>
<td>-0.156</td>
<td>&lt;0.001</td>
<td>-0.211, -0.101</td>
<td>-37.18</td>
</tr>
<tr>
<td>1997-2009</td>
<td>0.100</td>
<td>&lt;0.001</td>
<td>0.063, 0.137</td>
<td>44.70</td>
</tr>
<tr>
<td>Trend change</td>
<td>0.256</td>
<td>&lt;0.001</td>
<td>0.190, 0.322</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Men aged 65-79 years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987-1996</td>
<td>-0.072</td>
<td>&lt;0.001</td>
<td>-0.102, -0.042</td>
<td>-36.32</td>
</tr>
<tr>
<td>1997-2009</td>
<td>0.005</td>
<td>0.627</td>
<td>-0.015, 0.025</td>
<td>n/a</td>
</tr>
<tr>
<td>Trend change</td>
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<td>&lt;0.001</td>
<td>0.041, 0.113</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Women aged 65-79 years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987-1996</td>
<td>-0.127</td>
<td>&lt;0.001</td>
<td>-0.183, -0.070</td>
<td>-44.37</td>
</tr>
<tr>
<td>1997-2009</td>
<td>-0.020</td>
<td>0.296</td>
<td>-0.057, 0.018</td>
<td>n/a</td>
</tr>
<tr>
<td>Trend change</td>
<td>0.107</td>
<td><strong>0.004</strong></td>
<td>0.039, 0.175</td>
<td>n/a</td>
</tr>
</tbody>
</table>

*Unstandardized regression coefficient
DISCUSSION

Previous international reports and studies based on data from the end of the 20\textsuperscript{th} century, indicated that Sweden in similarity to other high-income countries were on the verge of a considerable increase in fall-related injuries (Marks, Allegrante et al. 2003, OECD 2007). The predicted increases were due to the combination of previously identified increases in incidence rate (Kanis, Johnell et al. 2002) and the predicted population increases amongst elderly (OECD 2007). The aim of this thesis, therefore, was to explore and update the trends of fall-related injuries amongst elderly in Sweden in order to present both an updated and more complete picture of the current fall-related injury risk panorama. Also, this thesis aimed to consider if fall-related injuries amongst elderly are still to be seen as an emerging risk in Sweden and how the future fall-related injury panorama may develop.

Current national fall-related injury trends in Sweden

Fall-related injuries amongst elderly are a complex and varied injury category with over 400 underlying risk factors (Ilinattiemi, Jokelainen et al. 2009) and a spectrum of injury types. In total, between forty and sixty per cent of falls lead to some type of injury and ninety per cent of these are minor, requiring no medical treatment (Masud, Morris 2001). Despite this, due to the shear number of falls, hospitalized fall-related injuries amongst elderly are a major public health issue in Sweden as well as other high-income countries.

Hip fracture morbidity trends

A number of previous local studies on hip fracture rates in Sweden observed increasing trends up to the 1990s (Jarnlo 1991, Johnell, Nilsson et al. 1984, Zetterberg, Elmerson et al. 1984). As was seen in paper I, these increasing trends continued up to the mid 1990s. However, as is also clear, from the turn of the century, hip fracture rates have decreased amongst both men and women. This pattern, with increasing trends during the 1990s to then be replaced with decreasing trends are very similar to other international studies in other high-income countries (Kannus, Niemi et al. 2006, Hartholt, Oudshoorn et al. 2011, Abrahamsen, Vestergaard 2010, Omsland, Holvik et al. 2012).
During the 2000s, when decreasing trends were observed with regards to hip fractures, hospitalized fall-related injuries remained largely stable amongst all elderly men whilst a small decrease was observed amongst elderly women. With regards to all hospitalized fall-related fractures, the results also suggest a similar pattern. However, contrary to these results, hip fracture mortality, both in terms of absolute numbers and case fatality, increased during this time period.

Fall-related injuries, and hip fractures especially, were prognosticated to increase based on the assumptions of an increased number of elderly and continued increases in rates, largely due to improved healthcare and therefore a longer period of frailty (Cummings, Melton 2002, McColl, Roderick et al. 1998). With downward trends now being observed, it could be assumed that one, or both, of the predicted causal factors were incorrect. However, as is seen in figure 11, the prediction of increasing elderly populations was correct.

![Figure 11. Elderly population trends in Sweden in age- and sex-specific groups (Statistics Sweden 2011).](image)

Percentagewise, between 1987 and 2010, all age- and sex-specific groups increased with men 80 years and above showing the largest increase (58.0%) and women 65-79 years, the least (1.3%) (Table 7 and figure 11). Despite this increase in the elderly population, not only did hip fracture incidence rates decrease after 1998, the absolute number of hip fractures also decreased very slightly between 1987 and 2009 (from 20 448 to 20 291).
Table 7. Percentage changes in the Swedish elderly population in age- and sex-specific groups

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Women 65-79</td>
<td>1.31</td>
<td>-4.82</td>
<td>6.45</td>
</tr>
<tr>
<td>Women 80+</td>
<td>42.94</td>
<td>28.82</td>
<td>10.97</td>
</tr>
<tr>
<td>Men 65-79</td>
<td>14.25</td>
<td>-4.21</td>
<td>19.28</td>
</tr>
<tr>
<td>Men 80+</td>
<td>58.02</td>
<td>29.39</td>
<td>22.13</td>
</tr>
</tbody>
</table>

An increase in the number of elderly, and older elderly specifically, represents a considerable progress in general health. Whilst general increases in life expectancy are often attributed to reductions in childbirth mortality and mortality risk amongst younger adults and therefore not directly applicable to studies on older individuals, life expectancy at 65 can give indications of the health amongst the elderly. Between 1987 and 2010, the total life expectancy at 65 in Sweden increased from 83.7 to 86 (2.3 years) for women and from 79.8 to 83.1 (3.3 years) for men (Statistics Sweden 2011), therefore indicating a general health improvement among the elderly.

Increases were also seen in the mean age of attaining a hip fracture in Sweden with a 2.5-year increase amongst women (from 81.3 to 83.8) and 2.3-year increase amongst men (from 79.8 to 82.1), i.e. a one-year increase for every 8.8 years (women) and 9.5 years (men). Whilst this is considerably less than a one-year increase for every five years that previous studies have suggested (Haleem, Lutchman et al. 2008), the mean age of attaining a hip fracture in Sweden is now clearly above 80 years for both men and women. The large decreases that were observed in the younger age groups are therefore not surprising. However, this does not fully explain why decreases were also observed in the older elderly group.

**Other fall-related fracture morbidity trends**

Whilst a decreasing or stable trend is now seen with regards to hip fractures, not all fall-related fractures are decreasing. Between 1998 and 2010, hospitalized fall-related fractures among those 65 years and above decreased for all age- and sex-specific groups apart from men 80 years and above, with considerably greater decreases observed in the younger age groups (65-79 years).
Also during this time period, both central and upper extremity fractures increased significantly for both men and women 80 years and above, while a statistically significant decrease was seen among women 65-79 years for central fractures. Lower extremity fractures decreased significantly amongst men 65-79 years. Internationally, these results partly support other studies. In The Netherlands, the increases shown between 1981 and the 1990s continued during the 2000s (Hartholt, van der Velde et al. 2010), contradicting the results found in Finnish studies (Kannus, Palvanen et al. 2009, Palvanen, Kannus et al. 2010), However, with regards to central fractures, differences are seen compared to Dutch results. While Oudshoorn et al observed large increases in fall-related vertebral fractures among elderly between 1986 and 2008 (Oudshoorn, Hartholt et al. 2012), it would seem as if in Sweden similar results are only seen amongst men, while the only significant statistical change among women is a decrease among women 65-79 years.

The fact that decreases are seen in hip fracture rates whilst increases are seen in other hospitalized fall-related injuries could indicate two aspects. Either this could be evidence of an actual increase of extremity fractures or an increase in hospitalization following minor fall-related fractures. If an increase in hospitalization has occurred this could in turn indicate two differing aspects; changes in hospitalization policies or a situation where minor fractures have a greater negative effect on the individual’s general health. Whilst no evidence exists that suggest fundamental, national policy changes have been made in Sweden that would affect the number of hospitalized cases, this factor cannot definitively be dismissed as a possibility. However, as argued below, it would seem more plausible that an increase in hospitalization of minor fall-related fractures has occurred.

**Fall-related injury morbidity trends by external cause**

Paper III provides further evidence of an increase in hospitalization due to minor injuries. With regards to all hospitalized fall-related injuries, differing trends are observed between younger and older elderly with increasing trends being seen in the older age group. Whilst large increases are observed in fall-related fractures in the older age group, as was seen in paper II, paper III also shows considerable increases in hospitalized superficial injuries as well as open wounds. The fact that these types of injuries are increasingly leading to
hospitalization clearly strengthens the argument that minor injuries are having a greater effect on older elderly.

Compared to previous studies on national fall-related injury trends, paper III cannot show the general decreases in the rates of fall-related hospitalization as in Finland (Korhonen, Niemi et al. 2012), even though a small decrease is seen in the incidence rates in the total elderly population. Likewise, the general increases as seen in The Netherlands and The United States (Hartholt, Stevens et al. 2011, Hartholt, van der Velde et al. 2010) are not apparent, although increases are observed in the older elderly groups. Also, contrary to the results from The Netherlands and The United States, intracranial injuries in Sweden are decreasing in all age- and sex-specific groups apart from men 80 years and above (Hartholt, Van Lieshout et al. 2011, Ramanathan, McWilliams et al. 2012).

The differences in the trends of intracranial injuries amongst elderly between The Netherlands, The United States and Sweden as well as the proportion of intracranial injuries in the total fall-related injury panorama are noteworthy. It would seem that compared to other countries, in Sweden, fractures are responsible for a greater percentage of all hospitalized fall-related injuries amongst elderly. This could be explained by differences in diagnosis, coverage and healthcare policies between the countries. However, it could also indicate greater bone fragility amongst elderly in Sweden or differences in fall behavior in which other body parts are absorbing the energy in the fall rather than the head.

The contrasting trends between the sexes with regards to intracranial injuries are also important to note. Not only are intracranial injuries the second most common type of hospitalized fall-related injury amongst men, compared to the third most common for women, but an increasing trend is seen amongst men 80 years and above. This distribution and development is similar to other international reports (Coronado, Thomas et al. 2005, Stevens, Sogolow 2005). However, the underlying causes are largely unknown and require further research (Thompson, McCormick et al. 2006).
**Hip fracture mortality trends**

Further signs of the serious, individual impact of fall-related injuries on the oldest old are seen in paper IV. Previous review articles have shown no changes in trend with regards to hip fracture mortality from the end of the 1950’s to the 1990s (Haleem, Lutchman et al. 2008). In Sweden, however, there are no signs of stable trends between 1987 and 2009. Whilst both the absolute number of deaths due to hip fractures and case fatality rates amongst younger elderly have decreased continuously since 1987, differing trends are seen amongst the older elderly. Amongst those 80 years and above, the absolute number of deaths as well as case fatality rates, decreased in the early 1990’s to then start an increasing trend. However, most noticeably, the trends of hip fracture morbidity and mortality amongst the oldest old seem to be contrasting, with increases in morbidity occurring simultaneously with decreases in mortality, followed by a time period of decreasing morbidity and increasing mortality. Amongst the younger elderly, meanwhile, the trends are confirmative with decreases in both mortality and morbidity.

A change in trend from a decreasing risk of hip fracture mortality to an increasing risk amongst the oldest old would suggest either a change in the hip fracture patient population or a change in the treatment strategies. If the older elderly populations are now in worse health, the effect of a hip fracture could be too great for the individual, leading to an increase in risk. Likewise, if hospital care and hip fracture treatment has changed considerably during this time period this could inadvertently affect mortality risk.

Previous research has shown that the level and type of healthcare received by the patient is crucial in determining the results of a serious injury (Larsson, Holgers 2011). Although Swedish healthcare is highly rated internationally, during the last decades considerable reductions in the length of stay for hip fracture patients has been shown (Brauer, Coca-Perraillon et al. 2009, Gehlbach, Avrunin et al. 2007). Whilst this is largely due to medical advances and positive from both an individual and societal perspective, with an increasing mean age of elderly hip fracture patients, the potential risk that patients are sent home prematurely and therefore not recovering from their injury, cannot be rejected.

Whilst hospital care could affect the mortality rate, the empirical evidence from the papers in this thesis could suggest a common underlying factor. The
increases in hospitalization of minor fall-related injuries amongst the oldest old coupled with the increasing hip fracture mortality trends could suggest an increasingly frail older population. However, an increasing mean age of attaining a hip fracture, slightly lagging behind a similarly increasing life expectancy at 65 years, could also indicate an increase in the frail population. In other words, the size of the frail population increases even if the level of frailty is constant. Regardless, in this population, the impact of minor injuries seems to be considerable. Similarly, the impact of major injuries seems to have an increasingly serious effect on the individual.

**Hypothetical determinants underlying the changes in the fall-related injury panorama**

Decreasing hip fracture rates in a majority of high-income countries coupled with increasing rates in middle-income countries has now been shown in two recently published review articles (Ballane, Cauley et al. 2014, Morin, Lix et al. 2013). Although the point in time when increasing trends reverted to decreasing trends varies between high-income countries, from the 1970s up to the 2000s, a number of suggestions as to why rates are decreasing are suggested. For example, healthier elderly populations, increases in BMI among the elderly population, improved functional ability, improved treatment of osteoporosis or fall prevention programs (Kannus, Niemi et al. 2006, Leslie, O'Donnell et al. 2009, Abrahamsen, Vestergaard 2010). Given the differences that were observed in relation to age- and sex-specific groups, other hospitalized fall-related injuries and mortality trends, it could be expected that differences are seen between the groups with regards to these hypothetical causes.

**Osteoporosis treatment and fall prevention programs**

In almost all hospitalized fall-related injury categories, women are at most risk. However, despite this, greater percentage decreases were observed amongst younger elderly women compared to men in the same age group. Likewise, in those cases where increases were observed in the older age groups, these increases were smaller amongst women. Fall-related injuries are, however, still a
considerably larger problem for women and therefore, preventative measures have often been focused on women (Wong, Wan et al. 2011).

In terms of fall-related injury prevention, a common approach has been to either focus on fall prevention or osteoporosis treatment. Osteoporosis is a degenerative process in the skeleton and is defined as "a disease characterized by low bone mass and micro-architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk" (Srivastava, Deal 2002). In the treatment of osteoporosis, vitamin D is a crucial ingredient as without it calcium cannot be absorbed and new bone created (Holick, Chen 2008). Vitamin D is most commonly absorbed through sunlight exposure, and specifically through Ultraviolet B (UVB) radiation that synthetises vitamin D in the body, leading to an increase in the uptake of calcium (Engelsen 2010). The importance of osteoporosis, vitamin D and sunlight on hip fracture risk has been shown in a number of previous studies (Marks 2010, Rubenstein 2006) and it has been argued that fracture rates in Sweden are higher than in more southerly countries due to a lack of UVB radiation (Kanis, Oden et al. 2012). Also within Sweden, it has been shown that elderly are at a slightly higher risk of hip fractures in the north of Sweden (Nilson, Moniruzzaman et al. 2014).

However, these results may be confounded by for example socio-economical factors, ice and snow (Ralis 1986) or impaired physical capacity during winter (Bastow, Rawlings et al. 1983). Also, although sunlight is one of the main sources for vitamin D, it is not the only source. Studies in northern Norway and Sweden indicate that an intake of vitamin D, either through diet or supplements, greatly reduces the effect of latitudinal and seasonal variations (Burgaz, Akesson et al. 2007, Brustad, Edvardsen et al. 2007). This would indicate that the low availability of sunlight-produced vitamin D could be compensated by dietary intake and studies have shown that vitamin D levels are successfully compensated for in high latitude populations (Moan, Porojnicu et al. 2005).

In terms of fall-related fracture trends, the effect of sunlight on the individual's vitamin D status will have had a very limited effect as no considerable changes in UVB exposure has occurred in Sweden during the last 30 years (SMHI 2013). Despite this, changes in diet, birth cohort effects, vitamin D supplementation or hormonal medication may have had an effect on fall-related fractures. Hiligsmann et al claim, for example, on the basis of observed reductions in hip fracture risk amongst women compared to no changes amongst men, that this
was due to the effectiveness of osteoporosis treatment (Hiligsmann, Bruyere et al. 2012). Kannus et al, however, question the effect of both osteoporosis treatment and fall prevention programs. This, as during the 1990’s, in Finland, fall prevention strategies and medical osteoporosis treatment were rare and would only have had a marginal effect on the hip fracture trends (Kannus, Niemi et al. 2006). Also Abrahamsen & Vestergaard question the importance of these factors as the hip fracture incidence in Denmark has decreased also among men, who traditionally have not been treated for osteoporosis (Abrahamsen, Vestergaard 2010). Also in Denmark, the use of hormone therapy has steeply declined parallel to the decline in hip fracture rates (Lokkegaard, Lidegaard et al. 2007), indicating that changes in the use of hormone therapy have had little counteracting effect on hip fracture risk. One of the reasons behind this lack of correlation could simply be the importance of osteoporosis. Previous studies have shown that in terms of hip fractures, less than fifty per cent of the patients had a bone mass density that categorized them as osteoporotic (Premaor, Pilbrow et al. 2010). Therefore, the success rate of treatment would have to be high in order to show effect.

In Sweden, in order for preventative measures to have had a considerable impact on the national trends of fall-related injuries, large-scale national programs and policies would be required. To our knowledge, no such comprehensive programs have been implemented, although local fall-reducing initiatives have shown effect and been spread across the country (Sahlen, Dahlgren et al. 2006). Whilst it has been argued that treatment of osteoporosis has had an impact on women’s fracture rates, studies have shown that the use of hormone therapy in Sweden has decreased considerably between 1999 and 2007 (Lambe, Wigertz et al. 2010). Also, the fact that not all types of fall-related fractures are decreasing confounds this argument due to the general effect of osteoporosis treatment. Finally, in similarity to Denmark, changes in trend were observed in Sweden also amongst men, therefore further questioning the effect of osteoporosis treatment.

**Increases in BMI**

The increases in hospitalized upper extremity fractures in all age- and sex-specific groups apart from younger women (65-79 years) in combination with the decreases in hip fracture rates seen in this thesis could indicate that
increases in BMI have affected the fall-related fracture incidence rates. Increases in BMI have previously been shown to correlate with increases in upper-arm fractures among elderly women (Gnudi, Sitta et al. 2009) as well as lower extremity fractures (Beck, Petit et al. 2009, Valtola, Honkanen et al. 2002). Also, studies have also shown strong correlations between low BMI and increased hip fracture risk and, albeit less strong, correlations between high BMI and decreased hip fracture risk (Gnudi, Sitta et al. 2009, Laet, Kanis et al. 2005, Lumbers, New et al. 2001, Nguyen, Pongchaykul et al. 2005, van Staa, Geusens et al. 2006).

The cause behind this non-uniform relationship is the effect of an increased BMI on the individual. BMI affects the fall-related injury risk in predominantly two ways; an increased mass and an increased absorption/dispersion ability of the body tissue. Although a higher mass increases the potential risk of injury, an increased mass has also shown to increase the bone mass density in the individual, leading to increased strength. The bone mass density may also be affected by the increased estrogen production in the fat cells (Lauritzen 1996). However, the most important effect of BMI seems to be the absorption and dispersion of kinetic energy (Gnudi, Sitta et al. 2009, Laet, Kanis et al. 2005). This would explain why distal fractures are more common amongst those with high BMI, given that soft body tissue is rarely stored on extremities, whilst hip fractures are less common as fat is often stored around the central parts of the body.

With increased rates of overweight and obesity between 1980/1981, 1986/1987 and 1996/1997 in the age group 65-84 (Lissner, Johansson et al. 2000) and continued increases between 1996/1997 and 2008/2009 (Statistics Sweden 2012), indications exist that BMI may have an important roll in the changed fall-related fracture panorama in Sweden. Although increased rates of overweight and obesity have been observed it should be noted that generally, individuals lose weight continuously after the age of 60 years (Seidell, Visscher 2000). Also, it would appear that elderly women, proportionately, lose more body weight than elderly men (Dey, Rothenberg et al. 1999).

If increases in BMI were to explain the decreases in hip fractures and increases in extremity fractures from a biomechanical perspective, it would be expected that similar decreases would have been observed with regards to central fractures. Central fractures should, if these theories are correct, decline due to
the increased absorption of central body tissue. Instead, central fractures increased in all age- and sex-specific groups apart from women 65-79 years.

Improved general health and functional ability

There is some evidence that supports the hypothesis that the reduction in hip fracture risk is due to a general improvement in health amongst elderly, at least in some subgroups. An increase in upper extremity fracture risk with a simultaneous decrease in hip fracture risk could be seen as an indication of improved functional ability. This is based on the experimental evidence that individuals with high functional ability are more likely to fall differently compared to unhealthy individuals with low functional ability (Sran, Stotz et al. 2010). For example, the risk of attaining a hip fracture rather than an extremity fracture is considerably greater when walking slowly and therefore increasing the risk of a sideways fall (Smeesters, Hayes et al. 2001). A forward fall, on the other hand, increases the chance of the individual using their upper extremities to cushion the fall (DeGoede, Ashton-Miller 2002), thereby increasing the risk of an extremity injury though simultaneously reducing the risk of a hip fracture (Cummings, Nevitt 1989).

Whilst evidence exists to suggest improved health in the elderly population, the fact that minor injuries seem to be hospitalized more often could also indicate a larger number of individuals with low general health. Although this may seem contradictory, the combined results seem to show parallel, diverging trends where younger elderly are increasingly healthier and attaining fall-related injuries to a lesser extent coupled with an older elderly group who are being hospitalized with minor injuries due to low general health.

This is further supported by the results from paper IV. The risk of dying as a direct cause of a hip fracture is closely connected to poor physical health. A steadily decreasing case fatality rate trend was observed amongst the younger elderly between 1987 and 2010, suggesting an improvement in physical health. Amongst the older elderly, however, the opposite trend was seen with large increases amongst both men and women during the last 15 years. This clearly supports the theory of two parallel trends, where younger elderly are generally in better health compared to the end of the 1990s whilst older elderly have a poorer general health.
Of the suggested hypothetical causes, therefore, it would seem as if no single cause can be identified as causing the changes in trend and the differentiation between age- and sex-specific groups seen in Sweden. However, some suggested causes seem to be more plausible than others. Firstly, although the treatment of osteoporosis and fall prevention programs is important and meaningful on an individual level, it would seem unlikely that they have affected the fall-related injury trends on a nationwide level given the diverging trends in fall-related fractures and the decreases amongst men. Also, with regards to osteoporosis treatment, the fact that downward trends of hip fractures started at around the same time as hormonal treatment decreased is peculiar and whilst the two trends may not be connected this requires further research. Instead, aspects interconnected with general health seem to be of a greater importance. Hypothetically, it would seem that younger elderly have an improved functional ability, higher BMI and higher general health leading to fewer hospitalized fall-related injuries and lower risks of hip fracture mortality. Parallel to this development, the group of frailer older elderly is increasing. This group seems to be requiring more comprehensive healthcare after relatively minor injuries and are increasingly unable to recover from more serious fall-related injuries.

**Impact on future trends and prevention strategies**

Despite considerable numbers of publications within the fall-related injury field, the target factors of interventions are still largely uncertain. With uncertainty concerning the underlying causes to the longitudinal, diverging trends, the future trends and suggested preventative strategies also become unclear (Jansson 2007).

In Sweden, it would appear that interconnected trends of increases in healthier younger elderly and frailer older elderly are occurring, due to younger elderly being more likely to survive diseases and therefore transition into a frailer old age. Whilst this is merely a hypothetical suggestion, if true, it gives indications of the future fall-related injury trends, where preventative measures to a large degree should be focused on older elderly. This is further supported by a study showing that a small number of individuals account for a large proportion of injuries and the associated costs due to repetitive injuries (Jansson, Stenbacka et al. 2004). This smaller subgroup, based on the study from Jansson, Stenbacka et
al, seems to largely be identifiable as a frail, multi-ill population. With proposed increases in the size of the frail older population, this raises concerns for the future trends of fall-related injuries, both from a societal and individual perspective.

For the frail older population, often residing in some form of nursing home, limited evidence-based methods are available to reduce the risk of falls (Cameron, Gillespie et al. 2012). Whilst this may be due to an inability of choosing the correct preventative methods based on the individual’s status, importing injury prevention methods from other arenas or sectors is also important (Jansson 2007). Some attempts of adapting other injury prevention strategies to frail elderly have occurred, for example, the use of hip protectors on patients who are especially prone to falling. With a shock absorbing material placed over the trochanter, hypothetically, the risk of a hip fracture is reduced in the event of a sideways fall. The theoretical idea of energy dispersion and absorption, based on work from for example De Haven and Haddon (De Haven 1942, Haddon 1974), has successfully been used within the transport sector and experimental studies of hip protectors showed promising results (Lauritzen, Petersen et al. 1993). However, limited effect has been seen in the following studies, most likely due to a low level of compliance (Gillespie, Gillespie et al. 2010).

The example of hip protectors clearly illustrates the importance of adapting and choosing interventions, both in research and in practice, based on the context (Jansson 2007). In order to achieve this, hip protectors have been further developed into shock absorbing flooring in nursing homes, now being tested in both The United Kingdom and Sweden, with promising results so far (Drahota, Gal et al. 2011, Gustavsson, Nilson et al. 2012).

Therefore, whilst it would seem as if the societal impact of fall-related injuries is generally decreasing and that prevention should to a greater extent be focused on older elderly, these prognoses are uncertain due to gaps in the scientific research. Without a clear understanding of the causes behind falls and fall-related injuries, an improved ability to choose the most relevant individual preventative strategy as well as studies on context-based interventions, the future trend predictions will largely be based on insufficient knowledge.
Limitations

This thesis has a number of limitations. Firstly, all papers in this thesis have been based on data from either the Swedish National Patient Register or the Swedish Cause of Death Register. Although both of these registers are regarded as reliable since 1987, due to not having control over the injury registration process, mistakes and misses cannot be ruled out. Also, although all data was controlled to eliminate double registrations due to readmissions within a single year, it was not possible to connect patients between different years. As a readmission can occur between two years, this is a limitation though was judged as a small risk that doesn’t substantially affect the results.

In paper I and IV, the results contain data registered in both ICD-9 and ICD-10. In paper I, the downturns that were observed seem to occur in conjunction with the ICD change, indicating that perhaps the downturns and coding change are interlinked. Whilst effects of ICD changes have previously been observed (Anderson, Rosenberg 2003, Jansson, Johansson et al. 1997, Pearson-Nelson, Raffalovich et al. 2004), these effects are commonly dramatic, with sharp increases or decreases between two years. In paper I, a gradual change in trend seems to occur at the time of the ICD change, a pattern that does not suggest a direct effect of the coding change. However, similar patterns have been seen and discussed in other hip fracture trend studies though the effect of the coding change has been judged as minimal (Leslie, O’Donnell et al. 2009). The conclusion has been that as no changes in the coding of hip fractures occurred between ICD-9 and ICD-10 this should not affect the observed trends, although cannot completely be dismissed.

In paper IV, the case fatality rate trend change also occurs simultaneously with the change in ICD coding. However, with regards to the absolute numbers, the changes in trends in the oldest age groups occurred several years before the ICD change. Also, no dramatic change in trend is observed in the younger group. Therefore, it would seem as if the change in case fatality rate trend between 1996 and 1997 is purely coincidental in this aspect and is rather connected to the fact that trends in absolute numbers of hip fractures changed from an increasing to a decreasing (or horizontal) trend at this time.

In paper II and III, not all fall-related fractures or injuries among elderly in Sweden are included and therefore the results from this study should be viewed in that context. In order for injuries to be registered in the NPR, the patient
needs to be admitted to hospital. A considerable number of fall-related injuries are treated in primary care or merely at an accident and emergency department and are therefore not included in this study. Whilst very few serious injuries are missed in the registration, a large number of minor injuries are not included. However, by studying hospitalized fall-related injuries, the impact of the injury on the individual as well as the societal impact is included. The trauma and consequences of hospitalization can be considerable for the individual and, from a societal perspective, a great deal more expensive, therefore motivating the study of hospitalized injuries.

In paper I and IV, hip fractures regardless if these were categorised as fall-related or not, were studied. This means that not only fall-related hip fractures were included but also all external causes such as those caused in traffic-related accidents or as a result of violence. Whilst this is a clear limitation, previous research has shown that at least ninety per cent of all hip fractures are caused by falls (Hayes, Myers et al. 1996). Therefore, it can be assumed that a large majority of hip fractures in these studies are caused by falls.

In papers I-III, cases have been included if they were registered as the primary diagnosis. Likewise, in paper IV, cases have been included when hip fractures were categorized as an underlying cause of death. Previous studies have argued that both underlying and contributing cause of death should be included when analysing mortality trends, especially when comparing data internationally (Jansson, Ahmed 2002) and the same could be argued with regards to morbidity primary and secondary causes. Whilst the inclusion of contributory causes is highly relevant in regards to long-term conditions such as epilepsy, diabetes, smoking, etc., with regards to the short-term effect of the hip fracture on the individual, using underlying causes was regarded as more relevant. Likewise, including secondary diagnoses, a risk was that minor fall-related injuries were included even though these, had they been the primary diagnosis, would have been treated without hospitalization. However, there is a risk that only including injuries registered as underlying cause or primary diagnosis inadvertently affected the rates. Therefore, when comparing with other countries, this factor must be taken into consideration.

In the articles included in this thesis fall-related injury rates have been analysed in age- and sex-specific groups. As has been shown previously, considerable differences in levels and trends have been observed with regards to these aspects. Likewise, other factors, such as socio-economical, could show similar
differences. However, although socio-economic development on a global scale has been shown to increase hip fracture risk (Johnell, Borgstrom et al. 2007), within countries, the associations between socio-economic status and fall-related injuries amongst elderly are weak. Although lower socio-economic status is associated with factors that increase the risk of hip fractures, for example an increased use of tobacco and alcohol (Robbins, Aragaki et al. 2007) or reduced physical activity (Feskanich, Willett et al. 2002), lower socio-economic status has also been strongly associated to high BMI (Wamala, Wolk et al. 1997). A factor known to reduce the risk of, for example, hip fractures.

Also with regards to socio-economic factors, important markers, such as income and educational level, are difficult to study in relation to elderly in general. In Sweden, the educational level is comparatively low amongst elderly. Similarly, the level of income is an uncertain marker with regards to elderly, as is material deprivation or the socio-economic status of the residing neighbourhood (Laflamme, Burrows et al. 2009). Whilst it could be possible to use pension levels, especially amongst elderly women, these are often low despite a high socio-economical level due to income from for example capital or a high-earning spouse.

It has also been argued that urbanisation could have a profound effect on the increasing hip fracture rates seen previously in high-income countries (Ballane, Cauley et al. 2014) and could therefore also have been used as a factor when studying fall-related injuries. Hypothetically, these differences are due to a more physically active lifestyle among rural populations (Sanders, Nicholson et al. 2002), an increase in hard surfaces, or calcium and vitamin D deficiencies (Ballane, Cauley et al. 2014). However, whilst an increased risk in urban populations has been shown in a number of studies (Becker, Crow et al. 2006, Meyer, Berntsen et al. 2004, Sanders, Nicholson et al. 2002, Finsen, Benum 1987, Finsen, Johnsen et al. 2004), in a Swedish context, the available evidence would rather suggest higher rates in rural populations (Nilson, Moniruzzaman et al. 2014). Whether this is due to differences in social security systems or other confounders is unknown. Regardless, whilst urbanisation may have coincided with increases in hip fracture rates, a ruralisation has not been reported despite decreasing trends. Therefore, the simultaneous increases in hip fracture rates and urbanisation rather seems to reflect an associated increase in prosperity and access to medical care (Ballane, Cauley et al. 2014).
CONCLUSIONS

For Sweden, fall-related injuries amongst elderly have been labelled as one of the most important emerging societal risks, on par with climate change, natural disasters, terrorism, etc. Although fall-related injuries amongst elderly are still a major problem in Sweden, as well as in a majority of other high-income countries, the dramatic prognoses published at the turn of the century now seem to be slightly exaggerated. Rather, in similarity to other comparable high-income countries, the general hospitalized fall-related injury rate trends in the total elderly population in Sweden are now decreasing. Also from a societal perspective, where arguably the total costs and numbers are most important, the prognoses are considerably improved with similarly hip fracture totals in 2009 as in 1987.

However, whilst the general patterns of fall-related injuries are positive, underlying age- and sex-specific trends suggest diverging directions. Specifically, two groups emerge in need of a stronger future preventative focus; the oldest old and elderly men. Despite the fact that the risk of almost all types of fall-related injuries in Sweden is greater amongst women, generally, fall-related injury rates amongst women are decreasing quicker, or increasing more slowly, compared to men. Likewise, the rates amongst the oldest old show a more negative development compared to younger elderly.

In terms of prognosticating future societal risks, this thesis has clearly shown that this is inherently difficult. Prognoses are often based on insufficient facts and a belief that certain factors will remain status quo. Despite this, healthcare and public health planning requires prognoses in order to proactively deal with important issues. Therefore, despite the problems of prognoses, this thesis does indicate some future trends and emerging risks.

Based on the current trends, it is clear that the number of elderly, both in terms of absolute numbers and proportion of the total population, will continue to increase during the 21st century. Likewise, it would seem plausible that the number of healthier elderly increases, as does the number of frailest elderly. In terms of fall-related injuries, based on the current trends and explanations, this would lead to continued increases in hospitalization of minor fall-related injuries and hip fracture mortality, with simultaneously decreasing trends in hip fracture rates and fall-related injury rates overall.
In conclusion, whilst more research is needed within this field in order to fully understand the prevailing trends and causes behind these, this thesis can conclude that although the predicted trends were exaggerated, some subgroups of fall-related injuries and death from these seem to be continuously increasing. Despite these segments of emerging risks, this thesis can show a fall-related injury development over the last 25 years that is generally very positive from both an individual and societal point of view.
FUTURE RESEARCH

A number of aspects of the fall-related injury research panorama that have been raised in this thesis require further studies and elaboration. Some of these aspects are listed below.

- Although it is possible to speculate as to why general decreases and diverging trends are observed, understanding the underlying causes requires considerable further research. Researching these underlying causes is of great importance, not only from a high-income countries perspective where similar trends are occurring, but also from a low- or middle-income countries perspective in order to efficiently and effectively meet this serious problem which otherwise seems to inherently follow with further economic development.

- The current diverging trends of fall-related injuries between the age-specific groups raises an important issue of the importance of differentiating trends with regards to age- and sex-specific groups. Whilst subgroup analyses can overcome the problems of different population groups, it would seem as if, in Sweden at least, defining elderly or old age as those 65 years and above, is now an out-dated definition. In this thesis, elderly have been defined as those 65 years and above in similarity to OECD and WHO (OECD 2007, WHO 2008). However, critique has been raised concerning this definition and authors have suggested a cut-off at an older age (Orimo 2006). In order to improve geriatric epidemiological research, this issue needs to be comprehensively investigated in future research.

- A further aspect in need of continued research is the issue of hip fracture mortality. Not only are now more individuals in Sweden dying as a result of hip fractures than within the traffic sector, poisoning-related accidents or violence (Socialstyrelsen 2013), the issue distinguishes itself with sharply increasing trends amongst the oldest old and an overrepresentation of men as victims. Whilst these aspects alone legitimise further research, the question of whether healthcare policies may have inadvertently affected these trends negatively needs to be studied further. With reduced lengths of stay at hospitals, in combination with frailer elderly, the question of whether patients are being sent home prematurely should be examined.
- Lastly, at present, effective fall-related injury prevention strategies for older elderly and especially amongst those living in nursing homes are scarce (Cameron, Gillespie et al. 2012). Based on the findings in the papers included in this thesis, considerable research in developing and evaluating preventative measures for these individuals is crucial in order to hinder a continued increasing injury trend in this subgroup.
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Fall-Related Injuries Amongst Elderly in Sweden

Injuries due to falls are the most common cause of injury-related hospitalization and injury-related death amongst elderly. During the 20th century, although increasing trends in fall-related injuries have been reported from other high-income countries, no studies from Sweden using national data have been published, despite this issue being pointed out as one of the most important emerging societal risks in Sweden.

National injury morbidity and mortality data from Sweden can show that in terms of hospitalized fall-related injuries as well as hip fractures, the risk is decreasing. However, diverging trends are observed in age- and sex-specific groups, with younger elderly now having considerably lower rates of fall-related injuries, whilst older elderly are increasingly hospitalized due to minor fall-related injuries. Also, amongst older elderly, increasing hip fracture mortality trends are observed.

This thesis can show a change in trend in fall-related injuries amongst elderly in Sweden since the turn of the century, apart from amongst older elderly and with regards to hip fracture mortality. The implications on future prognoses needs to be studied further as do the underlying causes behind this shift in trend.